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Eel River (Humboldt) Basin, California

(Province 80)

By Hugh McLean[1]

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[1]U.S. Geological Survey, 345 Middlefield Rd., MS 999, Menlo Park, CA

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INTRODUCTION

The Eel River basin is a Miocene through Pleistocene sedimentary basin located in northwestern California near the mouth of the Eel River (Fig. 1). Also known as the Humboldt basin, the onshore part is a triangular shaped structural depression or synclinorium that is bounded on the northeast by north-dipping thrust faults, and is bounded on the south by the False Cape shear zone. The thrust faults converge at an angle of approximately 30° with the Russ fault, the northwestmost major fault of the False Cape shear zone. The west side of the onshore basin is the north trending coastline. The offshore part of the basin extends for about 195 km (120 miles) northward into the waters of southern Oregon. The onshore part of the basin contains approximately 905 km^2 (350 mi^2) of prospective late Tertiary section that locally exceeds 3,350 m (11,000 ft) in thickness.

The Eel River basin lies just north of the Mendocino triple junction, and north of the San Andreas fault system, but the basin history since early Neogene time has been strongly influenced by both of these important tectonic features as well as the Blanco fracture zone. The basin is characterized by generally fine-grained detrital sediment fill that is lower Miocene and younger (Ogle, 1953). Most of the Miocene rocks reflect sedimentation at bathyal depths. Commencing in early Pliocene time, the basin filled with progressively shallower deposits, shoaling to shallow-marine depths by early Pleistocene, followed by nonmarine deposition in late Pleistocene and Recent time (Ogle, 1953). Most of the major folds within the basin probably began forming in the early- to middle-Pleistocene, and the basin remains tectonically active to the present time as evidenced by late Pleistocene strata that are overthrust by Franciscan Complex basement rocks (Carver, 1987).

The Tompkins Hill gas field (Fig. 2) has produced 87 Bcf since its discovery in 1937. The Table Bluff field produced approximately 109,000 Mcf before being abandoned, and a third field named Grizzly Bluff was never hooked up for production (Hobson, 1971). The information in this report is mainly abstracted from a symposium volume on the tectonics, sedimentation and evolution of the Eel River and other coastal basins of northern California published in the autumn of 1987 by the San Joaquin Geological Society. Descriptions of petroleum geology in the symposium volume draw in turn from the work of Ogle (1953) and Hopps and Horan (1984).

Stratigraphy

Basement rocks

The central part of the Eel River basin is underlain by a sequence of folded turbidite sandstone, mudrock, and conglomerate first called the Yager Formation by Ogle (1953), and later the Yager tectonic terrane by Blake et al., (1985) and then called the Yager Complex by Hopps and Horan (1987) . The age of the Yager is not well known, but palynomorphs suggest a Paleogene (mainly Eocene) age, although the age may range from Paleocene to Oligocene (?) (Underwood, 1983). Sandstone beds are hard and tight, being metamorphosed to zeolite (laumontite) facies and the formation is considered by petroleum explorationists to be economic basement, although strong gas shows in several wells have been associated with Yager strata (Horan and Hopps, 1987). Underwood (1985) interprets the Yager to be a sequence of slope-basin strata deposited on coeval accreted rocks called the Coastal terrane of the Franciscan Assemblage. The Yager is estimated to be at least 1650 m (5000 ft) thick beneath the Eel River basin (Fig. 3).

The western part of the Eel River basin is probably underlain by the coastal terrane (part of the Franciscan Coastal Belt), and the eastern part of the basin is underlain by the Central Belt of the Franciscan.

Bear River Formation

The oldest part of the Neogene sequence is called the Bear River Formation or "Bear River beds" of Haller (1980), which consist of diatomaceous shale and silty sandstone deposited on the Yager Formation (Fig.3). The Bear River beds are early and middle Miocene in age and might be a northerly (but less siliceous) correlative of the Monterey Formation (Horan and Hopps ,1987). The formation in the axial part of the basin is approximately 600 m (2000 ft) thick (Hopps and Horan, 1983). Shale within the sequence lacks fracture porosity and sandstone beds have conventional porosity. An angular unconformity separates the Bear River from strata of the overlying Wildcat Group along the south flank of the basin (Hopps and Horan, 1984; and Clarke 1987).

Wildcat Group

The Wildcat Group unconformably overlies the Bear River and Yager formations and consists of the Pullen, Eel River, Rio Dell formations and Scotia Bluffs Sandstone (Fig. 3), which range in age from late Miocene to middle Pleistocene (see summaries by Clarke, 1987; and Horan and Hopps, 1987). Wildcat strata tend to coarsen upward refecting an westward regression. Paleocurrents measured along the southern limb of the Eel River synclinorium show consistent northwestward transport (Clarke, 1987).

Pullen Formation--The base of the Wildcat Group is formed by the late Miocene and early Pliocene Pullen Formation, which is composed of siltstone and a basal sandstone sequence that is as much as 70 m (240 ft) thick. The Pullen Formation has good conventional reservoir properties, but is not yet productive.

Eel River Formation--The Eel River Formation rests gradationally on the Pullen Formation, and consists of mudstone, siltstone, and sandstone that is locally glauconitic. The formation has a maximum thickness of about 400 m (1200 ft), and locally overlies the Yager Formation. A sand-rich sequence in the Eel River called the Eel River sand that has a net thickness of approximately 110 m (350 ft) thick, is shown by Horan and Hopps (1987) to be restricted to the southwest part of the basin.

Rio Dell Formation--The Rio Dell Formation is the most productive part of the Wildcat Group. Rio Dell strata overlie the Eel River Formation and consist of up to 1450 m (4640 ft) of late Pliocene and Pleistocene fine-grained sandstone, siltstone, and mudstone that record progressive shoaling from bathyal to shelf depths (Ingle, 1976). Most of the gas produced from the Tompkins Hill field is from sandstone reservoirs in the middle part of the Rio Dell section (Figs. 3 and 4; Parker, 1987).

Scotia Bluffs Sandstone--Shoaling continued into Pleistocene time with deposition of the Scotia Bluffs Sandstone, a sequence of fine- to medium-grained sandstone and mudstone that has a maximum thickness of 640 m (2050 ft) and locally unconformably overlies the Rio Dell Formation (Ingle, 1987). The Scotia Bluffs Sandstone is the youngest marine unit in the Wildcat Group and is gradationally overlain by the largely nonmarine upper Pleistocene and Recent Carlotta Formation. The Hookton Formation and younger terraces, which are mainly nonmarine and not part of the gas producing section, complete the stratigraphic succession.

Play Description

Name: Eel River Basin Fill Play and Yager Formation (Speculative Play)

The Bear River Formation and Wildcat Group that range in age from lower Miocene through lower Pleistocene in the onshore Eel River basin are combined into one one play, and the underlying Yager Formation is considered to be a speculative play.

Reservoirs

Gas in the Tompkins Hill field is produced from groups of Pliocene turbidite sandstone in the Bear River Formation, known as the Anderson sands (Fig. 3), which are interbedded with siltstone and mudstone (Parker, 1987). Conventional sandstone porosity may be as high as 25%. Because loci of sand deposition during Miocene and Pliocene time shifted within the basin, estimates of net sand thickness over any particular structure are difficult to assess. Sandstone in the Pullen Formation is thickest near the present center of the basin, whereas the Eel River sand is restricted to the southwest part and the Anderson sand is thickest in the southeast part part of the basin (Horan and Hopps, 1987).

Traps and seals

Anticlines with four-way closure form most of the traps in the Tompkins Hill field, but faults also create small blocks of closure on the nose of the main anticline, and in some cases closure involves stratigraphic pinch outs. Seals are formed by thick sequences of mudrock (Horan and Hopps, 1987; Parker, 1987).

Source rocks

The source of the Tompkins Hill gas is not well known. Rocks with source potential exist not only within the Bear River Formation and Wildcat Group, but also exist in the Yager Formation beneath the basin (Underwood, 1985). Pelitic rocks of Miocene and Pliocene age from the coastal bluffs of the Centerville Beach section, sampled by Pat McCrory of Stanford University, have total organic carbon (TOC) values that range from 0.56 wt-% to 1.39 wt-%, and mean vitronite reflectance values (R_{om}) that range from 0.42 to 0.68, suggesting that the rocks sampled are within the zone of oil generation.

The Tompkins Hill field produces small quantities of water, and minor amounts of a volatile condensate that smells like paint thinner (J.D. Parker, oral commun., 1987).

Timing and migration

The major anticlines in the Eel River basin probably formed late in the basin evolution in response to compression generated by the thrust faults that form the northern and southern flanks. As illustrated by Carver (1987), folding probably began in the middle to late Pleistocene time and has continued to the present time.

Depth of Occurrence

The main producing intervals in the Tompkins Hill field are in the middle of the Rio Dell Formation (Fig. 4) and lie at an approximate drill depth of 1500 m (4500 ft), although the shallowest zone is at a drill depth of about 665 m (2000 ft). Structural closure on the Tompkins Hill anticline is approximately 530 m (1600 ft) (Parker, 1987).

Exploration status

The onshore part of the Eel River basin is in a mature stage of exploration. Gas has been produced from the Tompkins Hill field for fifty years since its discovery in 1937 by the Texas Company. A total of 39 wells have produced more than 87 Bcf of 1000-1030 BTU gas that is 98% methane (Horan and Hopps, 1987; Parker, 1987). Over the past fifty years field pressure has dropped from 2700 psi to 1200 psi. Cummulative production in 1960 was 24 Bcf, in 1968 was 44 Bcf, and in 1980 was 68 Bcf. Gas in the Grizzly Bluff and Table Bluff fields has been insufficient for sustained commercial production.

Acknowledgments

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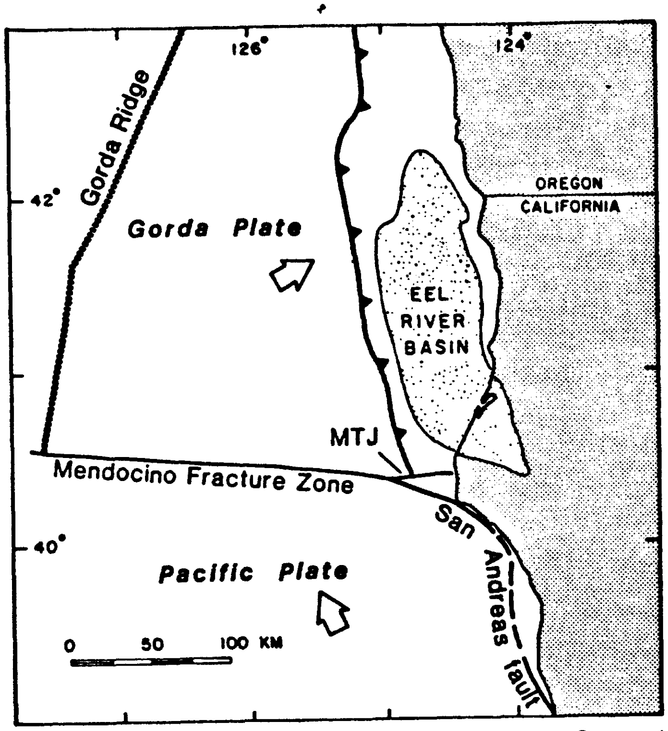

Figure 1. Map showing geographic location of and plate-tectonic setting of the Eel River basin. MTJ = Mendocino triple junction. From Underwood (1987).

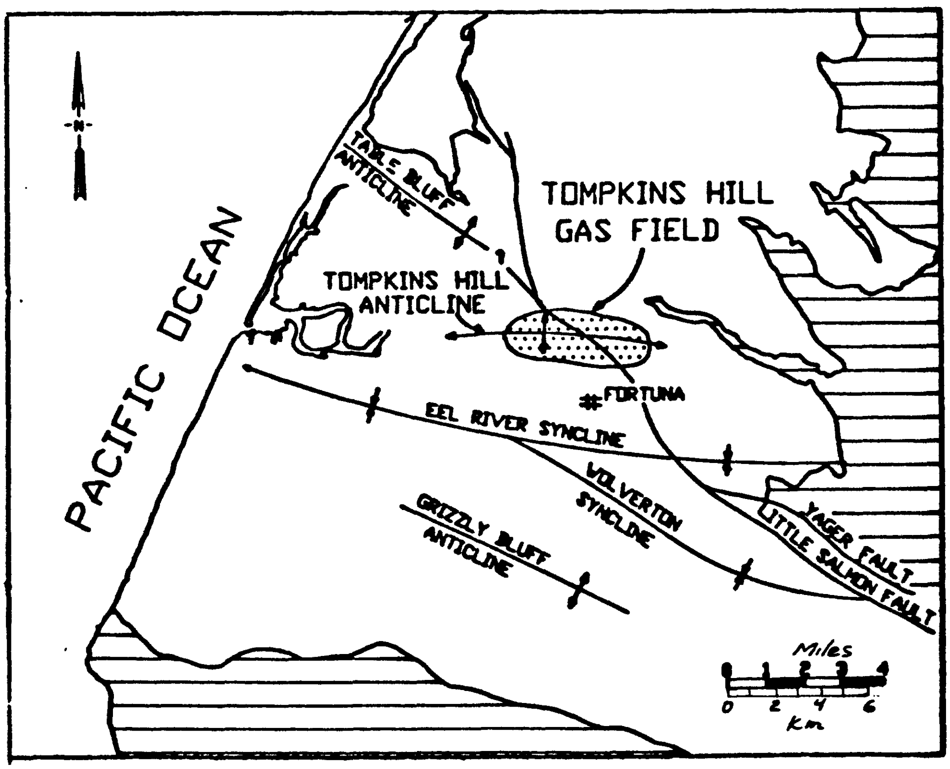

Figure 2. Map showing location of Tompkins Hill gas field, and major folds within the basin. Modified from Parker (1987).

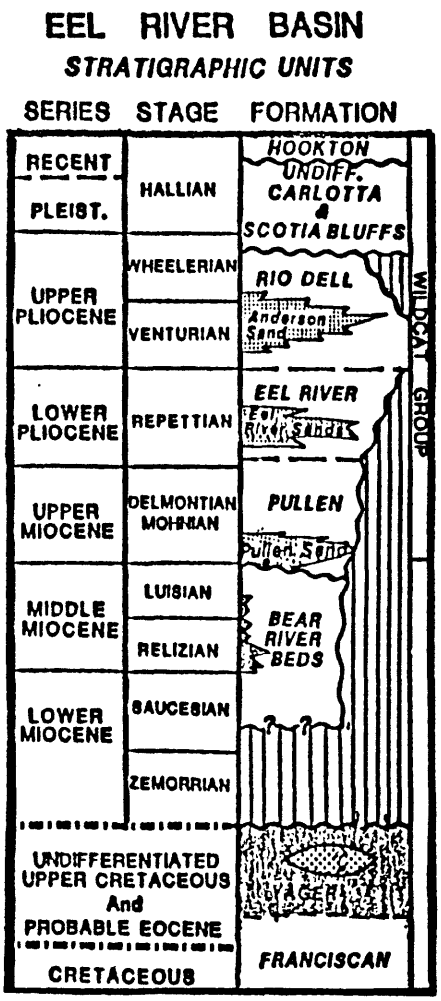

Figure 3. Generalized columnar section showing Eel River basin stratigraphic units. From Horan and Hopps (1987).

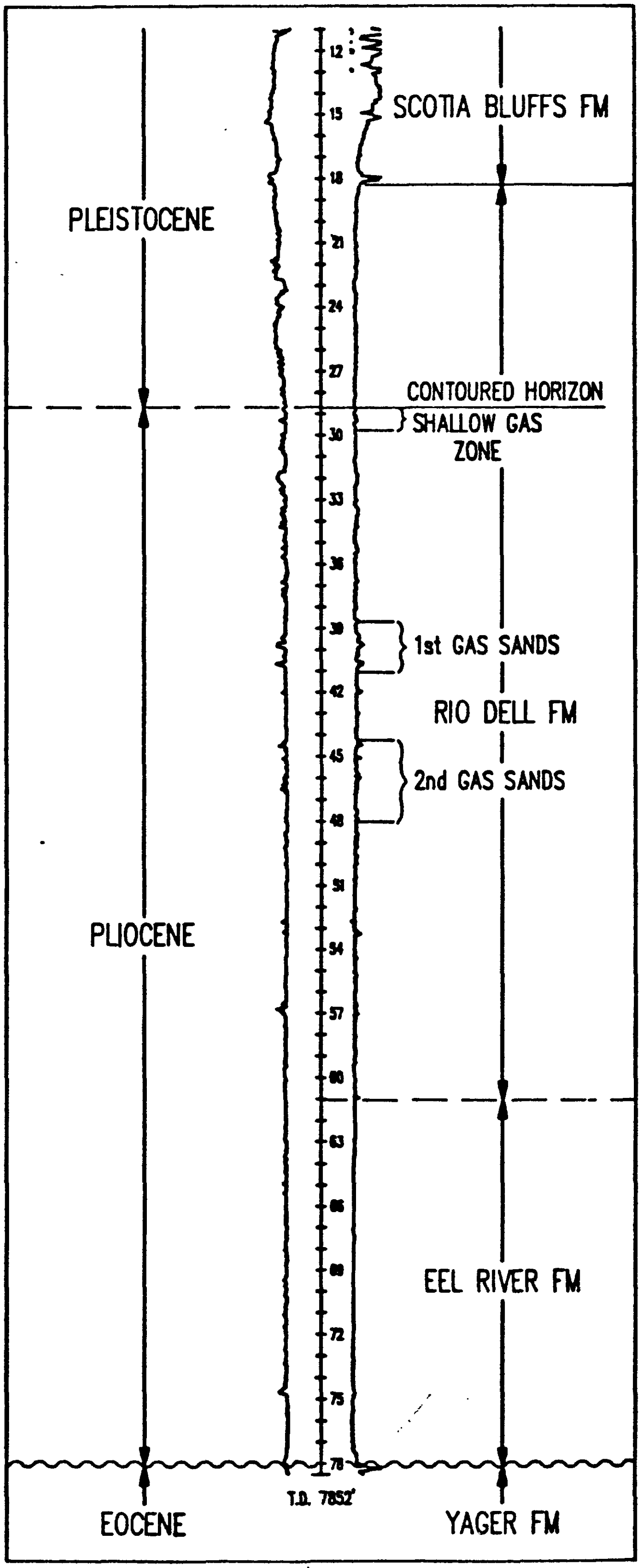

Figure 4. Type log showing stratigraphic relations in the Tompkins Hill field. The 1st and 2nd gas sands are the main producing intervals in the field. From Parker (1987).