Hydrocarbon Potential

of

Calista Regional Corporation Lands

Bethel Basin
Holitna Basin
Lower Yukon Delta Region

by

Petrotechnical Resources of Alaska, LLC.

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Calista Corporation

Calista is one of 13 Alaska Regional Native Corporations formed in 1972 by the Alaska Native Claims Settlement Act (ANCSA). Calista is the second largest ANCSA Corporation in terms of shareholders and land entitlement with 6.5 million acres of fee-simple land in the Yukon-Kuskokwim Delta and nearby mountainous terrain (Figure 1). One quarter of the villages in Alaska are located in the region and are characterized by Yupik and Cupik Eskimo and Athabascan cultures with subsistence life styles, no roads, few jobs and consequent poverty. Because the region has a history of gold, platinum and mercury production, Calista and local village corporation lands were selected on the basis of both subsistence and mineral resource potential.

Calista's primary goals are to preserve traditional cultural lifestyles while encouraging economic growth. The latter is measured in terms of shareholder and dependent jobs, and corporate revenues. Many of Calista peoples' hopes are dependent on the success of the Donlin Creek Project, where a world class, 11.5 million-ounce gold resource has been delineated. For several years now, during advanced exploration on the project, Placer Dome has made substantial shareholder payrolls as high as $1 million per annum. Those jobs and corporate revenues from joint ventures between Calista and companies such as Boart Longyear and Chiulista-Global Services result in shareholder pride in holding good jobs and a newfound hope of autonomy and economic well-being.

Calista and most village corporations welcome resource development on their lands. Generally, the village corporations own surface rights and Calista owns the subsurface. Exceptions to this arrangement exist in several areas where Calista has exercised its surface-subsurface entitlement. A major obstacle to economic development in this area is the lack of energy infrastructure. Electrical power in the region is dependent on stand-alone diesel generators and imported fuel. Development of local energy sources, such as natural gas, is critical in stimulating economic development and increasing the overall standard of living in the Calista area.

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EXECUTIVE SUMMARY

Calista Corporation lands, together with 46 Village Corporation lands in the Yukon-Kuskokwim delta region in southwestern Alaska, encompass some 6.5 million acres within a 56,000 square mile area (Figure 1). This region includes the Bethel and Holitna Basins as well as the Lower Yukon Delta. The Bethel and Holitna Basins are Cenozoic, nonmarine basins (Kirschner, 1994) (Figure 2). The Bethel Basin is a large lowland area bordered on the west and south by the Bering Sea and on the north by metamorphic highlands. The hydrocarbon potential of this area has been of interest for many years. However, the remote location, inaccessibility, and large geographic size of this area have combined to make exploration efforts expensive, disjointed, and risky. This modern deltaic area of the Yukon and Kuskokwim Rivers is largely composed of Quaternary alluvial sediments marked by tundra and innumerable small lakes. The marshy ground is underlain by permafrost and about 30 percent of the area is covered by lakes. Numerous basalt flows and cinder cones are present in the west central area of the plain. The interpretation of the subsurface geology in this area is based on geophysical profiling, extrapolation of mapping data from adjacent mountain areas northeast and south of the area, and from a single, exploratory well, the Napatuk Creek #1, drilled by Pan-American (later Amoco) in 1961. The area has seen a relatively low level of petroleum interest due to lack of evidence of a thick Tertiary section and poor source and reservoir potential in the Cretaceous sedimentary rocks.

The Napatuk Creek #1 encountered approximately 2,000 feet of Tertiary sediments underlain by almost 13,000 feet of Cretaceous (and older?) sedimentary rocks apparently coeval and lithologically similar to the flysch sequences mapped in outcrop to the north. The flysch comprises very thick marine and nonmarine graywacke and siltstone sequences derived largely from andesitic, arc-related rocks of the accretionary terranes. In outcrop, the Cretaceous flysch is strongly deformed, altered, and locally metamorphosed. Analogous rocks encountered in the Napatuk Creek #1 well appear flat-lying and less deformed. Analysis of outcrop samples from localities around the basin indicates relatively low porosities and permeabilities and variable TOC values.

Given that the thick, Cretaceous, sedimentary rocks seem to have limited source and reservoir potential, identification of a thickened Tertiary section could enhance the attractiveness of the area and focus future exploration efforts onto a manageable area. Typically, Tertiary fill in interior sedimentary basins of Alaska is nonmarine fluvial, and coal-bearing sedimentary rocks are deposited in fining-upward sequences (Kirschner, 1994). The Tertiary sedimentary fill is often less dense than the pre-Tertiary rocks, so that the basins form distinct gravity lows. A lack of distinct gravity lows in the Calista region has led to the assumption that the entire area has only a thin Tertiary cover. However, the identification of a thickened Tertiary section in the Bethel area may not be possible with the simple use of gravity lows; density contrasts between "basement" Cretaceous Kuskokwim Group and the overlying Tertiary section may too subtle to result in significant gravity anomalies.

Several geophysical surveys have been conducted in the Calista region by governmental agencies and by the oil industry. These studies include airborne magnetic surveys, gravity surveys, and reflection seismic surveys. All of this data, as well as data from the Napatuk Creek #1 well, is now housed at Calista Regional Corporation's office in Anchorage, Alaska and is available for study. Reflection seismic surveys of the lower Kuskokwim River area by Shell Oil Company and by Atlantic Richfield Company have resulted in a series of reconnaissance lines in the area. Presently, Calista Corporation has paper copies of the seismic data; no digital seismic records are available. The seismic data suffer from apparent energy coupling problems resulting in a general lack of consistent, deep reflections that can be used to map structural and stratigraphic relationships. However, the data are not devoid of deep reflections; several lines show dipping beds and may be useful in identifying thickened Tertiary sections.

Seismic data for the region should be converted to digital format and analyzed by modern technologies. Seismic lines with deeper reflections, integrated with surface structural data and remote sensing data, may well reveal areas of significant Tertiary deposits as well as subsurface structures and stratigraphic relationships. The use of current dispersed data sets with the addition of remote sensing redisplayed seismic and a GIS framework will allow the integration of the sparse data for a better picture of resource potential at a minimal cost. Petroleum exploration points of interest for the Calista rgion are summarized below.

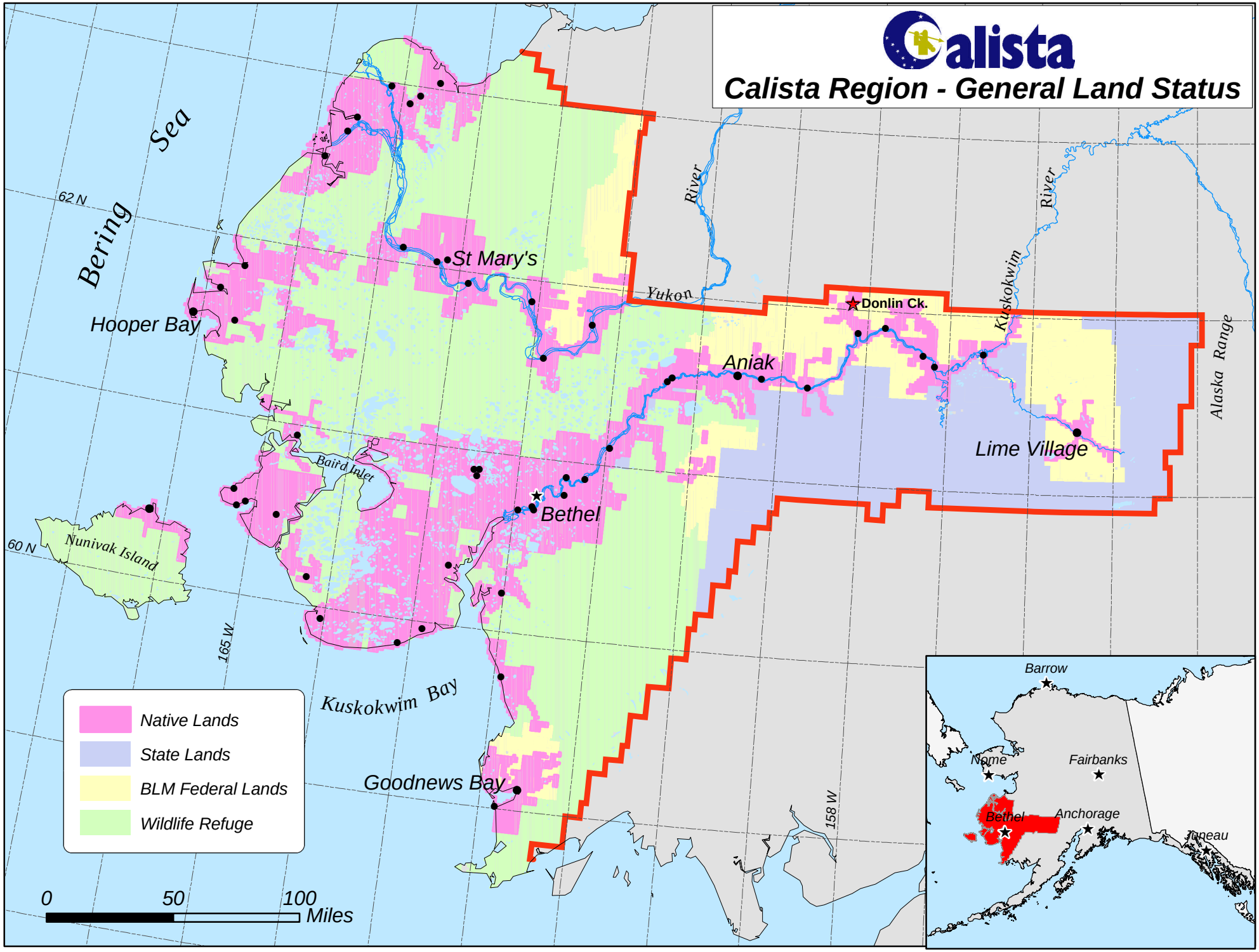
CALISTA AREA SUMMARY

- Calista Corporation and 46 Village Corporations in the Yukon-Kuskokwim delta area in southwestern Alaska own some 6.5 million acres in the 56,000 square mile region
- The Calista land can be geographically divided into three prospective areas of interest: 1) the Bethel Basin area, 2) the Holitna Basin, and 3) the Yukon Delta area. The Bethel and Holitna Basins are Cenozoic, nonmarine basins, and the area of the lower Yukon River is a large, modern, deltaic complex
- Bethel Basin is located near the greater Bethel population center (basin depocenter is approximately 5-40 miles from the population center)
- Concentrated, local village population and potential mine operations are now dependent on imported diesel and gasoline
    - present use for small engines in the region is 20 million gallons of liquid petroleum used per year or 50,000 gallons per day

    - village electrical power is presently dependent on diesel fuel
- Donlin Creek mining operations would require up to a 50-60 megawatt power plant demanding approximately 5 BCF natural gas/year as feedstock
- The Greater Bethel region could support a 5-10 megawatt power plant needing approximately 0.5 BCF natural gas/year as feedstock
- Potential exists for a gas-to-liquid (GTL) plant
- Hydrocarbon potential is greatest in the uppermost Cretaceous and Tertiary sedimentary rocks
- Poor quality reflection seismic data indicate the potential for thick (10,000 ft.) Tertiary sections to the north and south of the Napatuk #1 well
- Neighboring Norton Sound contains an estimated 2.7 trillion cubic feet of gas (risked, undiscovered, conventionally recoverable gas) in the Tertiary section
- A single well, the Pan American Petroleum Corporation Napatuk Creek #1 was drilled in 1961 to a total depth of 14,890 ft. near a minor gravity minimum of the Bethel Basin and failed to penetrate a thick Tertiary section
- In the Bethel area, identification of Tertiary basins may not be possible with the simple use of gravity lows; density contrasts between “basement” Cretaceous Kuskokwim Group and the overlying Tertiary section may too subtle to result in significant gravity anomalies.
- The area is dominated by Late Cretaceous and Early Tertiary large scale, strike-slip, northeast trending fault systems including the Iditarod-Nixon Fork, The Denali-Farewell, and the Kaltag fault systems

PROPOSED PROGRAM

- Evaluate and re-interpret existing seismic data
- Acquire and interpret remote sensing imagery
- Integrate surface, subsurface, and remote sensing data in a GIS database
- Follow-up seismic program leading to a drilling commitment


Calista
Calista Region - General Land Status
Bering Sea
62 N
60 N
165 W
158 W
St Mary's
Hooper Bay
Yukon
River
Donlin Ck.
Kuskokwim
River
Aniak
Alaska Range
Lime Village
Baird Inlet
Bethel
Nunivak Island
Kuskokwim Bay
Goodnews Bay
Native Lands
State Lands
BLM Federal Lands
Wildlife Refuge
0
50
100
Miles
Barrow
Nome
Fairbanks
Bethel
Anchorage
Juneau

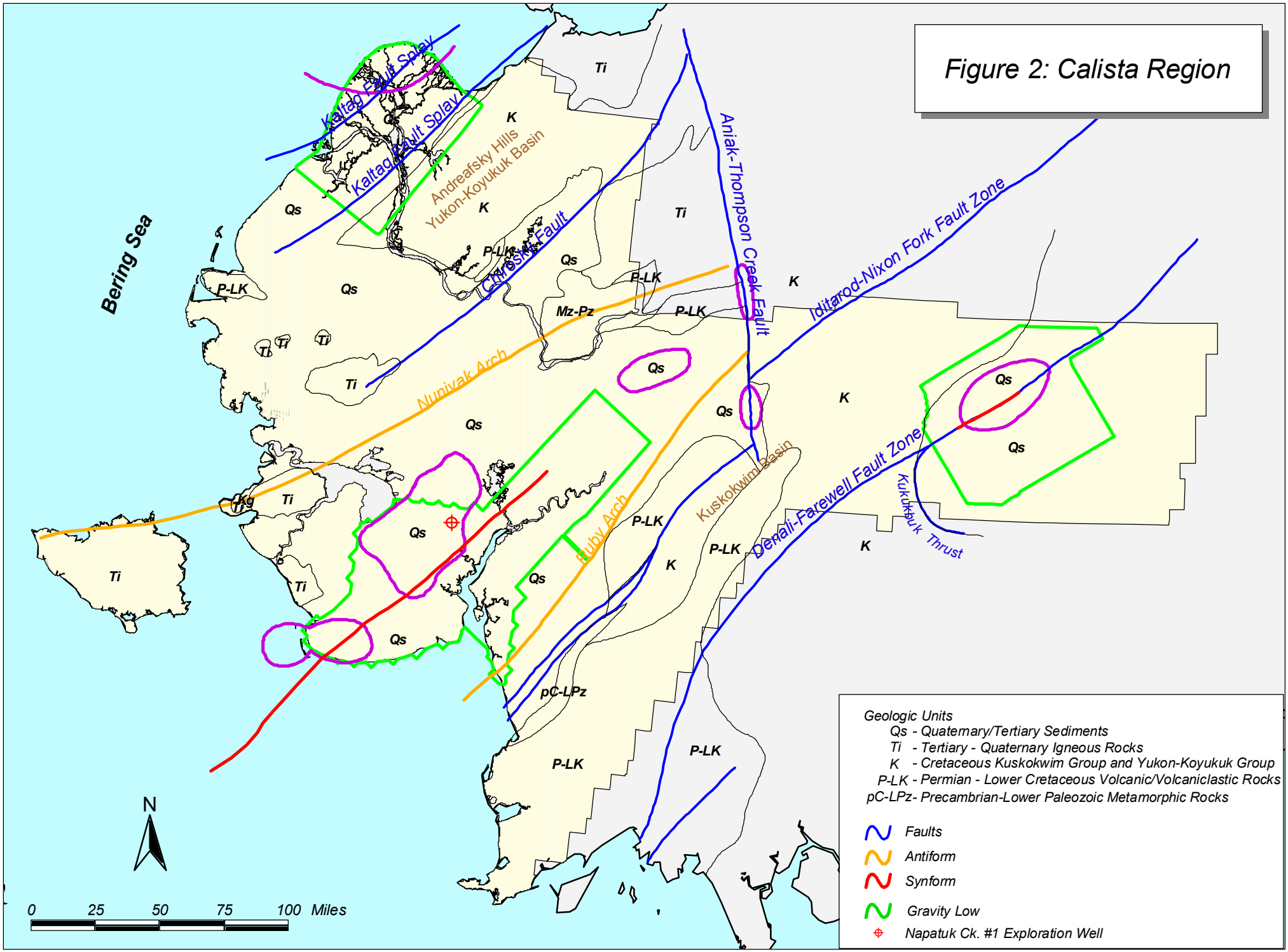


Figure 2: Calista Region
Bering Sea
Kaltag Fault Splay
Kaltag Fault Splay
Andreafsky Hills
Yukon-Koyukuk Basin
Chirosh Fault
Aniak-Thompson Creek Fault
Iditarod-Nixon Fork Fault Zone
Nunivak Arch
Ruby Arch
Kuskokwim Basin
Denali-Farewell Fault Zone
Kukukpuk Thrust
Qs
Ti
K
P-LK
Mz-Pz
pC-LPz
N
0 25 50 75 100 Miles
Geologic Units
Qs - Quaternary/Tertiary Sediments
Ti - Tertiary - Quaternary Igneous Rocks
K - Cretaceous Kuskokwim Group and Yukon-Koyukuk Group
P-LK - Permian - Lower Cretaceous Volcanic/Volcaniclastic Rocks
pC-LPz- Precambrian-Lower Paleozoic Metamorphic Rocks
Faults
Antiform
Synform
Gravity Low
Napatuk Ck. #1 Exploration Well

CALISTA AREA REGIONAL GEOLOGY

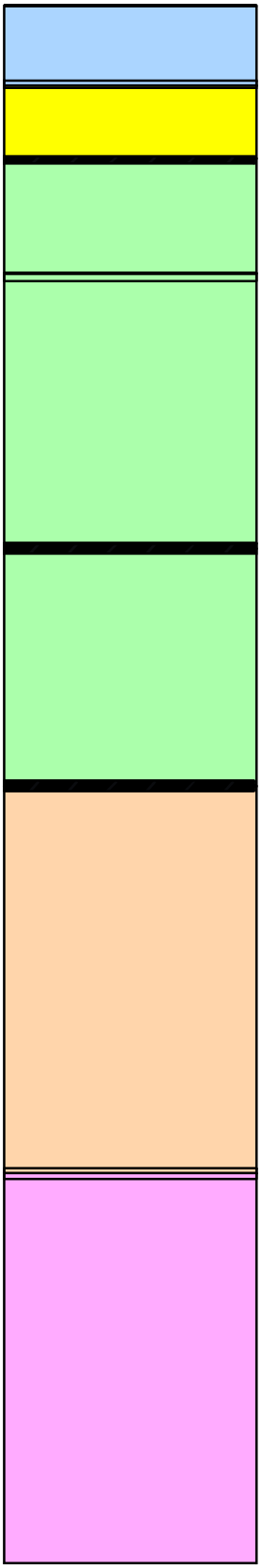
Rocks of the greater Calista Region are broadly subdivided into three categories: 1) pre-accretionary, Late Proterozoic to Paleozoic continental margin rocks, 2) Mesozoic accretionary rocks (mainly volcanic and volcaniclastic rocks), and 3) post-accretionary sedimentary overlap assemblages of Cretaceous and Tertiary ages (Mull and Buntzen, 1995) (Figure 3). Tertiary sedimentary rocks are not known in outcrop in the Bethel area (Kirschner, 1994), but may exist in the subsurface in areas of Tertiary subsidence. Poor quality reflection seismic data indicate the potential for thick (10,000 ft.) Tertiary sections to the north and south of the Napatuk #1 well in the Bethel Basin (Figure 4). The Holitna Basin, a long, narrow gravity trough localized along the Denali-Farewell Fault Zone, may be filled with as much as 14,500 feet of Cenozoic fill (Kirschner, 1994, Smith et al., 1985). The area of the lower Yukon River is a large, modern, deltaic complex that is adjacent to Norton Basin. Norton Basin comprises two subbasins which each contain up to 24,000 ft. of marine and nonmarine Tertiary strata. Biostratigraphic studies of cuttings and cores from the Norton Basin COST wells indicate that the early Tertiary section, Paleocene and E. Oligocene rocks, were deposited in a nonmarine environment, while the later Tertiary rocks, L. Oligocene and younger, were deposited in a marine environment.

Flysch-dominated sedimentary rocks of the Upper Cretaceous Kuskokwim Group dominate the post-accretionary bedrock units of the Calista Region. The Kuskokwim Group is a regionally extensive, basin fill sequence that covers approximately 29,000 square miles and consists primarily of marine turbidites deposited in a northeast trending, elongate, fault-controlled basin (Mull and Buntzen, 1995). The uppermost Kuskokwim rocks consist of relatively clean, quartzose sandstone and siltstone, cross-bedded sandstone and siltstones, finely-laminated shales and local leaf-rich beds and represent a marine regression after the basinal turbidites of the lower Kuskokwim Group.

TECTONIC/ BASIN EVOLUTION

- The rocks of southwest Alaska can be grouped into three assemblages: 1) Precambrian-Paleozoic pre-accretionary continental margin rocks, 2) Mesozoic accretionary (arc-related) rocks, and 3) Late Cretaceous and Tertiary post-accretionary rocks
    - Precambrian-Paleozoic pre-accretionary continental margin rocks include Precambrian metamorphic rocks, thick carbonate sequences, deep water shales and mudstones that represent a stable, passive, Lower Paleozoic continental margin sequence (includes the Farewell, Minchumina, and Nixon Fork terranes) that lies upon Precambrian crystalline basement (Kilbuck and Ruby terranes)
    - Mesozoic, accretionary, arc-related rocks include basaltic to dacitic flows, breccias and associated epiclastic rocks (including the Togiak, Innoko, and Koyukuk terranes) as well as complex trench-related rocks (Angayucham-Tozitna and Goodnews terranes) that represent a Late Triassic to earliest Cretaceous arc-trench complex that collided with the North American continental margin during early Cretaceous time
    - Late Cretaceous and Tertiary post-accretionary rocks include Upper Cretaceous and lower Tertiary terrigenous sedimentary and igneous rocks; sedimentary rocks are dominated by a flyschoid assemblage of graywacke and mudstone turbidites capped by a fluvial and shallow marine package dominated by conglomerates, sandstones and shale

Stratigraphic Section for the Yukon Kuskokwim Delta Area



Miocene - Pliocene - near-shore marine

Paleocene - Oligocene - nonmarine

Cretaceous Kuskokwim Group (Albian - Coniacian)
uppermost - Clean quartzose sandstone, cross-bedded sandstone and siltstone, finely-laminated shale with local leaf-rich beds, minor coquina, brackish, nonmarine bivalves. This uppermost section unconformably overlaps
main Kuskokwim Group, which is a regionally extensive basin-fill sequence that covers 25,000 square miles of SW and WCentral AK. The Group comprises marine turbidites deposited in a NE trending, elongate, fault-controlled basin with lesser shallow marine and fluvial strata deposited along basin margins. The Group is flysch-dominated with interbedded vocaniclastic-rich sandstone, siltstone, shale and minor conglomerate beds. Unit varies from 10,000- 30,000 ft. thick.

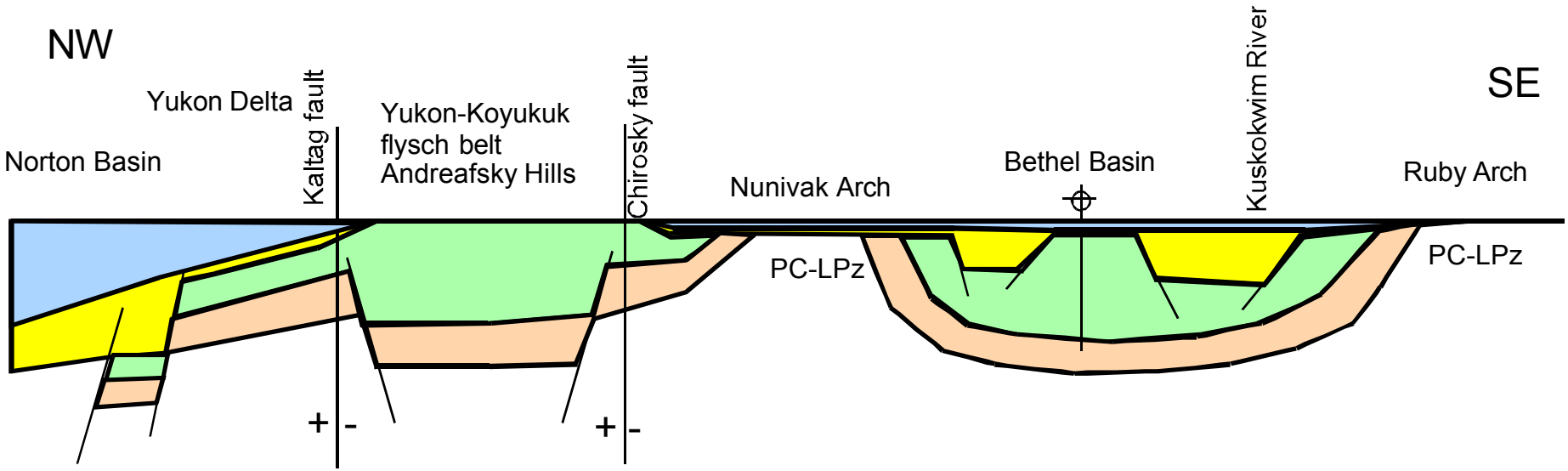
Lower Cretaceous Yukon-Koyukuk Group
Tuffaceous sandstone and siltstone sequence

Permian-Lower Cretaceous
Volcanic and Volcaniclastic Rocks
Arc-related volcanic rocks which
probably form much of the "basement" in the Y-K area

Proterozoic -Paleozoic
Metamorphic Rocks - Terranes of varied affinity

Figure 3

N-S Cross Section of Greater Bethel Area



Miocene - Pliocene marine rocks

Paleocene - Oligocene nonmarine rocks

Cretaceous Kuskokwim & Yukon-Koyukuk Group
largely marine turbidites - graywackes, sandstone, siltstone, shale

Permian-Lower Cretaceous volcanic and volcaniclastic rocks
arc-related

PC-LPz Precambrian-Lower Paleozoic metamorphic rocks
of varied affinity

Quaternary not shown

After C.M. Molenaar, Shell Oil Co., 1962 and L.G. Brown, Amoco, 1980 and Mulland Buntzen, 1995.

Figure 4

BETHEL BASIN

The Bethel Basin is a large, lowland area bordered on the south and west by the Bering Sea, and to the north by metamorphic uplifted rocks of the Yukon-Koyukuk Basin (Figures 2, 5). Patchy permafrost and numerous small lakes underlie this marshy area. During the Cretaceous, the Bethel Basin area was part of the larger, active Kuskokwim Basin; the Bethel Basin proper was active during the Tertiary. The Bethel Basin has seen a low level petroleum industry interest due to the perception of a thin Tertiary section and poor source rock potential in the Cretaceous and older section (Kirschner, 1994). However, identification of Tertiary 'thicks' in the Bethel area may not be possible with the simple use of gravity lows; density contrasts between "basement" Cretaceous Kuskokwim Group and the overlying Tertiary section may be too subtle to result in significant gravity anomalies. Poor quality reflection seismic data indicate the potential for thick (10,000 ft.) Tertiary sections to the north and south of the Napatuk #1 well (Figure 6). Furthermore, the uppermost Kuskokwim rocks consist of relatively clean, quartzose sandstone and siltstone, cross-bedded sandstone and siltstones, finely-laminated shales and local leaf-rich beds and represent a marine regression after the basinal turbidites of the lower Kuskokwim Group. Petroleum exploration points of interest for the Bethel Basin are summarized below.

EXPLORATION STATUS/ DATA ACQUIRED

- Pan American Petroleum Corporation (later Amoco, now BP-Amoco) drilled Napatuk Creek #1 (1961)
    - Total depth 14,890 ft.
    - Drilled near a gravity minimum
    - Penetrated a sedimentary section consisting dominantly of Cretaceous sandstone and interbedded siltstone and shale with minor amounts of carbonaceous material
    - Penetrated a thin, 2,000 ft. thick Tertiary section
    - Possible unconformity and sequence boundary at 5,305 ft. depth in Cretaceous rocks which may tie to the marine regression seen in uppermost Kuskokwim Group outcrops
    - No visible hydrocarbon shows were noted in the drill cuttings, but no mudlog was run
    - 3 drill stem tests recovered no hydrocarbons and had good to weak blows that died
- 2D seismic data acquired by Petty-Ray for Shell Oil Company in 1974 over the Bethel Basin (12-fold, dynamite)
- 2D seismic data acquired by Western Geophysical for Shell Oil Company in 1975 over the Lower Kuskokwim River area and Bethel Basin (12-fold, airgun)
- 1994 airborne magnetic survey was flown by Geonex Aeroservice in an approximately 1,800 square mile area southwest of Bethel
- 1996 airborne magnetic study by Sander Geophysics over 5,800 square miles was merged with the Geonex Aeroservice data

TECTONIC/ BASIN EVOLUTION

- Cretaceous/Tertiary basin
- Cretaceous basin fill includes the upper Cretaceous, flysch-dominated Kuskokwim Group which consists of marine turbidites deposited in a NE trending, fault-controlled basin
- Previous interpretations of shallow gravity lows (min. 0 mgals) have indicated that the Tertiary fill in the Bethel Basin does not greatly exceed 2,000 ft., and may be less than that over most of the basin. However, identification of Tertiary 'thicks' in the Bethel area may not be possible with the simple use of gravity lows in that the density contrasts between "basement" Cretaceous Kuskokwim Group and the overlying Tertiary section may too subtle to result in significant gravity anomalies

SOURCE ROCK AND HYDROCARBON GENERATION

- Amoco 1979-80 source rock study of the Yukon-Kuskokwim delta area
    - 61 outcrop samples from 6 areas in the region ranging in age from Paleozoic to Tertiary
    - Of the 61 outcrop samples:

# samples	% TOC	% of total
6	>1.5%	10%
10	1-1.5%	16%
29	0.6-1.0%	48%
7	0.4-0.6	11%
9	<0.4%	15%
61		100%

    - Of those 61 samples, 29 samples are Cretaceous:

# samples	% TOC	% of total
4	1-1.5%	14%
18	0.6-1.0%	62%
3	0.4-0.6	10%
4	<0.4%	14%
29		100%

- Napatuk Creek #1
    - No TOC analysis available
    - Visual analysis revealed the dominant kerogen type is cellulosic which is commonly considered to be capable of generating gaseous hydrocarbons if present in sufficient quantities and subjected to adequate thermal heating
    - Thermal maturity: vitrinite reflectance data indicates that the Tertiary rocks are immature (0-2,000 ft. depth), the Upper Cretaceous rocks are mature (2,000-5,300 ft. depth), and the Cretaceous and older rocks overmature (over 5,000 ft. depth)

RESERVOIR ROCK DEVELOPMENT

- Tertiary rocks in the Napatuk Creek #1 are 2,000 ft. thick and are comprised of compositionally immature, nonmarine rocks; poor compaction in these rocks may indicate adequate porosity and permeability
- The Napatuk well may have missed a thick, nonmarine Tertiary section that exists in Norton Sound and in other Tertiary, interior Alaska basins
- Tertiary rocks in nearby Norton Sound comprise older Paleocene – Early Miocene nonmarine sediments overlain by Late Miocene – Pliocene marine rocks
- Biostratigraphic data from Napatuk #1 well indicate that most of the 2,000 ft. of Tertiary rocks encountered in the well are Late Miocene/Pliocene in age and were deposited in a shallow marine environment while a thin, (<100 ft. thick) interval just above the Cretaceous rocks is of an indeterminate (older than L. Miocene) age and consists of nonmarine sediments;
- Most of the rocks in the Kuskokwim Group are marine rocks which were deposited in an active turbidite depositional environment (although some shallow marine and nonmarine rocks are present) and contain large amounts of clay matrix; source rocks for the Kuskokwim sediments included volcanic rocks
- A possible unconformity at 5,305 ft. depth in the Napatuk #1 may represent a significant sequence boundary in the well; attractive reservoir rock may be present not only in the thin Tertiary rocks of the Bethel basin, but also in the upper Cretaceous, clean, sedimentary rocks above this unconformity
- In outcrop, the uppermost Kuskokwim rocks consist of relatively clean, quartzose sandstone and siltstone, cross-bedded sandstone and siltstones, finely-laminated shales and local leaf-rich beds and represent a marine regression after the basinal turbidites of the lower Kuskokwim Group

POTENTIAL TRAPS

- Complex tectonics argue in favor of Cretaceous and lower Tertiary structures below the undisturbed Quaternary outcrops in the Bethel Basin area that are as yet seismically unrecognized

- Upper Cretaceous and Tertiary shales may act as reservoir seals

PROSPECTIVITY

- A single well, the Napatuk #1, penetrated a thick section of Cretaceous rocks with poor source rock and reservoir rock potential overlain by thin uppermost Cretaceous and Tertiary rocks with good source rock and reservoir potential
- Poor quality reflection seismic data indicate the potential for thick (10,000 ft.) Tertiary sections to the north and south of the Napatuk #1 well
- Location of Tertiary basins may not be possible with the simple use of gravity lows; density contrasts between "basement" Cretaceous Kuskokwim Group and the overlying Tertiary section may too subtle to result in significant gravity anomalies
- A possible unconformity at 5,305 ft. depth in the Napatuk #1 may represent a significant sequence boundary in the well; attractive reservoir rock may be present not only in the thin Tertiary rocks of the Bethel basin, but also in the upper Cretaceous, clean, sedimentary rocks above this unconformity

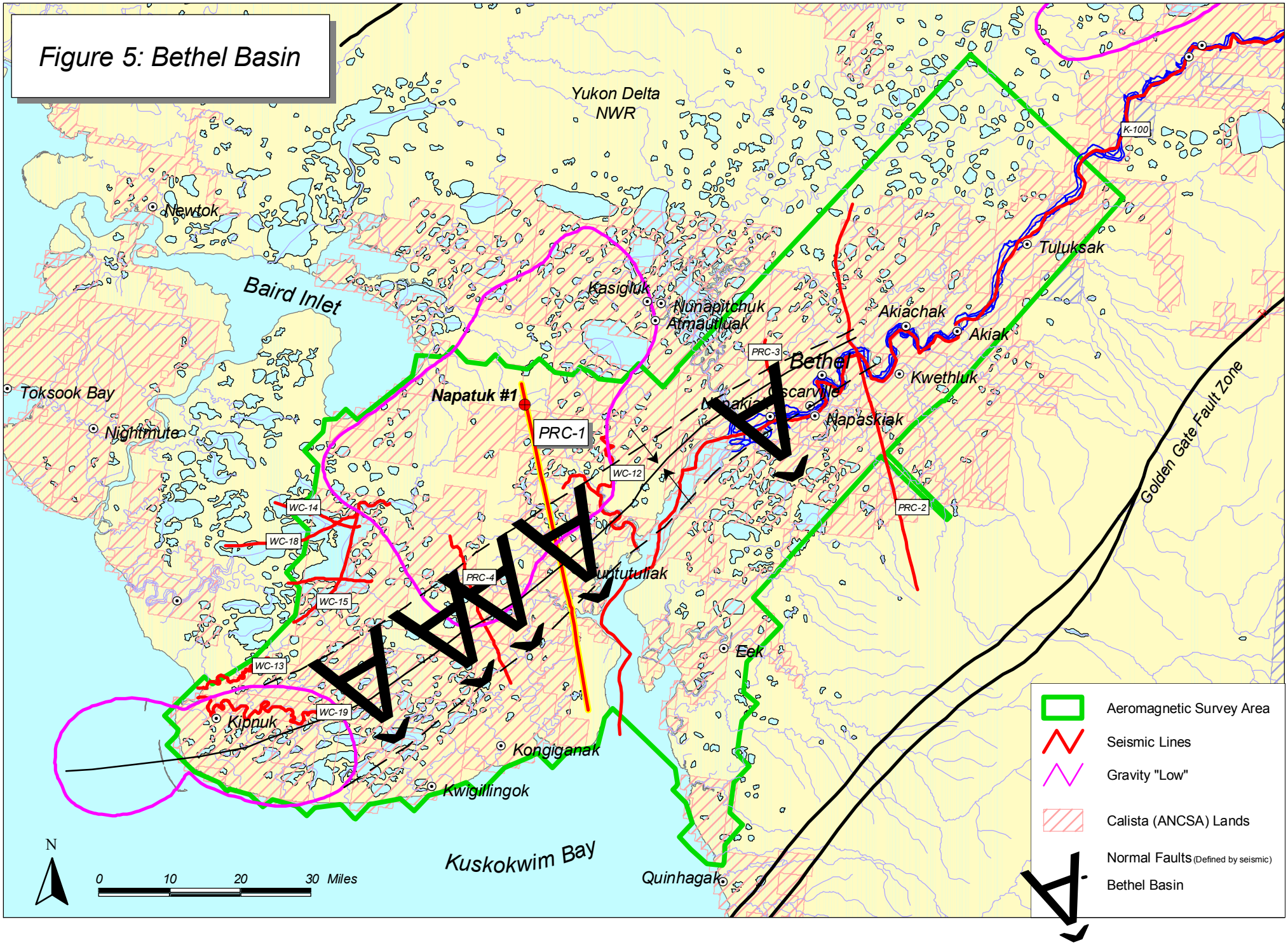


Figure 5: Bethel Basin
Yukon Delta NWR
Newtok
Baird Inlet
Toksook Bay
Nightmute
Kasigluk
Nunapitchuk
Atmautluak
Napatuk #1
PRC-1
PRC-3
Bethel
Oscarville
Napaskiak
Akiachak
Akiak
Kwethluk
Tuluksak
K-100
WC-12
WC-14
WC-18
WC-15
WC-13
WC-19
PRC-4
PRC-2
Eek
Kipnuk
Kongiganak
Kwigillingok
Quinhagak
Kuskokwim Bay
Golden Gate Fault Zone
N
0 10 20 30 Miles
Aeromagnetic Survey Area
Seismic Lines
Gravity "Low"
Calista (ANCSA) Lands
Normal Faults (Defined by seismic)
Bethel Basin

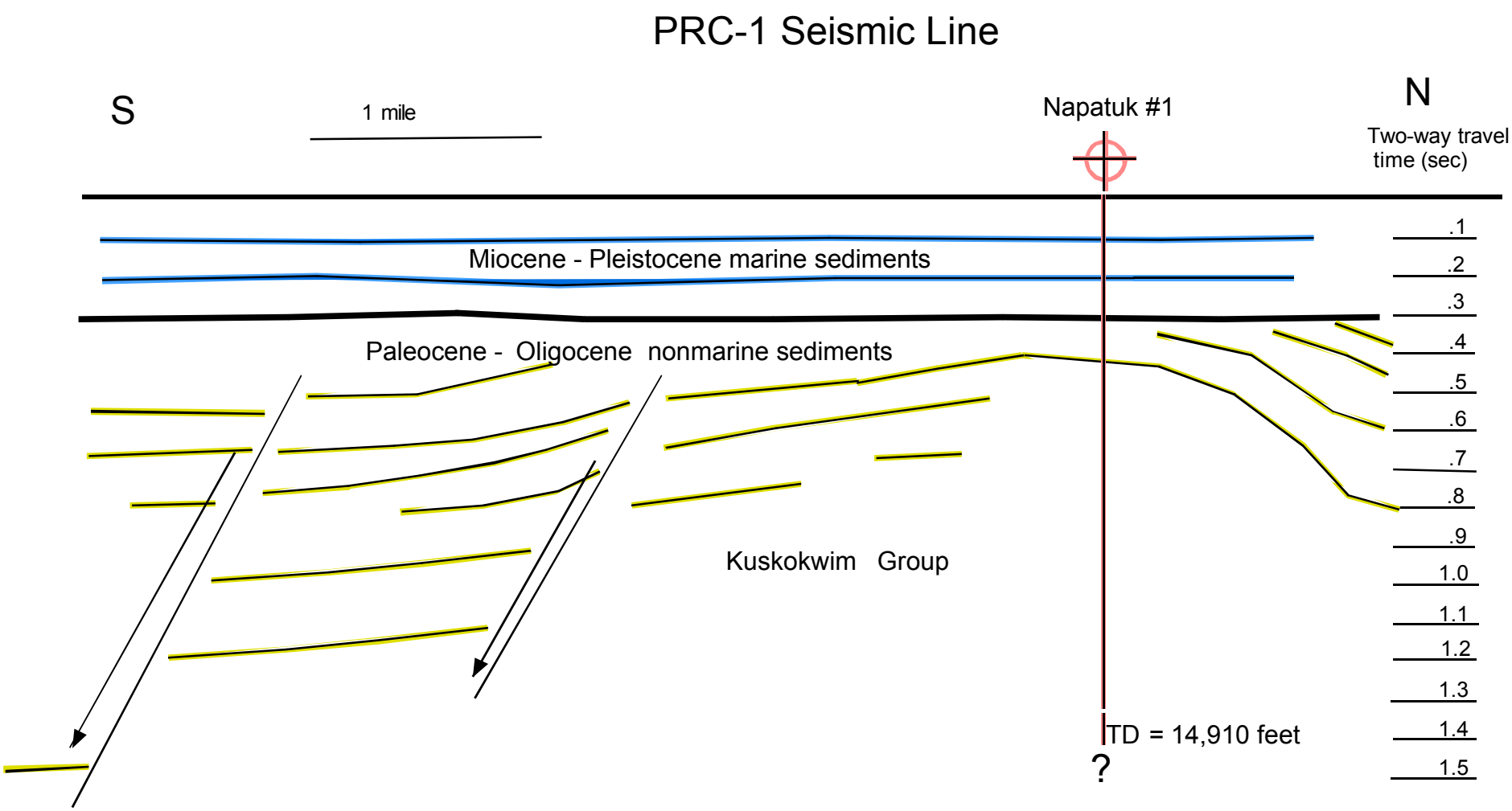


Figure 6: Seismic Reflection Sketch from Line PRC-1

HOLITNA BASIN

The Holitna Basin is a small, Cenozoic basin on the Denali-Farewell fault zone (Figures 2 and 7). A long, narrow gravity trough localized along the fault zone, which suggests a rift graben with as much as 14,500 feet of Cenozoic fill, defines the Holitna Basin (Kirschner, 1994, Smith et al., 1985). Small outcrops of Tertiary, nonmarine coal-bearing strata are locally present along the fault zone on trend with the Holitna Basin (Kirschner, 1994). Petroleum exploration points of interest for the Holitna Basin are summarized below.

EXPLORATION STATUS/ DATA ACQUIRED

- No wells drilled to date
- No seismic surveys to date
- 1998 DGGS field study of Paleozoic and Mesozoic petroleum potential included an aeromagnetic survey of the area
- Proximity to Donlin Creek gold deposit

TECTONIC/ BASIN EVOLUTION

- Cenozoic basin
- 2,000 square mile areal extent
- Long, narrow gravity trough (min. -40 mgals) located along the trend of the right lateral Denali-Farewell fault
- Extensional rift graben formed due to oblique stresses caused by major strike-slip faults with up to 14,500 ft. of Tertiary fill (Smith et al., 1985)
- Small outcrops of Tertiary nonmarine, coal-bearing strata are on trend with basin; coal-bearing rocks could generate gas
- Basin basement may be strongly deformed flysch of the Cretaceous Kuskokwim Group
- Holitna may be similar to the extensional Nenana and Minchumina basins that also show local sharp gravity lows

SOURCE ROCK AND HYDROCARBON GENERATION

- No subsurface samples available
- Tertiary nonmarine coals occur in a series of small, fault-bounded sedimentary basins along the Denali-Farewell fault system; these rock assemblages are similar to the Usibelli Group in the Healy area
- Fluvial-lacustrine rocks are common in strike-slip basins where Tertiary lacustrine shales are expected
- 1998 DGGS field study indicates little potential (low TOC contents) in the older, pre-accretionary carbonates and shales of the area

RESERVOIR ROCK DEVELOPMENT

- No subsurface samples available
- Tertiary sediments occur in a series of small, fault-bounded basins along the Denali-Farewell fault system; these rock assemblages may be similar to the Usibelli Group in the Healy area which are dominated by thick sandstone and conglomerate packages
- Fluvial-lacustrine rocks are common in strike-slip basins where Tertiary fluvial sandstones are expected

POTENTIAL TRAPS

- In strike-slip, pull-apart basins, the most important traps are structural and may develop en echelon anticlines
- Traps may also form in folds in transpressional zones

PROSPECTIVITY

- A –40 mgal gravity low indicates a thick (14,500 ft.) Tertiary section
- Small basin size (2,000 square miles)
- Local Tertiary coal outcrops support interpretation of fluvial-lacustrine sedimentary package in the basin
- Potential for coal-bed methane and biogenic gas
- Donlin Creek mining operations would require as much as a 50-60 megawatt power plant

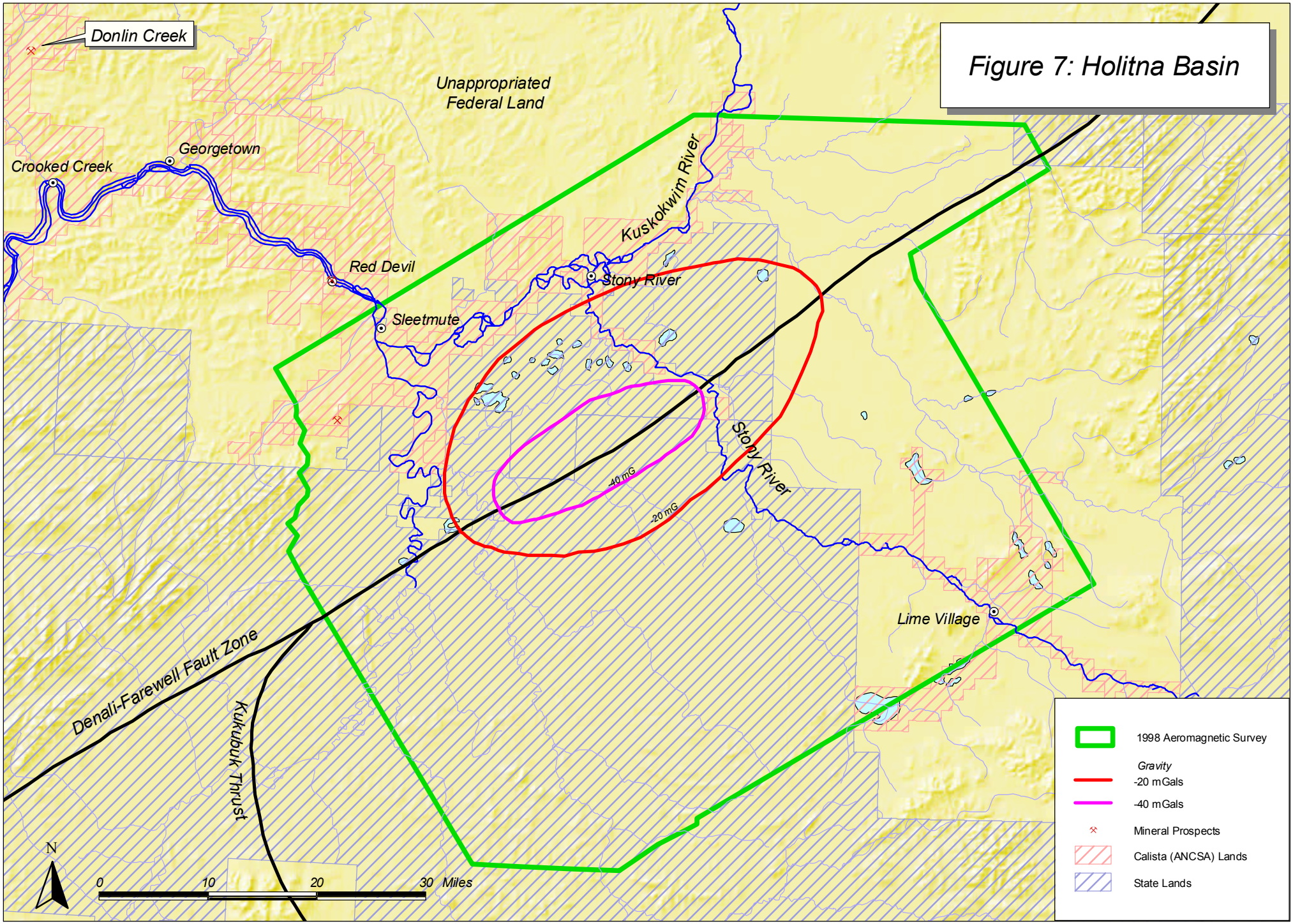


Figure 7: Holitna Basin
Donlin Creek
Unappropriated Federal Land
Georgetown
Crooked Creek
Kuskokwim River
Red Devil
Stony River
Sleetmute
Stony River
-40 mG
-20 mG
Lime Village
Denali-Farewell Fault Zone
Kukhbuk Thrust
N
0
10
20
30 Miles
1998 Aeromagnetic Survey
Gravity
-20 mGals
-40 mGals
Mineral Prospects
Calista (ANCSA) Lands
State Lands

YUKON DELTA

The lower Yukon River area is a large, modern, deltaic complex that is adjacent to the Norton Basin (Figures 2, 8). Amoco seismically identified an anticline on the coast of the Lower Yukon delta, but it was never drilled (Figures 8, 9). The Norton Basin comprises two subbasins that each contain up to 24,000 ft. of marine and nonmarine Tertiary strata. Biostratigraphic studies of cuttings and cores from the Norton Basin COST wells indicate that the early Tertiary section, Paleocene and E. Oligocene rocks, were deposited in a nonmarine environment, while the later Tertiary rocks, L. Oligocene and younger, were deposited in a marine environment. Petroleum exploration points of interest for the lower Yukon Delta region are summarized below.

EXPLORATION STATUS/ DATA ACQUIRED

- No wells drilled to date
- Acquisition of 24-fold, 2D Amoco seismic data (1981)
- Amoco anticline identified seismically but never drilled
- Two COST wells and 6 exploration wells drilled in the deep, adjacent Norton Basin to the north; no discoveries were reported
- Norton Sound contains an estimated 2.7 trillion cubic feet of gas (risked, undiscovered, conventionally recoverable gas) in the Tertiary section (OCS Monograph MMS 98-0054, 1995)

TECTONIC/ BASIN EVOLUTION

- Active fluvial delta
- May have thickened Tertiary section
- Shallow gravity low (min. -10 mgal) on the delta represents edge of the deep Tertiary Norton Basin to north
- The neighboring Norton Basin
    - is a large extensional basin that probably began to form in the earliest Cenozoic and is bounded by major normal faults
    - Tertiary rocks in nearby Norton Sound comprised thick sections of older Paleocene – Early Miocene nonmarine sediments overlain by Late Miocene – Pliocene marine rocks
    - Extensive 2D seismic coverage
    - Gravity and aeromagnetic surveys acquired over basin
    - Two COST wells drilled in 1980 and 1982
    - 1 ARCO and 5 Exxon exploration wells drilled in 1984 and 1985
    - Extensional basin containing up to 24,000 feet of Tertiary strata
    - Basin tectonics consists of an early extensional phase and a late regional subsidence phase
        - Early extensional phase (Paleocene-Oligocene)
            - Top as shallow as 2,000+ feet
            - Over 15,000 feet thick
            - Lacustrine/fluvial to deepwater marine
            - Coal-bearing
            - Excellent terrestrial source rocks capable of generating biogenic and thermogenic gas, condensates, and waxy and light paraffinic oils
            - Potential of Type II marine source rocks which could generate oil
        - Late regional subsidence phase (Miocene-Pleistocene)
            - Up to 7,500 feet thick
            - Areally extensive
            - Nonmarine to shallow marine environment
            - Coal-bearing
- Although major normal faults have been active adjacent to the Yukon Delta, gravity data suggest that the Norton Basin does not extend beneath the land areas covered by the delta

SOURCE ROCK AND HYDROCARBON GENERATION

- A thickened, lower Tertiary, lacustrine-fluvial-deltaic sedimentary section may contain organic-rich shales

RESERVOIR ROCK DEVELOPMENT

- A thickened Tertiary, fluvial-delta sedimentary section may contain highly porous and permeable lithologies

POTENTIAL TRAPS

- Fluvial-deltaic shales may act as excellent seals in deltaic environments

- Amoco anticline identified seismically but never drilled

PROSPECTIVITY

- Tertiary rocks may comprise thick sections of older Paleocene – Early Miocene nonmarine sediments overlain by Late Miocene – Pliocene marine rocks
- An Amoco seismically-identified anticline exists on the Bering Sea coast

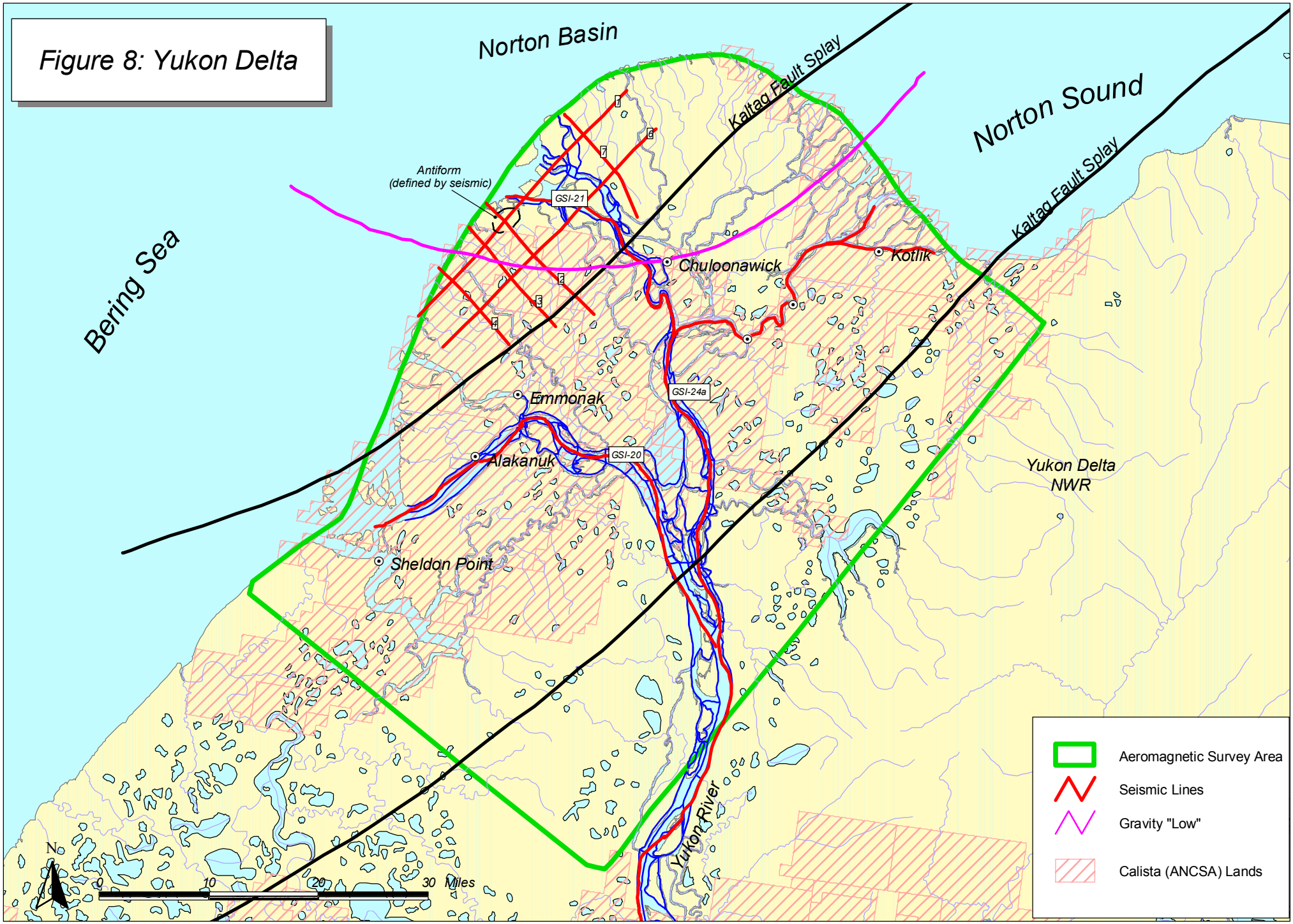


Figure 8: Yukon Delta
Norton Basin
Norton Sound
Bering Sea
Kaltag Fault Splay
Kaltag Fault Splay
Antiform
(defined by seismic)
GSI-21
GSI-24a
GSI-20
Chuloonawick
Kotlik
Emmonak
Alakanuk
Sheldon Point
Yukon Delta
NWR
Yukon River
N
0
10
20
30 Miles
Aeromagnetic Survey Area
Seismic Lines
Gravity "Low"
Calista (ANCSA) Lands

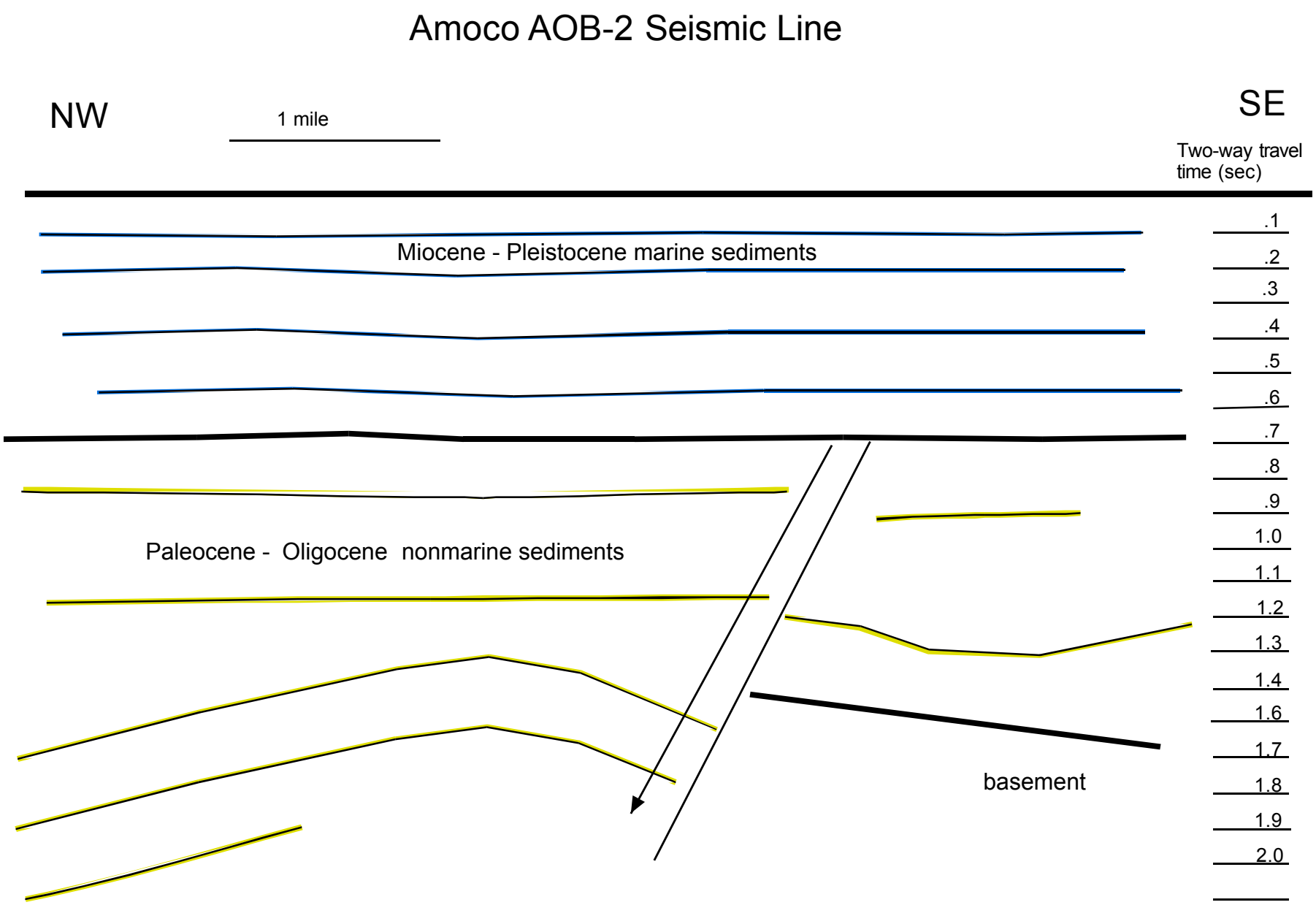


Figure 6: Seismic Reflection Sketch from Line AOB-2

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