SALTON TROUGH PROVINCE (016)

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INTRODUCTION

The Salton Trough Province is defined as the Neogene basin existing east of the igneous-metamorphic complex that forms the Peninsular Ranges of Southern California and west of the San Andreas Fault in the vicinity of the Salton Sea. The north and northwest terminus of the trough is formed by the igneous and metamorphic rocks of the Transverse Range at San Gorgonio Pass. The trough widens from its northern terminus to a maximum of 46 mi at its southern end in the Gulf of California, some 115 mi away. The trough reaches a maximum depth of 21,000 ft near the Mexican border. Province 16 has a roughly triangular shape some 100 mi long and about 60 mi wide at the Mexico border, an area of about 4500 sq mi. The Salton Trough extends into Mexico and the Gulf of California, but this portion of the tough is not assessed.

The Salton Trough is considered a landward extension of the Gulf of California tectonic zone and is the result of active rifting of the continental crust (Elders and others, 1972). The portion of this rift valley in the United States has been filled by predominantly continental sediments derived from the Colorado River delta from the north and by detritus from the adjacent Peninsular and Transverse Ranges from the west and northwest. The oldest potential source rock in the Salton Trough is the upper Miocene to Pliocene Imperial Formation, which is composed of marine sediments deposited in shallow water resulting from a transgression of the Gulf of California. The Colorado River introduced fluvial and deltaic sediment as early as 5.5 Ma (Shafiquallah and others, 1980) in the Salton Trough. The Colorado River delta rapidly prograded southward across the Gulf of California to its present position by 4.0 Ma (Winkler and Kidwell, 1986). Since progradation of the Colorado River Delta, fluvial and lacustrine sediments have filled the rapidly subsiding Salton Trough toward the northwest into what now is the United States (van de Kamp, 1973; Lonsdale, 1989). In Mexico, oil and gas productive rocks, probably younger than the upper Miocene to Pliocene Imperial Formation, apparently interfinger with the prograding Colorado River delta where it intersects the Gulf of California. There are no reported significant hydrocarbon occurrences in the Salton Trough north of the Mexican border.

Rounds (1981) reports that Eagle Exploration Co., Denver, Colo., filed for Federal leases in California along its border with Mexico, based on the report of a major gas discovery by PEMEX at the mouth of the Colorado River delta, some 50 mi away in Mexico. The play was based on speculation that the gas-bearing rocks related to the Mexican gas find extend into California. Younger post-marine incursion rocks in the Salton Trough usually are discontinuous sand bodies that are unlikely to extend continuously over 50 mi from the gas discovery in Mexico, making long distance hydrocarbon migration a poor possibility. By 1993, Eagle Exploration had abandoned their leases in the area.

Traces of thermogenic hydrocarbons have been reported in gas samples from the Cerro Prieto geothermal system, Mexico (Nehring and others, 1982; Des Marias and others, 1988). Traces of thermogenic hydrocarbons are typical of sedimentary-rock-hosted geothermal systems, and, although not studied, other geothermal systems in the Salton trough probably will show similar gases.

Neogene to Holocene source rocks, if present within the U.S. portion of the Salton Trough are probably lacustrine mudstones. Rock-Eval and total organic carbon (TOC) analysis of 24 samples of mudrock from Holocene Lake Cahuilla sediments and older Neogene rocks exposed at the surface indicate poor source rock potential. The richest sample in this sample suite had only 0.34 weight percent TOC.

The Salton Trough has been extensively drilled with wells commonly penetrating 5,000-10,000 ft deep. The Chevron Wilson-1 (sec. 20, T. 14 S., R. 15 E.) a dry hole, penetrated 13,400 ft of Cenozoic rocks that at total depth are hot (280^{o} C) and overmature (3.0 percent mean random vitrinite reflectance). TOC analyses of five mudstone samples ranging from 7,375 to 13,407 ft depth in Wilson-1 all contain less than 0.5 weight percent. Similarly, 15 mudstone samples taken from 1,560-9,900 ft depth in Cal State 2-14 (sec. 14, T. 11 S., R. 13 E.) all have a TOC content of less than 0.4 weight percent.

Organic geochemistry and vitrinite reflectance evidence suggests that the prospects for oil and probably gas are poor in the Salton Trough. Even though over 100 geothermal wells have been drilled in the U.S. portion of the trough, there are no oil shows and only a few shows of hydrocarbon gas. Although no source rocks have been identified, several hypothetical plays are still considered but not assessed because of risk. The play outlines would essentially coincide with the province boundary because the possible source rocks would potentially underlie all of the province.

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HYPOTHETICAL PLAY SUMMARIES

Geologically Established Examples

THERMOGENIC GAS

Deep burial in the high geothermal gradient typical of the Salton Trough has overmatured the most likely potential source rocks, the marine mudstones of the upper Miocene Imperial Formation (V. Frizzel, written commun., 1985). Less deeply buried but thermally mature source rocks within the U.S. portion of the Salton Trough apparently contain little organic matter and have no demonstrated source rock potential. Resource potential for the play is small.

BIOGENIC GAS

Shallow gas shows of apparently biogenic origin are reported in the Palm Springs and Borrego Formations (Tarbet, 1951). Resource potential for the play is small.

HYDROCARBON GENERATION BY GEOTHERMAL SYSTEMS

Hydrocarbon generation caused by geothermal systems apparently occurs in Nevada (Huelen and others, 1990a, 1990b; Schalla and others, 1994). The geologic features of geothermal systems are attractive for producing accumulations of hydrocarbons because they are known to self seal by mineral deposition at their periphery, create secondary porosity within the reservoir, cause source rock maturation, and produce fluid flow for possible secondary migration of the generated hydrocarbons. Geothermal systems are common in Province 16 and they can cause rapid thermal maturation of organic matter (Barker, 1991) of a considerable volume of rock (Barker and Pawlewicz, 1990).

The analog for geothermal systems in Province 16 are apparently oil-bearing geothermal systems in the Basin and Range of northern Nevada and west-central Utah (Eastern Great Basin Province-19). In areas where there are good seals and source rocks, prolific oil production is possible. The Grant Canyon field in Railroad Valley, Nev., is a three-well field spread over 3 acres that ultimately will produce about 25 MMBO--over half of the total Nevada production to date. There the problem is finding an adequate seal to trap thermogenic gas, and there is no gas production in the northern Basin and Range. The seals with respect to gas are apparently disrupted by the continuing faulting and by the intrusions themselves, and most of the gaseous hydrocarbons generated seem to be lost quickly. Nevertheless, hydrocarbon generation caused by geothermal systems is capable of producing and concentrating considerable quantities of hydrocarbons in a small surface area. Resource potential for the play is small.

GEOLOGICALLY SPECULATIVE EXAMPLES

Contact Metamorphism by Intrusives

Young intrusives commonly occur in the Salton Trough (for example, de Boer, 1979). Generation and migration of petroleum during contact-metamorphism is widely observed but usually only involves relatively small volumes of hydrocarbons. A contact metamorphism mechanism for generating commercial quantities of hydrocarbons is speculative in the sense that the volume of rock in which the thermal maturity is increased is generally small.

The analog for the Salton Trough Contact Metamorphism Play is the Spanish Peaks dike complex of southern Colorado. In this deeply eroded area of some 3,844 sq mi, there are over 100 dikes and sills exposed along with several major intrusive plugs. These Miocene mafic rocks intrude Cretaceous oil (marine marls) and gas (coal) source rocks. Studies of dike contact metamorphism in the Spanish Peaks area (C.E. Barker, U.S. Geological Survey, unpublished data) show that these dikes overmature rocks out to a distance equal to 1/2 the dike thickness. In the coal near the dikes, however, methane content and producibility may be enhanced by increased thermal maturity and cleat development. The intruded area, in general, has an elevated thermal maturity. Where the dikes intrude, oil source rocks are in the mature range and considerable amounts of extractable hydrocarbons may be present. Vugs and fractures in dikes, as well as porosity and fractures within the host rock, may be oilbearing. Resource potential for the play is small.

Local Generation from Neogene Lacustrine beds

In the Salton Trough Province, exploration to date has emphasized drilling in the deepest portions of the basin in an attempt to find Neogene source rocks thermally matured by burial (such as the Chevron Wilson-1 well). the deepest portions of the basin, the depocenter are also where it is likely that lacustrine rocks with source potential will be deposited. So far, the rocks in the deeper portion of the trough have been found to be lean in TOC content and overmature at a relatively shallow depth because of the high temperatures encountered at shallow depth in the Salton trough (Higgins, 1980; Sturtz, 1989). In this play, the source potential of Neogene lacustrine source rocks must be preserved until now when heating to hydrocarbon generation occurs. Earlier phases of hydrocarbon generation from Neogene rocks have a poor preservation potential because ongoing extensional faulting disrupts trap sealing. Further, the basin margins would appear to be a better place for source rock preservation (and exploration) than the hot central portion of the trough. However, the Salton Trough margins are dominated by alluvial deposition and are less likely sites of lacustrine source rock deposition. Fluid flow out from the geothermal systems in the hot central portion of the basin toward the cooler trough margins may also carry hydrocarbons to the conjectured reservoirs in the porous alluvial rocks at the edges of the trough, although there may be a lack of adequate seal rock there.

Other subplays involving Neogene lacustrine beds should be considered: (1. Neogene lacustrine beds near the trough margin laterally interbedded with marginal alluvial fans-- (overlying seal= continental evaporites, lateral seal= fault truncation); (2. shallow heating of source rocks by geothermal convection, shallow intrusions, or fluid flow up basin faults, especially near the trough boundaries where reservoirs are conjectured to occur in the coarser grained rocks at the edges of the trough. Resource potential for the play is small.

DISTANT GENERATION AND MIGRATION FROM NEOGENE TO RECENT

Terrestrial or Marine Source Rocks in Mexico

Thermal maturation studies suggest mostly overmature upper Miocene to Pliocene marine rocks of the Imperial Formation underlying most of the Salton Trough. However, in the distal portion of the Colorado River delta in Mexico, younger prodelta or marine rocks with better source rock richness and improved chances of hydrocarbon potential preservation may exist (Brennan, 1989). Earlier phases of hydrocarbon generation, if they occurred, have a poor preservation potential because ongoing extensional and strike-slip faulting disrupts trap sealing. The heat source for thermal maturation may be burial under valley fill, shallow intrusions, and hydrothermal convection in geothermal systems.

Long-distance migration from possible source rocks in the Mexican portion of the Salton trough are considered a poor possibility because of the apparent discontinuous nature of the sandstone bodies within the basin (van de Kamp, 1973; Wagoner, 1977; Elders, 1979; among many others), and numerous major faults that would impede regional fluid flow. However, without apparent conduits, long distance migration from possible source rocks in the Mexican portion of the Salton Trough is considered a poor possibility. Resource potential for the play is small.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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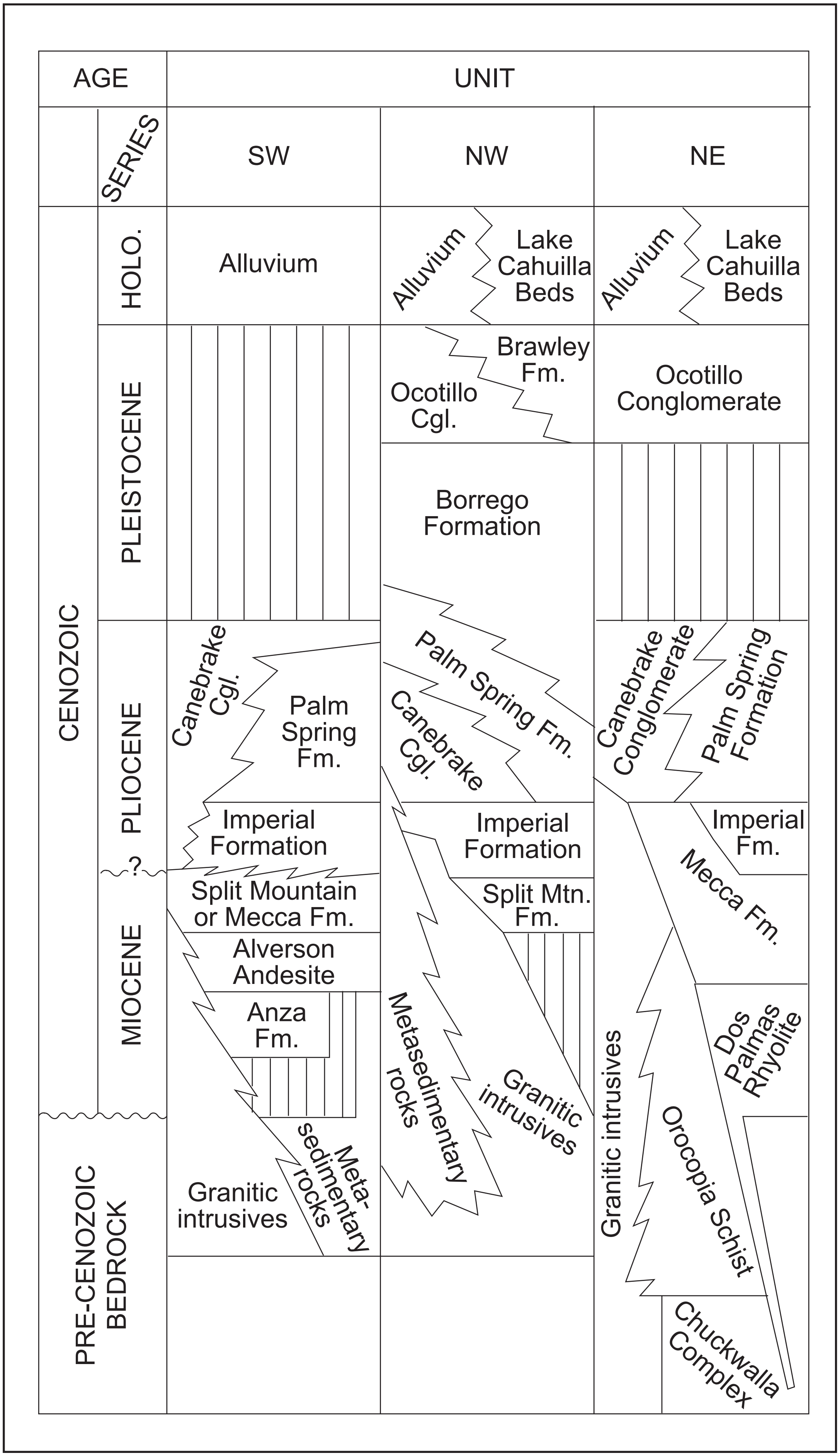

AGE
UNIT
SERIES
SW
NW
NE
CENOZOIC
HOLO.
PLEISTOCENE
PLIOCENE
MIOCENE
PRE-CENOZOIC BEDROCK
Alluvium
Alluvium
Lake Cahuilla Beds
Alluvium
Lake Cahuilla Beds
Brawley Fm.
Ocotillo Cgl.
Ocotillo Conglomerate
Borrego Formation
Canebrake Cgl.
Palm Spring Fm.
Palm Spring Fm.
Canebrake Cgl.
Canebrake Conglomerate
Palm Spring Formation
Imperial Formation
?
Imperial Formation
Imperial Fm.
Split Mountain or Mecca Fm.
Split Mtn. Fm.
Mecca Fm.
Alverson Andesite
Anza Fm.
Metasedimentary rocks
Granitic intrusives
Dos Palmas Rhyolite
Granitic intrusives
Orocopia Schist
Meta-sedimentary rocks
Granitic intrusives
Chuckwalla Complex