PS Petroleum Exploration History and Subsurface Geology of the Castle Mountain Fault Anticline Near Houston, South-Central Alaska*

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Search and Discovery Article #30526 (2017)**
Posted November 13, 2017

*Adapted from poster presentation given at AAPG 2017 Pacific Section Annual Meeting, Anchorage, Alaska, May 21-24, 2017

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Abstract

The Castle Mountain fault anticline (Haeussler and Saltus, 2011) is located on the north side of the seismogenic and right-lateral Castle Mountain fault near Houston, Alaska, about 30 miles north of Anchorage. Previous work, including a published seismic-reflection profile, showed that the anticline is cored by several steeply-dipping faults and that the crest of the anticline is coincident with an aeromagnetic high that parallels the surface trace of the Castle Mountain fault. Here we provide a short history of petroleum exploration on the anticline and report new isotopic and biostratigraphic results that yield further insights into its subsurface stratigraphy and structure.

Coal was discovered near the crest of the anticline in Houston in 1917 during excavation for a cut along the Alaska Railroad (Barnes and Ford, 1952; May and Warfield, 1957). A mine was established and produced subbituminous coal from the Tyonek Formation, which yielded plant fossils of the Seldovian floristic stage indicating an age of early to middle Miocene (Wolfe et al., 1966; Magoon et al., 1976).

During 1951-1952, the U.S. Bureau of Mines drilled three core holes to subsea depths of -137 to -812 feet near Houston and found sandstone intervals in the Tyonek Formation that flowed methane gas and brackish water (May and Warfield, 1957). During 1954-1963, five wells named for Rosetta, wife of one of the operators (Roderick, 1997, p. 51), were drilled as oil and gas exploration wells to subsea depths of -887 to -5,774 feet. All five Rosetta wells were dry holes with confirmed shows of gas and unconfirmed reports of minor oil stains. During 1998-2004, four wells were drilled on and near the anticline in search of coalbed methane. No commercial production was established but the Houston 3 well reportedly flowed gas at 2-3 mcf/day from perforations in five coal beds in the Tyonek Formation at subsea depths of -1,027 to -1,545 feet.

The Houston Pit 1 well, drilled in 2004 as a coalbed methane test near the crest of the anticline, spudded in the Tyonek Formation. At a subsea depth of -1,042 feet, this well encountered the top of the Arkose Ridge Formation, consisting of nonmarine conglomerate, sandstone, and basalt. Two core samples of basalt from depths of -1,247.0 and -1,279.5 feet yielded whole-rock $^{40}Ar/^{39}Ar$ ages of 58.6 ± 1.6 Ma and 58.8 ± 2.4 Ma, respectively, indicating a late Paleocene age for these rocks. We hypothesize that basalt in the Arkose Ridge Formation may be the source of the aeromagnetic high associated with the Castle Mountain fault anticline.

The Rosetta 3 well spudded in the Tyonek Formation on the south flank of the Castle Mountain fault anticline and found the top of the Arkose Ridge Formation at a subsea depth of -1,655 feet. At -2,165 feet the well apparently penetrated a fault and entered an interval of sandstone, siltstone, shale, and coal that persists to near the total depth of the well at -5,774 feet. Core samples from this interval contain fossil leaf impressions and a freshwater clam, and palynomorphs indicate a probable Miocene age and terrestrial depositional setting. These results suggest that the interval from -2,165 feet to near the total depth of the well is correlative with the Tyonek Formation. If this interpretation is correct, then there is likely an unnamed contractional fault at -2,165 feet in the Rosetta 3 well that places Paleocene Arkose Ridge Formation above Miocene Tyonek Formation. The geometry of this unnamed fault is unclear; it may be a north-dipping synthetic reverse fault that parallels the Castle Mountain fault, or it may connect at depth with the surface trace of the Castle Mountain fault in a positive flower structure.

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USGS science for a changing world

HIGHLIGHTS

- A dozen wells drilled near a historic coal mine in the Houston area, located about 30 miles north of Anchorage on the north side of the Castle Mountain fault, found indications of natural gas but not in sufficient quantities for commercial gas production.
- Several of the wells penetrated Miocene Tyonek Formation and the underlying Paleocene Arkose Ridge Formation; the contact between the two units is marked by abrupt changes in lithology and log response, is relatively easy to correlate from well to well, and defines an anticline in the hanging wall of the north-dipping, right-lateral Castle Mountain fault.
- The Miocene Tyonek Formation consists mainly of sandstone, siltstone, mudstone, and coal; its Miocene age is based on plant fossils found in the Houston coal mine (Wolfe et al., 1966) and on new palynological data obtained by us from the Rosetta 3 well and reported here for the first time.
- The Paleocene Arkose Ridge Formation consists mainly of coarse sandstone, conglomerate, and volcanic rocks; its Paleocene age is based on new isotopic ages from basalt in the Houston Pit well, analyzed at the Geochronology Laboratory, University of Alaska, Fairbanks, reported here for the first time.
- A previously-unrecognized fault in the Rosetta 3 well that places Paleocene Arkose Ridge Formation above Miocene Tyonek Formation may be (1) a north-dipping reverse fault that parallels the Castle Mountain fault, or (2) a steeply-dipping fault in a positive flower structure.

Summary

The Castle Mountain fault anticline (Haeussler and Saltus, 2011) is located on the north side of the seismogenic and right-lateral Castle Mountain fault near Houston, about 30 miles north of Anchorage. Previous work, including a published seismic-reflection profile, showed that the anticline is cored by several steeply-dipping faults and that the crest of the anticline is coincident with an aeromagnetic high that parallels the surface trace of the Castle Mountain fault. Here we provide a short history of petroleum exploration on the anticline and report new isotopic and biostratigraphic results that yield further insights into its subsurface stratigraphy and structure.

Coal was discovered near the crest of the anticline in Houston in 1917 during excavation for a cut along the Alaska Railroad (Barnes and Ford, 1952; May and Warfield, 1957). A mine was established and produced subbituminous coal from the Tyonek Formation, which yielded plant fossils of the Seldovian floristic stage indicating an age of early to middle Miocene (Wolfe et al., 1966; Magoon et al., 1976). During 1951-1952, the U.S. Bureau of Mines drilled three core holes to subsea depths of -137 to -812 feet near Houston and found sandstone intervals in the Tyonek Formation that flowed methane gas and brackish water (May and Warfield, 1957). During 1954-1963, five wells named for Rosetta, wife of one of the operators (Roderick, 1997, p. 51), were drilled as oil and gas exploration wells to subsea depths of -887 to -5,774 feet. All five Rosetta wells were dry holes with confirmed shows of gas and unconfirmed reports of minor oil stains. During 1998-2004, four wells were drilled on and near the anticline in search of coalbed methane. No commercial production was established but the Houston 3 well reportedly flowed gas at 2-3 mcf/day from perforations in five coal beds in the Tyonek Formation at subsea depths of -1,027 to -1,545 feet.

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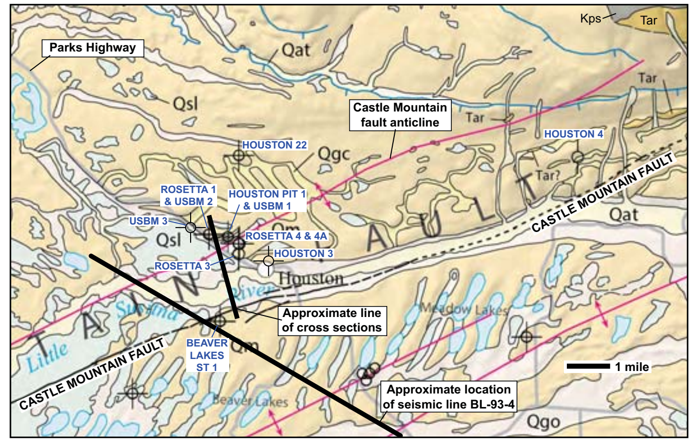
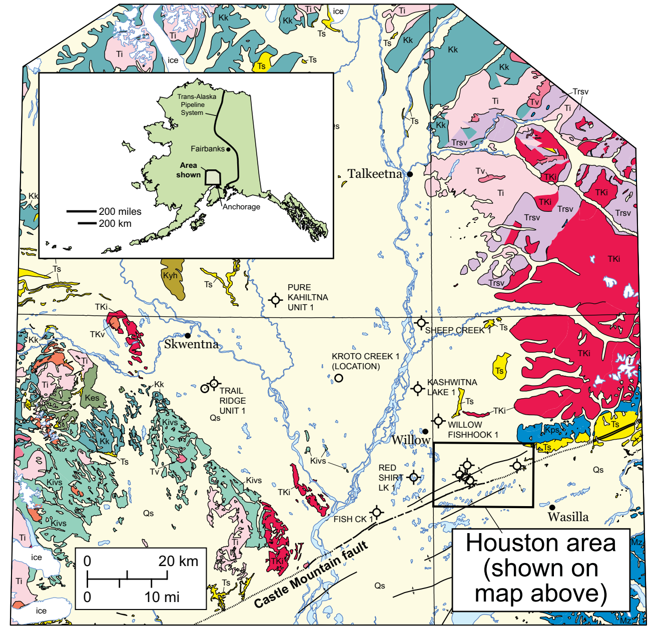
Wells and seismic line near Houston, Alaska



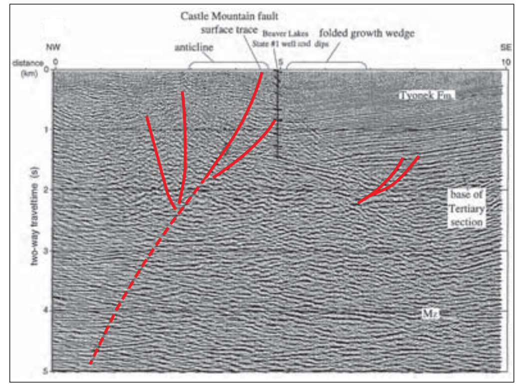
The City of Houston, Alaska, is located on the north side of the Castle Mountain fault, a north-dipping, right-lateral strike slip fault. Evidence for right-lateral displacement on the Castle Mountain fault includes right-lateral earthquake focal mechanisms (Haeussler et al., 2000), geophysical anomalies offset right-laterally about 26 km since about 35 Ma (Haeussler et al., 2000; Haeussler and Saltus, 2005, 2011), and a Late Jurassic basin margin offset right-laterally about 110-130 km since about 145 Ma (Trop et al., 2005). A coal mine formerly existed at the location of the Houston Pit 1 and USBM 1 wells. The geologic map snippet shown above is from Wilson et al. (2012); see map below for location. Geologic map units include Kps, pelitic schist of Hatcher Pass area with Cretaceous protolith and 60 Ma metamorphic age (Bleick et al., 2012); Tar, Paleocene Arkose Ridge Formation; Qgc, Qgo, and Qm, Quaternary glacial deposits; Qsl, Quaternary lacustrine and swamp deposits; and Qat, Quaternary alluvium.



SURFACE GEOLOGIC MAP UNITS (MODIFIED AND GENERALIZED FROM WILSON ET AL., 2012)

Qs	Quaternary deposits	TKi	Tertiary & Cretaceous intrusive rocks	Kps	Pelitic schist of the Hatcher Pass area (Cretaceous protolith)
Ts	Tertiary sedimentary rocks	Kivs	Metavolcanic & sedimentary rocks (Cretaceous and/or Paleogene)	Kes	Flysch of the Tordrillo Mountains (Cretaceous & Jurassic)
Tv	Tertiary volcanic rocks	Kk	Kahiltna flysch sequence (Cretaceous)	Trsv	Triassic igneous, sedimentary, & metamorphic rocks, undivided
Ti	Tertiary intrusive rocks				
TKv	Tertiary & Cretaceous volcanic rocks	Kyh	Graywacke of the Yenlo Hills (Cretaceous & Jurassic)	Mz	Mesozoic rocks, undivided

Seismic across the Castle Mountain fault



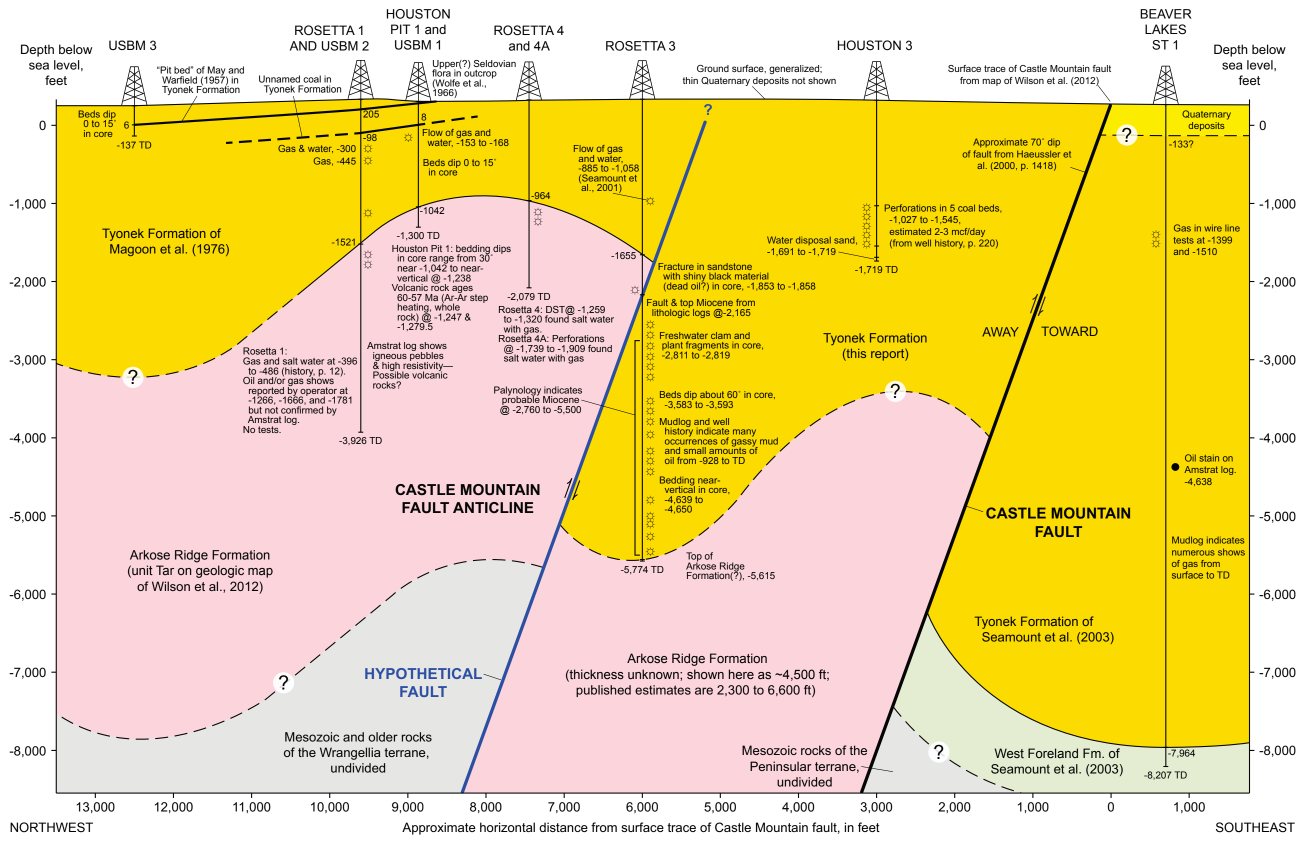
This interpretation of seismic line BL-93-4 (modified from Haeussler et al., 2000, with red lines added to emphasize faults) shows a hanging-wall anticline and flower structure along the northwest-dipping, right-lateral Castle Mountain fault in the Houston area.

Historic coal mine at Houston, Alaska

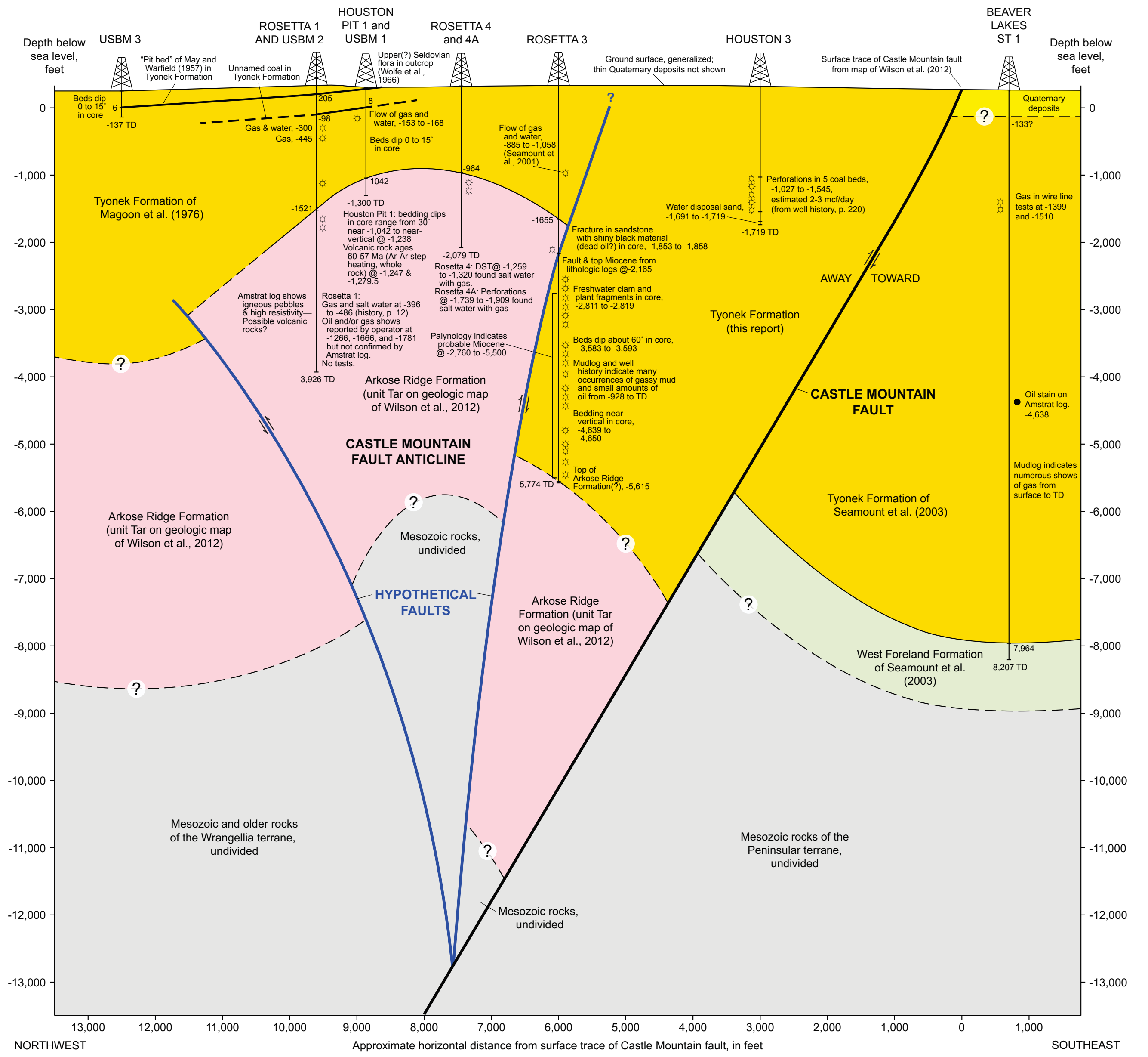
The strip mine at Houston, no longer in operation, was located along the Alaska Railroad and supplied coal to Alaska military bases until at least 1955 (Barnes and Ford, 1952; Fairbanks Daily News-Miner, Nov. 8, 1955). The photo above shows the tipple in October 1950. Photo by Don Oesau and used with permission.

View looking northeast at the Houston coal mine, showing the Alaska Railroad in the foreground, tipple near photo center, and mining excavations behind the tipple. Photo dated September 22, 1955, and used with permission from Steve McCutcheon, McCutcheon Collection; Anchorage Museum, B1990.014.5.P.1.149.

Hypothesis 1, showing a hypothetical reverse fault that parallels the Castle Mountain fault



Hypothesis 2, showing hypothetical steeply-dipping faults in a positive flower structure



Oil rig in the Houston area, 1955

George Tucker's and Ralph Peterson's Anchorage Gas and Oil Development, Inc., drilling rig at Houston, Sept. 26, 1955. On the basis of the date of the photo this is likely the Rosetta 1 well, which spudded in June 1954. The remaining 4 Rosetta wells were spudded in 1956 and later years. Photo used with permission from Steve McCutcheon, McCutcheon Collection; Anchorage Museum, B1990.014.5.P.1.229.

Gas flare at Houston well

Gas flare at a coalbed methane test well near Houston, probably the Houston 1 well or the Houston 3 well. This photo was obtained in 2000 or thereabouts from the Lapp Resources, Inc., web site. The company and the web site no longer exist.

Fossil clam in Rosetta 3 core

Impression of a shell fragment from a fossil clam, identified by R.B. Blodgett as a freshwater clam of the family Unionidae, in bioturbated dark gray siltstone of probable Miocene Tyonek Formation from core no. 8 at subsea depths of -2,811 to -2,819 feet (measured depths of 3,146 to 3,154 feet) in the Rosetta 3 well.

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