DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Federal Lands Assesment Program:

Alaska Peninsula, Alaska

(Province 68)

By Hugh McLean[1]

Open-File Report

87-450 H

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

1988

Contents

Federal Lands Assesment Program:
Alaska Peninsula, Alaska
(Province 68)

By
Hugh McLean

Introduction

Province 68 includes most of the Alaska Peninsula, located in southwestern Alaska. This report addresses the petroleum potential of two plays. One play includes the onshore area of the Bristol Basin, which underlies the lowland area located between the mountainous core of the Alaska Peninsula and also underlies the shallow marine waters of Bristol Bay. The offshore basin is called the North Aleutian basin. A second play which is speculative, includes the Mesozoic strata that form much of the mountainous part of the Alaska Peninsula.

The onshore (Bristol) basin is approximately 320 km long by 25 km wide (Fig.1), and contains as much as 4,700 m (15,000 ft) of Tertiary sedimentary fill. Since 1959 nine exploratory wells have drilled unsuccessfully for commercial hydrocarbons (Fig. 1). Basin fill consists mainly of Tertiary sandstone, siltstone, mudstone, conglomerate, and stringers of coal. The play is for non-associated gas in Miocene and Oligocene sandstone beds that have conventional porosity. Exploratory drilling confirms the presence of sandstone beds with good porosity, but also suggests that source rocks contain woody and immature kerogen, McLean (1977, and 1979a).

Stratigraphy

The Bristol basin and contiguous North Aleutian basin, began to form in early Tertiary time and were filled with as much as 3750 m (12,000') of mostly marine, siliciclastic sediment. Basin fill was probably derived from as many as three source areas, including the Aleutian volcanic arc, the Kuskokwim River, and the Nushagak River. Offshore seismic data shows that much of the sedimentary fill is little-deformed and thins by onlap around the northern and eastern basin margins.

Four wells in the northeast part of the basin have drilled from 1,220 to 3,350 m (4,000 to 10,720 ft). The nearly flat-lying Eocene to Holocene sequence overlies granitic and metamorphic basement rocks that are presumably part of the Mesozoic Bruin Bay Batholith. Significant shows of oil or gas have not been reported in the northern group of wells.

Four wells have also tested the Tertiary section in the southwestern part of the Alaska Peninsula (Fig. 1). Gas shows mostly related to coal-stringers were encountered in one well (the Gulf Sandy River Federal No. 1) in the middle part of the Bear Lake Formation (Miocene), and oil shows appeared near the bottom of the hole. The Tertiary fill of the southern area is juxtaposed by a normal fault against Mesozoic strata that form much of the central and southern parts of the Peninsula (McLean, 1979a).

The lower Tertiary section consists of coal-bearing sandstone, siltstone, and mudstone, and includes a sequence of Eocene volcaniclastic sandstone and

mudstone strata called the Tolstoi Formation, and a sequence of marine Oligocene strata called the Stepovak Formation. The Neogene part of the section consists shallow marine to nonmarine sandstone, siltstone, and coal called the Bear Lake Formation, which is mainly Miocene. The overlying Milky River Formation, consists mainly of nonmarine Pliocene and Pleistocene sand and gravel.

Play Description

Name: Oligocene-Miocene Gas Play

Reservoir rocks

Exploratory wells drilled in the Bristol Basin indicate that some of the Bear Lake Formation contains sandstone beds with porosities as high as 25% to 30% (eg. the Gulf Sandy River Federal No. 1 well; Fig. 1). Porosity in the lower part of the Bear Lake Formation (below 2,500m or 8,000 ft), and in older rocks is reduced by grain interpenetration, and/or cementation by zeolites. Some of the upper Bear Lake sandstone is quartzose and very friable, and probably represents a beach or near-shore dune environment (McLean, 1977). Other sandstone however, is volcaniclastic and is hard and tight.

Source beds

Organic carbon is abundant in the Bear Lake Formation, but occurs in coaly beds that contain woody and immature kerogen. Total organic carbon of coaly beds averages 11% (TOC), and vitrinite reflectance of kerogen is in the immature range (R_o 0.29 to 0.51%), (McLean, 1977). Potential source beds are dark-colored, marine siltstone and shale beds in the Oligocene Stepovak Formation. Stepovak strata have yielded scattered shows of oil and gas from three of the southern area wells. Organic material in the Eocene Tolstoi Formation tends to be woody or herbaceous in composition. Beds of coal have produced small gas shows in some of the wells. A fundamental problem for hydrocarbon accumulation in the Bristol basin and basins offshore in the adjacent Bering Sea (for example, St. George and North Aleutian basins) is that because geothermal gradients are low, and mature source rocks are stratigraphically separated by from 310 to 620 m (1,000 ' to 2,000 ')from good reservoir rocks, Turner (1984).

Traps

Seismic data in the adjacent offshore basin indicates that strata in the Bristol basin are mainly flat-lying and undeformed (Marlow and others, 1976). Low amplitude folds overlie buried basement highs, and closure diminishes stratigraphically upward. Folds of unknown size and distribution may lie onshore where the section is faulted against the central part of the Alaska Peninsula. Stratigraphic traps associated with facies changes may also exist, but the size and distribution is unknown.

Timing and migration

A major problem with the petroleum potential in the basins of the Bering Shelf region is the stratigraphic separation of potential source rocks from potential reservoir rocks (Steffy and others, 1985). An additional problem is that low geothermal gradients necessitate deep burial for source rocks to enter the hydrocarbon generating window, and at such depths, reservoir quality (conventional porosity) has diminished.

Exploration status

Bristol Basin is a frontier area that has been tested by nine wells drilled between 1959 and 1981. Results in the northern area were discouraging because of lack of show thought to be the result of lean and immature source rocks. Results in the southern area have been slightly more encouraging, but significant problems exist in the stratigraphic distribution of source and reservoir rocks. Exploration in the Bristol Basin has been further dampened by the discouraging results of drilling in the adjacent St. George and Aleutian basins located offshore on the adjacent Bering Shelf (Steffy and others, 1985; Turner, 1984).

Play Description

Mesozoic Sequence (Speculative Play)

The Mesozoic sequence on the Alaska Peninsula consists of 4,680 to 6,250 m (15,000 to 20,000 ft) of clastic marine strata that range in age from Late Triassic to Late Cretaceous. Tertiary rocks are excluded from this play because of limited subsurface distribution. The sequence is folded into a series of northeast-trending en-echlon anticlines and synclines, intruded by volcanic and granitic rocks, and locally overlain by Quaternary strato volcanoes and associated volcanic complexes. Exploratory drilling of the Mesozoic rocks was stimulated originally by oil seeps in Middle Jurassic strata near Puale Bay, but to date no commercial discoveries have been made.

Reservoir rocks

The Upper Jurassic Naknek Formation contains the highest percentages of quartz and feldspar in Mesozoic sandstones. Sandstone in the Naknek Formation was derived from erosion of a nearby granitic source and consists of massive, medium- and coarse-grained rocks, which locally (eg. Puale Bay) to have good reservoir potential. Petrographic studies however, show that Naknek sandstone throughout most of the Alaska Peninsula is cemented with laumontite, and has low conventional porosity (McLean, 1979b). Lower and Middle Jurassic sandstone is volcaniclastic and is generally hard and tight with pore spaces plugged with a variety of primary and secondary clay minerals and zeolites. Triassic rocks exposed at Puale Bay consist of approximately 700 m (2240 ft) of thin-bedded limestone and chert, with interbeds of basaltic lava and volcanic breccia (Wang and others, in press).

Reservoir quality of Mesozoic rocks along the Peninsula has been adversely effected by the intrusion of volcanic and granitic rocks throughout much of Late Mesozoic and Tertiary time. Granitic intrusives mapped in reconnaissance fashion by Burk (1965), suggests that adjacent Mesozoic sections have virtually no petroleum potential. Areas that have not been intruded by large bodies of igneous rock have limited potential due to widespread intrusion of volcanic dikes, and sills of late Tertiary and Quaternary age.

Source rocks

Much of the Mesozoic sequence of the Alaska Peninsula contains marine shale and mudstone. Black shale is especially abundant in the Hoodoo Formation of Late Cretacoeus age, which crops out in the southwestern part of the Peninsula. The Triassic limestone and chert section at Puale Bay is thermally mature and according to pyrolysis data of Wang and others (in press)

lies within the oil generating window. Oil seeps near Puale Bay presumably emanate from Middle Jurassic shale and mudstone. In summary, the Mesozoic sequence in some parts of the Alaska Peninsula contains source rocks that lie within the window for oil and gas generation.

Traps and seals

Several large surface anticlines have been drilled by exploratory wells without commercial success. Potential seals within the sedimentary sequence consist of abundant thicknesses of shale and mudstone.

Timing and migration

Burk (1965) suggests that most of the broad open folds on the Peninsula formed in Pliocene time, which may help explain why the major structures tested by drilling have been dry. By Pliocene time, Mesozoic rocks would have been subjected to diagenesis associated with late Tertiary arc volcanism and plutonism that caused potential reservoirs and other potential migration paths to be hard and tight.

Exploration status

The Mesozoic section on the Alaska Peninsula has been sporadically explored by approximately 13 wells over the last sixty years. Most of the deep tests drilled on large-scale structures were plugged and abandoned between 1951 and 1977. The last wildcat was drilled in 1981, when Chevron drilled the Koniag No. 1 well on the Pacific coast side of the Peninsula near Amber Bay. Prospects for drilling additional deep exploratory wells on the Alaska Peninsula should be viewed with guarded optimism.

References Cited

Brockway, R, Alexander, B., Day, P., Lyle, W., Hiles, R., Decker, W., Polski, W., and Reed, B., 1975, Bristol Bay region, "Stratigraphic correlation section" southwest Alaska: Alaska Geological Society, unnumbered publication.

Burk, C.A., 1965, Geology of the Alaska Peninsula Island arc and continental margin. Geological Society of America Memoir 99, 250 p.

Marlow, M.S., McLean, Hugh, Vallier, T.L., Scholl, D.W., Gardner, J.V., and Powers, Richard, 1977, Preliminary report on the regional geology, oil and gas potential and environmental hazards of the Bering Sea shelf south of St. Lawrence Island, Alaska: U.S. Geological Survery Open-File Report 76-785, 98 p.

McLean, Hugh, 1977, Organic geochemistry, lithogy, and paleontology of Tertiary and Mesozoic rocks from wells on the Alaska Peninsula: U.S. Geological Survey Open-File Report 77-813, 63p.

_____,1979a, Sandstone petrology: Upper Jurassic Naknek Formation of the Alaska Peninsula and coeval rocks on the Bering Sea Shelf: Journal of Sedimentary Petrology, v. 49, p. 1263-1268.

_____, 1979b, Tertiary stratigraphy and petroleum potential of the Cold Bay-False Pass area, Alaska Peninsula: American Associaion of Petroleum

Geologists Bulletin, v. 63, p. 1522-1526.

Steffy, D.A., Turner, R.F., Martin, G.C., and T.O. Flett, 1985, Evolution and petroleum geology of the Navarin basin, Bering Sea, Alaska: Oil and Gas Journal, v. 83, no. 31, p. 116-124.

Turner, R.F., 1984, Summary and conclusions, in Turner, R.F. ed., Geological and Operational Summary, Navarin Basin COST No. 1 Well, Bering Sea, Alaska: United States Department of the Interior Minerals Management Service, OCS Report MMS 84-0031, p. 230-232.

Wang, Jason, Newton, C.R., and Dunne, Lorie, 1988, Upper Triassic volcanic arc initiation on the Peninsular terrane: implications for early Mesozoic evolution of southern Alaska (abs.): Geological Society of America, 84th Annual Meeting, Cordilleran Section, Abstracts with Programs, v. 20, No. 3, p. 241.

Wang, Jason, Newton, C.R., and Dunne, Lorie, in press, Late Triassic transition from biogenic to arc sedimentation on the Peninsular terrane: Puale Bay, Alaska Peninsula: Geological Society of America Bulletin.

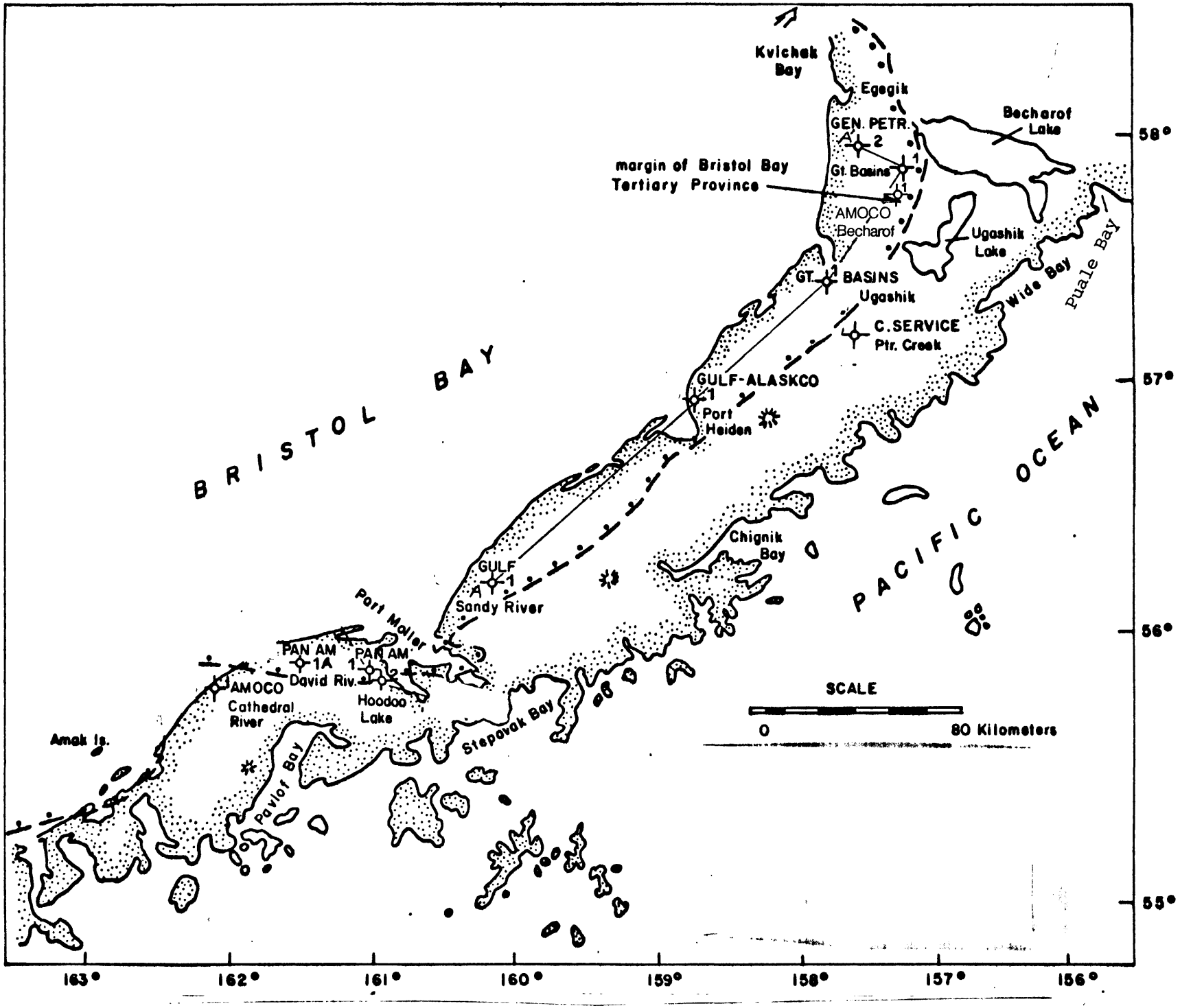
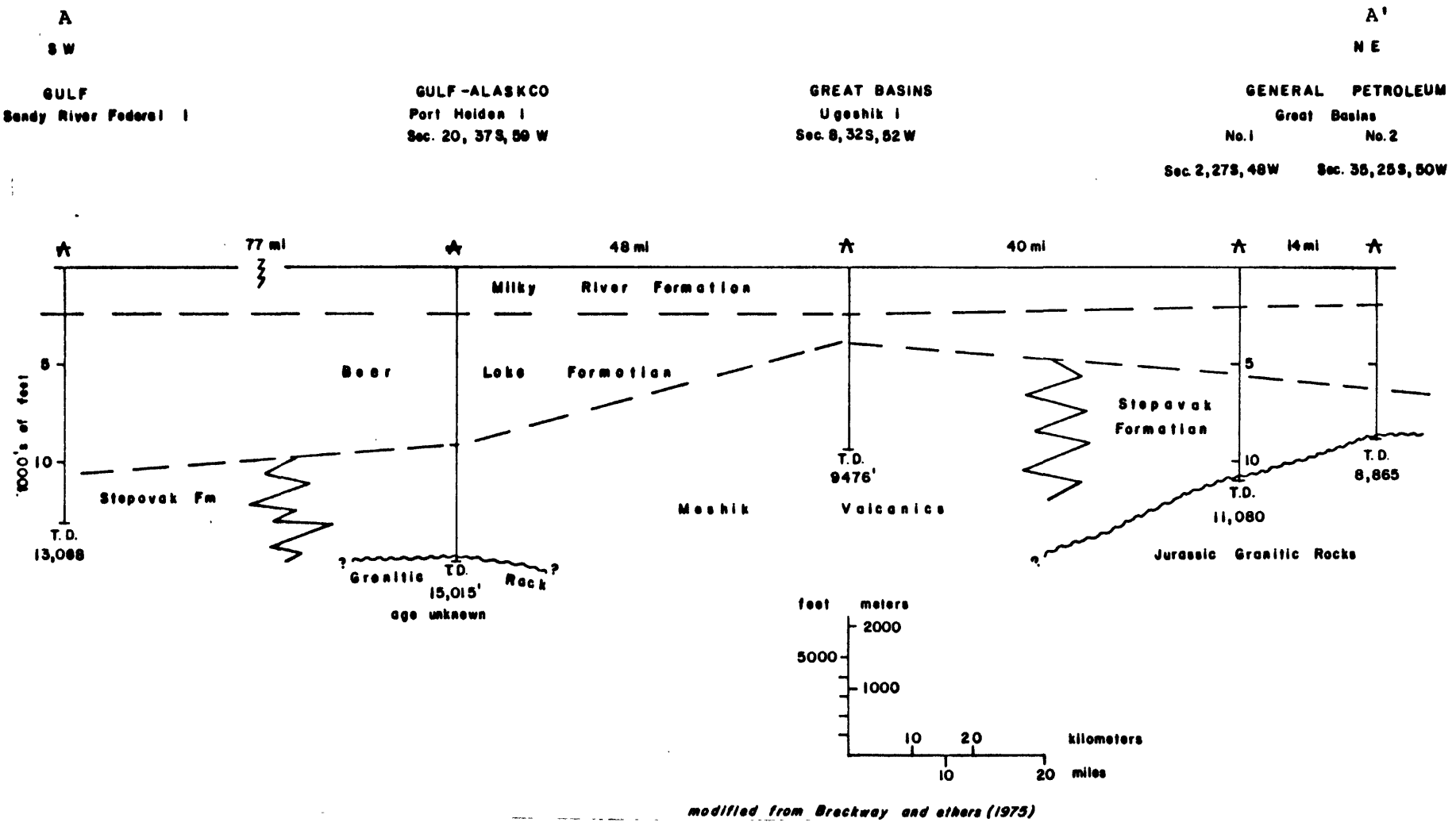


Figure 1--Index map of Bristol Basin, exploratory wells, and line of section shown in Figure 2.



modified from Brockway and others (1975)

Figure 2--Generalized northeast-southwest stratigraphic cross section of Bristol Basin. Line of section shown in Figure 1.