Petroleum Systems and Geologic Assessment of Oil and Gas in the San Joaquin Basin Province, California

Chapter 9

Petroleum Systems of the San Joaquin Basin Province, California—Geochemical Characteristics of Oil Types

By Paul G. Lillis and Leslie B. Magoon

Contents

Abstract

New analyses of 120 oil samples combined with 139 previously published oil analyses were used to characterize and map the distribution of oil types in the San Joaquin Basin, California. The results show that there are at least four oil types designated MM, ET, EK, and CM. Most of the oil from the basin has low to moderate sulfur content (less than 1 weight percent sulfur), although a few unaltered MM oils have as much as 1.2 weight percent sulfur.

Reevaluation of source rock data from the literature indicate that the EK oil type is derived from the Eocene Kreyenhagen Formation, and the MM oil type is derived, in part, from the Miocene to Pliocene Monterey Formation and its equivalent units. The ET oil type is tentatively correlated to the Eocene Tumey formation of Atwill (1935). Previous studies suggest that the CM oil type is derived from the Late Cretaceous to Paleocene Moreno Formation.

Maps of the distribution of the oil types show that the MM oil type is restricted to the southern third of the San Joaquin Basin Province. The composition of MM oils along the southern and eastern margins of the basin reflects the increased contribution of terrigenous organic matter to the marine basin near the Miocene paleoshoreline. EK oils are widely distributed along the western half of the basin, and ET oils are present in the central and west-central areas of the basin. The CM oil type has only been found in the Coalinga area in southwestern Fresno County. The oil type maps provide the basis for petroleum system maps that incorporate source rock distribution and burial history, migration pathways, and geologic relationships between hydrocarbon source and reservoir rocks. These petroleum system maps were used for the 2003 U.S. Geological Survey resource assessment of the San Joaquin Basin Province.

Introduction

A petroleum system consists of a pod of active source rock; reservoir rock with an adequate seal; favorable timing of petroleum generation, migration, and trap formation; and all genetically related hydrocarbons that occur as petroleum shows, seeps, and accumulations (Magoon and Dow, 1994). The first step in identifying petroleum systems is to characterize and map the geographical distribution of oil and gas types. This paper presents the results of a petroleum geochemical study that characterizes oil types that, in turn, establish a basis for mapping petroleum systems in the San Joaquin Basin, California (Magoon and others, this volume, chapter 8). The petroleum system maps were used for the 2003 U.S. Geological Survey (USGS) resource assessment of the basin (USGS San Joaquin Basin Province Assessment Team, this volume, chapter 1).

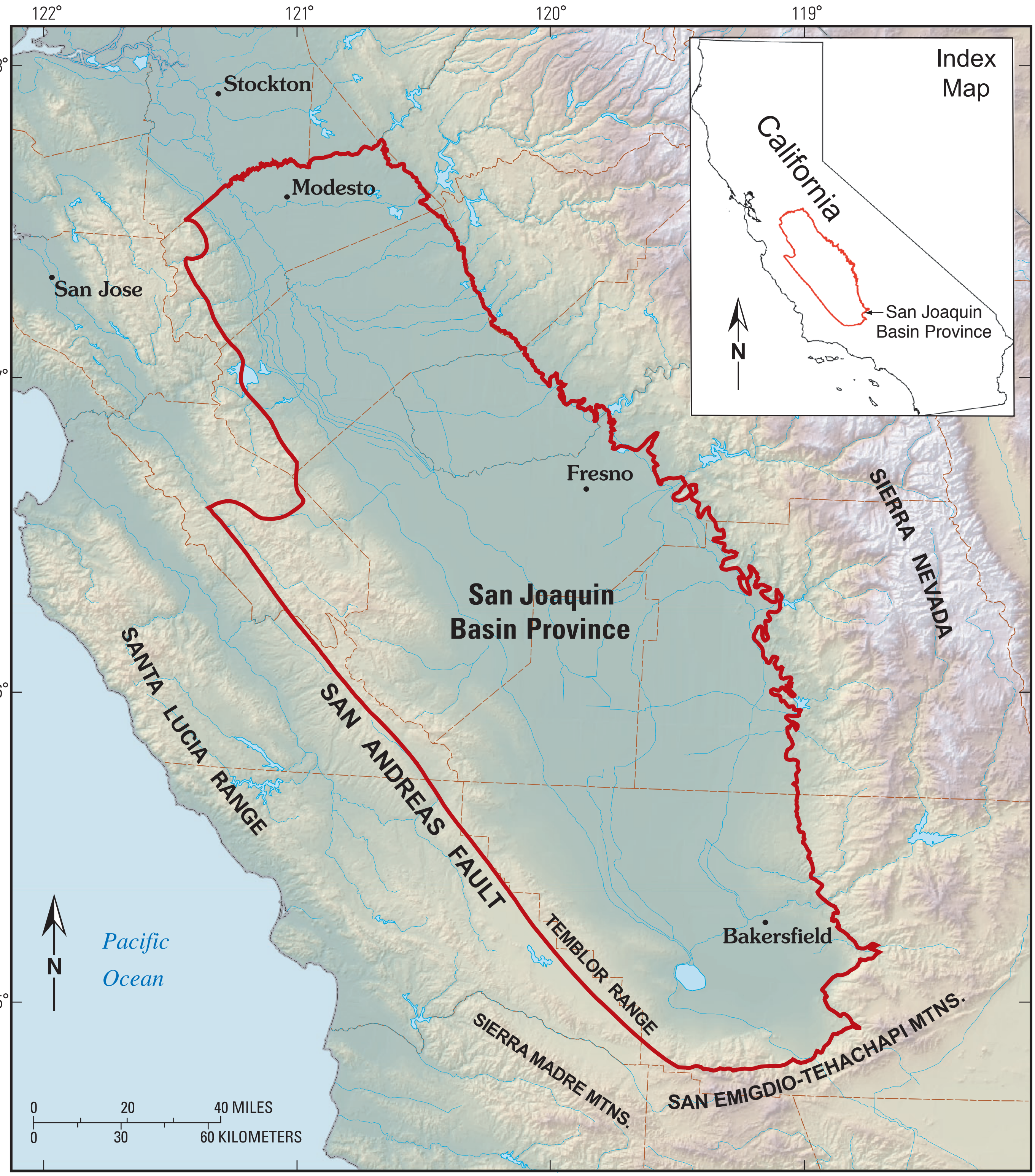

Figure 9.1. Location map of San Joaquin Basin Province (red outline) showing topography and location of county lines and some cities. Inset shows location of San Joaquin Basin Province (red outline) within the State of California.

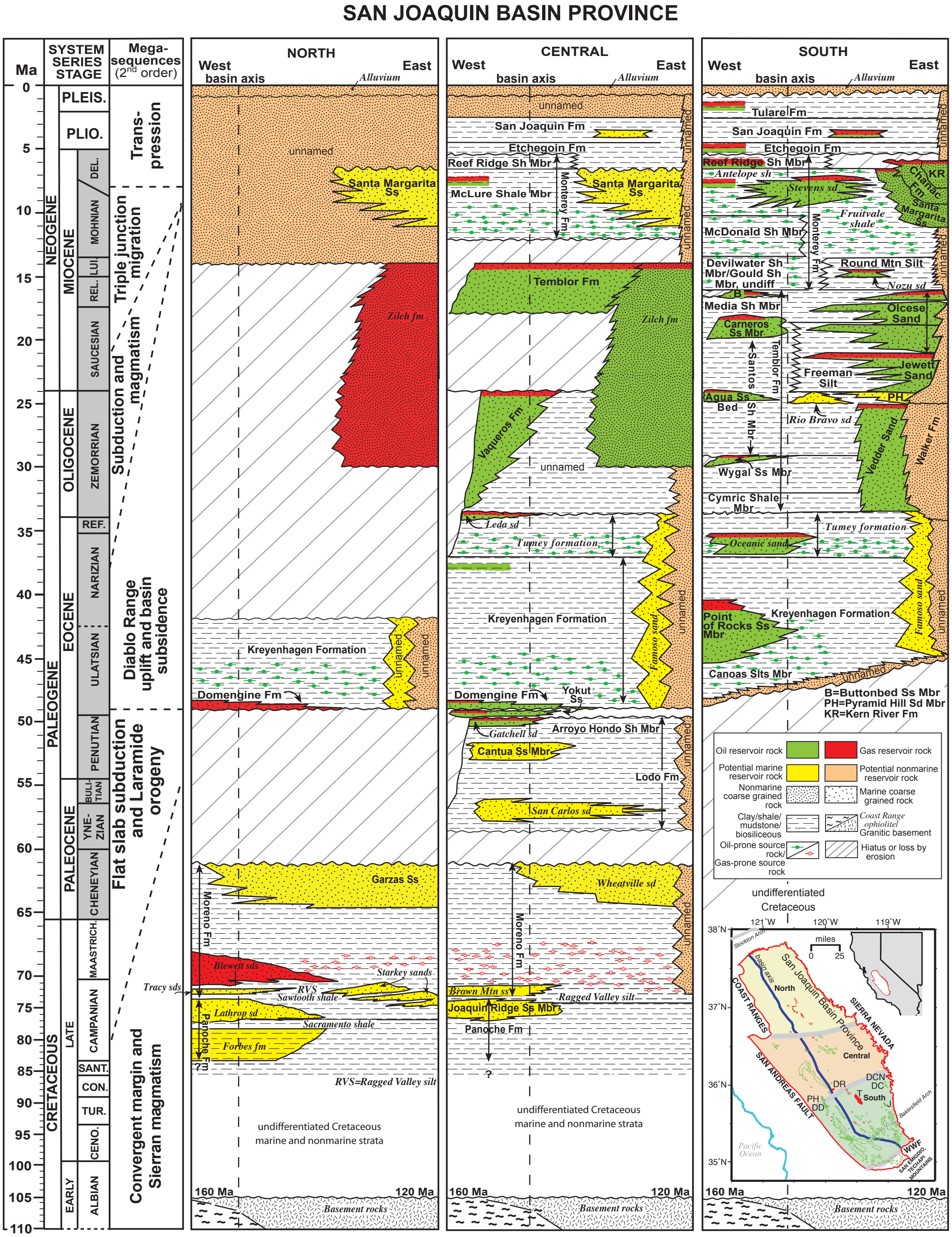

Figure 9.2. San Joaquin Basin Province stratigraphy showing hydrocarbon reservoir rocks and potential hydrocarbon source rocks. See Hosford Scheirer and Magoon (this volume, chapter 5) for complete explanation of the figure. Formation names in italics are informal and are defined as follows (in approximate age order): Forbes formation of Kirby (1943), Sacramento shale and Lathrop sand of Callaway (1964), Sawtooth shale and Tracy sands of Hoffman (1964), Brown Mountain sandstone of Bishop (1970), Ragged Valley silt, Starkey sands, and Blewett sands of Hoffman (1964), Wheatville sand of Callaway (1964), San Carlos sand of Wilkinson (1960), Gatchell sand of Goudkoff (1943), Oceanic sand of McMasters (1948), Leda sand of Sullivan (1963), Tumey formation of Atwill (1935), Famoso sand of Edwards (1943), Rio Bravo sand of Noble (1940), Nozu sand of Kasline (1942), Zilch formation of Loken (1959), Stevens sand of Eckis (1940), Fruitvale shale of Miller and Bloom (1939), and Antelope shale of Graham and Williams (1985).

The San Joaquin Basin is primarily an oil-producing province located in the southern part of the Great Valley of central California between the Coast Ranges and the Sierra Nevada (fig. 9.1). Several potential petroleum source rocks have been recognized in the basin (fig. 9.2), suggesting the possibility of several oil types and petroleum systems (Magoon and others, this volume, chapter 8, and Peters, Magoon, Valin and Lillis, this volume, chapter 11). Peters and others (1994) previously recognized petroleum systems along the western margin of the basin, but the geographic and stratigraphic extents of the systems were not addressed in their study.

The approach for this study was to first separate crude oil samples into types or families by evaluating the similarities of various bulk and molecular geochemical parameters, and then to map the geographical distribution of the oil types in the petroleum province. Defined oil types were then compared with source-rock data derived from the literature in order to establish a genetic relationship, typically called oil-source rock correlation. Preliminary findings of this study are reported in Lillis and Magoon (2004a,b).

Chemical parameters most useful for oil correlation are stable carbon isotope ratios and biological marker compositions. Biological markers ("biomarkers") are organic compounds found in petroleum and petroleum source rocks that have distinctive stereochemical and/or structural configurations reflecting precursor compounds of biological origin (Peters and others, 2005). Biomarkers used in this study include acyclic isoprenoids (pristane and phytane) and polycyclic isoprenoids (triterpanes and steranes).

Stratigraphy

Details of the stratigraphy of the San Joaquin Basin are covered by Gautier and others (this volume, chapter 2), Hosford Scheirer and Magoon (this volume, chapter 5), and Johnson and Graham (this volume, chapter 6); a summary stratigraphic correlation chart appears in figure 9.2. Source rocks are discussed in more detail by Peters, Magoon, Valin, and Lillis (this volume, chapter 11). The Tumey formation of Atwill (1935), hereafter referred to as the Tumey formation, requires further discussion to clarify the stratigraphic nomenclature used in this study. The Tumey formation as defined by Atwill (1935) consists of a sandstone unit and a conformably overlying diatomaceous shale unit that he determined to be Oligocene in age. The shale unit contains benthic foraminiferal zone fauna from the Refugian Stage (Schenck and Kleinpell, 1936; Stinemeyer, 1974), which has subsequently been reassigned to the late Eocene (Warren and Newell, 1980; Armentrout, 1983). Some workers consider the Tumey formation to be a member of the Kreyenhagen Formation (Milam, 1985). For example, Bartow (1996) assigned the Tumey formation to the Kreyenhagen Formation because he saw no significant lithologic difference between the units in outcrop and could not map the contact in places where the sandstone unit was missing. For this study we follow the published correlation chart of Bishop and Davis (1984) and industry usage (Callaway, 1990), in which the Tumey formation is a distinct late Eocene (Refugian benthic foraminiferal zone) unit overlying the Kreyenhagen Formation (fig. 9.2).

Previous Geochemical Studies

Previous petroleum geochemical studies within the San Joaquin Basin recognized the middle Miocene to Pliocene Monterey Formation and the middle Eocene Kreyenhagen Formation as the main source rocks for petroleum, whereas the Late Cretaceous portion of the Moreno Formation was considered a minor source. Early oil-to-oil correlation work in the basin includes Seifert (1977) and Seifert and Moldowan (1978), in which three oil types were identified using biomarker and stable carbon isotope composition. Two of the oil types, produced from the Miocene Carneros Sandstone Member of the Temblor Formation and the Eocene Oceanic sand of McMasters (1948), were correlated to the Miocene Antelope shale of Graham and Williams (1985) (hereafter referred to as Antelope shale) and the Eocene Kreyenhagen Formation, respectively (Seifert, 1978). The source of the third oil type, produced from the Oligocene Phacoides sandstone of Curran (1943), was not identified. Other early studies also suggested that the Antelope shale was an oil source in the San Joaquin Basin (Welte and others, 1975; Leythaeuser and others, 1977). Curiale and others (1985) used stable carbon isotopes and biomarkers to characterize variations in Monterey Formation rock extracts and produced oils from several California basins including the San Joaquin. On the basis of biomarker chemistry, Lu and Kaplan (1987) suggested that oils from the northern San Joaquin Basin originated from either Late Cretaceous or Eocene age source rocks. McGuire (1988) correlated the geochemistry of an oil sample from the Oil City pool of Coalinga field to an oil sample from the Griswold Canyon area of the Vallecitos field. By process of elimination, he suggested a Moreno Formation source rock for the oil because its biomarker composition differed from both the Miocene and Eocene oil types.

Kaplan and others (1988) identified two main oil types in the San Joaquin Basin and correlated them to the Miocene to Pliocene Monterey Formation and Eocene Kreyenhagen Formation. They also suggested that oils with intermediate isotopic compositions are either mixtures of these two types or originate from the late Eocene Kreyenhagen Formation, late Eocene Tumey formation, or Oligocene-age source rocks. Peters and others (1994) identified three oil types along the western margin of the San Joaquin Basin and correlated two of these to source rocks—the Eocene Kreyenhagen Formation and the Miocene to Pliocene Monterey Formation. The source of the third oil type is presumed to be the Cretaceous to Paleocene Moreno Formation (Peters and others, 1994). They further subdivided the Monterey oil type into three sub-types based on porphyrin composition. Fonseca-Rivera and Moldowan (1996) and Fonseca-Rivera (1998) noted similarities in the biomarker composition of oil from Oil City and pyrolyzed rock samples of the Marca Shale Member of the Moreno Formation. Alimi and Kaplan (1997a,b) used biomarkers and stable carbon isotope data to suggest that oil from a deep well in Elk Hills field was generated from source rocks of Paleogene age (probably Temblor Formation, Tumey formation, or Kreyenhagen Formation). Finally, Lillis and others (2001) used stable carbon isotopes to identify three oil types (Cretaceous, Eocene, Miocene) in northern California.

Methods and Approach

To characterize the petroleum systems in the San Joaquin Basin Province, 120 crude oil samples were analyzed for bulk and molecular properties, including API gravity, sulfur content, stable carbon isotope and biomarker composition. The asphaltene fraction of the oil was separated by precipitation in excess volumes of isooctane followed by centrifugation and filtration. The saturated hydrocarbon, aromatic hydrocarbon, and polar hydrocarbon fractions were separated by column chromatography with alumina-silica columns and successive elution with isooctane, benzene, and benzene-methanol azeotrope, respectively. Gas chromatography of the C_{9+} hydrocarbon fractions was performed on a Hewlett-Packard 6890 gas chromatograph with a DB-1 (bonded-phase 100 percent dimethylpolysiloxane) capillary column (60 m long by 0.32 mm inner diameter), programmed heating (40˚ to 330˚C at 4.5˚C per minute, and hold at 330˚C for 15 minutes), a splitless injector, and a flame ionization detector. Identification of acyclic isoprenoids (pristane and phytane) and *n*-alkanes was determined by elution time and comparison with external standards. Relative concentration was determined by chromatogram peak height.

Biological marker distributions of the oil samples were determined on a Hewlett-Packard 5890 gas chromatograph/JEOL GCmate magnetic-sector mass spectrometer by selected-ion monitoring (SIM) at mass-to-charge (*m*/*z*) ratios of 191.1800, 217.1956, 231.1174, and 253.1956. The gas chromatograph used a DB-1701 (bonded-phase 14 percent cyanopropylphenyl, 86 percent dimethylpolysiloxane copolymer) capillary column (60 m long by 0.31 mm inner diameter), splitless injector, and an oven-heating program of 50° to 150˚C at 50˚C per minute, 150˚ to 300˚C at 3˚C per minute, and hold at 300˚C for 9 minutes.

Huffman Laboratories in Golden, Colorado, analyzed some of the oil samples for nickel, vanadium, and sulfur content. The remaining crude oil sulfur contents were determined by the USGS using a Carlo Erba 1110 elemental analyzer.

The stable carbon isotope values ($\delta^{13}C$) of the C_{15+} saturated and aromatic hydrocarbon fractions of the oil samples were determined using a Carlo Erba elemental analyzer (EA) interfaced to a Micromass Optima continuous-flow isotope-ratio mass spectrometer (IRMS). Sample aliquots were flash combusted at approximately 1,800°C in the EA quartz combustion tube filled with oxygen. The evolved CO_2 passed through chromium oxide (to complete oxidation), copper granules (reducing agent), and anhydrone (to remove water) before being swept into the IRMS with helium carrier gas. The results are expressed in the delta (δ) notation that represents the deviation of the $^{13}C/^{12}C$ ratio in parts per thousand (per mil, or ‰) relative to the Peedee belemnite (PDB) standard.

Oil-Oil Correlation

Results of the crude oil analyses from this study, as well as all data from the literature utilized for this study, are given in appendix 9 in Microsoft Access database format and Microsoft Excel spreadsheet format. Selected results are also presented in tables 9.1 and 9.2 for analyses performed by the USGS and in tables 9.3 and 9.4 for analyses obtained in the literature.

Because biodegradation can adversely affect petroleum geochemical data that are used in oil-oil and oil-source rock correlation, the degree of biodegradation was evaluated for each oil sample analyzed in the USGS laboratory (column I in table 9.2) using the following criteria: mild biodegradation = *n*-alkanes are reduced in concentration or not present; moderate biodegradation = acyclic isoprenoids (pristane and phytane) are reduced in concentration or not present; heavy biodegradation = C_{30} to C_{35} hopanes or regular steranes appear altered; and severe biodegradation = C_{30} to C_{35} hopanes and regular steranes are severely depleted or absent. Those samples with heavy and severe degrees of biodegradation, combined with anomalously high (> 0.7) bisnorhopane/hopane ratios, were excluded from further data analyses. High-API-gravity oils (> 45 degrees) also were eliminated from further consideration, as were pristane/phytane values greater than 5.0.

Oil Analyses From USGS Laboratory

Results of isotope analysis of 120 oil samples examined for this study (table 9.2) are shown in figure 9.3. Three major groups of oil samples are clearly distinguished and are herein designated oil types MM, ET, and EK. The CM oil type consists of only four oil samples from the Oil City pool of Coalinga field that have a similar isotopic composition as ET oils but can be distinguished on the basis of other geochemical parameters (discussed below). The polygons on figure 9.3, which were constructed to circumscribe the three groups of data, are used in later figures for comparison with other isotope data sets from the literature. Oil type outliers (for example, MM outlier) are defined as samples that match an oil type based on some, but not all, geochemical parameters. A few of these oil type outliers plot within the parent polygons but are considered a poorer match than other samples in the polygon on the basis of other geochemical parameters (see below).

To investigate whether the analyzed oil samples derive primarily from marine or terrigenous organic matter, we use the linear relationship defined by Sofer (1984), which separates waxy oil from nonwaxy oil on the basis of the stable carbon isotopes of the saturated and aromatic hydrocarbon fractions of petroleum. Waxy oil is usually derived from terrigenous organic matter, whereas nonwaxy oil is usually derived from marine organic matter. On the basis of the application of the Sofer (1984) relationship to the data from the San Joaquin Basin Province, most oil samples derive from marine organic matter.

Because sulfur content of oil increases with biodegradation, it is more difficult to use biodegraded samples for oil typing. The MM oil type has low to medium sulfur content (fig. 9.4) (using the criteria for the Monterey Formation of Orr, 2001) and is indistinguishable from the other oil types. However, a few unaltered MM oil samples have sulfur contents as much as 1.2 weight percent, such as samples 68 and 96 (table 9.2), and some low-gravity oil samples that are probably biodegraded MM oil type have as much as 1.7 weight percent (fig. 9.5). The sulfur content of unaltered EK oil type is generally less than 0.7 weight percent, and unaltered ET oil type contains less than 0.6 weight percent sulfur (fig. 9.4). The sulfur content of CM oil type is less that 0.2 weight percent (fig. 9.4).

Oil gravity and sulfur content data from tables 9.2 and 9.4 are plotted in figure 9.5*A*, and California crude oil data from a publicly available database of crude oil analyses (National Institute for Petroleum and Energy Research, 1995) are plotted in figure 9.5*B* (see also appendixes 9.2 and 9.3). Most oil in the San Joaquin Basin Province contains low amounts of sulfur, where "low" is defined as less than 1 weight percent by Tissot and Welte (1984), and thus is not likely derived from Type II-S kerogen (high sulfur content) as defined by Orr (2001) for the Monterey Formation. In contrast, most oil from the Santa Maria and Santa Barbara Basins has a high sulfur content (greater than 1 weight percent) and is derived from Type II-S kerogen in the Monterey Formation (fig. 9.5b) (Orr, 2001).

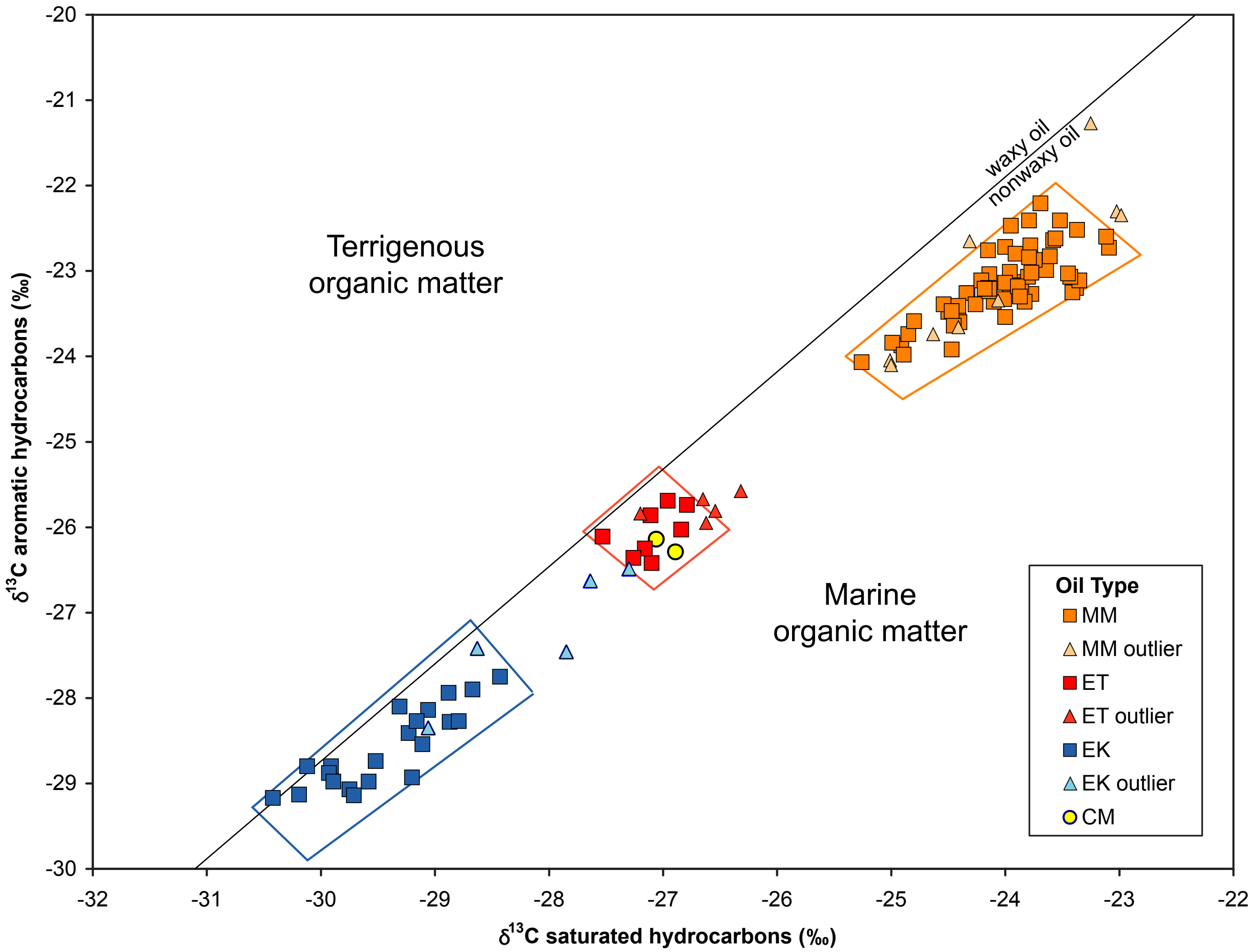

Figure 9.3. Plot of stable carbon isotope ratios ($\delta^{13}C$) of saturated and aromatic hydrocarbon fractions for oil types from San Joaquin Basin Province. Three oil types can be identified, which are designated MM, ET and EK. Data are from the U.S. Geological Survey (table 9.2). See text for explanation of the polygons. The diagonal line separates waxy oil (terrigenous organic matter) from nonwaxy oil (marine organic matter), according to the relationship defined by Sofer (1984).

In addition to the distinctive stable carbon isotope composition discussed above, the biomarker composition is useful in distinguishing oil types. The MM oil type typically contains lower pristane/phytane values (fig. 9.6), and higher bisnorhopane/hopane and C_{26} tricyclic/C_{24} tetracyclic terpane values (fig. 9.7) than the other oil types, although there is some overlap, particularly in the pristane/phytane ratio of the ET and MM oil types. In previous studies, the MM oil type has been subdivided into subtypes on the basis of Ni/(Ni + V) porphyrin values (Peters and others, 1994) and biomarker chemistry (Lillis and Magoon, 2004b). However, the consideration of subtypes within the MM oil type was beyond the scope of the 2003 USGS resource assessment of the San Joaquin Basin Province. The EK oil type is generally distinguished by pristane/phytane values between 1.8 and 2.6 (fig. 9.6) and C_{26} tricyclic/C_{24} tetracyclic terpane values less than 4 (fig. 9.7). The ET oil type may be distinguished by pristane/phytane values between 1.4 and 1.7 (fig. 9.6) and low bisnorhopane/hopane values (fig. 9.7). The CM oil type has isotope values similar to the ET oil type but can be distinguished on the basis of pristane/phytane values (fig. 9.6).

Oil Analyses From the Literature

Stable carbon isotope and pristane/phytane data from this study (polygons from figs. 9.5 and 9.6) were compared with oil data from the literature (table 9.4) for the purpose of oil-oil correlation. Sulfur data were generally not useful for oil correlation, and biomarker data were unavailable on most oil analyses obtained from the literature. In general, the majority of oil sam-

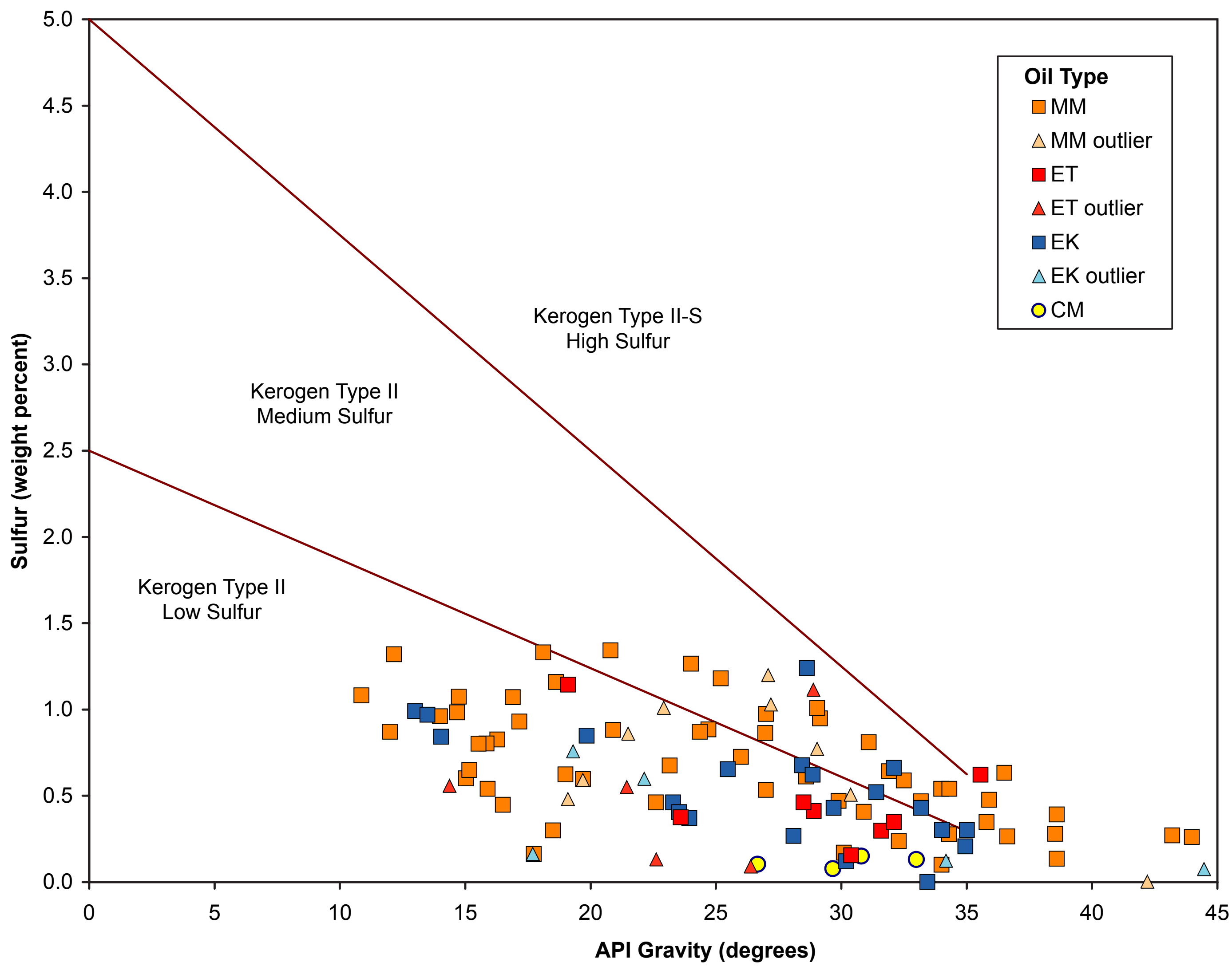

Figure 9.4. Plot of oil gravity versus sulfur content for oil samples from the San Joaquin Basin Province. Data are from USGS (table 9.2). MM oil type generally has higher sulfur content than the ET, EK, or CM oil types. Kerogen type II source rock classification for the Monterey Formation (2 diagonal lines) is from Orr (2001).

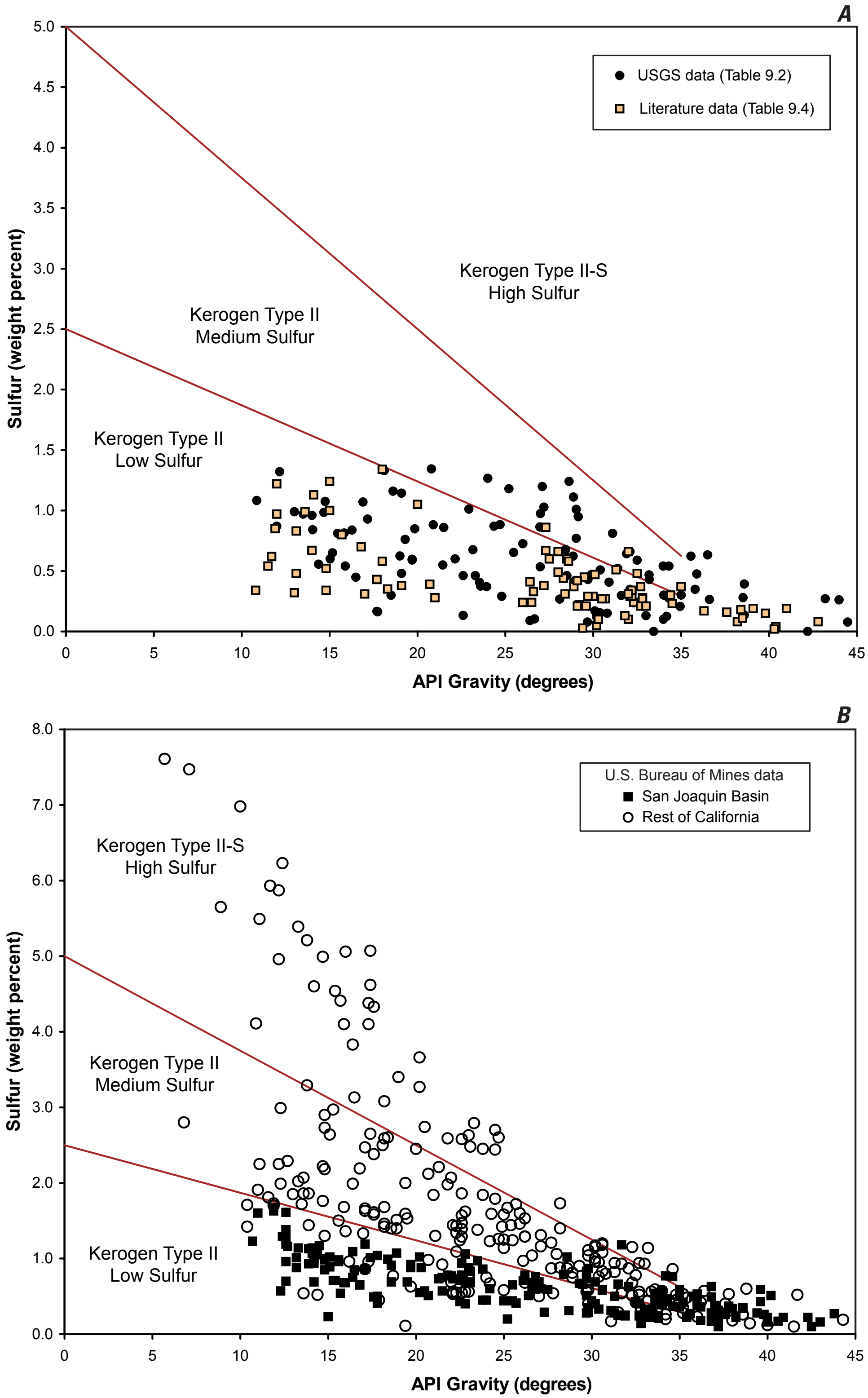

Figure 9.5. *A*, Plot of API (American Petroleum Institute) gravity versus sulfur content for oil samples from fields in the San Joaquin Basin Province using data from the U.S. Geological Survey (table 9.2), and from the literature (table 9.4). *B*, Similar oil sample data from California fields taken from a database provided by the Department of Energy (National Institute for Petroleum and Energy Research, 1995). Most oil from the San Joaquin Basin Province contains low amounts of sulfur, where "low" is defined as less than one weight percent by Tissot and Welte (1984). Kerogen type II source rock classification for the Monterey Formation (2 diagonal lines) is from Orr (2001). Note different scale on ordinate axis in the two panels.

ples in the literature data set correlate to the three same oil types (figs. 9.8 and 9.9) defined from crude oil analyses by the USGS. Some of the data that plot somewhat outside the oil-type polygons are correlated to an oil type because the data shift likely reflects secondary alteration (for example, biodegradation) or differences in analytical methods, rather than a distinctive, unidentified oil type. A few samples (filled circles, figs. 9.8 and 9.9) fail to correlate with the oil types defined in this study.

Oil-Source Rock Correlation

Source-rock data of Curiale and others (1985) and Kaplan and others (1988) were reevaluated in the context of the oil types defined in this study. Samples with Rock-Eval hydrogen index values less than 200 mg hydrocarbons/g organic carbon or total-organic-carbon values less than 2 weight percent were excluded from evaluation because they lack the criteria needed to be considered an oil-prone source rock (see data in appendix 9.1). Samples with Rock-Eval production index greater than 0.2 or extractable organic matter greater than 20 weight percent of the total organic carbon content (Tissot and Welte, 1984) were also excluded from evaluation because they may contain migrated oil. Source rock data from Alimi and Kaplan (1997b) were not used due to suspected contamination from oil-based drilling mud (Fishburn, 1990). Biomarker data were not used for correlation due to inadequate representation of formations with source potential. Some of the formation names used by Kaplan and others (1988) were reassigned in our study (table 9.5) on the basis of regional cross sections published by the Pacific Section of the American Association of Petroleum Geologists (cited in references as PS-AAPG, 1957, 1959, 1989) and structure and isopach maps derived for this assessment (Peters, Magoon, Valin, and Lillis, this volume, chapter 11). The best quality source rock data (table 9.5) were correlated to oil data from the USGS (table 9.2) using stable carbon isotopes of the saturated and aromatic hydrocarbons and the pristane/phytane ratio. For purposes of comparison, the oil-type polygons defined by our analyses of 120 crude oil samples are superimposed on the geochemical analyses of organic matter in suspected petroleum source rocks in figures 9.10 and 9.11.

Stable carbon isotope data for source rock bitumen and oil samples show that the EK oil type correlates with the Eocene Kreyenhagen Formation, the ET oil type correlates with the Eocene Tumey formation, and the MM oil type correlates with the Miocene to Pliocene Monterey Formation and its equivalent units (specifically, the Antelope shale, Fruitvale shale of Miller and Bloom, 1939, and McLure Shale Member of the Monterey

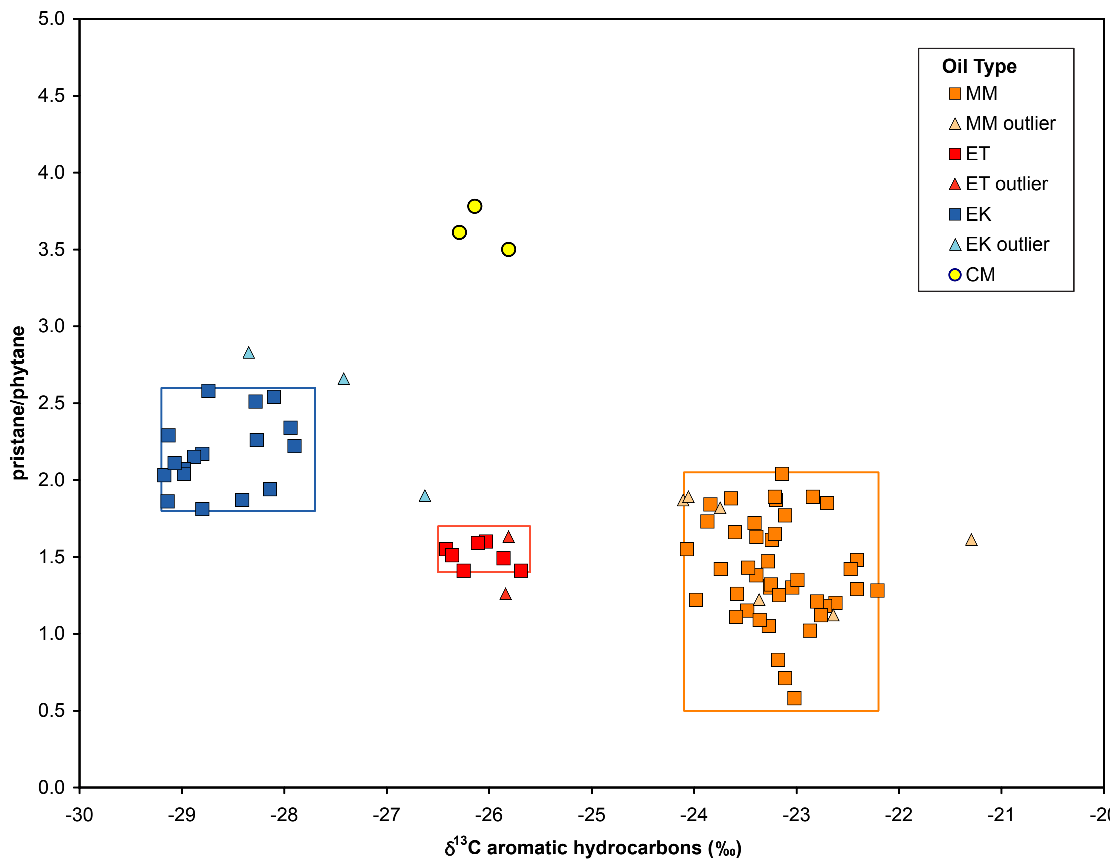

Figure 9.6. Plot of $\delta^{13}C$ aromatic hydrocarbons versus pristane/phytane ratio of oil samples from the San Joaquin Basin Province. See text for explanation of polygons. Data are from the U.S. Geological Survey (table 9.2).

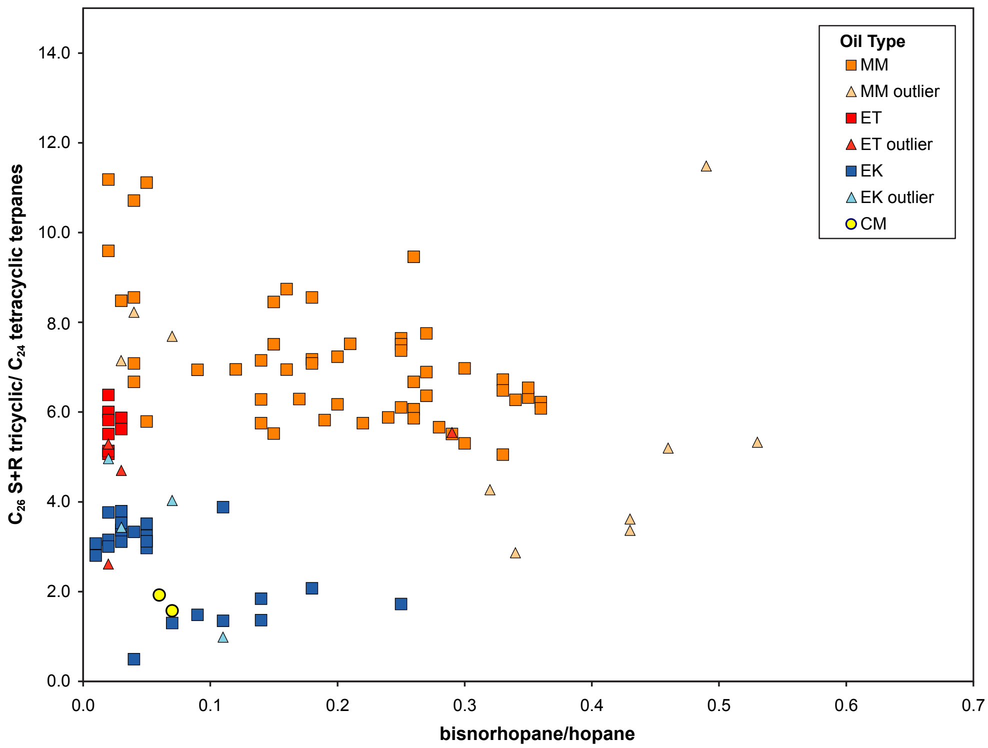

Figure 9.7. Plot of C_{28} bisnorhopane/C_{30} hopane vs. C_{26} S+R tricyclic/C_{24} tetracyclic terpanes of oil samples from the San Joaquin Basin Province. Data are from the U.S. Geological Survey (table 9.2).

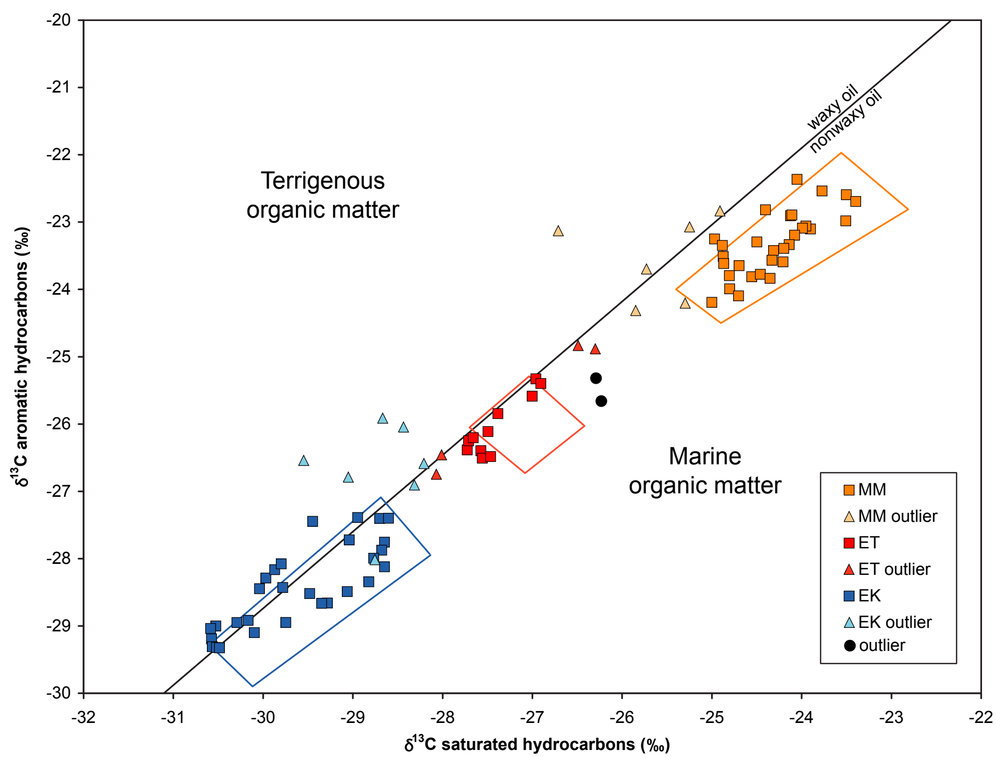

Figure 9.8. Plot of stable carbon isotope ratios ($\delta^{13}C$) of saturated and aromatic hydrocarbon fractions for oil samples from San Joaquin Basin Province. Data are from the literature (table 9.4) and oil-type polygons represent crude oil data analyses from the U.S. Geological Survey (polygons in fig. 9.5). The diagonal line separates waxy oil (terrigenous organic matter) from nonwaxy oil (marine organic matter) (Sofer, 1984).

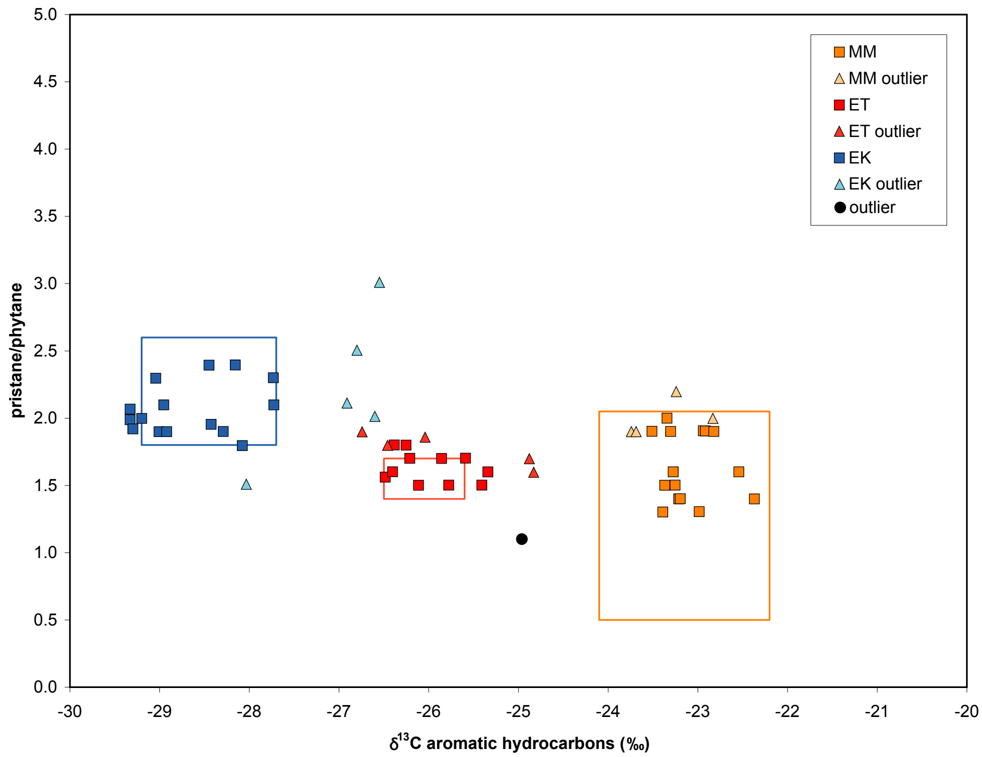

Figure 9.9. Plot of δ[13]C aromatic hydrocarbons versus pristane/phytane of oils from the San Joaquin Basin Province. Data are from the literature (table 9.4) and the oil-type polygons represent oil data from the U.S. Geological Survey (polygons from fig. 9.6).

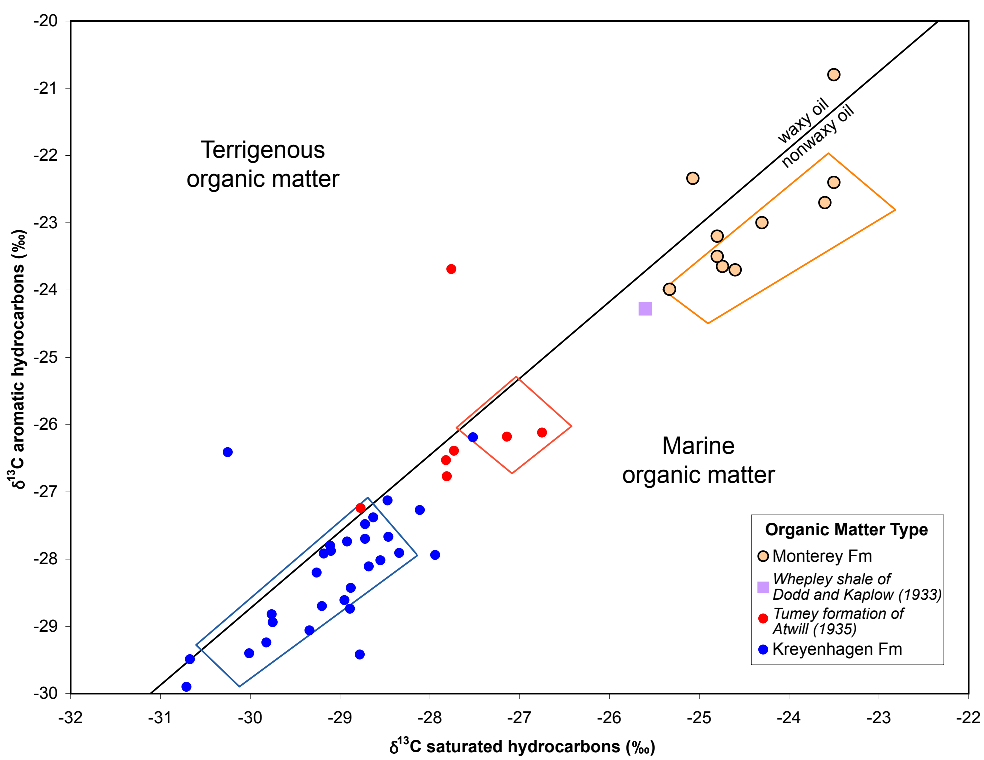

Figure 9.10. Plot of stable carbon isotope ratios (δ[13]C) of saturated and aromatic hydrocarbon fractions for source rocks from the San Joaquin Basin Province. Data are from table 9.5 and oil-type polygons represent crude oil data analyses from the U.S. Geological Survey (polygons in fig. 9.5). The diagonal line separates waxy oil (terrigenous organic matter) from nonwaxy oil (marine organic matter) (Sofer, 1984).

Formation) (fig. 9.10). However, the pristane/phytane data for the bitumen samples is of little use for correlation to the EK and ET oil types because the bitumen data from the Kreyenhagen Formation and Tumey formation overlap considerably (fig. 9.11). The bitumen data from the Monterey Formation generally have lower pristane/phytane ratios than the Kreyenhagen Formation and Tumey formation, and correlate fairly well with the MM oil type.

Monterey Formation and Kreyenhagen Formation oil-source rock correlations in the San Joaquin Basin Province have already been documented (for example, Peters and others, 1994) and are confirmed in this study. However, the proposed correlation of the ET oil type to the Tumey formation requires more discussion. The most common reservoir rocks for this oil type are sandstone beds (for example, Wygal Sandstone Member and Agua Sandstone Bed of Santos Shale Member) within the Oligocene to early Miocene Temblor Formation. Seifert (1977) first recognized the distinct chemistry of oil within the Phacoides sandstone of Curran (1943) in the Temblor Formation but failed to identify a source rock. Kaplan and others (1988) suggested that some oil produced from the Temblor Formation is either a mixture of two oil types or is derived from upper Eocene Kreyenhagen Formation, Tumey formation, or Oligocene-age source rocks. Alimi and Kaplan (1997a; 1997b) suggested that an oil sample from a deep well in Elk Hills field was generated from source rocks of Paleogene age, which might include the Tumey formation.

The most likely source of oil in Temblor Formation reservoirs would be from source rocks immediately below or interbedded within the reservoir rocks. Candidates include the Eocene Kreyenhagen Formation, Eocene Tumey formation, Oligocene to Miocene Whepley shale of Dodd and Kaplow (1933), and the shales within the Oligocene to early Miocene Temblor Formation, such as the Cymric Shale Member. We reject the possibility that the ET oil type is a mixture of EK (derived from the Kreyenhagen Formation) and MM (derived from the Monterey Formation) oil types on the basis of the geographic distribution of the three types—if ET oils were a mixture of MM and EK oils, ET oils should be found in the same pools as the MM and EK oils, which is not supported by maps of each of the oil types (figs. 9.12, 9.14, and 9.15). The Oligocene-age Whepley shale of Dodd and Kaplow (1933) is unlikely to be the source of the ET oil type (as suggested by Kaplan and others, 1988) because it is geographically restricted to a small area at Kettleman North Dome field, is likely to be thermally immature (Peters, Magoon, Lampe, and others, this volume, chapter 12), and shows more affinity with Monterey Formation organic matter

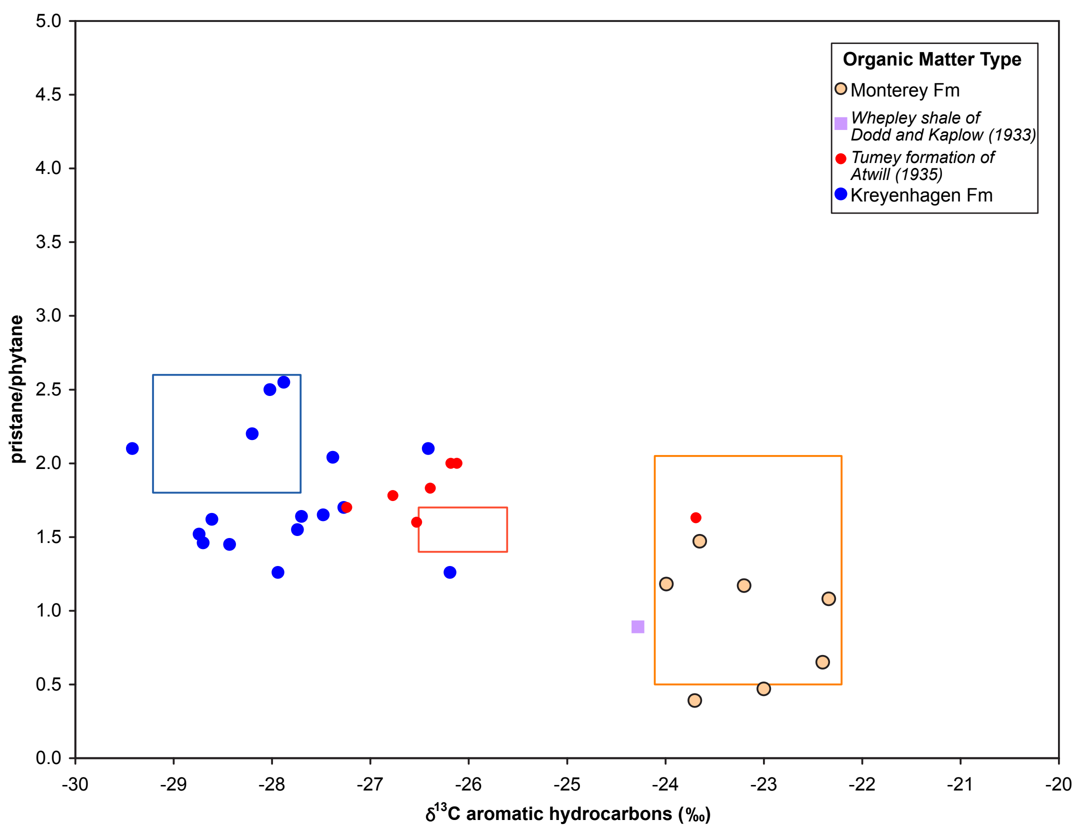

Figure 9.11. Plot of $\delta^{13}C$ aromatic hydrocarbons versus pristane/phytane of source rocks from the San Joaquin Basin Province. Data are from the table 9.5 and the oil-type polygons represent oil data from the U.S. Geological Survey (polygons in figure 9.6).

than with either of the Eocene-age source rocks (figs. 9.10 and 9.11). In summary, the Tumey formation is believed to be the most likely source of the ET oils on the basis of tentative geochemical correlations and geological considerations. Definitive conclusions await future source rock analyses.

For the CM oil type, source-rock data of Lu and Kaplan (1987), Fonseca-Rivera and Moldowan (1996), and Fonseca-Rivera (1998) were not reevaluated to correlate the crude oil samples with the Late Cretaceous to Paleocene Moreno Formation.

Geographic Distribution of Oil Types

The first step in mapping the geographic extent of a petroleum system is to identify the occurrence of similar oil

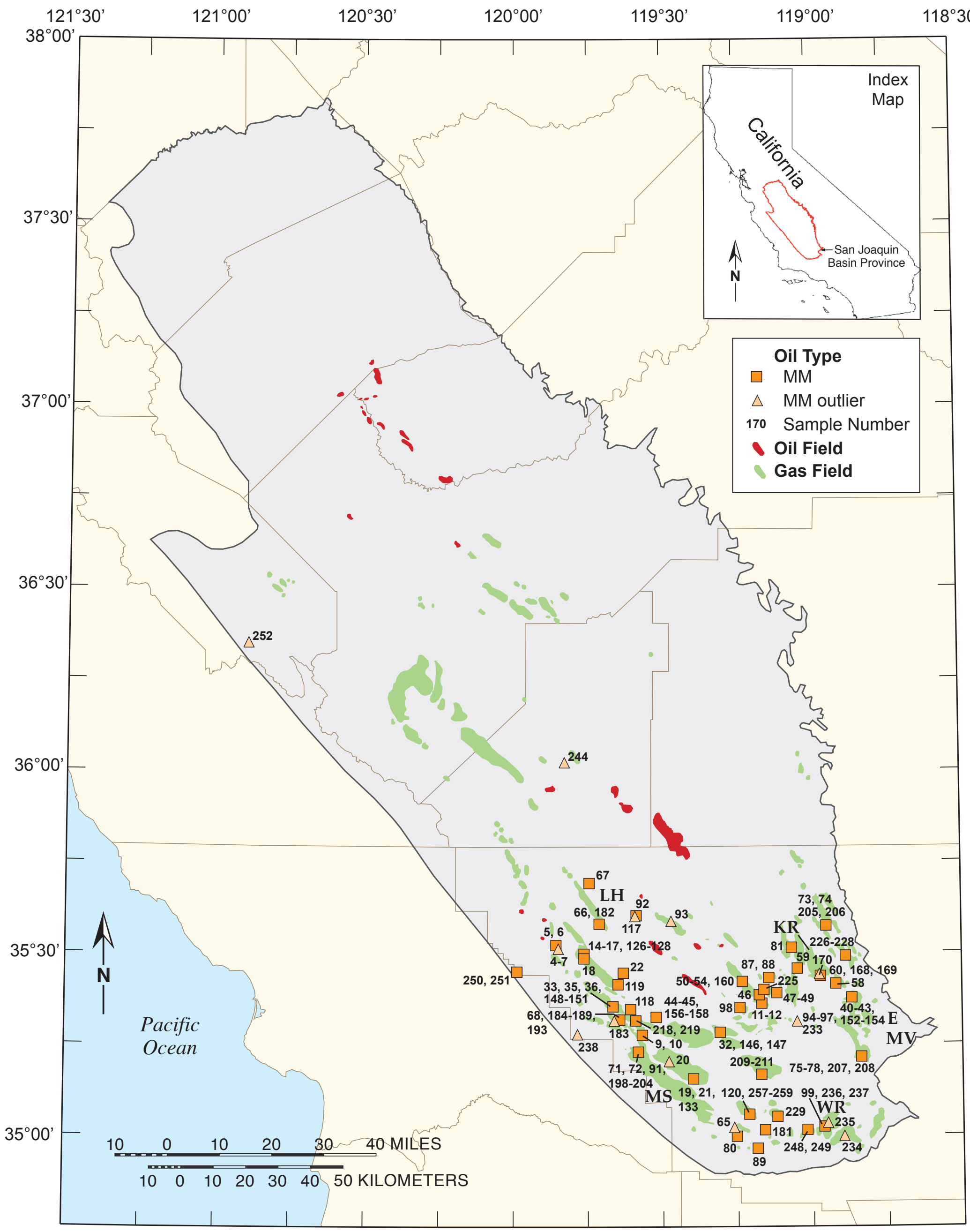

Figure 9.12. Map of the MM oil-type localities in the San Joaquin Basin Province; gray shading defines the province as used by the U.S. Geological Survey. Oil field labels are Lost Hills (LH), Midway-Sunset (MS), Kern River (KR), Wheeler Ridge (WR), Edison (E), and Mountain View (MV). Numbers adjacent to colored symbols correspond to column labeled "Oil Sample Number" in tables 9.1 through 9.4 and appendix 9.1.

types throughout a petroleum province. This helps to clarify migration networks through the country rock, effectively linking hydrocarbon source rocks with hydrocarbon reservoir rocks. We mapped the distribution of the MM, EK, and ET oil types throughout the San Joaquin Basin Province.

The MM (Miocene to Pliocene Monterey Formation) oil type is restricted to the southern end of the San Joaquin Basin Province (fig. 9.12). Most MM oil is produced from Miocene-, Pliocene-, and Pleistocene-age reservoir rocks, such as at Midway-Sunset, Lost Hills, and Kern River fields. However, along the margins of the basin, oil migrated into older rocks, including Jurassic-, Eocene-, and Oligocene-age reservoir rocks (for example, Wheeler Ridge, Edison, and Mountain View fields). Variations in organic facies of the Miocene source rock are reflected in the oil chemistry of the MM oil type. For example, some MM oil found in fields along the southern and eastern

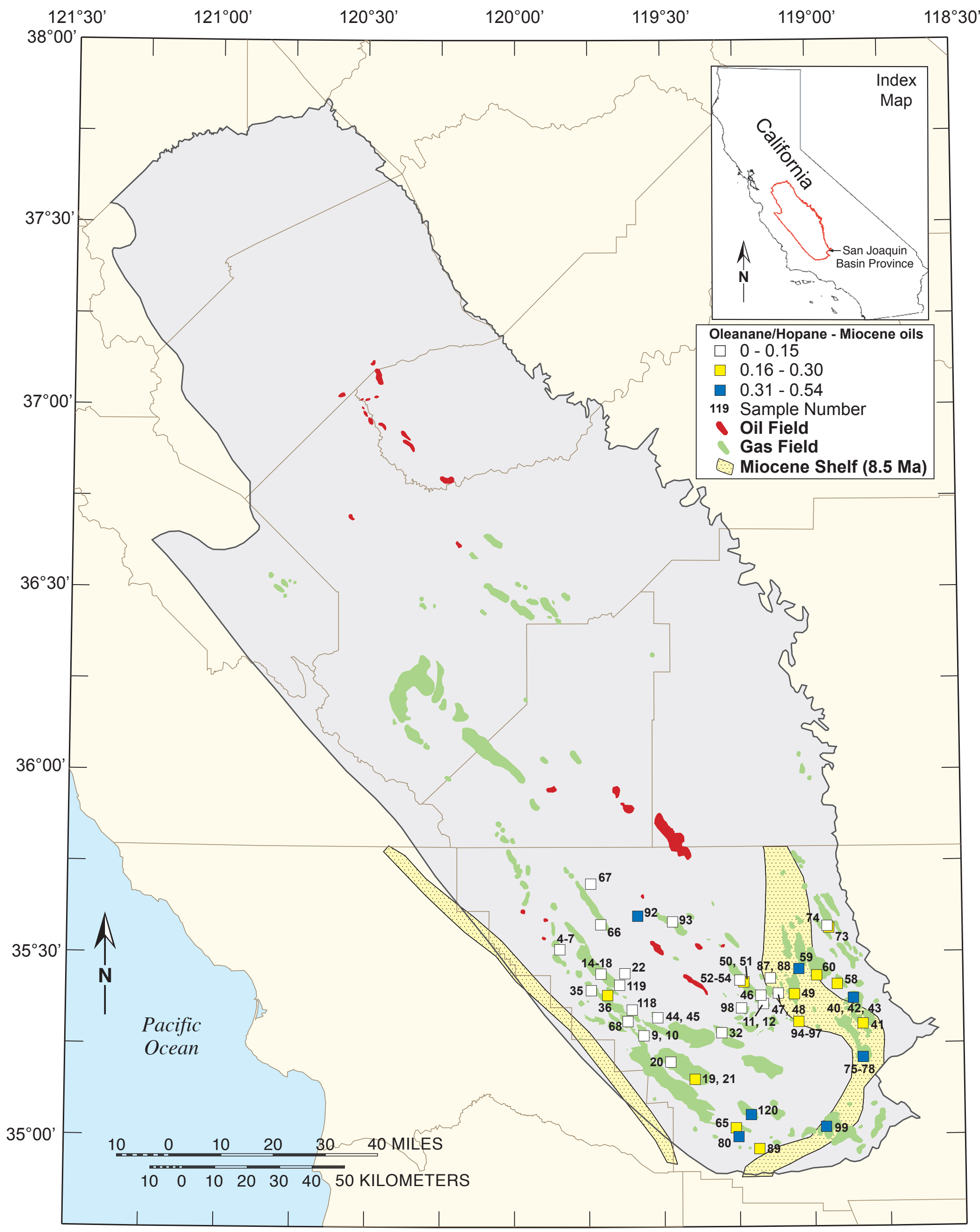

Figure 9.13. Map of the oleanane/hopane values for MM oils in the San Joaquin Basin Province; gray shading defines the province as used by the U.S. Geological Survey. Pale-yellow stippled area is the Miocene shelf (Santa Margarita Sandstone) at 8.5 Ma in the southern San Joaquin Basin Province (Reid, 1995). Numbers adjacent to colored symbols correspond to column labeled “Oil Sample Number” in tables 9.1 through 9.4 and appendix 9.1.

margins of the basin have elevated oleanane/hopane values (fig. 9.13); oleanane is a biomarker derived from angiosperms and indicates a greater contribution of terrigeneous plant material to the marine environment (Ekweozor and others, 1979; Ekweozor and Udo, 1988). Biomarker evidence thus suggests that these oils originated from a source rock that is proximal to the Miocene paleoshoreline (fig. 9.13) and received significant land-plant contribution to the marine depositional environment.

The EK oil type from the Eocene Kreyenhagen Formation is widely distributed along the western half of the basin from Paloma field in the southern San Joaquin Basin Province to Raisin City field in the north (fig. 9.14). EK oil is found predominantly in Eocene-age reservoir rocks, but is also

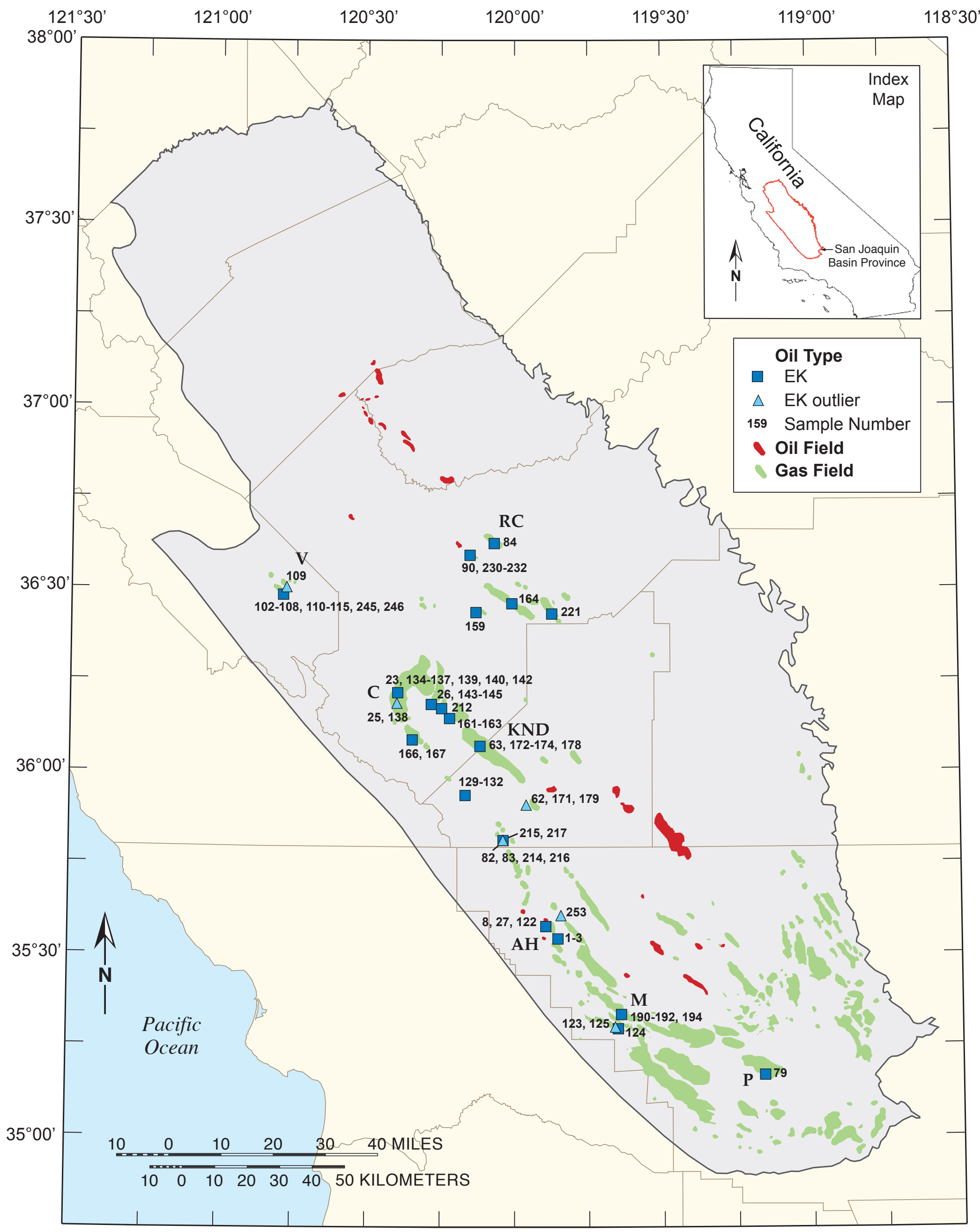

Figure 9.14. Map of the EK oil-type localities in the San Joaquin Basin Province; gray shading defines the province as used by the U.S. Geological Survey. Oil field labels are Raisin City (RC), Vallecitos (V), Coalinga (C), Kettleman North Dome (KND), Antelope Hills (AH), McKittrick (M), and Paloma (P). Numbers adjacent to colored symbols correspond to column labeled "Oil Sample Number" in tables 9.1 through 9.4 and appendix 9.1.

in Oligocene-age reservoir rocks at Antelope Hills field, Paleocene-age reservoir rocks at Vallecitos field and early Miocene-age reservoir rocks in the Coalinga area. The ET oil type from the Eocene Tumey formation is also found predominantly along the west side of the basin, but a few occurrences appear on the east side at Deer Creek and Jasmin fields (fig. 9.15). ET oil occurs mostly in Oligocene and early Miocene Temblor Formation sandstone reservoir rocks. The CM oil type, which possibly derives from the Late Cretaceous Moreno Formation, has been found only in the Oil City pool of Coalinga field, southwestern Fresno County (fig. 9.16). Although McGuire (1988) reports Moreno Formation oil at the Griswold Canyon area of Vallecitos field, San Benito County, results of this study indicate that the oil

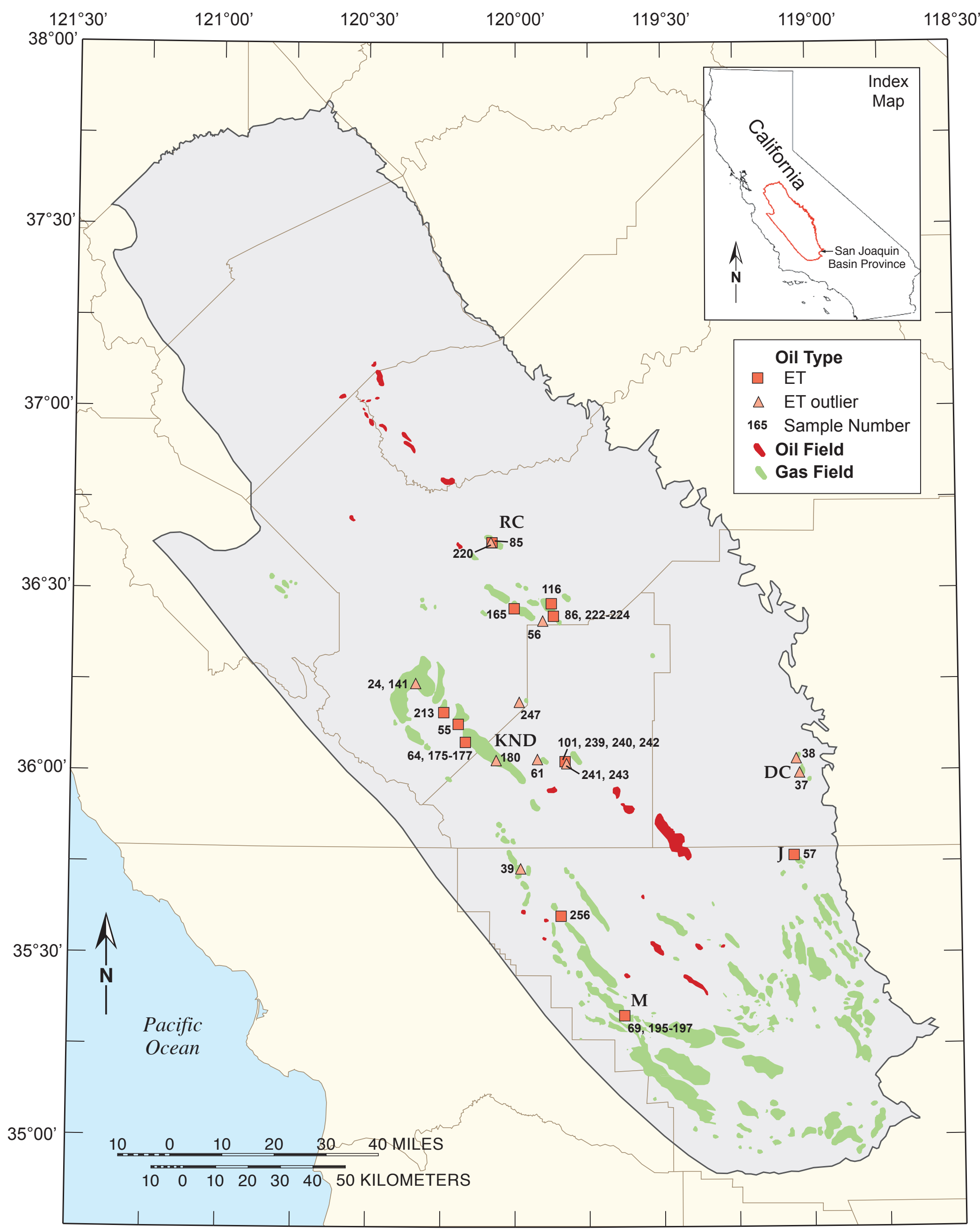

Figure 9.15. Map of the ET oil-type localities in the San Joaquin Basin Province; gray shading defines the province as used by the U.S. Geological Survey. Oil field labels are Raisin City (RC), Kettleman North Dome (KND), Deer Creek (DC), Jasmin (J), and McKittrick (M). Numbers adjacent to colored symbols correspond to column labeled "Oil Sample Number" in tables 9.1 through 9.4 and appendix 9.1.

samples at Vallecitos field are derived instead from the Kreyenhagen Formation (tables 9.1 and 9.3).

Conclusions

One-hundred and twenty crude oil samples from the San Joaquin Basin Province were analyzed by the USGS for bulk and molecular properties including API gravity, sulfur content, stable carbon isotope, and biomarker composition. The results show that there are three major oil types, which are designated MM, ET, and EK. A fourth oil type, CM, has only been found in the Oil City pool of Coalinga field. Previous studies in the literature documented only two major oil types, correlated with the Monterey Formation and Kreyenhagen Formation. The primary

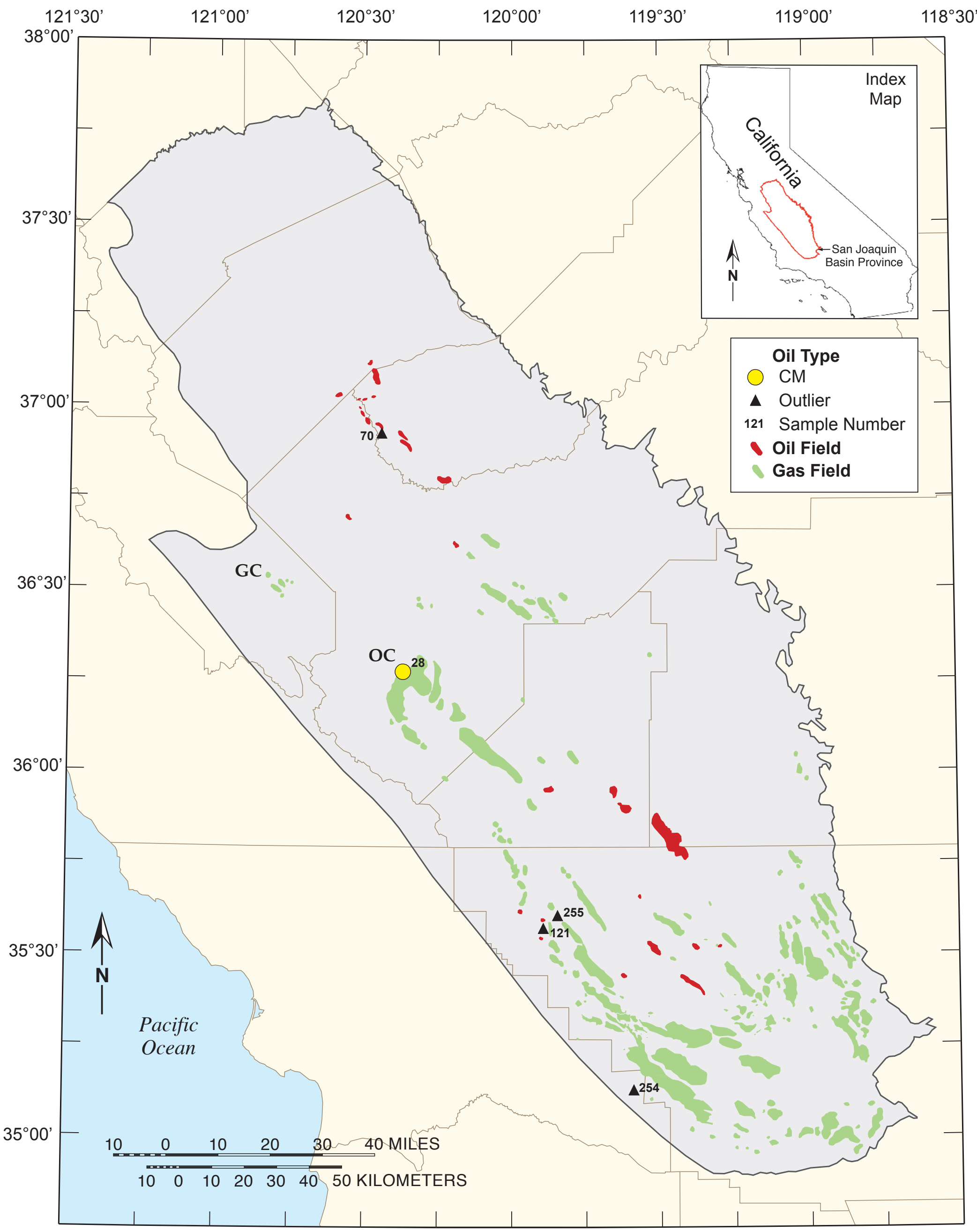

Figure 9.16. Map of the CM oil type and outlier localities in the San Joaquin Basin Province; gray shading defines the province as used by the U.S. Geological Survey. Outliers are oil samples with compositions that fail to correlate with the main oil types. Oil field labels are Oil City pool of Coalinga field (OC) and Griswold Canyon area of Vallecitos field (GC). Numbers adjacent to colored symbols correspond to column labeled "Oil Sample Number" in tables 9.1 through 9.4 and appendix 9.1.

criteria used to distinguish oil types are stable carbon isotope and pristane/phytane values. However, biomarker data are useful for correlation and reflect variations in source-rock organic facies.

Unaltered oil from the San Joaquin Basin Province generally has low to moderate sulfur content (less than 1 weight percent) and biodegraded oils have as much as 1.7 weight percent. The MM oil type generally has higher sulfur content than the EK and ET oil types, but the MM oil type lacks the sulfur content to be classified as high-sulfur (that is, derived from Type II-S kerogen). In contrast, most oil from the Monterey Formation in the Santa Maria and Santa Barbara Basins has high sulfur content (greater than 1 weight percent) and is derived from Type II-S kerogen (Orr, 2001).

USGS results from this oil study were compared with San Joaquin Basin Province oil data from the literature. Taking into account the effects of biodegradation, thermal alteration, and differences in analytical methods, the crude oil analyses derived from the literature can be correlated to the three main oil types (MM, ET and EK oil types) defined in this study. A reevaluation of source-rock data derived from the literature suggests that the source of EK oil type is the Eocene Kreyenhagen Formation, and the source of the MM oil type is the Miocene to Pliocene Monterey Formation and its equivalent units. The ET oil type is tentatively correlated to the Eocene Tumey formation. Previous studies have suggested that the CM oil type might be derived from the Moreno Formation.

Maps of the distribution of the oil types show that the MM (Miocene to Pliocene Monterey Formation) oil type is restricted to the southern third of the San Joaquin Basin Province. The composition of MM oils along the southern and eastern margins of the basin reflects the increased contribution of terrigenous organic matter to the marine basin near the Miocene paleoshoreline.

Both the EK (Eocene Kreyenhagen Formation) and ET (Eocene Tumey formation) oil types are widely distributed along the western half of the basin, and the ET oil type extends to oil fields in the central and eastern San Joaquin Basin. However, the CM (Cretaceous Moreno Formation) oil type has only been found in the Coalinga area, southwestern Fresno County. The results of this study provide the basis on which to map petroleum systems in the San Joaquin Basin Province (Magoon and others, this volume, chapter 8).

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Tables

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey.

[Oils correlated to an oil type are designated CM, EK, ET and MM. Oil samples classified with lower confidence are designated EKo, ETo and MMo. Oil samples that do not correlate to any oil type are outliers (O). Sec-Twn-Rng, location of sample in notation of public land survey system. Field, area, and pool names are designated by the State of California, Department of Conservation (CDOGGR, 1998). Formation name and reservoir rock are modified to comply with USGS geologic name standards. N/A, not applicable. --, no data available. See appendix 9.1 for more information on each sample]

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
1	Antelope Hills	Hopkins	Phacoides	Temblor Formation	Leda sand	EK	elevated sulphur content for EK oil type	Hopkins A 62X	2412-2429	31-27S-20E
2	Antelope Hills	Hopkins	Phacoides	Temblor Formation	Leda sand	EK	elevated sulphur content for EK oil type, sample analyzed twice	Hopkins A 62X	2412-2429	31-27S-20E
3	Antelope Hills	Hopkins	Point of Rocks	Kreyenhagen Formation	Point of Rocks Sandstone Member	EK	elevated sulphur content for EK oil type	Hopkins A No. 56X	2045-2132	31-27S-20E
4	Antelope Hills	Williams	Agua	Temblor Formation	Agua Sandstone Bed of Santos Shale Member	MMo	outlier isotope values	Phippen 18	2350-2460	8-28S-20E
5	Antelope Hills	Williams	Button Bed	Temblor Formation	Buttonbed Sandstone Member	MM	none	Voigt 503-6	2176-2306	6-28S-20E
6	Antelope Hills	Williams	Button Bed	Temblor Formation	Buttonbed Sandstone Member	MM	none	Williams No. 274-6	2100-2220	6-28S-20E
7	Antelope Hills	Williams	Button Bed	Temblor Formation	Buttonbed Sandstone Member	MMo	outlier isotope values	Phippen 18	2295-2460	8-28S-20E
8	Antelope Hills North	Main	Point of Rocks	Temblor Formation	Phacoides sandstone	EK	none	47X [Fussel Fee No. 2]	1560-1636	14-27S-19E
9	Asphalto	Main	Olig	Monterey Formation/Reef Ridge Shale Member	Stevens sand	MM	none	Holland 324X-36Z	4821-5447	36-30S-22E
10	Asphalto	Main	Stevens	Monterey Formation	Stevens sand	MM	none	Government Ferguson 21 [SEC 23Z 38]	approx. 5940	26-30S-22E
11	Bellevue	Main	Stevens	Fruitvale shale	Stevens sand	MM	none	Argonaut 1	8200-8500	34-29S-26E
12	Bellevue	South	Stevens	Fruitvale shale	unknown	MM	none	KCL 61 52X-10	7530-7572	10-30S-26E
13	Bellevue	South	Stevens	Fruitvale shale	unknown	--	condensate, MM oil from same well (no. 12)	KCL 61 52X-10	7530-7572	10-30S-26E
14	Belridge South	Main	Diatomite	Etchegoin Formation/Reef Ridge Shale Member of Monterey Formation	unknown	MM	none	Sec 33 577CR-33	775-2615	33-28S-21E
15	Belridge South	Main	Diatomite	Reef Ridge Shale Member of Monterey Formation	Belridge Diatomite Member	MM	none	Belridge V 7384B-2	1420-2700	2-29S-21E
16	Belridge South	Main	Etchegoin	Etchegoin Formation/Reef Ridge Shale Member of Monterey Formation	unknown	MM	none	Sec 29 573-29	1490-2390	29-28S-21E
17	Belridge South	Main	Etchegoin	Monterey Formation/Reef Ridge Shale Member/Etchegoin Formation	unknown	MM	none	Sebu T 7624-1	1195-3020	1-29S-21E

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
18	Belridge South	Main	Etchegoin	Tulare and Etchegoin Formations	Etchegoin Formation	MM	none	Sec 13 88-A	0-1500	13-28S-20E
19	Buena Vista	Buena Vista Hills	Antelope Shale-East Dome	Monterey Formation	Antelope shale	MM	none	SEC 9D 555	4900-5100	9-32S-24E
20	Buena Vista	Buena Vista Hills	Antelope Shale-West Dome	Monterey Formation	unknown	MMo	outlier (high) bisnorhopane value	Crimson 523	4000-5000	26-31S-23E
21	Buena Vista	Buena Vista Hills	Calitroleum	Etchegoin Formation	unknown	MM	none	Crimson Sec 25B 1-7A	2900-3390	25-31S-23E
22	Cal Canal	Main	Stevens	Monterey Formation	Stevens sand	MM	biomarkers lean, mixed charge? from same source	Pierson Fee 11, 12, 13, 14 Mix	10700-11927	32-28S-22E
23	Coalinga	N/A	undesignated	Kreyenhagen Formation (?)	unknown	EK	oil from abandoned well north of main field	Rock	shallow	20-19S-15E
24	Coalinga	Main (eastside)	Temblor	Temblor Formation	unknown	ETo	outlier saturated isotope value	Coalinga 45-27	1122-1724	27-19S-15E
25	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EKo	biodegradation altered isotopes and biomarkers, outlier isotope values	Sec 13D 122	approx. 1350	13-20S-14E
26	Coalinga East Extension	Coalinga Nose	Gatchell	Lodo Formation	Gatchell sand	EK	none	Coalinga Nose Unit 26-31B	7695-8040	31-19S-16E
27	Coalinga seep	N/A	undesignated	Lodo Formation (?)	unknown	EK	north of field	Coalinga seep	surface	20-19S-15E
28	Coalinga	Main (Oil City)	Cretaceous	Moreno Formation	unknown	CM	none	Coast Range 1	521-572	17-19S-15E
29	Coalinga	Main (Oil City)	Cretaceous	Moreno Formation	unknown	CM	none	Coast Range 1	521-572	17-19S-15E
30	Coalinga	Main (Oil City)	Cretaceous	Moreno Formation	unknown	CM	abandoned well; collected from vertical string	Coast Range 15	shallow	17-19S-15E
31	Coalinga	Main (Oil City)	Cretaceous	Moreno Formation	unknown	CM	Implied Moreno Formation source rock (Peters and others, 1994)	SEC 20A 4	approx. 800	20-19S-15E
32	Coles Levee, North	Main	Stevens	Monterey Formation	Stevens sand	MM	none	Coles Levee A 78-29	approx. 7484	29-30S-25E
33	Cymric	Welport (1-Y)	undesignated	Etchegoin Formation	unknown	MM	biodegradation affects biomarker interpretation	Sec 1Y 1401E	501-760	1-30S-21E
34	Cymric	Salt Creek	Carneros	Temblor Formation	Carneros Sandstone Member	--	nickel and vanadium data only	Anderson 74A-19W	1414-1898	19-29S-21E
35	Cymric	Sheep Springs	Carneros	Temblor Formation	Carneros Sandstone Member	MM	none	Anderson 37W [17W]	approx. 3500	17-29S-21E
36	Cymric	Welport	Phacoides	Temblor Formation	Phacoides sandstone	MM	biomarker composition indicates mixture or MM outlier	Sauer Dough 25	approx. 5800	23-29S-21E
37	Deer Creek	Main	Santa Margarita	Santa Margarita Sandstone	Santa Margarita Sandstone	ETo	heavy biodegradation affects biomarker interpretation	Rhodes 1	713-914	22-22S-27E
38	Deer Creek, North	Main	Santa Margarita	Santa Margarita Sandstone	unknown	ETo	heavy biodegradation affects biomarker interpretation	Karen 2	881-1000	10-22S-27E

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
39	Devils Den	Old	Cymric (Salt Creek)	Temblor Formation	Carneros Sandstone Member	ETo	outlier (high) bisnorhopane value	D&M Unit 7 (K&M Oil 1)	approx. 610	24-25S-18E
40	Edison	Edison Groves	Kern River-Chanac	Chanac Formation	unknown	MM	elevated terrigenous organic matter	Ryan-Brown 4B	approx. 800	28-29S-29E
41	Edison	Main	Kern River-Chanac	Kern River Formation	lower Kern River Formation	MM	elevated terrigenous organic matter	Young Fee Dos Tres 72	1961-2192	23-30S-29E
42	Edison	Main	Schist	schist	unknown	MM	elevated terrigenous organic matter	Young Fee 13	2050-2200	23-30S-29E
43	Edison	Main	Schist	schist	unknown	MM	elevated terrigenous organic matter	CORP FEE 35	1336-1833	13-30S-29E
44	Elk Hills	Main	undesignated	Monterey Formation	Stevens sand	MM	none	UONPR NO. 1 371-17R	10011-10023	17-30S-23E
45	Elk Hills	Main	Mulinia	Etchegoin Formation	unknown	MM	none	UONPR NO. 1 81NE-9G	2812-2849	9-31S-24E
46	English Colony	Main	Stevens (28-22)	Fruitvale shale	Stevens sand/28-22 sand	MM	none	Kern County Lease 28-22	6924-6950	22-29S-26E
47	Fruitvale	Green Acres	Chanac	Chanac Formation	unknown	MM	none	Billington 2	approx. 4400	19-29S-27E
48	Fruitvale	Main	Kernco	Chanac Formation	Chanac Formation	MM	suspect sulphur value (too low; should be about 1% S)	Kern County Lease B 30	unknown	14-29S-27E
49	Fruitvale	Main	Kernco	Chanac Formation	Chanac Formation	MM	none	Hensley No. 1	approx. 4300	22-29S-27E
50	Greeley	Main	Olcese 12-21	Freeman Silt-Jewett Sand	unknown	MM	none	KCL 51 114-7	10260-10652	7-29S-26E
51	Greeley	Main	Rio Bravo-Vedder	Freeman Silt-Jewett Sand	unknown	MM	none	KCL 12 8	11234-11327	7-29S-26E
52	Greeley	Main	Rio Bravo-Vedder	Freeman Silt-Jewett Sand	Rio Bravo sand	MM	none	Lewis 4	approx. 11000	12-29S-25E
53	Greeley	Main	Stevens	Fruitvale shale	Stevens sand	MM	none	KCL 63 43-20	8677-9143	20-29S-26E
54	Greeley	Main	Stevens	Fruitvale shale	Stevens sand	MM	none	Kern County Land 11A-56	approx. 7800	19-29S-26E
55	Guijarral Hills	Polvadero	Sanger	Temblor Formation	Sanger sand	ET	none	Bourdieu 45-1	approx. 8300	1-21S-16E
56	Helm	Main	Zilch (Miocene)	Zilch formation	Zilch formation	ETo	low confidence in source, condensate, outlier (high) pristane/phytane value	Covey 3X	7057-7061	33-17S-19E
57	Jasmin	Main	Cantleberry sands	Vedder Sand	Cantleberry sand	ET	possibly some MM oil mixed	Quinn 14-10	2823-2852	10-25S-27E
58	Kern Bluff	Main	Santa Margarita	Santa Margarita Sandstone	unknown	MM	elevated terrigenous organic matter	Vedder Parkford USL 14	1066-1109	12-29S-28E
59	Kern Front	Main	Etchegoin-Chanac	Chanac Formation	Chanac Formation	MM	biodegradation affects biomarker interpretation	Fee 10-11	approx. 2700	27-28S-27E
60	Kern River	Main	Kern River	Kern River Formation	unknown	MM	elevated terrigenous organic matter	San Joaquin Fee 769	380-750	5-29S-28E
61	Kettleman City	Main	Temblor-Vaqueros	Temblor Formation	unknown	ETo	outlier (low) pristane/phytane value	Davis 1	approx. 14000	9-22S-19E

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
62	Kettleman Middle Dome	Main	Kreyenhagen	Kreyenhagen Formation	unknown	EKo	EK biomarkers, outlier isotope values	KMDC 38-19V	11152-11471	19-23S-19E
63	Kettleman North Dome	Main	Lower McAdams	Lodo Formation	lower McAdams sandstone	EK	none	Kettleman N Dome Unit 324-21J	approx. 12000	21-21S-17E
64	Kettleman North Dome	Main	Temblor	Temblor Formation	Temblor zone III	ET	none	Kettleman North Dome Unit 78-19J	approx. 7800	19-21S-17E
65	Los Lobos	Main	Reef Ridge	Reef Ridge Shale	unknown	MMo	outlier (high) bisnorhopane value, elevated terrigenous organic matter	San Emidio A 76-19	approx. 6900	19-11N-22W
66	Lost Hills	Main	Cahn	Monterey Formation	Cahn zone	MM	none	Monte Cristo 16 174I	4546-4782	16-27S-21E
67	Lost Hills	East	undesignated	Temblor Formation	Gibson sand	MM	higher uncertainty in oil type because high maturity and no biomarkers	Berkeley 1	19370-19698	6-26S-21E
68	McKittrick	Northeast	Antelope	Monterey Formation	Antelope shale	MM	none	Spreckles Sec 16Z 326	3985-5350	16-30S-22E
69	McKittrick	Northeast	Wygal (Phacoides)	Temblor Formation	Phacoides sandstone	ET	none	McKittrick Sec 8Z 65X-2	9058-9074	8-30S-22E
70	Merrill Avenue, Southeast	Main	Blewett	Blewett sands	Blewett sands	O	isotopes similar to EK oil type, outlier biomarker composition	Triangle-T 1-33	6220-6243	33-11S-14E
71	Midway-Sunset	Main	Potter	Reef Ridge Shale Member of Monterey Formation	Potter sand	MM	and nondegraded n-alkanes indicate mixed charge	Shale 284-D	1516-1690	14-31S-22E
72	Midway-Sunset	Main	Tulare	Tulare Formation	unknown	MM	biodegradation affects biomarker interpretation	SEC 25A 3	approx. 1000	25-31S-22E
73	Mount Poso	Dorsey	Vedder	Vedder Sand	unknown	MM	none	Glide 15 15-5	approx. 1600	15-27S-28E
74	Mount Poso	Dorsey	Vedder	Vedder Sand	unknown	MM	none	Glide 15 tank	approx. 1600	15-27S-28E
75	Mountain View	Arvin	Chanac	Chanac Formation	unknown	MM	elevated terrigenous organic matter	Jewett 1-23	5696-6418	23-31S-29E
76	Mountain View	Arvin	Schist	schist	unknown	MM	elevated terrigenous organic matter	Stockton 3	5605-6140	25-31S-29E
77	Mountain View	Main	Nicols	Chanac Formation	unknown	MM	elevated terrigenous organic matter	Abadie 1	approx. 4500	13-30S-28E
78	Mountain View	Vaccaro	Cattani (upper Miocene)	Chanac Formation	unknown	MM	elevated terrigenous organic matter	Simpson 1	6930-7013	26-31S-29E
79	Paloma	Main	undesignated	Temblor Formation	Carneros Sandstone Member	EK	source based on saturated isotopes and high maturity, collected as condensate	Paloma 28X-2	approx. 18300	2-32S-26E
80	Pioneer	Main	Pioneer	Temblor Formation	first Pioneer sand	MM	elevated terrigenous organic matter	Kern County Lease 44 34	2995-4030	32-11N-22W
81	Poso Creek	Premier	Basal Etchegoin	Etchegoin Formation	basal sand of Etchegoin Formation	MM	biodegradation affects biomarker interpretation	Premier 8-1	2265-2340	9-28S-27E

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
82	Pyramid Hills	Norris	Eocene	Kreyenhagen Formation	unknown	EKo	high maturity oil, outlier aromatic isotope, C26tet, and pristane/phytane values	Norris-Drilexico-Hand 15	3542-3600	28-24S-18E
83	Pyramid Hills	Norris	KR (Point of Rocks sand)	Kreyenhagen Formation	Point of Rocks Sandstone Member	EKo	isotopes altered by maturity, biodegradation, biomarkers like EK	Norris-Drilexico-Hand 1-9-28	850-883	28-24S-18E
84	Raisin City	Main	Eocene	Kreyenhagen Formation	unknown	EK	none	Ripperdan 56-13	6174-6300	13-15S-17E
85	Raisin City	Main	Eocene	Kreyenhagen Formation (or Zilch formation)	unknown	ET	suspected producing unit is actually Miocene Zilch formation	Surfluh 1	6104-6306	13-15S-17E
86	Riverdale	Main	Zilch	Zilch formation	unknown	ET	none	Robertson/Stockdale 2-26	6638-6642	26-17S-19E
87	Rosedale Ranch	Main	Lerdo	Etchegoin Formation	unknown	MM	none	KCL 31 16-1	4190-4328	1-29S-26E
88	Rosedale Ranch	Main	Lerdo	Etchegoin Formation	Lerdo zone	MM	none	Kern County Land Lease 31-12 [-1]	4194-4353	12-29S-26E
89	San Emigdio Creek	Main	Eocene (27-12)	Tejon Formation	Tejon Formation	MM	elevated terrigenous organic matter	Kern County Lease 27-12	8675-8690	12-10N-22W
90	San Joaquin	Main	Eocene	Domengine Formation	Domengine Formation	EK	none	Schramm 71	approx. 7800	31-15S-17E
91	Seep 4-21A	N/A	undesignated	unknown	unknown	MM	south end of Midway-Sunset field, biomarkers altered	seep	surface	20-11N-23W
92	Semitropic	N/A	undesignated	unknown	unknown	MM	elevated terrigenous organic matter	EKHO 1	> 17000	3-27S-22E
93	Semitropic	Main	Randolph	Etchegoin Formation	Randolph sand	MMo	outlier isotope values	Community 1	7500-8000	14-27S-23E
94	Stockdale	Panama Lane	Nozu	Round Mountain Silt	unknown	MMo	low maturity biomarkers, outlier (low) C26tet value	Panama 2-14	11073-11140	14-30S-27E
95	Stockdale	Panama Lane	Nozu	Round Mountain Silt	unknown	MMo	low maturity biomarkers, outlier (high) bisnorhopane and (low) C26tet values	Panama 2-15	11150-11250	15-30S-27E
96	Stockdale	Panama Lane	Nozu	Round Mountain Silt	unknown	MMo	outlier (high) bisnorhopane and (low) C26tet values	Panama 3-15	11035-11170	15-30S-27E
97	Stockdale	Panama Lane	Nozu	Round Mountain Silt	unknown	MMo	well, suspect sulphur content, outlier (low) C26tet value	Panama (Condensate) 3-15;2-15; 2-14	11035-11170	15-30S-27E
98	Strand	Northwest	Lower Stevens	Fruitvale shale	Stevens sand	MM	none	Kern County Lease 56 53-1	9924-9977	1-30S-25E
99	Tejon, North	Main	Metralla	Tejon Formation or Vedder Sand or both	unknown	MM	elevated terrigenous organic matter	KCL-G North 65-24	8475-10,695	24-11N-20W
100	Tulare Lake	Main	undesignated	Lodo Formation	Gatchell sand	--	sample is solid and not soluble in solvent	KCDC 71-17	14633-14995	17-22S-20E

Table 9.1. Oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments[3]	Well Name	Depth (ft)	Sec-Twn-Rng
101	Tulare Lake	Main	54-8M	Temblor Formation	lower Burbank sand	ET	none	Salyer 665-X	13172-13172	8-22S-20E
102	Vallecitos	Ashurst	Domengine-Yokut	Yokut Sandstone	unknown	EK	none	Bunker 34-4	unknown	34-16S-11E
103	Vallecitos	Cedar Flat	San Carlos	Lodo Formation	San Carlos sand	EK	none	Ashurst 2	unknown	27-16S-11E
104	Vallecitos	Central	Ashurst	Kreyenhagen Formation	Ashurst sand	EK	none	Ashurst 1A-5	5355-5380	5-17S-11E
105	Vallecitos	Central	Ashurst	Kreyenhagen Formation	Ashurst sand	EK	none	Ashurst 43-5	5370-5385	5-17S-11E
106	Vallecitos	Central	Yokut	Yokut Sandstone	unknown	EK	none	F & I 37-31	unknown	31-16S-11E
107	Vallecitos	Franco	Yokut	Yokut Sandstone	unknown	EK	none	Bryant-U S L 16A-28	unknown	28-16S-11E
108	Vallecitos	Franco	Yokut	Yokut Sandstone	unknown	EK	none	Bryant-U S L 16A-28	unknown	28-16S-11E
109	Vallecitos	Franco	Yokut	Yokut Sandstone	unknown	EKo	outlier (high) pristane/phytane value	Ashurst 38-28	unknown	28-16S-11E
110	Vallecitos	Griswold Canyon	Moreno	Moreno Formation	unknown	EK	none	Olson-McDonald 1	unknown	19-16S-11E
111	Vallecitos	Griswold Canyon	San Carlos	Lodo Formation	San Carlos sand	EK	none	Panoche 1	unknown	24-16S-10E
112	Vallecitos	Los Pinos Canyon	Kreyenhagen	Kreyenhagen Formation	unknown	EK	none	Cal-O-Tex Exploration Co. 1	approx. 1957	8-17S-11E
113	Vallecitos	Silver Creek	San Carlos	Lodo Formation	San Carlos sand	EK	sample from stock tank from several shut-in wells	Ash 1,2,3,5,6,9	1165-1201	28-16S-12E
114	Vallecitos	Silver Creek	San Carlos	Lodo Formation	San Carlos sand	EK	none	Ash 6	approx. 1130	28-16S-12E
115	Vallecitos	Silver Creek	San Carlos	Lodo Formation	San Carlos sand	EK	none	Nicholas 5	1270-1280	28-16S-12E
116	Van Ness Slough	Main	Zilch	Zilch formation	Zilch formation	ET	none	Kleinhammer 1	approx. 6900	11-17S-19E
117	Wildcat well	N/A	undesignated	unknown	unknown	MMo	outlier isotope values, high maturity affects biomarker interpretation	Great Basins 31X-10	17248-17728	10-27S-22E
118	Wildcat well	N/A	undesignated	unknown	unknown	MM	none	SEC 4Z 385X	8750-8995	4-30S-22E
119	Wildcat well	N/A	undesignated	unknown	Devilwater Shale Member & Gould Shale Member	MM	none	SMUG 528-7X	10412-10852	7-29S-22E
120	Yowlumne	Main	10-4 (Stevens)	Monterey Formation	Yowlumne sand	MM	elevated terrigenous organic matter	Potter Fee 4	approx. 11500	10-11N-22W

[1] Informally described formation names: Fruitvale shale of Miller and Bloom (1939), Zilch formation of Loken (1959), and Blewett sands of Hoffman (1964).

[2] Informally described reservoir rocks: Leda sand of Sullivan (1963), Phacoides sandstone of Curran (1943), Stevens sand of Eckis (1940), Antelope shale of Graham and Williams (1985), Gatchell sand of Goudkoff (1943), 28-22 sand of Hluza (1964), Rio Bravo sand of Noble (1940), Sanger sand of Sullivan (1963), Zilch formation of Loken (1959), Cantleberry sand of Hluza (1959), McAdams sandstone of Sullivan (1963), Temblor zone III of Sullivan (1966), Cahn zone of Hardoin (1964), Gibson sand of Williams (1938), Blewett sands of Hoffman (1964), Potter sand of Callaway (1962), first Pioneer sand of Barnes (1961), Lerdo zone of Betts (1955), Randolph sand of Mitchell and Chamberlain (1983), Burbank sand of Sullivan (1966), San Carlos sand of Wilkinson (1960), Ashurst sand of Wilkinson (1960), and Yowlumne sand of Metz and Whitworth (1984).

[3] Informally described formation name: Zilch formation of Loken (1959).

Table 9.2. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey.

[Additional sample information is given in table 9.1. USGS Lab. Number, analysis number for U.S. Geological Survey Organic Geochemistry Laboratory, Denver, Colorado; $\delta^{13}C_{sat}$ and $\delta^{13}C_{sat}$ are in per mil relative to the Peedee belemnite (PDB) standard; CV, canonical variable defined as $-2.53\delta^{13}C_{sat} + 2.22\delta^{13}C_{aro} - 11.65$, where sat is saturated hydrocarbons and aro is aromatic hydrocarbons (Sofer, 1984); Gravity, oil gravity in degrees API; Pr/Ph= pristane/phytane; CPI=carbon preferential index (Hunt, 1979, p. 303); V and Ni, vanadium and nickel concentration in ppm (w/w); Sat/Aro = saturated/aromatic hydrocarbons; Bisnorhopane = 28,30 bisnorhopane/C_{30} hopane; C_{26}Tet= C_{26} R+S tricyclic terpane/C_{24} tetracyclic terpane, Oleanane, oleanane/C_{30} hopane. Biodegradation is defined as: mild, n-alkanes are reduced in concentration or not present; moderate, acyclic isoprenoids (pristane and phytane) are reduced in concentration or not present; heavy, C_{30} to C_{35} hopanes or regular steranes appear altered; severe, C_{30} to C_{35} hopanes and regular steranes are severely depleted or not present. --, no data available]

Oil Sample Number	Field or Seep Name	USGS Lab. Number	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	CV	Gravity (degrees)	Sulfur (weight percent)	Bio-degradation	Pr/Ph	CPI	V	Ni	Sat/Aro	Bisnor-hopane	C_{26}Tet	Oleanane
1	Antelope Hills	98018005	-29.06	-28.14	-0.60	31.4	0.52	none	1.94	1.08	9	39	2.9	0.01	3.07	0.12
2	Antelope Hills	00049052	-29.23	-28.41	-0.77	32.1	0.66	none	1.87	1.13	4	9	3.0	0.02	3.15	0.10
3	Antelope Hills	98018006	-29.20	-28.93	-2.00	13.0	0.99	moderate	--	--	12	40	1.6	0.01	2.80	0.11
4	Antelope Hills	00049055	-23.02	-22.31	-2.94	19.1	0.48	moderate	--	--	--	--	3.0	0.03	7.14	0.14
5	Antelope Hills	00049054	-23.91	-23.13	-2.51	15.9	0.54	heavy	--	--	4	18	2.3	0.03	8.48	0.12
6	Antelope Hills	00049053	-24.00	-23.54	-3.19	16.5	0.45	heavy	--	--	--	--	1.8	0.04	8.55	0.13
7	Antelope Hills	98018001	-22.99	-22.34	-3.08	19.7	0.59	moderate	--	--	--	--	1.8	0.04	8.22	0.15
8	Antelope Hills North	98018003	-28.43	-27.75	-1.33	13.5	0.97	moderate	--	--	--	--	1.6	0.02	3.00	0.11
9	Asphalto	00049004	-24.41	-23.58	-2.24	24.7	0.88	mild	1.26	--	--	--	2.3	0.27	6.36	0.10
10	Asphalto	00049003	-24.50	-23.48	-1.79	27.0	0.97	none	1.15	1.07	45	37	2.5	0.34	6.27	0.12
11	Bellevue	00049005	-24.33	-23.26	-1.73	32.5	0.59	none	1.31	1.05	--	--	2.6	0.30	6.97	0.14
12	Bellevue	02026011	-24.14	-23.04	-1.72	33.2	0.47	none	1.30	1.05	--	--	3.7	0.26	6.67	0.12
13	Bellevue	02026012	--	--	--	60.6	0.16	none	--	--	--	--	--	0.22	2.45	0.15
14	Belridge South	02026034	-23.58	-22.64	-2.25	24.4	0.87	moderate	--	--	--	--	2.5	0.33	6.72	0.08
15	Belridge South	02026033	-23.56	-22.62	-2.26	29.2	0.95	mild	1.20	--	--	--	1.7	0.36	6.22	0.08
16	Belridge South	02026035	-24.21	-23.11	-1.70	18.1	1.33	moderate	0.71	--	--	--	1.5	0.35	6.32	0.06
17	Belridge South	02026032	-23.96	-23.01	-2.11	18.6	1.16	heavy	--	--	--	--	1.7	0.35	6.54	0.07
18	Belridge South	94048001	-23.13	-22.59	-3.28	15.5	0.81	moderate	--	--	40	65	1.8	0.16	6.94	0.06
19	Buena Vista	00049008	-24.34	-23.26	-1.71	31.9	0.64	none	1.30	1.10	--	--	2.3	0.19	5.82	0.16
20	Buena Vista	02026030	-24.41	-23.66	-2.42	22.9	1.01	moderate	--	--	--	--	0.5	0.46	5.19	0.14
21	Buena Vista	02026031	-23.96	-23.28	-2.71	27.0	0.86	mild	1.47	--	--	--	2.7	0.36	6.08	0.18
22	Cal Canal	00049010	-23.69	-22.21	-1.02	38.6	0.13	none	1.28	1.07	--	--	4.8	0.25	7.64	0.12
23	Coalinga	02026047	-29.16	-28.27	-0.63	14.0	0.84	heavy	--	--	--	--	1.8	0.03	3.79	0.26
24	Coalinga	02026003	-26.54	-25.81	-1.80	21.5	0.55	mild	1.63	--	--	--	2.4	0.03	4.70	0.16

Table 9.2. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	USGS Lab. Number	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	CV	Gravity (degrees)	Sulfur (weight percent)	Bio-degradation	Pr/Ph	CPI	V	Ni	Sat/Aro	Bisnor-hopane	C_{26}Tet	Oleanane
25	Coalinga	94048002	-27.85	-27.46	-2.15	19.3	0.76	heavy	--	--	7	24	1.0	6.01	3.51	2.21
26	Coalinga East Extension	02026004	-29.91	-28.80	0.09	34.0	0.30	none	2.17	1.05	--	--	3.0	0.03	3.37	0.09
27	Coalinga seep	02026001	-29.11	-28.54	-1.36	--	0.79	heavy	--	--	--	--	2.0	0.11	3.88	0.76
28	Coalinga	02018007	--	-25.81	--	30.8	0.15	none	3.50	--	2	6	--	--	--	--
29	Coalinga	02026045	-27.06	-26.14	-1.22	29.7	0.08	none	3.78	1.07	--	--	6.1	0.06	1.92	0.06
30	Coalinga	02026002	-26.89	-26.29	-1.98	26.7	0.10	none	3.61	1.06	--	--	7.3	0.07	1.57	0.06
31	Coalinga	02018008	-27.72	-25.20	2.54	33.0	0.13	none	--	--	1	1	--	--	--	--
32	Coles Levee, North	00049012	-24.54	-23.39	-1.49	38.6	0.39	none	1.38	1.08	8	18	3.2	0.14	6.28	0.11
33	Cymric	00049014	-24.47	-23.92	-2.84	20.8	1.34	severe	--	--	71	56	1.7	3.26	6.58	3.56
34	Cymric	02018012	--	--	--	--	--	--	--	--	9	6	--	--	--	--
35	Cymric	00049013	-23.64	-22.99	-2.88	19.7	0.60	mild	1.35	1.09	6	44	3.1	0.20	7.23	0.14
36	Cymric	94048003	-25.26	-24.07	-1.18	34.0	0.54	none	1.55	1.03	2	8	2.1	0.04	7.08	0.16
37	Deer Creek	00047009	-26.32	-25.58	-1.85	22.6	0.13	heavy	--	--	--	--	2.6	1.16	10.05	3.54
38	Deer Creek, North	02026027	-26.65	-25.67	-1.21	14.4	0.56	heavy	--	--	--	--	2.3	2.01	7.84	4.17
39	Devils Den	00049015	-26.62	-25.95	-1.91	26.4	0.09	heavy	--	--	--	--	2.6	0.29	5.54	0.50
40	Edison	94048004	-23.09	-22.73	-3.69	15.0	0.60	moderate	--	--	--	--	1.3	0.33	5.05	0.41
41	Edison	02026019	-23.38	-23.20	-4.00	15.2	0.65	moderate-heavy	--	--	--	--	1.8	0.16	8.74	0.27
42	Edison	02026018	-23.41	-23.25	-4.04	17.2	0.93	moderate-heavy	1.32	--	--	--	1.9	0.27	7.75	0.50
43	Edison	02026017	-23.35	-23.11	-3.88	23.2	0.68	mild	1.77	--	--	--	2.4	0.26	9.46	0.36
44	Elk Hills	00049016	-23.79	-22.41	-1.21	34.0	0.10	none	1.29	1.09	5	5	4.2	0.14	7.15	0.13
45	Elk Hills	00049017	-23.77	-23.27	-3.17	26.0	0.73	mild	1.05	--	--	--	2.1	0.24	5.88	0.15
46	English Colony	00049018	-24.40	-23.60	-2.31	43.2	0.27	none	1.66	--	--	--	13.4	0.21	7.52	0.11
47	Fruitvale	00049045	-23.74	-22.87	-2.36	19.0	0.62	moderate	1.02	--	--	--	3.3	0.15	8.45	0.09
48	Fruitvale	00049011	-23.86	-23.17	-2.72	18.5	0.30	mild	1.25	1.12	--	--	2.8	0.20	6.17	0.15
49	Fruitvale	00049019	-23.83	-23.36	-3.22	16.9	1.07	moderate	1.09	--	--	--	1.6	0.28	5.66	0.16
50	Greeley	02026014	-24.91	-23.87	-1.62	29.0	1.01	none	1.73	1.14	--	--	2.8	0.09	6.94	0.19
51	Greeley	02026015	-24.41	-23.41	-1.86	27.0	0.53	none	1.72	1.06	--	--	3.4	0.02	9.59	0.17
52	Greeley	00049021	-24.26	-23.39	-2.20	34.3	0.28	none	1.63	1.11	--	--	4.0	0.04	10.71	0.14
53	Greeley	02026013	-24.85	-23.74	-1.48	10.9	1.08	none	1.42	1.08	--	--	2.4	0.25	7.51	0.12
54	Greeley	00049020	-24.00	-22.72	-1.37	32.3	0.24	none	1.18	1.09	--	--	4.9	0.12	6.95	0.11

Table 9.2. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	USGS Lab. Number	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	CV	Gravity (degrees)	Sulfur (weight percent)	Bio-degradation	Pr/Ph	CPI	V	Ni	Sat/Aro	Bisnor-hopane	C_{26}Tet	Oleanane
55	Guijarral Hills	00049022	-26.96	-25.69	-0.47	28.9	0.41	none	1.41	1.11	--	--	4.3	0.03	5.87	0.10
56	Helm	00049023	-27.67	--	--	51.5	0.00	none	2.52	--	--	--	16.9	0.02	5.29	0.13
57	Jasmin	00047010	-26.79	-25.74	-1.01	19.1	1.14	heavy	--	--	--	--	1.5	0.02	6.38	0.16
58	Kern Bluff	02026020	-23.43	-23.07	-3.59	14.7	0.98	heavy	--	--	--	--	1.9	0.15	5.52	0.25
59	Kern Front	94048005	-23.37	-22.52	-2.52	14.0	0.96	heavy	--	--	--	--	1.3	1.68	6.76	0.49
60	Kern River	02026026	-23.80	-23.07	-2.65	14.8	1.07	moderate-heavy	--	--	--	--	1.9	0.33	6.48	0.24
61	Kettleman City	00049024	-27.20	-25.84	-0.20	28.9	1.11	mild	1.26	1.07	3	27	2.1	0.02	2.61	0.30
62	Kettleman Middle Dome	02026044	-27.64	-26.63	-0.84	34.2	0.13	none	1.90	1.05	1	2	5.4	0.03	3.44	0.17
63	Kettleman North Dome	00049026	-30.12	-28.80	0.62	30.2	0.12	none	1.81	1.04	2	9	3.3	0.02	3.76	0.05
64	Kettleman North Dome	00049025	-27.11	-25.86	-0.47	31.6	0.30	none	1.49	1.09	1	7	4.4	0.03	5.62	0.13
65	Los Lobos	00049027	-24.06	-23.35	-2.62	21.5	0.86	none	1.23	1.07	8	41	2.9	0.53	5.32	0.28
66	Lost Hills	02026038	-23.91	-22.80	-1.77	38.5	0.28	none	1.21	1.03	--	--	6.2	0.25	7.37	0.10
67	Lost Hills, East	02026036	-24.99	-23.84	-1.35	50.9	0.08	none	1.84	1.05	--	--	8.2	--	--	--
68	McKittrick	00049028	-24.89	-23.98	-1.91	25.2	1.18	none	1.22	1.02	--	--	2.3	0.27	6.89	0.09
69	McKittrick	00049029	-26.84	-26.03	-1.53	32.1	0.35	none	1.60	1.04	--	--	3.9	0.02	5.51	0.15
70	Merrill Avenue, SE	00049002	-29.40	-28.33	-0.16	24.8	0.29	mild	7.19	--	--	--	8.1	0.45	1.74	0.19
71	Midway-Sunset	02026029	-24.80	-23.59	-1.28	12.2	1.32	heavy	1.11	1.08	--	--	2.5	2.70	5.94	3.32
72	Midway-Sunset	00049030	-23.45	-23.03	-3.45	24.0	1.27	severe	--	--	--	--	9.2	0.91	5.86	2.76
73	Mount Poso	02026025	-24.10	-23.36	-2.54	16.3	0.84	heavy	--	--	--	--	2.4	0.05	11.11	0.17
74	Mount Poso	02026024	-24.01	-23.33	-2.70	15.8	0.81	heavy	--	--	--	--	2.0	0.02	11.18	0.15
75	Mountain View	02026022	-24.15	-23.20	-2.05	34.3	0.54	none	1.87	1.08	--	--	3.1	0.25	6.10	0.44
76	Mountain View	02026021	-24.00	-23.14	-2.30	36.6	0.26	none	2.04	1.09	--	--	2.9	0.14	5.75	0.54
77	Mountain View	00049031	-24.14	-23.24	-2.17	22.6	0.46	none	1.61	1.15	--	--	2.6	0.22	5.75	0.33
78	Mountain View	02026023	-24.14	-23.21	-2.10	36.5	0.63	none	1.89	1.09	--	--	3.3	0.26	6.06	0.45
79	Paloma	00049033	-28.04	--	--	68.9	0.22	none	--	--	--	--	8.9	0.04	0.49	0.03
80	Pioneer	00049034	-23.78	-22.70	-1.88	29.9	0.47	none	1.85	1.09	--	--	5.4	0.18	7.17	0.38
81	Poso Creek	00049035	-23.61	-22.83	-2.60	12.0	0.87	severe	--	--	--	--	1.4	7.53	7.34	1.24
82	Pyramid Hills	02026005	-28.63	-27.42	-0.09	44.5	0.08	none	2.66	1.03	--	--	6.7	0.02	4.96	0.09
83	Pyramid Hills	00049036	-27.30	-26.49	-1.39	17.7	0.17	moderate	--	--	--	--	3.1	0.07	4.03	0.17

Table 9.2. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed by the U.S. Geological Survey—Continued.

Oil Sample Number	Field or Seep Name	USGS Lab. Number	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	CV	Gravity (degrees)	Sulfur (weight percent)	Bio-degradation	Pr/Ph	CPI	V	Ni	Sat/Aro	Bisnor-hopane	C_{26}Tet	Oleanane
84	Raisin City	02026028	-30.19	-29.13	0.06	28.4	0.68	none	2.29	1.05	--	--	2.7	0.03	3.37	0.13
85	Raisin City	00049037	-27.10	-26.42	-1.74	23.6	0.37	mild	1.55	--	--	--	3.4	0.02	5.07	0.12
86	Riverdale	00049038	-27.53	-26.11	0.04	30.4	0.15	none	1.59	1.09	--	--	3.5	0.02	6.00	0.11
87	Ranch	02026016	-23.89	-23.18	-2.67	17.7	0.16	moderate	0.83	--	--	--	1.8	0.18	7.08	0.10
88	Rosedale Ranch	00049039	-23.77	-23.02	-2.62	20.9	0.88	moderate	0.58	--	--	--	2.2	0.15	7.51	0.10
89	San Emigdio Creek	00049040	-24.45	-23.64	-2.27	28.6	0.61	none	1.88	1.08	--	--	4.4	0.05	5.79	0.23
90	San Joaquin	00049041	-30.42	-29.17	0.56	28.1	0.27	none	2.03	1.09	--	--	2.8	0.03	3.11	0.10
91	Seep 4-21A	00049042	-23.87	-23.30	-2.98	--	0.35	severe	--	--	--	--	1.1	3.26	5.14	10.08
92	Semitropic	02026006	-23.52	-22.41	-1.89	44.0	0.26	none	1.48	1.06	--	--	5.0	0.18	8.55	0.36
93	Semitropic	00049043	-24.32	-22.64	-0.38	30.4	0.51	none	1.13	1.07	--	--	6.2	0.07	7.68	0.05
94	Stockdale	02026009	-24.63	-23.74	-2.04	29.0	0.77	none	1.82	1.17	--	--	2.0	0.32	4.27	0.24
95	Stockdale	02026008	-25.00	-24.10	-1.90	27.2	1.03	none	1.87	1.17	--	--	1.8	0.43	3.37	0.24
96	Stockdale	02026007	-25.01	-24.05	-1.77	27.1	1.20	none	1.89	1.16	--	--	1.7	0.43	3.60	0.25
97	Stockdale	02026010	--	--	--	60.7	1.34	none	2.79	--	--	--	8.0	0.34	2.86	0.21
98	Strand	00049044	-24.47	-23.47	-1.84	31.1	0.81	none	1.43	1.08	--	--	2.6	0.29	5.51	0.13
99	Tejon, North	00049032	-23.79	-22.84	-2.17	30.1	0.17	none	1.89	1.06	--	--	3.3	0.17	6.29	0.36
100	Tulare Lake	00049046	--	--	--	--	6.81	--	--	--	--	--	--	--	--	--
101	Tulare Lake	00049047	-27.16	-26.25	-1.21	28.5	0.46	none	1.41	1.05	--	--	3.7	0.02	5.82	0.11
102	Vallecitos	04013004	-28.87	-28.28	-1.39	29.7	0.43	none	2.51	1.10	--	--	5.3	0.09	1.48	0.21
103	Vallecitos	04013005	-30.66	-30.18	-1.08	28.6	1.24	mild	1.74	1.10	--	--	2.8	0.05	3.24	0.08
104	Vallecitos	02026043	-29.52	-28.74	-0.77	28.9	0.62	none	2.58	1.10	--	--	3.5	0.14	1.36	0.17
105	Vallecitos	02026042	-28.67	-27.90	-1.05	25.5	0.65	none	2.22	1.06	--	--	4.7	0.25	1.72	0.18
106	Vallecitos	04013003	-28.79	-28.27	-1.57	23.9	0.37	none	2.26	1.09	--	--	6.9	0.07	1.30	0.16
107	Vallecitos	04014002	-29.31	-28.10	0.12	33.4	0.00	none	2.54	1.11	--	--	1.9	0.11	1.35	0.27
108	Vallecitos	04014003	--	--	--	58.5	0.10	none	2.65	--	--	--	2.5	0.18	2.07	0.26
109	Vallecitos	04013002	-29.06	-28.35	-1.07	22.1	0.60	none	2.83	1.13	--	--	4.4	0.11	0.99	0.29
110	Vallecitos	04013006	-29.93	-28.88	-0.04	33.2	0.43	none	2.15	1.03	--	--	5.1	0.04	3.33	0.07
111	Vallecitos	04013001	-29.89	-28.98	-0.36	35.0	0.30	none	2.07	1.03	--	--	5.0	0.03	3.53	0.07
112	Vallecitos	02026046	-28.88	-27.94	-0.61	35.0	0.21	none	2.34	1.07	--	--	5.2	0.14	1.84	0.13
113	Vallecitos	02026039	-29.58	-28.98	-1.15	23.3	0.46	mild	2.04	1.10	--	--	4.5	0.05	3.51	0.08
114	Vallecitos	02026040	-29.75	-29.07	-0.92	23.5	0.40	mild	2.11	1.06	--	--	3.6	0.05	2.97	0.08
115	Vallecitos	02026041	-29.71	-29.14	-1.17	19.9	0.85	mild	1.86	--	--	--	3.4	0.05	3.12	0.07
116	Van Ness Slough	00049048	-27.26	-26.36	-1.20	35.6	0.62	none	1.51	1.09	--	--	2.9	0.02	5.13	0.10
117	Wildcat well	00049009	-23.25	-21.27	-0.05	42.2	0.00	none	1.62	1.02	--	--	4.5	0.49	11.48	1.32
118	Wildcat well	00049050	-24.15	-22.76	-1.08	30.9	0.41	none	1.12	1.06	--	--	3.3	0.26	5.86	0.06
119	Wildcat well	00049049	-23.95	-22.47	-0.94	35.9	0.48	none	1.42	1.04	--	--	3.6	0.04	6.67	0.08
120	Yowlumne	00049051	-24.18	-23.21	-2.00	35.8	0.35	none	1.65	1.10	--	--	4.2	0.30	5.30	0.33

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies.

[Oils correlated to an oil type are designated CM, EK, ET and MM. Oils classified with lower confidence are designated EKo, ETo and MMo (oil type outliers). Oils that do not correlate to any oil type are outliers (O). Sec-Twn-Rng, location of sample in notation of public land survey system. Field, area, and pool names are designated by the State of California, Department of Conservation (CDOGGR, 1998). Formation name and reservoir rock are modified to comply with USGS geologic name standards. N/A, not applicable. --, no data available. See appendix 9.1 for more information on each sample]

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
121	Antelope Hills North	Main	Agua	Temblor Formation	Agua Sandstone Bed of Santos Shale Member	O	may be MM-EK mix, Miocene Group IIIC[3]	Hopkins B-61X	2352-2478	23-27S-19E
122	Antelope Hills North	Main	Packwood	Monterey Formation	Packwood sand	EK	source based on isotopes	Carlton Investment 100-15	882-927	15-27S-19E
123	Belgian Anticline	Main	Oceanic	Tumey formation	Oceanic sand	EKo	outlier aromatic isotope values, may be mixed ET	Getty Veen (-24) 75A	5750-5815	24-30S-21E
124	Belgian Anticline	Main	Point of Rocks	Kreyenhagen Formation	unknown	EK	source based on isotopes and pristane/phytane	Midway & McKittrick A 32-30	6235-7608	30-30S-22E
125	Belgian Anticline	Northwest	Point of Rocks	Kreyenhagen Formation	third Point of Rocks Sandstone Member	EKo	outlier isotope values, Kreyenhagen Formation source[3]	CWOD 3-31-21V	4195-4425	22-30S-21E
126	Belridge South	Main	Diatomite	Reef Ridge Shale Member of Monterey Formation	Belridge Diatomite Member	MM	source based on saturated and whole oil isotope values, high sulfur, and reservoir	Fee 81A-13	approx. 1220	13-28S-20E
127	Belridge South	Main	Diatomite	Reef Ridge Shale Member of Monterey Formation	Belridge Diatomite Member	MM	source based on isotopes and pristane/phytane	Fee 265X	2000-2460	12-28S-20E
128	Belridge South	Main	Tulare	Tulare Formation	unknown	MM	Location uncertain, source based on whole oil isotopes	unknown	unknown	unknown
129	Big Tar Canyon Seep	N/A	N/A	Kreyenhagen Formation	unknown	EK	source based on isotopes, Kreyenhagen Formation[3]	seep	surface	18-23S-17E
130	Big Tar Canyon seep	N/A	N/A	Kreyenhagen Formation	unknown	EK	source based on isotopes, Kreyenhagen Formation[3]	seep	surface	18-23S-17E
131	Big Tar Canyon Seep	N/A	N/A	Kreyenhagen Formation	unknown	EK	source based on isotopes	seep	surface	18-23S-17E
132	Big Tar Canyon seep	N/A	N/A	Kreyenhagen Formation	unknown	EK	source based on isotopes, Kreyenhagen Formation[3]	seep	surface	18-23S-17E
133	Buena Vista	Buena Vista Hills	Antelope Shale-East Dome	Monterey Formation	Antelope shale	MM	source based on aromatic isotopes, pristane/phytane and oil from same zone	6D-503	3724-4203	6-32S-24E
134	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes	Penn Zier Mix	approx. 700	1-20S-14E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
135	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes	Premier Mix	approx. 1370	24-20S-14E
136	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes, Kreyenhagen Formation[3]	SEC 25D 3-8	approx. 900	25-20S-14E
137	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes	3	1400-1674	18-20S-15E
138	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EKo	source based on saturated isotope value, outlier aromatic isotope value	Deutsch 1	2392-2517	30-20S-15E
139	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes	CMS M-1 (Mix 1)	approx. 500	31-19S-15E
140	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on isotopes	Empire 2	2645-2677	6-21S-15E
141	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	ETo	outlier pristane/phytane value, well ID uncertain, suspect aromatic isotope data	Empire 4	2633-2794	6-21S-15E
142	Coalinga	Main (westside)	Etchegoin-Temblor	Temblor Formation	unknown	EK	source based on aromatic isotope (anomalously high saturate value -24.05; probably bad data)	AOQ mix	approx. 570	14-20S-14E
143	Coalinga East Extension	Coalinga Nose	Gatchell	Lodo Formation	Gatchell sand	EK	source based on isotopes and pristane/phytane	unknown	unknown	18(?)-20S-16E
144	Coalinga East Extension	Coalinga Nose	Gatchell	Lodo Formation	Gatchell sand	EK	source based on saturated and whole oil isotopes, pristane/phytane low	composite	approx. 7750	18-20S-16E
145	Coalinga East Extension	Coalinga Nose	Gatchell	Lodo Formation	Gatchell sand	EK	source based on isotopes	66-7F	7940-8015	7-20S-16E
146	Coles Levee, North	Main	Stevens	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Coles Levee A 34-31	unknown	31-30S-25E
147	Coles Levee, North	Main	Stevens	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Coles Levee A 38-30	unknown	30-30S-25E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
148	Cymric	McKittrick Front	Tulare (Amnicola)	Tulare Formation	Amnicola sand	MM	source based on isotopes, Miocene Group IIIA[3]	Cymric 22-11-31X	620-700	31-29S-22E
149	Cymric	Salt Creek	Carneros	Temblor Formation	unknown	MM	source based on isotopes	Temblor 5	2814-2990	17-29S-21E
150	Cymric	Welport	Etchegoin	Etchegoin Formation	unknown	MM	source based on isotopes	Anderson 251	1803-1912	25-29S-21E
151	Cymric	Welport	Tulare (Amnicola)	Tulare Formation	Amnicola sand	MM	source based on isotopes	Fitzgerald 26-42C	632-1050	26-29S-21E
152	Edison	Race Track Hill	Pyramid Hill	Freeman Silt-Jewett Sand	Pyramid Hill Sand Member of Jewett Sand	MM	polar isotope value is MM outlier, pristane/phytane higher	34-26	4534-4650	34-29S-29E
153	Edison	Race Track Hill	Pyramid Hill	Freeman Silt-Jewett Sand	Pyramid Hill Sand Member of Jewett Sand	MM	polar isotope value is MM outlier	34-38	4605-4610	34-29S-29E
154	Edison	Race Track Hill	Pyramid Hill	Freeman Silt-Jewett Sand	Pyramid Hill Sand Member of Jewett Sand	MM	polar isotope value is MM outlier, pristane/phytane higher	34-51A	4581-4604	34-29S-29E
155	Elk Hills	Main	undesignated	Tumey formation	Oceanic sand	--	Miocene aromatic isotope value, possible contaminant	934-29R (DST 4)	17400-17500	29-30S-23E
156	Elk Hills	Main	Agua	Temblor Formation	Agua Sandstone Bed of Santos Shale Member	MM	source based on isotopes pristane/phytane and sulphur	583-30R	9266-9744	30-30S-23E
157	Elk Hills	Main	Carneros	Temblor Formation	first Carneros Sandstone Member	MM	source based on isotopes pristane/phytane and sulphur	578-24Z	9080-9590	24-30S-22E
158	Elk Hills	Main	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on pristane/phytane and another oil in same zone, polar isotope value is MM outlier	555-30R	9255-9350	30-30S-23E
159	Five Points	Main	Eocene	Lodo Formation	Gatchell sand	EK	source based on isotopes and pristane/phytane	Airway Farms 2-21	unknown	21-17S-17E
160	Greeley	Main	Stevens	Fruitvale shale	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	62-24 (62X)	unknown	24-29S-25E
161	Guijarral Hills	Main	Gatchell	Lodo Formation	Gatchell sand	EK	source based on isotopes	Gatchell 45-34 (55-34)	10235-10327	34-20S-16E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
162	Guijarral Hills	Main	Gatchell	Lodo Formation	Gatchell sand	EK	source based on isotopes and pristane/phytane	55-34	10235-10327	34-20S-16E
163	Guijarral Hills	Polvadero	Bourdieu	Lodo Formation	Gatchell sand	EK	source based on isotopes	Palvadero Unit 55-1	10614-10721	1-21S-16E
164	Helm	Main	Eocene & K	Domengine Formation	unknown	EK	pristane/phytane	Sample 21-15	unknown	15-17S-18E
165	Helm	Main	Zilch (Miocene)	Zilch formation	unknown	ET	source based on isotopes and pristane/phytane	Capital 57X-15	unknown	15-17S-18E
166	Jacalitos	Main	Temblor	Temblor Formation	unknown	EK	source based on isotopes, Kreyenhagen Formation[3]	75-21E	3396-3968	21-21S-15E
167	Jacalitos	Main	Temblor	Temblor Formation	unknown	EK	source based on polar isotopes	Sherman 63	3464-3527	20-21S-15E
168	Kern River	Main	Kern River	Kern River Formation	unknown	MM	source based on isotopes	Redbank Central Point Mix	approx. 875	4-29S-28E
169	Kern River	Main	Vedder	Vedder Sand	second Vedder Sand	MM	source based on isotopes and pristane/phytane	Central Point 73-X	4731-4741	4-29S-28E
170	Kern River	Main	Vedder	Vedder Sand	third Vedder Sand	MMo	outlier pristane/phytane value, source based on aromatic and polar isotope values	Appollo WD-1	4881-4924	4-29S-28E
171	Kettleman Middle Dome	Main	Kreyenhagen	Kreyenhagen Formation	unknown	EKo	outlier aromatic isotope value	KMDC 38-19V	11152-12221	19-23S-19E
172	Kettleman North Dome	Main	Lower McAdams	Lodo Formation	lower McAdams sandstone	EK	source based on isotopes and pristane/phytane	334-27J	11383-11743	27-21S-17E
173	Kettleman North Dome	Main	Lower McAdams	Lodo Formation	lower McAdams sandstone	EK	source based on isotopes and pristane/phytane	333	11208-11444	20-21S-17E
174	Kettleman North Dome	Main	Lower McAdams	Lodo Formation	lower McAdams sandstone	EK	source based on isotopes, Kreyenhagen Formation source[4]	21-J (maybe E27)	unknown	21-21S-17E
175	Kettleman North Dome	Main	Temblor	Temblor Formation	unknown	ET	source based on isotopes and pristane/phytane	E38-26Q	6764-8300	26-22S-18E
176	Kettleman North Dome	Main	Temblor	Temblor Formation	unknown	ET	source based on isotopes and pristane/phytane	71-35Q	7555-8005	35-22S-18E
177	Kettleman North Dome	Main	Temblor	Temblor Formation	Temblor zones IV, V	ET	source based on isotopes and pristane/phytane	43-7Q	7755-8555	7-22S- 18E
178	Kettleman North Dome	Main	Upper McAdams	Lodo Formation	McAdams sandstone	EK	source based on isotopes and pristane/phytane	K333	8860-9750	21-22S-18E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
179	Kettleman North Dome	Main	Upper McAdams	Lodo Formation	upper McAdams sandstone	EKo	isotope values	E 423-34J	9680-9910	34-21S-17E
180	Kettleman North Dome	Main	Vaqueros	Vaqueros Formation	unknown	ETo	outlier isotope and pristane/phytane values	632	9026-9165	7-22S-18E
181	Landslide	Main	Stevens	Monterey Formation	Stevens sand	MM	source based on isotopes and pristane/phytane	63X-30	12190-12556	30-11N-21W
182	Lost Hills	Main	Cahn	Monterey Formation	Cahn zone	MM	source based on isotopes and pristane/phytane	Getty A-134	4750-5050	15-27S-21E
183	McKittrick	Main	Stevens	Monterey Formation	Stevens sand	MMo	outlier saturated isotope value - source based on aromatic and polar isotope values	Del Monte 73A	2743-2866	13-30S-21E
184	McKittrick	Main	Tulare-San Joaquin	Tulare Formation	unknown	MM	source based on isotopes	McLennon A 304	1010-1226	18-30S-22E
185	McKittrick	Northeast	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on whole oil isotope value	536-6Z [6-Z Fox 536 Upper]	approx. 5655	6-30S-22E
186	McKittrick	Northeast	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on whole oil isotope value	576A-7Z	5872-5915	7-3S-22E
187	McKittrick	Northeast	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on whole oil isotope value	Socal 581-17Z	6480-6513	17-30S-22E
188	McKittrick	Northeast	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on whole oil isotope value	Socal 581-17Z	6425-6463	17-30S-22E
189	McKittrick	Northeast	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on whole oil isotope value	1-1 Fee [17Z-511]	5950-5990	17-30S-22E
190	McKittrick	Northeast	Oceanic	Tumey formation	Oceanic sand	EK	source based on whole oil isotope and oil data from same well (sample 191)	Socal 585-7Z	approx. 8858	7-30S-22E
191	McKittrick	Northeast	Oceanic	Tumey formation	Oceanic sand	EK	source based on isotopes, Kreyenhagen Formation[3]	585R-7Z	8840-8964	7-30S-22E
192	McKittrick	Northeast	Oceanic	Tumey formation	Oceanic sand	EK	source based on whole oil isotope value	Socal Jacobsen 574-18Z	8834-8919	18-30S-22E
193	McKittrick	Northeast	Olig	Monterey Formation	Reef Ridge Shale Member	MM	source based on isotopes	McKittrick NE Socal 343-17Z	approx. 1900	17-30S-22E
194	McKittrick	Northeast	Point of Rocks	Kreyenhagen Formation	Point of Rocks Sandstone Member	EK	source based on isotopes, Kreyenhagen Formation source[4]	731	unknown	17-30S-22E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
195	McKittrick	Northeast	Wygal (Phacoides)	Temblor Formation	Wygal Sandstone Member (Phacoides sandstone)	ET	source based on whole oil isotope value and sample from same reservoir	Socal 556 7Z	8210-8241	7-30S-22E
196	McKittrick	Northeast	Wygal (Phacoides)	Temblor Formation	Wygal Sandstone Member (Phacoides sandstone)	ET	source based on whole oil isotope value and duplicate analysis (sample 69)	McKittrick Sec 8Z 65X-2	9058-9074	8-30S-22E
197	McKittrick	Northeast	Wygal (Phacoides)	Temblor Formation	Phacoides sandstone	ET	source based on whole oil isotope value and sample from same reservoir	11-12A [587 No. 2]	7828-8630	7-30S-22E
198	Midway-Sunset	Main	MOCO	Monterey Formation	unknown	MM	source based on isotopes	MOCO 35-399	approx. 2680	35-12N-24W
199	Midway-Sunset	Main	Leutholtz (Metson)	Monterey Formation	Metson sand	MM	source based on isotopes	Metson 47-24	approx. 1000	24-11N-23W
200	Midway-Sunset	Main	Antelope Shale	Monterey Formation	Antelope shale	MM	source based on isotopes and pristane/phytane	37-X	2600-3800	35-30S-22E
201	Midway-Sunset	Main	Antelope Shale	Monterey Formation	Antelope shale	MM	source based on saturated and whole isotope values	MOCO 35 WT-243	approx. 1931	35-12N-24W
202	Midway-Sunset	Main	Obispo	Fruitvale shale	Antelope shale	MM	source based on isotopes and pristane/phytane	Cal Energy-USA 2	approx. 5400	10-11N-23W
203	Midway-Sunset	Main	Potter	Reef Ridge Shale Member of Monterey Formation	Potter sand	MM	source based on isotopes	438	995-1225	28-30S-22E
204	Midway-Sunset	Main	Tulare	Tulare Formation	unknown	MM	source based on saturated and whole isotope values	MOCO 35 337	approx. 733	35-12N-24W
205	Mount Poso	Main	Vedder	Vedder Sand	unknown	MM	source based on isotopes and S and oil from same zone	Bowles 6	1750-1834	29-26S-28E
206	Mount Poso	Main	Vedder	Vedder Sand	unknown	MM	source based on isotopes and S and oil from same zone	Vedder 54P	approx. 1960	9-27S-28E
207	Mountain View	Arvin, West	Brite	Freeman Silt-Jewett Sand	unknown	MM	source based on isotopes and pristane/phytane	Frick-Hogan 2	approx. 7000	9-31S-29E
208	Mountain View	Main	Wharton (Hogan)	Santa Margarita Sandstone	unknown	MM	source based on isotopes	Mott 3	unknown	9-31S-29E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
209	Paloma	Main	Lower Stevens	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	GBX-58	unknown	3-32S-26E
210	Paloma	Main	Lower Stevens	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Paloma 78X-3	approx. 11600	3-32S-26E
211	Paloma	Main	Lower Stevens	Monterey Formation	lower Stevens sand	MM	source based on isotopes, and pristane/phytane	Paloma 28X-2	11613-12182	2-32S-26E
212	Pleasant Valley	Main	Gatchell	Lodo Formation	Gatchell sand	EK	source based on isotopes, and pristane/phytane	Gatchell 86-20	8752-9005	20-20S-16E
213	Pleasant Valley	Main	Temblor	Temblor Formation	unknown	ET	source based on isotopes, and pristane/phytane	Gatchell 33-28	6950-6960	28-20S-16E
214	Pyramid Hills	Norris	Eocene	Avenal Sandstone	unknown	EKo	outlier aromatic isotope value	Norris-Drilexico-Hand 26-28	4732-4745	28-24S-18E
215	Pyramid Hills	Norris	KR (Point of Rocks sand)	Kreyenhagen Formation	Point of Rocks Sandstone Member	EK	source based on isotopes	Norris-Drilexico-Hand 1-9-28	784-875	28-24S-18E
216	Pyramid Hills	Norris	KR (Point of Rocks sand)	Kreyenhagen Formation	Point of Rocks Sandstone Member	EKo	outlier saturated isotope value, source based on another sample from same zone	Norris Drilexco 1-10	approx. 1000	28-24S-18E
217	Pyramid Hills	Norris	Eocene	Kreyenhagen Formation	unknown	EK	source based on isotopes, and pristane/phytane	Norris Drilexico Baylis 72-29	1938-2210	29-24S-18E
218	Railroad Gap	Main	Carneros	Temblor Formation	Carneros Sandstone Member	MM	source based on isotopes	386	approx. 7262	15-30S-22E
219	Railroad Gap	Main	Carneros	Temblor Formation	Member	MM	source based on whole oil isotope	Socal 5-5 [544-15Z]	7194-7221	15-30S-22E
220	Raisin City	Main	Miocene Tar	Zilch formation	unknown	ETo	outlier saturated isotope value, ET polar isotope value	Surfluh 8-14	4749-4760	14-15S-17E
221	Riverdale	Main	Eocene	Kreyenhagen Formation	Courtney sand	EK	source based on isotopes, and pristane/phytane	Jensen Stockdale Energy I-26	7838-7841	26-17S-19E
222	Riverdale	Main	Zilch	Zilch formation	unknown	ET	source based on isotopes, and pristane/phytane	Mathias	unknown	15-17S-19E
223	Riverdale	Main	Zilch	Zilch formation	unknown	ET	source based on isotopes	Conoco-Goldin 1	unknown	22-17S-19E
224	Riverdale	Main	Zilch	Zilch formation	unknown	ET	source based on isotopes, and pristane/phytane	Evangello 1-25	6837-6842	25-17S-19E
225	Rosedale	Main	Main Stevens	Fruitvale shale	Stevens sand	MM	source based on isotopes, and pristane/phytane	Rosedale Oil Unit 2-2	approx. 6000	14-29S-26E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
226	Round Mountain	Main	Pyramid Hill	Freeman Silt-Jewett Sand	Pyramid Hill Sand Member of Jewett Sand	MM	source based on isotopes	187	1710-1825	18-28S-29E
227	Round Mountain	Main	Pyramid Hill	Freeman Silt-Jewett Sand	Pyramid Hill Sand Member of Jewett Sand	MM	source based on isotopes	187	1710-1825	18-28S-29E
228	Round Mountain	Main	Vedder	Vedder Sand	unknown	MM	source based on isotopes and S and oil from same zone in Mount Poso field	11	2068-2107	18-28S-29E
229	San Emidio Nose	Main	Stevens	Monterey Formation	unknown	MM	source based on isotopes	KCL-H 87-9	approx. 12835	9-11N-21W
230	San Joaquin	Main	Eocene	Domengine Formation	Domengine Formation	EK	source based on isotopes and pristane/phytane	Yager B-1	unknown	30-15S-17E
231	San Joaquin	Main	Eocene	Domengine Formation	Domengine Formation	EK	source based on isotopes and pristane/phytane	Yager 2	unknown	30-15S-17E
232	San Joaquin	Main	Eocene	Kreyenhagen Formation	shale of Kreyenhagen Formation	EK	source based on isotopes and pristane/phytane	Keisson 35-32	4981-4984	32-15S-17E
233	Stockdale	Panama Lane	Nozu	Round Mountain Silt	Nozu sand	MMo	outlier based on other oils from same reservoir	Barron 1	11558-11748	23-30S-27E
234	Tejon	Central	Olcese	Olcese Sand	unknown	MMo	outlier aromatic isotope value	Reserve-E.W. Pauley 213-34	5673-5750	34-11N-19W
235	Tejon, North	Main	Basalt Sand	unknown	Zemorrian	MMo	outlier aromatic isotope value	W-T 338-18	10835-11960	18-11N-19W
236	Tejon, North	Main	Metralla	unknown	Zemorrian Tejon Formation	MM	source based on isotopes, sulphur and pristane/phytane	KCL I 52-24	8780-11428	24-11N-20W
237	Tejon, North	Main	Metralla	Tejon Formation or Vedder Sand or both	unknown	MM	source based on isotopes, sulphur and pristane/phytane	KCL-G North 65-24	8495-11258	24-11W-20W
238	Temblor Hills	Main	Agua	Temblor and Kreyenhagen Formations	Agua Sandstone Bed of Santos Shale Member and Point of Rocks Sandstone Member	MMo	outlier isotope values, low sulphur, Miocene Group IIIB[3]	Hotchkiss Unit 24-25	3720-4014	25-30S-20E
239	Tulare Lake	Main	54-8L	Temblor Formation	Burbank sand	ET	source based on isotopes and pristane/phytane	Salyer 678X (DST 6)	13165-13190	8-22S-20E
240	Tulare Lake	Main	54-8U	Temblor Formation	Burbank sand	ET	source based on isotopes and pristane/phytane	Salyer 665-X	13033-13063	8-22S-20E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
241	Tulare Lake	Main	Boswell	Temblor Formation	Burbank sand	ETo	outlier saturated isotope value	Salyer 678 (DST 1)	13268-13273	8-22S-20E
242	Tulare Lake	Main	Boswell	Temblor Formation	Burbank sand	ET	source based on isotopes and pristane/phytane	Salyer 665-X (DST 1)	13234-13235	8-22S-20E
243	Tulare Lake	Main	KCDC	Temblor Formation	Burbank sand	ETo	outlier aromatic isotope value, polar isotope and pristane/phytane values like ET	Salyer 667X	13090-13115	8-22S-20E
244	Tulare Lake	Main	Salyer	Temblor Formation	Burbank sand	MMo	outlier saturated isotope value	Salyer 667X	12920-12935	8-22S-20E
245	Vallecitos	Central	Ashurst	Kreyenhagen Formation	Ashurst sand	EK	source based on isotopes, Kreyenhagen Formation[3]	Ashurst 3-5	5345-5508	5-17S-11E
246	Vallecitos	Central	Ashurst	Kreyenhagen Formation	Ashurst sand	EK	source based on isotopes, Kreyenhagen Formation source[4]	F & I 12X	unknown	5-17S-11E
247	Westhaven	Main	Temblor	Temblor Formation	unknown	ETo	outlier saturated and aromatic isotope values	Aqueduct 1-14	11053-11058	14-20S-18E
248	Wheeler Ridge	Central	Coal Oil Canyon	Santa Margarita Sandstone	unknown	MM	source based on isotopes	Tenneco West Inc. A-4	1474-1603	28-11N-20W
249	Wheeler Ridge	Central	Eocene	Tejon Formation	unknown	MM	source based on isotopes and pristane/phytane	WRU 41-28	10370-10841	28-11N-20W
250	Wildcat well	unknown	unknown	unknown	unknown	MM	source based on isotopes, Miocene Group IIIA[3]	Gene Reid 53-36	1674-1692	36-28S-18E
251	Wildcat well	unknown	unknown	unknown	unknown	MM	source based on isotopes, Miocene Group IIIA[3]	Gene Reid 53-36	1660-1674	36-28S-18E
252	Wildcat well	unknown	unknown	unknown	unknown	MMo	outlier isotope values, Miocene Group IIIB[3]	Tully 1	1670-1678	21-18S-10E
253	Wildcat well	unknown	unknown	Kreyenhagen Formation	unknown	EKo	source based on isotopes, outlier (low) pristane/phytane value	BLC 2 (DST 1)	approx. 13000	5-27S-20E
254	Wildcat well	unknown	unknown	Temblor Formation	unknown	O	may be MM-EK mix, Miocene Group IIIC[3], oil-stained sandstone	Frank Short Melinda 2	1598-1604	22-32S-22E
255	Wildcat well	unknown	unknown	Temblor Formation	Agua Sandstone Bed of Santos Shale Member	O	outlier aromatic isotope and pristane/phytane values, polar isotope value like ET	BLC 2 (DST 4)	approx. 11400	5-27S-20E

Table 9.3. Oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Area of Field	Pool Name	Formation Name[1]	Reservoir Rock[2]	Oil Type	Comments	Well Name	Depth (ft)	Sec-Twn-Rng
256	Wildcat well	unknown	unknown	Temblor Formation	Gibson sand	ET	source based on isotopes and pristane/phytane	BLC 2 (DST 3)	approx. 12200	5-27S-20E
257	Yowlumne	N/A	unknown	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Yowlumne Unit B 41X-10	unknown	10-11N-22W
258	Yowlumne	N/A	unknown	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Yowlumne Unit B 23X-3	unknown	3-11N-22W
259	Yowlumne	N/A	unknown	Monterey Formation	Stevens sand	MM	source based on isotopes, Monterey Formation source[4]	Yowlumne Unit B 57X-34	unknown	34-12N-22W

[1] Informally described formation names: Tumey formation of Atwill (1935), Fruitvale shale of Miller and Bloom (1939), Zilch formation of Loken (1959).

[2] Informally described reservoir rocks: Packwood sand of Foss and Blaisdell (1968), Oceanic sand of McMasters (1948), Antelope shale of Graham and Williams (1985), Gatchell sand of Goudkoff (1943), Stevens sand of Eckis (1940), Amnicola sand of Foss and Blaisdell (1968), McAdams sandstone of Sullivan (1963), Temblor zone IV and V of Sullivan (1966), Cahn zone of Hardoin (1964), Phacoides sandstone of Curran (1943), Metson sand of Foss and Blaisdell (1968), Potter sand of Callaway (1962), Courtney sand of Hunter (1953), Nozu sand of Kasline (1942), Burbank sand of Sullivan (1966), Ashurst sand of Wilkinson (1960), and Gibson sand of Williams (1938).

[3] Peters and others (1994).

[4] Franks and others (2001).

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies.

[Additional sample information is given in table 9.3. Reference Number, sample or analysis number given by reference; Ref., Reference; $\delta^{13}C$, in per mil relative to the Peedee belemnite (PDB) standard, where subscripts are: sat, saturated hydrocarbons, aro, aromatic hydrocarbons, pol, polar hydrocarbons, and oil, whole oil; CV, canonical variable defined as $-2.53\delta^{13}C_{sat} + 2.22\delta^{13}C_{aro} - 11.65$ (Sofer, 1984); Gravity, oil gravity in degrees API; Pr/Ph= pristane/phytane; V and Ni are vanadium and nickel concentration in ppm (w/w); --, no data available]

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
121	Antelope Hills North	Tbl 26.1.1 - COFRC 32835-1	1	-26.23	-25.66	--	--	-2.25	15.0	1.00	--	--	--
122	Antelope Hills North	GGC P-71	2	-29.06	-28.49	-28.49	--	-1.38	11.9	0.85	--	--	--
123	Belgian Anticline	GGC P-75	2	-28.21	-26.60	-26.52	--	0.67	32.1	0.29	2.00	--	--
124	Belgian Anticline	GGC P-196; IK-025	2	--	-27.73	-26.20	--	--	32.3	0.24	2.30	--	--
125	Belgian Anticline	Tbl 26.1.2 - COFRC 13838-1	1	-28.44	-26.06	--	--	2.45	32.0	0.10	--	--	--
126	Belridge South	Calif-6	3	-22.9	--	--	-22.20	--	20.0	1.05	--	3	5
127	Belridge South	GGC P-42; IK-117	2	-23.77	-22.54	-22.78	--	-1.55	27.3	0.67	1.60	--	--
128	Belridge South	232	4	--	--	--	-23.00	--	--	--	--	--	--
129	Big Tar Canyon Seep	Tbl 26.1.10 - COFRC 49,198-Spl 1	1	-29.28	-28.65	--	--	-1.17	--	0.59	--	--	--
130	Big Tar Canyon seep	Tbl 26.1.11 - COFRC 49199-Spl 2	1	-29.35	-28.66	--	--	-1.02	--	0.66	--	--	--
131	Big Tar Canyon Seep	GGC P-127; IK-014	2	-28.68	-27.87	-28.57	--	-0.96	11.7	0.62	--	--	--
132	Big Tar Canyon seep	Tbl 26.1.12 - COFRC 49200-Spl 3	1	-28.65	-28.12	--	--	-1.59	--	0.57	--	--	--
133	Buena Vista	GGC P-209	2	--	-23.19	-22.65	--	--	29.5	0.45	1.40	--	--
134	Coalinga	GGC P-2	2	--	-27.63	--	--	--	14.1	--	--	--	--
135	Coalinga	GGC P-4	2	--	-27.87	--	--	--	16.4	--	--	--	--
136	Coalinga	Tbl 26.1.9 - COFRC 30482-1	1	-28.82	-28.34	--	--	-1.65	13.0	0.32	--	--	--
137	Coalinga	GGC P-63	2	-28.77	-27.99	-27.65	--	-1.00	13.1	0.48	--	--	--
138	Coalinga	GGC P-5	2	-28.67	-25.93	-26.89	--	3.32	14.7	--	--	--	--
139	Coalinga	GGC P-1; IK-028	2	-28.65	-27.75	-26.95	--	-0.77	14.8	0.52	--	7	21
140	Coalinga	GGC P-6; IK-039	2	--	-28.17	--	--	--	16.5	--	--	--	--
141	Coalinga	GGC P-7	2	--	-26.04	--	--	--	27.5	0.60	1.86	--	--
142	Coalinga	GGC P-3	2	--	-27.68	--	--	-12.25	13.1	0.83	--	--	--

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
143	Coalinga East Extension	--	5	-29.78	-28.43	--	--	0.58	32.0	--	1.96	--	--
144	Coalinga East Extension	Calif-7	3	-29.1	--	--	-28.50	--	32.7	0.37	1.69	78	56
145	Coalinga East Extension	GGC P-10(no 9); IK-043	2	-29.97	-28.29	-28.29	--	1.37	32.8	0.28	1.90	--	--
146	Coles Levee, North	94W0013	6	-24.8	-24.00	--	-24.00	-2.19	--	--	--	--	--
147	Coles Levee, North	94W0014	6	-25	-24.20	--	-24.20	-2.12	--	--	--	--	--
148	Cymric	Tbl 26.1.3 - COFRC 32723-1	1	-24.35	-23.84	--	--	-2.97	12.0	1.22	--	--	--
149	Cymric	GGC P-70	2	-24.31	-23.43	-23.35	--	-2.16	18.0	0.58	--	--	--
150	Cymric	GGC P-69	2	-24.55	-23.81	-23.35	--	-2.40	14.1	1.13	--	--	--
151	Cymric	GGC P-68; IK-119	2	-24.33	-23.57	-23.41	--	-2.42	12.0	0.97	--	53	54
152	Edison	GGC P-178; IK-012	2	--	--	-24.31	--	--	32.2	0.29	1.80	--	--
153	Edison	GGC P-177; IK-026	2	--	--	-24.83	--	--	39.1	0.19	1.90	--	--
154	Edison	GGC P-179; IK-017	2	--	--	-24.17	--	--	32.7	0.21	1.80	--	--
155	Elk Hills	GGC P-210; IK-065	7, 2	-25.4	-22.83	--	--	1.93	39.0	--	2.33	--	--
156	Elk Hills	GGC P-206; IK-066	7, 2	-24.88	-23.36	-23.25	--	-0.56	20.7	0.39	1.50	--	--
157	Elk Hills	GGC P-204; IK-067	7, 2	-24.97	-23.25	-23.09	--	-0.53	27.2	0.38	1.50	--	--
158	Elk Hills	GGC P-205	2	--	--	-23.99	--	--	40.3	0.02	1.60	--	--
159	Five Points	--	5	-30.56	-29.30	--	--	0.62	27.0	--	1.92	--	--
160	Greeley	94W0002	6	-24.8	-23.80	--	-23.80	-1.74	--	--	--	--	--
161	Guijarral Hills	GGC P-15; IK-035	2	-30.17	-28.92	--	--	0.48	30.0	0.29	--	--	--
162	Guijarral Hills	GGC P-15; IK-037	2	-30.17	-28.92	-28.47	--	0.48	29.7	0.29	1.90	--	--
163	Guijarral Hills	GGC P-18; IK-038	2	--	-28.93	--	--	--	28.3	--	--	--	--
164	Helm	--	5	-30.51	-29.33	--	--	0.43	29.0	--	1.99	--	--
165	Helm	--	5	-27.57	-26.40	--	--	-0.51	34.0	--	1.60	--	--

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
166	Jacalitos	Tbl 26.1.6 - COFRC 14740	1	-29.48	-28.52	--	--	-0.38	35.0	0.37	--	--	--
167	Jacalitos	GGC P-202; IK-021	2	--	--	-27.80	--	--	34.4	0.30	1.90	--	--
168	Kern River	GGC P-172	2	--	-23.42	-22.82	--	--	13.6	0.99	--	--	--
169	Kern River	GGC P-169; IK-020	2	--	-23.34	-23.02	--	--	32.5	0.48	2.00	--	--
170	Kern River	GGC P-167; IK-034	2	--	-23.24	-23.71	--	--	38.2	0.08	2.20	--	--
171	Kettleman Middle Dome	GGC P-99; IK-064	2	-28.32	-26.91	--	--	0.26	38.4	0.18	2.10	1	2
172	Kettleman North Dome	GGC P-104	2	-30.04	-28.45	-27.00	--	1.19	29.2	0.22	2.40	--	--
173	Kettleman North Dome	GGC P-114; IK-061;CRC2967	2	-30.29	-28.95	-28.46	--	0.71	27.9	--	2.10	--	--
174	Kettleman North Dome	94W0015	6	-30.1	-29.10	--	-29.40	-0.10	--	--	--	--	--
175	Kettleman North Dome	GGC P-109	2	-26.9	-25.41	-24.81	--	0.00	32.2	0.34	1.50	--	--
176	Kettleman North Dome	GGC P-112	2	-26.95	-25.34	-25.35	--	0.28	30.3	0.10	1.60	--	--
177	Kettleman North Dome	GGC P-110	2	-27	-25.59	-24.91	--	-0.15	31.3	0.51	1.70	--	--
178	Kettleman North Dome	GGC P-103; IK-101	2	-29.04	-27.73	-27.05	--	0.26	28.9	0.37	2.10	--	--
179	Kettleman North Dome	GGC P-105	2	-29.55	-26.55	--	--	4.17	40.4	0.04	3.00	--	--
180	Kettleman North Dome	GGC P-107; IK-099	2	-28.07	-26.74	-26.34	--	0.00	34.5	0.23	1.90	--	--
181	Landslide	GGC P-145	2	--	-23.39	-22.95	--	--	27.3	0.86	1.30	--	--
182	Lost Hills	GGC P-76; IK-116	2	-24.05	-22.37	-22.57	--	-0.46	36.3	0.17	1.40	--	--
183	McKittrick	GGC P-41	2	-26.71	-23.12	-23.30	--	4.60	15.5	--	--	--	--
184	McKittrick	GGC P-73	2	-23.96	-23.07	-23.01	--	-2.25	11.5	0.54	--	--	--
185	McKittrick	Tbl 4 #1 (COFRC 31042)	8, 9	--	--	--	-24.57	--	--	--	--	--	--
186	McKittrick	Tbl 4 #2 (NO COFRC#)	8, 9	--	--	--	-24.67	--	--	--	--	--	--
187	McKittrick	Tbl 4 #6 (COFRC 34312)	8	--	--	--	-24.18	--	--	--	--	--	--
188	McKittrick	Tbl 4 #5 (COFRC 26635)	8, 9	--	--	--	-24.18	--	--	--	--	--	--
189	McKittrick	Tbl 4 #3 (COFRC 30931)	8, 9	--	--	--	-25.06	--	--	--	--	--	--
190	McKittrick	Tbl 4 #10 (COFRC 25321)	8, 9	--	--	--	-27.77	--	--	--	--	--	--

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
191	McKittrick	Tbl 26.1.4 - COFRC 25322	1	-28.95	-27.39	--	--	0.79	32.0	0.66	--	--	--
192	McKittrick	Tbl 4 #11 (COFRC 26099)	8, 9	--	--	--	-28.35	--	--	--	--	--	--
193	McKittrick	45-1	10	-24.5	-23.30	--	--	-1.39	17.0	--	--	--	--
194	McKittrick	95W0052	6	-28.6	-27.40	--	-28.30	-0.12	--	--	--	--	--
195	McKittrick	Tbl 4 #8 (COFRC 25098-2)	8, 9	--	--	--	-26.71	--	--	--	--	--	--
196	McKittrick	Tbl 4 #9 (COFRC 30930)	8, 9	--	--	--	-26.51	--	--	--	--	--	--
197	McKittrick	Tbl 4 #7 (COFRC 30928)	8, 9	--	--	--	-26.61	--	--	--	--	--	--
198	Midway-Sunset	45-5	10	-23.4	-22.70	--	--	-2.84	16.0	--	--	--	--
199	Midway-Sunset	45-2	10	-23.5	-22.60	--	--	-2.37	11.0	--	--	--	--
200	Midway-Sunset	GGC P-61; IK-142	2	-24.08	-23.20	-23.11	--	-2.23	15.7	0.80	1.40	--	--
201	Midway-Sunset	Calif-5	3	-23.3	--	--	-22.70	--	18.0	1.34	--	25	65
202	Midway-Sunset	GGC P-139; IK-024	2	--	-23.27	-22.73	--	--	28.5	0.60	1.60	--	--
203	Midway-Sunset	GGC P-60; IK-141	2	-24.14	-23.33	-23.35	--	-2.37	11.1	--	--	--	--
204	Midway-Sunset	Calif-4	3	-23.5	--	--	-22.80	--	15.0	1.24	--	24	125
205	Mount Poso	GGC P-84; IK-096	2	-24.35	--	-23.26	--	--	14.8	0.34	--	--	--
206	Mount Poso	GGC P-83; IK-093	2	-24.86	-23.62	-23.58	--	-1.19	17.7	0.43	--	--	--
207	Mountain View	GGC P-160; IK-031	2	--	-23.30	-22.70	--	--	30.1	0.47	1.90	--	--
208	Mountain View	--	5	-24.21	-23.59	--	--	-2.77	--	--	--	--	--
209	Paloma	95W0058	6	-24	-23.10	--	-23.60	-2.21	--	--	--	--	--
210	Paloma	94W0011	6	-24.2	-23.40	--	-23.60	-2.37	--	--	--	--	--
211	Paloma	GGC P-151; IK-023	2	--	-22.93	-23.78	--	--	39.8	0.15	1.90	--	--
212	Pleasant Valley	GGC P-11; IK-055	2	-30.53	-29.00	-28.61	--	1.21	28.3	0.44	1.90	--	--
213	Pleasant Valley	GGC P-14	2	-27.49	-26.11	-25.85	--	-0.06	28.0	0.49	1.50	--	--
214	Pyramid Hills	GGC P-33; IK-042	2	-29.05	-26.80	-28.04	--	2.35	37.6	0.16	2.50	--	--
215	Pyramid Hills	GGC P-36; IK-049	2	-29.45	-27.44	-27.26	--	1.94	17.0	0.31	--	--	--

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
216	Pyramid Hills	Calif-9	3	-27.5	--	--	-27.50	--	18.3	0.35	--	4	9
217	Pyramid Hills	GGC P-35	2	-29.87	-28.16	-28.51	--	1.41	41.0	0.19	2.40	--	--
218	Railroad Gap	45-4	10	-23.9	-23.10	--	--	-2.47	24.0	--	--	--	--
219	Railroad Gap	Tbl 4 #4 (COFRC 23616)	8, 9	--	--	--	-24.28	--	--	--	--	--	--
220	Raisin City	GGC P-21; IK-030	2	-28.09	--	-25.69	--	--	16.8	0.70	--	--	--
221	Riverdale	GGC P-77	2	-29.8	-28.08	-28.27	--	1.41	32.8	0.27	1.80	--	--
222	Riverdale	--	5	-27.46	-26.48	--	--	-0.96	32.0	--	1.56	--	--
223	Riverdale	--	5	-27.55	-26.51	--	--	-0.80	34.0	--	--	--	--
224	Riverdale	GGC P-79; IK-092	2	-27.7	-26.25	-25.87	--	0.16	28.4	0.31	1.80	--	--
225	Rosedale	GGC P-163; IK-027	2	--	-22.98	-22.80	--	--	29.1	0.42	1.30	--	--
226	Round Mountain	GGC P-173; IK-019	2	--	-23.36	-23.79	--	--	14.0	0.67	--	--	--
227	Round Mountain	GGC P-173; IK-045	2	--	-23.36	--	--	--	14.0	0.67	--	--	--
228	Round Mountain	GGC P-174; IK-029	2	--	-23.63	-24.27	--	--	10.8	0.34	--	--	--
229	San Emidio Nose	45-3	10	-24.1	-22.90	--	--	-1.52	29.0	--	--	--	--
230	San Joaquin	--	5	-30.49	-29.33	--	--	0.38	29.0	--	2.07	--	--
231	San Joaquin	--	5	-30.58	-29.20	--	--	0.89	29.0	--	2.00	--	--
232	San Joaquin	GGC P-23; IK-139	2	-30.58	-29.04	-28.86	--	1.25	26.6	0.33	2.30	--	--
233	Stockdale	GGC P-142; IK-018	2	--	-23.74	-23.23	--	--	28.0	0.66	1.90	--	--
234	Tejon	GGC P-58; IK-140	2	-25.25	-23.07	-23.66	--	1.02	26.5	0.24	--	--	--
235	Tejon, North	GGC P-59; IK-144	2	-24.91	-22.83	-23.29	--	0.69	30.7	0.27	2.00	--	--
236	Tejon, North	GGC P-27; IK-032	2	-24.88	-23.51	-23.44	--	-0.90	30.5	0.27	1.90	--	--
237	Tejon, North	GGC P-28	2	-24.12	-22.91	-23.66	--	-1.49	29.6	0.21	1.90	--	--
238	Temblor Hills	Tbl 26.1.5 - COFRC 34758-1	1	-25.3	-24.20	--	--	-1.37	26.0	0.24	--	--	--
239	Tulare Lake	GGC P-116;IK-006;CRC41345	2	-27.65	-26.21	-25.85	--	0.12	29.4	0.03	1.70	--	--
240	Tulare Lake	GGC P-97; IK-100	2	-27.38	-25.85	-25.84	--	0.23	32.0	0.31	1.70	--	--

Table 9.4. Geochemical data of oil samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Oil Sample Number	Field or Seep Name	Reference Number	Ref.	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	$\delta^{13}C_{pol}$	$\delta^{13}C_{oil}$	CV	Gravity (degrees)	Sulfur (weight percent)	Pr/Ph	V	Ni
241	Tulare Lake	GGC P-115	2	-28.01	-26.46	-25.89	--	0.47	26.4	0.41	1.80	--	--
242	Tulare Lake	GGC P-96	2	-27.72	-26.38	-25.95	--	-0.08	33.0	0.21	1.80	--	--
243	Tulare Lake	GGC P-93; IK-097	2	-26.3	-24.88	-25.21	--	-0.34	31.8	0.13	1.70	--	--
244	Tulare Lake	GGC P-95	2	-25.73	-23.69	-25.47	--	0.86	42.8	0.08	1.90	--	--
245	Vallecitos	Tbl 26.1.8 - COFRC A15329-1	1	-29.75	-28.95	--	--	-0.65	21.0	0.28	--	--	--
246	Vallecitos	95W0067	6	-28.7	-27.40	--	-28.60	0.13	--	--	--	--	--
247	Westhaven	GGC P-85	2	-26.49	-24.83	-25.53	--	0.25	38.5	0.11	1.60	--	--
248	Wheeler Ridge	GGC P-40	2	-23.51	-22.99	-23.44	--	-3.21	19.1	0.38	--	--	--
249	Wheeler Ridge	GGC P-29; IK-040	2	-24.4	-22.82	-23.13	--	-0.58	29.1	0.21	1.90	--	--
250	Wildcat well	Tbl 26.1.17 - COFRC 49204-4	1	-24.46	-23.78	--	--	-2.56	--	1.78	--	--	--
251	Wildcat well	Tbl 26.1.16 - COFRC 49204-3	1	-24.7	-23.65	--	--	-1.66	--	1.90	--	--	--
252	Wildcat well	Tbl 26.1.15 - COFRC 49205	1	-25.85	-24.31	--	--	-0.22	--	1.50	--	--	--
253	Wildcat well	GGC P-128; IK-009	2	-28.76	-28.03	-27.91	--	-1.11	30.2	0.05	1.50	--	--
254	Wildcat well	Tbl 26.1.14 - COFRC 49202	1	-26.29	-25.32	--	--	-1.35	--	0.65	--	--	--
255	Wildcat well	GGC P-130; IK-008	2	--	-24.96	-25.02	--	--	28.6	0.58	1.10	--	--
256	Wildcat well	GGC P-129; IK-010	2	--	-25.78	-24.56	--	--	35.3	--	1.50	--	--
257	Yowlumne	94W0007	6	-24.8	-23.80	--	-23.80	-1.74	--	--	--	--	--
258	Yowlumne	94W0008	6	-24.8	-24.00	--	-23.80	-2.19	--	--	--	--	--
259	Yowlumne	94W0003	6	-24.7	-24.10	--	-23.60	-2.66	--	--	--	--	--

[1] Peters and others (1994), [2] Kaplan and others (1988), [3] Lewan (1980), [4] Craig (1953), [5] Sofer (1984), [6] Franks and others (2001), [7] Alimi and Kaplan (1997a), [8] Seifert and Moldowan (1978), [9] Seifert (1977), [10] Curiale and others (1985).

Table 9.5. Source rock data for samples from the San Joaquin Basin Province, California, analyzed in previous studies.

[Reference Number, sample number from reference, where GGC prefix is from Kaplan and others (1988) and 49 prefix is from Curialie and others (1985); Sec-Twn-Rng, location of sample in notation of public land survey system; $\delta^{13}C$, in per mil relative to the Peedee belemnite (PDB) standard, where subscripts are: sat, saturated hydrocarbons, aro, aromatic hydrocarbons; Pr/Ph = pristane/phytane]

Formation Name[1]	Field Name	Well Name	Sec-Twn-Rng	Reference Number	Depth (ft)	Sample Type	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	Pr/Ph	Formation Comment[2]
Monterey Formation	Jerry Slough	Breen 1	14-28S-23E	49-2	13380	core	-23.5	-22.4	0.65	probably Antelope shale
Monterey Formation	San Emigdio Nose	KCL-H-33-15	15-11N-21W	49-3	13555	core	-24.3	-23	0.47	probably Antelope shale
Monterey Formation	San Emigdio Nose	KCL-H-33-15	15-11N-21W	49-4	13598	core	-24.6	-23.7	0.39	probably Antelope shale
Monterey Formation	McKittrick	McKittrick 1	unknown	49-5	6238	core	-24.8	-23.5	---	none
Monterey Formation	McKittrick	McKittrick 1	unknown	49-6	7150	core	-24.8	-23.2	1.17	none
Monterey Formation	Midway-Sunset	Ethyl "D" 101	36-12N-24W	49-7	2216	core	-23.6	-22.7	---	probably Antelope shale
Monterey Formation	Midway-Sunset	Ethyl "D" 101	36-12N-24W	49-8	3058	core	-23.5	-20.8	---	probably Antelope shale
Monterey Formation	Kettleman North Dome	7-26Q	26-22S-18E	GGC#196	5584-5594	core	-25.07	-22.34	1.08	McLure Shale Member
Monterey Formation	Wheeler Ridge	KCLD-26-29	29-11N-20W	GGC#234	2792	core	-25.33	-23.99	1.18	Luisian zone, changed from Santa Margarita Sandstone
Monterey Formation	Wheeler Ridge	KCLD-26-29	29-11N-20W	GGC#236	4303	core	-24.74	-23.65	1.47	Relizian zone, changed from Santa Margarita Sandstone
Whepley shale	Tulare Lake	West Lake 36-1	36-21S-19E	GGC#311	13318	core	-25.6	-24.28	0.89	none
Tumey formation	Westhaven	Aqueduct 1-14	14-20S-18E	GGC#10	12470-12500	cuttings	-27.81	-26.77	1.78	changed from Kreyenhagen Shale[3]
Tumey formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#151	10926-10935	cuttings	-27.14	-26.18	2	changed from Kreyenhagen Shale[4]
Tumey formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#154	10963-10970	cuttings	-27.82	-26.53	1.6	changed from Kreyenhagen Shale[4]
Tumey formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#156	10976-10987	cuttings	-26.75	-26.12	2	changed from Kreyenhagen Shale[4]
Tumey formation	wildcat well	BLC 2	5-27S-20E	GGC#281	12450-12480	cuttings	-27.76	-23.69	1.63	none
Tumey formation	wildcat well	BLC 2	5-27S-20E	GGC#283	12510-12540	cuttings	-27.73	-26.39	1.83	none
Tumey formation	wildcat well	BLC 2	5-27S-20E	GGC#285	12570-12600	cuttings	-28.77	-27.24	1.7	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#256	11090-11120	cuttings	-28.46	-27.67	1.69	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#262	11270-11300	cuttings	-29.75	-28.94	1.65	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#265	11360-11390	cuttings	-29.82	-29.24	2.12	none

Table 9.5. Source rock data for samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Formation Name[1]	Field Name	Well Name	Sec-Twn-Rng	Reference Number	Depth (ft)	Sample Type	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	Pr/Ph	Formation Comment[2]
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#268	11450-11480	cuttings	-30.81	-30.04	2.07	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#270	11510-11540	cuttings	-30.67	-29.49	1.96	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#274	11630-11660	cuttings	-30.01	-29.4	1.93	none
Kreyenhagen Formation	wildcat well	Bravo Oil 1-35	35-19S-16E	GGC#276	11690-11720	cuttings	-29.76	-28.82	2.26	includes Domengine in part
Kreyenhagen Formation	Westhaven	Aqueduct 1-14	14-20S-18E	GGC#28	13010-13040	cuttings	-28.34	-27.91	1.62	none
Kreyenhagen Formation	Westhaven	Aqueduct 1-14	14-20S-18E	GGC#30	13070-13100	cuttings	-28.68	-28.11	1.92	near bottom, changed from Domengine Formation[3]
Kreyenhagen Formation	Kettleman North Dome	4-18J	18-21S-17E	GGC#217	9760-9764	core	-28.47	-27.13	1.9	none
Kreyenhagen Formation	Kettleman North Dome	4-18J	18-21S-17E	GGC#219	9902-9907	core	-29.11	-27.8	1.8	none
Kreyenhagen Formation	Kettleman North Dome	4-18J	18-21S-17E	GGC#224	10284-10290	core	-30.71	-29.9	2.19	none
Kreyenhagen Formation	Kettleman North Dome	4-18J	18-21S-17E	GGC#225	10490-10496	core	-29.18	-27.92	2.2	none
Kreyenhagen Formation	wildcat well	J.G. Boswell 31-1	31-21S-21E	GGC#55	12690-12720	cuttings	-30.47	-30.11	1.31	none
Kreyenhagen Formation	wildcat well	J.G. Boswell 31-1	31-21S-21E	GGC#59	12810-12840	cuttings	-29.34	-29.06	1.45	none
Kreyenhagen Formation	wildcat well	J.G. Boswell 31-1	31-21S-21E	GGC#62	12900-12920	cuttings	-29.2	-28.7	1.46	none
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#158	10998-11007	cuttings	-30.25	-26.41	2.1	none
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#160	11021-11036	cuttings	-28.63	-27.38	2.04	none
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#165	11358-11366	cuttings	-28.11	-27.27	1.7	changed from Markley Shale[4]
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#167	11525-11534	cuttings	-28.78	-29.42	2.1	changed from Markley Shale[4]
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#171	11775-11783	cuttings	-28.55	-28.02	2.5	changed from Markley Shale[4]
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#173	11792-11802	cuttings	-29.1	-27.88	2.55	changed from Markley Shale[4]

Table 9.5. Source rock data for samples from the San Joaquin Basin Province, California, analyzed in previous studies—Continued.

Formation Name[1]	Field Name	Well Name	Sec-Twn-Rng	Reference Number	Depth (ft)	Sample Type	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	Pr/Ph	Formation Comment[2]
Kreyenhagen Formation	Kettleman Middle Dome	73-30V	30-23S-19E	GGC#179	11911-11921	cuttings	-29.26	-28.2	2.2	changed from Markley Shale[4]
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#303	12914	sidewall	-28.95	-28.61	1.62	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#301	12960	sidewall	-28.89	-28.74	1.52	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#287	12960-12990	cuttings	-28.92	-27.74	1.55	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#299	13005	sidewall	-27.94	-27.94	1.26	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#297	13046	sidewall	-28.88	-28.43	1.45	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#288	13080-13110	cuttings	-28.72	-27.48	1.65	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#290	13140-13170	cuttings	-28.72	-27.7	1.64	none
Kreyenhagen Formation	wildcat well	BLC 2	5-27S-20E	GGC#292	13200-13230	cuttings	-27.52	-26.19	1.26	none

[1] Informally described formation names: Whepley shale of Dodd and Kaplow (1933) and Tumey formation of Atwill (1935).

[2] Informally described formation name: Antelope shale of Graham and Williams (1985).

[3] Some of the rock samples in Kaplan and others (1988) have incorrect formation assignments. In their table 1a the samples in the Aqueduct 1-14 well in Westhaven field are listed as Oligocene "Hilliard Sand" from 12,200 to 12,260 ft and Eocene Kreyenhagen Formation from 12,260 to 13,070 ft (no Tumey formation listed). The Pacific Section American Association of Petroleum Geologists cross section 9 (PS-AAPG, 1957) shows a well (B.L.C. 44-14) in the same section as the Aqueduct 1-14 well (section 14-20S-18E) with Oligocene to Miocene Vaqueros Formation from about 11,200 to about 12,200 ft, "Tumey shale" from about 12,200 to about 12,500 ft, and Eocene Kreyenhagen Formation from about 12,500 to about 13,100 ft. Therefore, we reinterpret the samples in the Aqueduct 1-14 well from 12,260 to 12,560 ft to be Tumey formation of Atwill (1935).

[4] Similarly, in table 1a of Kaplan and others (1988) the samples in the 73-30V well in Kettleman Middle Dome field are listed as Eocene Kreyenhagen Formation from 10,652 to 11,265 ft and Eocene "Markley Shale" from 11,358 to 11,921 ft. The stratigraphic name "Markley Shale" is not applicable in this area based on the Pacific Section American Association of Petroleum Geologists cross section near the well (PS-AAPG, 1959); we reassign this interval to the Kreyenhagen Formation. The cross section also shows the Tumey formation from about 11,000 to 11,300 ft in a nearby well (Standard 38-19V), which is within 300 feet down structure of the 73-30V well. Therefore, we reassign the interval from 10,652 to 10,987 feet in the 73-30V well to the Tumey formation of Atwill (1935).