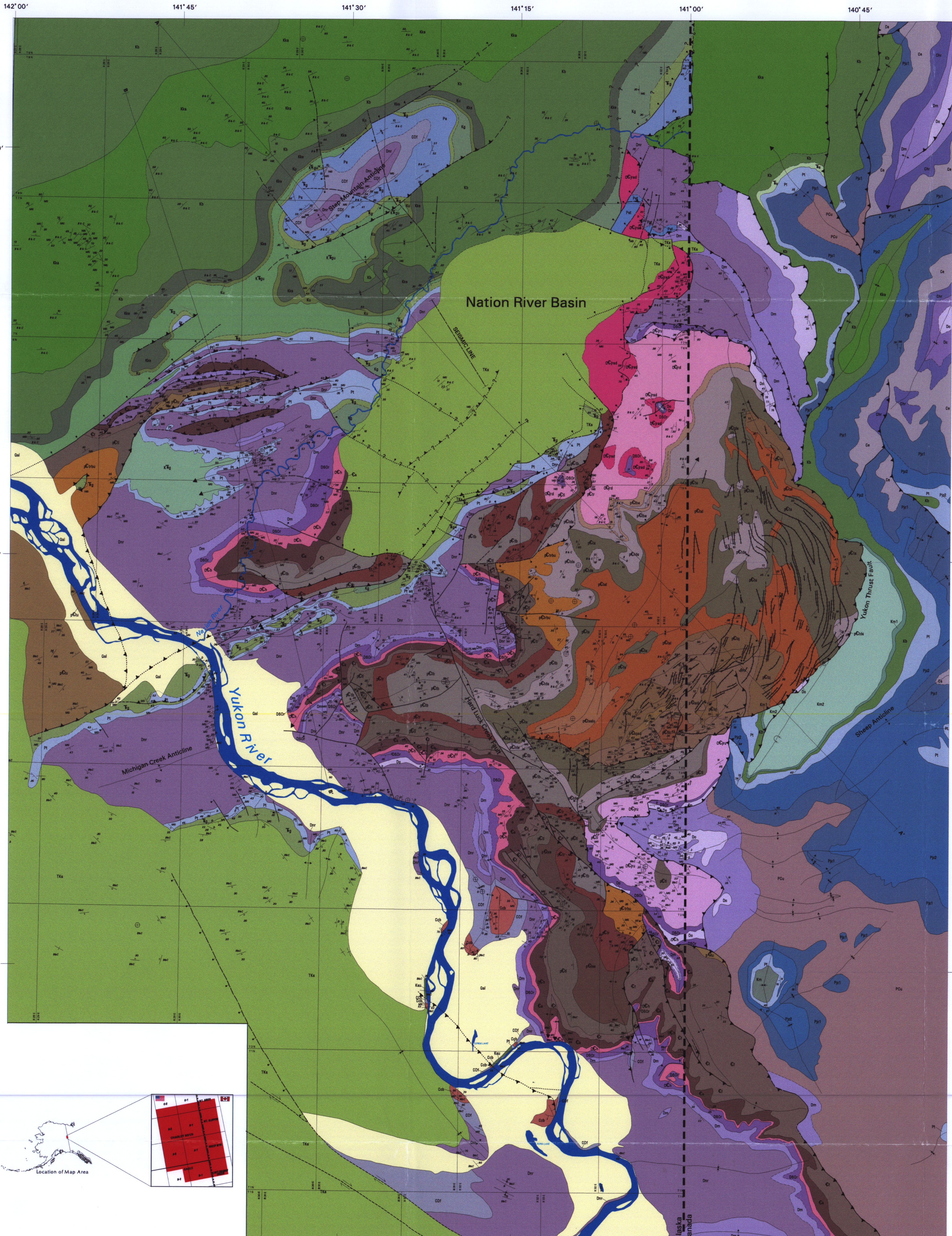
ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
IN COOPERATION WITH ARCO ALASKA, INC., AND DOYON, LIMITED

REPORT OF INVESTIGATIONS 96-6a
Van Kooten and others (1997), sheet 1 of 3



Location of Map Area

Cartography by L. Katherine Queen and Don Hodges; assisted by Peggy Young

SCALE 1:125,000

5 2.5 0 5 10 Kilometers

2.5 0 5 Miles

MAGNETIC DECLINATION (1990) ALONG SOUTH EDGE OF MAP VARIES FROM 31° TO 33° EAST

GEOLOGIC INVESTIGATIONS OF THE KANDIK AREA, ALASKA AND ADJACENT YUKON TERRITORY, CANADA

by

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Department of Natural Resources
Division of Geological and Geophysical Surveys
Geologic Data Modeling System

1997

/files1/kathie/kandik/amls/kanrisht1.aml /files1/kathie/kandik/plots/ri96_6ash1.gra Date: 04/23/97

DESCRIPTION OF MAP UNITS

U.S.A. & CANADA | CANADA ONLY

Qal — Unconsolidated floodplain deposits of the Yukon and Seventymile Rivers

TKs — Tertiary and Upper Cretaceous sandstone, mudstone, and conglomerate with thin lignitic coal stringers

Ksu | Km, Km2, Km1 — Ksu---Undifferentiated Cretaceous sediments along the Yukon River, U.S.
Monster Formation (Km, Km1 and Km2)
Km---Undifferentiated mudstone, sandstone, and conglomerate
Km2---(middle part) Silty mudstone and conglomeratic carbonaceous sandstone (nonmarine?)
Km1---(lower part) Brown weathering, fine-grained, arkosic sandstone, -possibly marine

Kka — **Kathul Graywacke** ---Sandstone, conglomerate, and argillite

Kb — **Biederman Argillite** ---Argillite rhythmically interbedded with quartz-rich sandstone and siltstone

Kke — **Keenan Quartzite** ---Resistant quartzite and sandstone with occasional siltstone and argillite interbeds

Ku — Unnamed sandstone about 70 m thick along Nation River. Brown to gray to reddish-brown weathering, fine- to coarse-grained sandstone with interbedded black shale and siltstone. Percentage of sandstone increases in upper part of unit

KTrgu — Undifferentiated Glenn Shale and Upper Glenn Shale

Kg — **Upper Glenn Shale** (informal name)---Grayish-black shale with subordinate siltstone and quartzite

Trg | Trs — Trg---**Glenn Shale** (lower)---Grayish and brownish-black carbonaceous and calcareous shale with limestone in the lower part. Abundant *Halobia Monotis* pelecypods in places
Trs---Calcareous shale (may include the Shublik Formation)

PCu — Undifferentiated limestone, sandstone, and conglomerate

Pst, Ps, Pt — Pst---Undifferentiated **Step and Tahkandit Formations**
Ps---**Step Conglomerate** ---Chert-pebble conglomerate and chert arenite, U.S.
Pt---**Tahkandit Limestone** Canada and U.S.---Coarse-grained bioclastic limestone, Canada and U.S.

Pjc2, Pjc1 — **Jungle Creek Formation** (Pjc1 and Pjc2)
Pjc2---(upper) Calcareous cherty mudstone and silty micritic limestone and shale (marine), Canada
Pjc1---(lower) Chert-pebble conglomerate, sandstone and shale (marine)

Ccb | Ce — Ccb---**Calico Bluff Formation** ---Limestone and shale, U.S.
Ce---**Ettrain Formation** ---Limestone and shale, Canada

Chr — **Hart River Formation** ---Limestone, dolomite, and chert, Canada

CDf — **Ford Lake Shale** ---Laminated shale and chert

Dnr — **Nation River Formation** ---Mudstone, sandstone, and conglomerate

Dm, Do | Dc, Do — Dm---**McCann Hill Chert** ---Often weathers yellowish-red
Dc---**Canol Formation** ---Black siliceous shale, displays yellowish-red weathering
Do---**Ogilvie Formation** ---Massive bioclastic limestone

DSOr — **Road River Formation** ---Gray graptolitic shale with subordinate chert and limestone

O€jru, O€jrsd, O€jrd — **Jones Ridge Formation**
O€jru---Undifferentiated upper and lower Jones Ridge Formation. Massive limestone and dolomite. Upper part of unit highly silicified
O€jrsd---Silicified dolomite in upper Jones Ridge Formation
O€jrd---dolomite

O€h — **Hillard Limestone** ---Gray to yellow-brown limestone with minor dolomite chert and shale

€a — **Adams Argillite** ---Argillite, siltstone, and quartzite

€f — **Funnel Creek Limestone** ---Light-gray limestone and dolomite

TINDIR GROUP

Upper

p€tu — Undifferentiated Tindir Group

p€tl — Limestone---Locally includes quartzite, commonly fetid

p€tss — Dolomitic sandstone

p€trbu, p€tr, p€tb — p€trbu---Undifferentiated redbeds and basalt
p€tr---Grayish-red shale and siliceous shale
p€tb--Gray to green-gray tholeiitic basalt
Amygdules and pillow structures common, locally calcareous

p€tbs — Basalt and gray shale---Red-orange sandstone present at base of basalt

Diabase dikes--Dikes in p€tds show a K/Ar whole rock age of 588 ± 14 Ma and a K/Ar plagioclase age of 572 ± 16 Ma. Dikes in p€ts show a K/Ar-feldspar age of 532 ± 11 Ma and dikes intruding P€tq show a K/Ar hornblende age of 644 ± 18 Ma

p€tds — Dolomite and shale---Cream-colored, thinly laminated dolomite forms conspicuous yellow-weathering hills. Includes yellow-weathering, thinly-bedded gray, cherty mudstone near Mt. Slipper

Disconformity

p€tsslu — Undifferentiated shale, limestone and dolomite

p€ts — Shale---Black, fissile shale with red iron staining, interfingers with underlying stromatolitic limestone. Contains abundant quartzite in the northeastern part of the Yukon Thrust

p€tsl — Stromatolitic limestone---Gray, massive limestone with thick stromatolitic intervals in middle of unit. Interfingers to the southwest with shale and to the east with shale and quartzite

Angular Unconformity

Lower

p€tq, p€tsd, p€tqsd — p€tq---Gray to light-gray, quartzite and quartzitic sandstone. Trough crossbeds locally developed. Typically weathers dark gray with black lichens on weathered surfaces. Thin-bedded limestone at top of unit. Locally present at Cathedral Creek
p€tsd---Upper part of unit is gray-yellow-weathering dolomite and dolomitic limestone. Lower part of unit is gray-weathering blocky limestone. Stromatolites are well-developed near middle of unit.
p€tqsd---Interbedded quartzite and dolomite

p€tlc — Lower clastic unit---Gray, medium-bedded quartzite in upper part of unit, locally replaced by hematite. Gray to black, thinly bedded mudstones in lower part of unit

EXPLANATION OF MAP SYMBOLS

Contact---Dashed where inferred, dotted where inferred and concealed; queried where uncertain

High-angle fault---Dashed where inferred, dotted where inferred and concealed; showing lateral movement; queried where uncertain

Normal fault---Bar and ball on relatively downthrown block; dashed where inferred; dotted where inferred and concealed; queried where uncertain

Low-angle fault---Sawteeth on upper plate; dotted where inferred and concealed; queried where uncertain

Anticline---Dashed where inferred

Overturned anticline---Dashed where inferred

Syncline---Showing trace of axial plane and plunge; dashed where inferred

Overturned syncline---Showing trace of axial plane; dashed where inferred

A—A′ Line of structural transect

Seismic line

25 Strike and dip of dominant foliation

32 Apparent strike and dip of dominant foliation; inferred from aerial photos

24 Strike and dip of beds

55 Strike and dip of overturned beds

Strike of vertical beds; stratigraphic tops to the north

B&C Brabb & Churkin (1969)

N D.K. Norris (1979)

D J. Dover (1992)

MG M.C. Gardener (1984 field season)

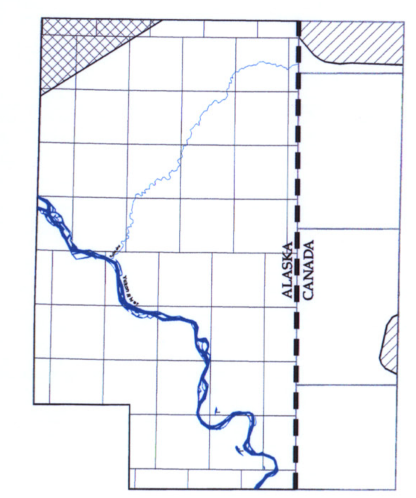
WG W. G. Grether (compiled 1982-1989 field seasons)

ARCO Field Program (1990 field season)

15 Bearing and plunge of lineation

Horizontal beds

COMPILATION INDEX



SOURCES FOR GEOLOGIC MAP

ARCO mapping area

Brabb, E.E., and Churkin, M., Jr., 1969, Geologic map of the Charley River quadrangle, east-central Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-573, scale 1:250,000 map.

Norris, D.K., 1982, Ogilvie River geology, Yukon Territory: Geological Survey of Canada Map 1526A, 1:250,000 scale, 1 sheet.

INTRODUCTION

The data compiled in this map series are the result of geological investigations by ARCO Alaska, Inc., from about 1982 to 1991 to evaluate the hydrocarbon potential of the Kandik area and Doyon, Limited, lands in particular. This multidisciplinary effort included six field seasons of geologic mapping and interpretation, two seasons of gravity acquisition, one season of seismic source and receiver testing, and geochemical and geochronological analyses. The project was extended into the Yukon Territory, Canada, in order to evaluate the Yukon Thrust system, which spans the international border. The extensive Paleozoic stratigraphy in the study area is complicated by numerous facies changes from east to west, corresponding to a Paleozoic shelf to basin transition. The typical transition of Paleozoic carbonates in Canada to shale in the United States generally reflects this shelf edge.

This publication consists of a geologic map, stratigraphic column, hydrocarbon source rock geochemistry column, structural cross-section models, surface soil and plant geochemistry plots, and a seismic profile. In conjunction with this map the Alaska Division of Geological and Geophysical Surveys is also publishing a sample location map (Van Kooten and others, 1996a) and gravity maps (Van Kooten and others, 1996b).

ACKNOWLEDGMENTS

Many people at Atlantic Richfield have contributed significantly through the years to the Kandik study. The authors gratefully acknowledge Thomas J. Barnes, Grant Cushing, Elizabeth A. Eide, Bill Gilmore, and William J. Grether for field mapping and regional geological evaluation; Michael Gardner and Kris E. Meisling for field mapping and structural analysis; Fred H. Behnken and Tim Carr for conodont separation and identification; Jim Chatham and Leslie Lee Lundell for surface and source rock geochemistry; Jeff Corrigan and James Talbot for geochronology; Ray Christopher and H.M. (Bud) Simpson for palynological analysis; and Gerry Arp for soil and plant geochemistry. Michael Churkin, Jr., and Don K. Norris led field trips to introduce us to the area. Useful discussion with David G. Howell, Mark J. Johnsson, and Michael B. Underwood are appreciated. Helpful reviews by David Howell, Laurel Burns and Frank Larson significantly improved the final product. ARCO Alaska, Inc., and Doyon, Limited, provided permission and financial support to publish this study.

REFERENCES

Brabb, E.E., and Churkin, M., Jr., 1969, Geologic map of the Charley River Quadrangle, East-Central Alaska; U.S. Geological Survey Miscellaneous Investigations Map I-573, scale 1:250,000, 1 sheet.

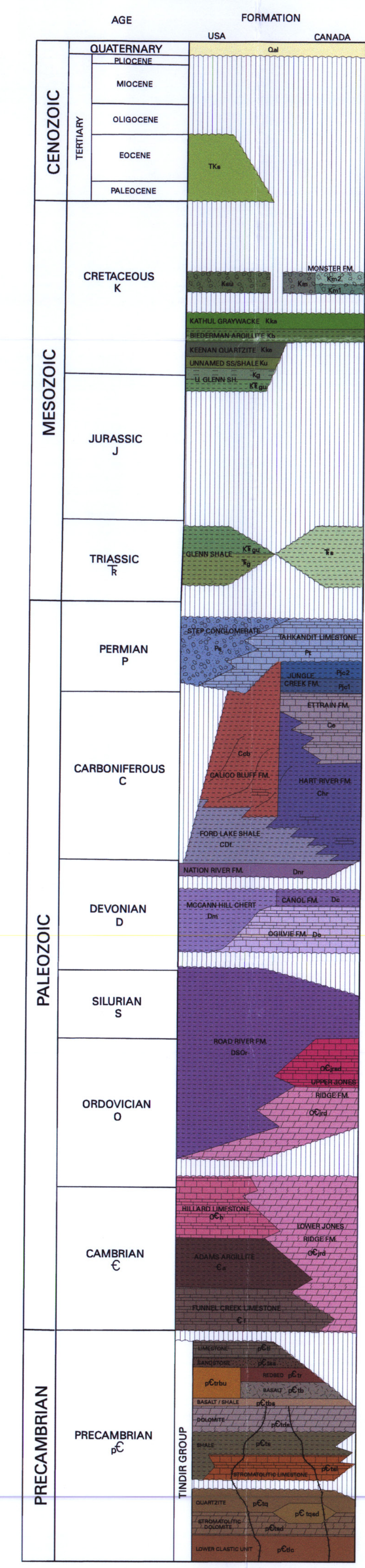
Dover, J.H., 1992, Geologic map and fold and thrust belt interpretation of the south eastern part of the Charley River Quadrangle, East-Central Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-1942, scale 1:100,000, 2 sheets.

Norris, D.K., 1979, Ogilvie River geology, Yukon Territory: Geological Survey of Canada Map 1526A, scale 1:250,000, 1 sheet.

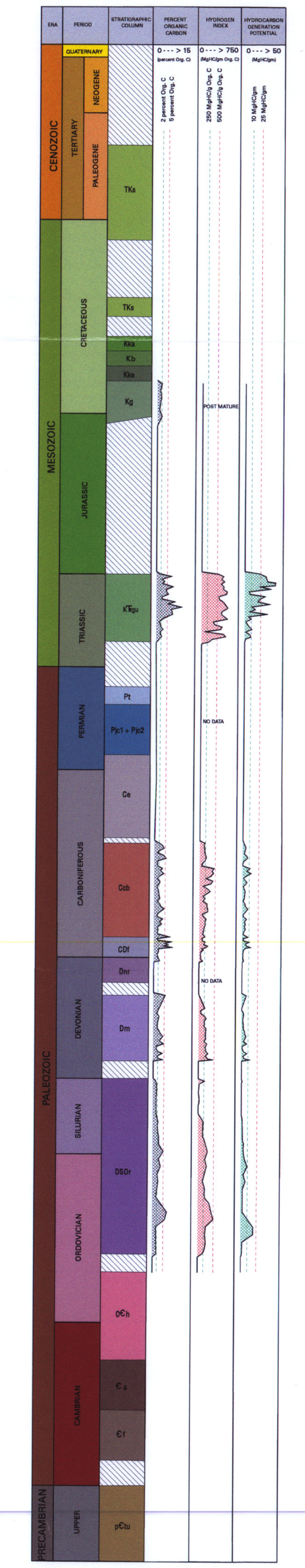
Van Kooten, G.K., Watts, A.B., Coogan, J., Mount, V.S., Swenson, R.F., Daggett, P.H., Clough, J.G., Roberts, C.T., and Bergman, S.C., 1996, Station locations in the Kandik Area, Alaska and adjacent Yukon Territory, Canada, Report of Investigations 96-6b, Alaska Division of Geological & Geophysical Surveys, scale 1:125,000, 1 sheet.

Van Kooten, G.K., Watts, A.B., Coogan, J., Mount, V.S., Swenson, R.F., Daggett, P.H., Clough, J.G., Roberts, C.T., and Bergman, S.C., 1996, Gravity Maps of the Kandik Area, Alaska and Adjacent Yukon Territory, Canada, Report of Investigations 96-6c, Alaska Div. Geol. & Geophys. Surv., scale 1:250,000, 1 sheet.

STRATIGRAPHIC COLUMN OF KANDIK AREA



HYDROCARBON SOURCE ROCK POTENTIAL



KANDIK AREA HYDROCARBON SOURCE ROCKS AND SEEPS

The Kandik area has long attracted attention as a potential hydrocarbon province because of the presence of numerous bitumen seeps and excellent hydrocarbon source rocks. In this study, surface bitumen was found at more than 20 localities and occurs in rocks of nearly every age from Precambrian to Cretaceous. The most extensive bitumen occurrences are found in the Triassic-age lower Glenn Shale along the eastern margin of the Nation River basin at Waterfall, Tindir, and Ettrain Creeks. Numerous bitumen veins up to four inches thick are present. Saturate chromatograms show that the bitumen is not significantly biodegraded. Other bitumen localities include one occurrence in Keenan quartzite on the northwest margin of the Nation River basin along the Nation River, numerous localities along Hard Luck Creek and the thrust extension of the Hard Luck Creek fault to the southeast, several occurrences at the northeastern edge of the Yukon Thrust in Canada in both hanging wall rocks and footwall thrust imbricates, and one occurrence in footwall Permian Jungle Creek Formation in the southeastern part of the map area. All of the bitumen localities in the upper plate of the Yukon Thrust are associated with significant faults, probably implying that hydrocarbons were generated in the footwall and migrated vertically along faults through the overlying Precambrian section to the surface. The only Precambrian "bitumen" unrelated to significant faulting is graphitic material at one locality in the Tindir Group dolomite and shale unit (p€tds) that appears to be thermally very mature and of a different origin.

The chart entitled Hydrocarbon Source Rock Potential shows that the Triassic-age lower Glenn Shale is an excellent hydrocarbon source rock. About 600 feet of this shale is exposed south of the Yukon River at Michigan Creek in T6N R29E and 29 samples contain total organic carbon (TOC) from 2-7% (average about 3.5%) with associated hydrogen index (HI) values between about 400 to 700 (average about 500). At Hard Luck Creek near the southern end of the Nation River Basin in T5N R31E, the exposed lower Glenn Shale is about 480 feet thick and is covered at the top. Thirty samples of the lower Glenn Shale from Hard Luck Creek, including four samples from shallow drill holes in covered intervals, contain TOC averaging about 2% (range 1-3.5%). The HI values increase systematically from 100-200 near the base to 300-420 at the top of the exposed section. One anomalous sample about 350 feet from the top of the exposed section contains TOC of 7% and HI of about 510. The source quality of the Glenn Shale generally improves upwards in the section and it is possible that the covered interval at the top of the section contains better hydrocarbon source material than was sampled. The vitrinite reflectance of the lower Glenn Shale at Hard Luck Creek averages 0.50 and is immature.

The Carboniferous, Devonian, and Ordovician age rocks contain fair to good hydrocarbon source rocks (see Hydrocarbon Source Rock Potential chart) and are probably responsible for the bitumen occurrences at the front of the Yukon Thrust in the footwall and hanging wall rocks. An unconformity of probable Jurassic age eroded the Triassic-age lower Glenn Shale and underlying Permian Tahkandit Limestone in the footwall of the Yukon Thrust in Canada. In Canada, the lower Glenn Shale reappears only at the northeastern corner of the study area and, using Canadian terminology, is mapped as the equivalent "Shublik Formation." The Shublik Formation is also present east of the study area along the margins of the Monster Syncline. These relationships indicate that the lower Glenn Shale is missing from at least the eastern part of the footwall beneath the Yukon Thrust and that it is unlikely to be the source of bitumen occurrences in the eastern part of the Yukon Thrust and footwall rocks. Our structural interpretation of the Yukon Thrust indicates that the Carboniferous, Devonian, and Ordovician rocks are present in the footwall beneath the Yukon Thrust and these rocks probably generated the hydrocarbons that formed the seeps at the front of the Yukon Thrust. Measured thermal maturity of footwall rocks north of the Tatonduk River near the Canada-U.S. border range from immature to gas window.