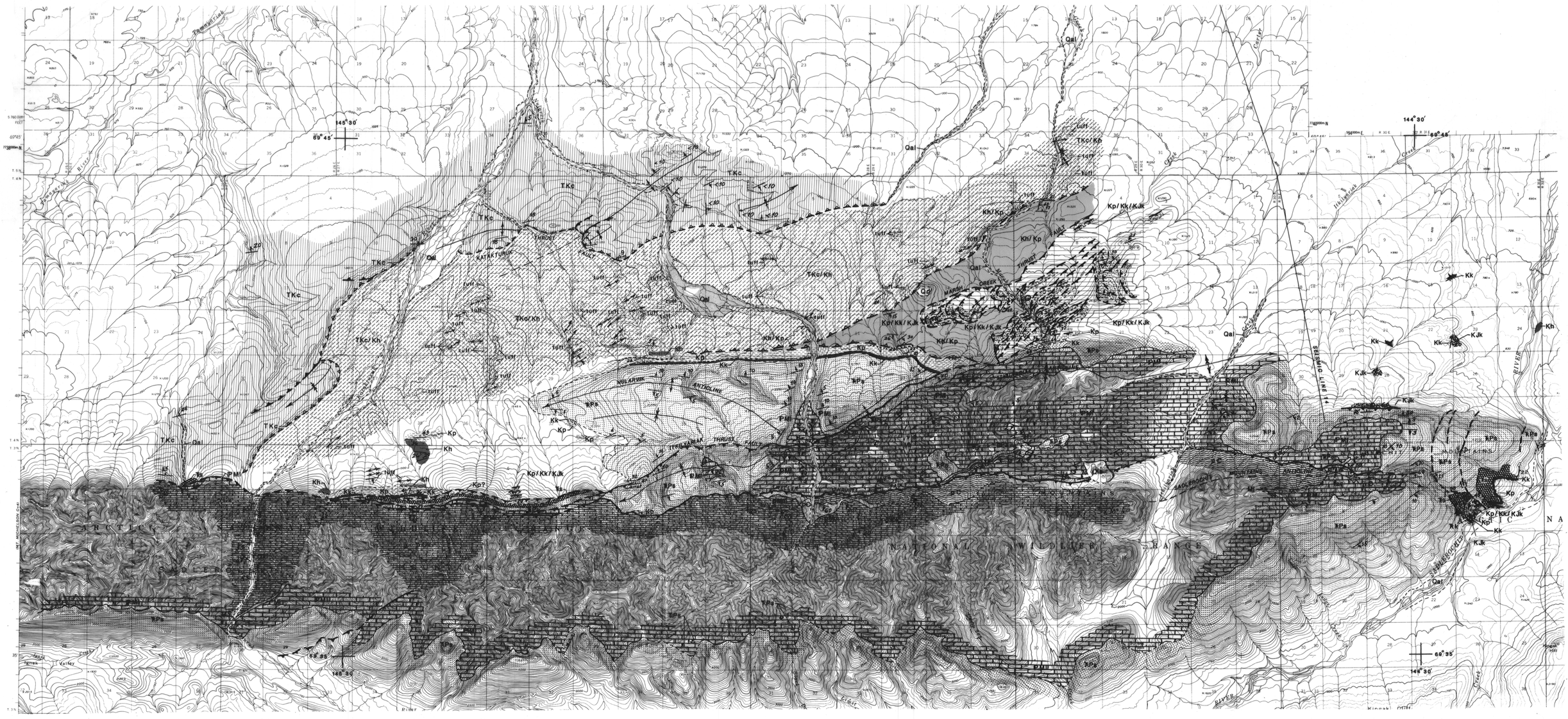
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 89-11



Base from U.S. Geological Survey Mt. Michelson C-1, C-2, and C-3 1:63,360 quadrangles, 1955

Field mapping by J.S. Kelley and C.M. Molenaar, 1984 and 1985

34°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1955

SCALE 1:63360
1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 0 1 2 3 4 5 KILOMETRES
CONTOUR INTERVAL 50 FEET
DOTTED LINES REPRESENT 25-FOOT CONTOURS

INTRODUCTION

This map presents information relevant to published syntheses. The map shows new mapping, location of critical field relations, and the degree of extrapolation from previous mapping in the interpretation of the structural style and framework of the Sadlerochit Mountains and adjacent areas.

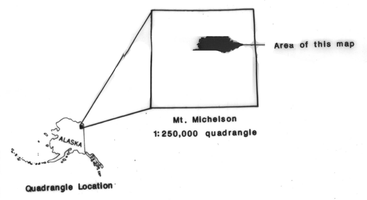
Mapping compiled here was conducted by the authors during field investigations in 1984 and 1985. The field investigations were part of the U.S. Geological Survey's contribution to a study of the Arctic National Wildlife Refuge mandated by Section 1002 of the Alaska National Interest Lands Conservation Act of 1980. The mapping was done between July 12 and 17, 1984 and July 1 and 18, 1985.

The purpose our field investigations was to gain insight into the structural style and framework of areas adjacent to the coastal plain of the Arctic National Wildlife Refuge. Syntheses of our observations were presented in Kelley and Molenaar (1985), Kelley and Foland (1987), and Kelley and others (1987).

This compilation comprises original mapping by the authors and field-checked mapping of Reiser and others (1970 and 1971). The map also shows the location of part of seismic line 14, the means of extrapolating field relations in the Sadlerochit Mountains to the the subsurface geology of the adjacent coastal plain (Kelley and Foland, 1987; Kelley and others, 1987).

EXPLANATION OF MAP UNITS

The map includes map units that are widely recognized lithostratigraphic units and compound map units. In areas of little structural complexity, single units such as widely recognized formations and groups are mapped. In areas of structural complexity and poor exposure, map units comprised of two or more lithostratigraphic units, the elements of which are mapped as formations or intervals within formations elsewhere in the map area, are used.
Compound map units show the distribution of particular stratigraphic sequences without regard to poorly exposed structures. Imbricate faulting, detachment folding, and limited exposure preclude mapping most elements of compound map units individually beyond the confines of isolated outcrops and at very large map scales.
Compound map units infer the distribution of major structural blocks. Structural repetition of a lithostratigraphic sequence within each compound map unit implies that the compound units correspond to structural blocks separated by decollement from adjacent map units. Since a major purpose in producing the map is to show structural relations, compound map units are extensively employed. The distribution of thrust faults that repeat the stratigraphic sequence of compound map units are shown where possible to illustrate structural repetition within compound map units



DESCRIPTION OF MAP UNITS

Qal — Quaternary alluvium. This unit comprises fluvial gravel in active stream channels and fluvially deposited gravel underlying floodplains adjacent to active stream channels.

Qls — Quaternary landslide deposit. This deposit consists of limestone and dolomite rubble including large blocks derived from the Lisburne Group.

Qd — Quaternary deposits. This unit mostly comprises thin deposits of heterolithic fluvially deposited debris underlying prominent terraces and overlying shallow-dipping erosional surfaces cut in bedrock.

TKc — Canning Formation (Upper Cretaceous to Paleocene) Only the lower 2,000 feet (600 m) of formation is exposed in map area. The formation comprises interbedded shale and sandstone. Shale is silty, dark-gray to greyish-brown, nonfissile, and bentonitic. Sandstone is mostly very fine to fine-grained but includes medium-grained sandstone that typically occurs in graded beds a few inches (cm) to a few feet (m) thick; most beds are massive to laminated and have sharp basal contacts with common groove casts and minor flute casts. Carbonaceous debris is common. The unit includes turbidites (See Molenaar and others, 1987). Parts of unit containing more sandstone are more resistant to erosion; shalier parts are less resistant to erosion and have limited exposure. Unit is deformed into open synclines and narrow and faulted anticlines. Sandstone of the Canning Formation occurs subjacent to poorly developed north-northwest-dipping cuestas along southern margin of the formation.

Kh — Hue Shale (Lower to Upper Cretaceous) This formation comprises interbedded shale, bentonite, and lesser amounts of tuff in middle of formation. The formation is about 700 feet (210 m) thick on south side of Sadlerochit Mountains and the depositional thickness in map area is probably comparable. The formation is structurally incompetent and complex. Shale is dark-gray to black, noncalcareous, mostly fissile, and bentonitic. The lower 100 to 150 feet (30 to 45 m) of the formation is highly radioactive shale (gamma-ray zone). Immediately above the radioactive shale is a 20 to 25-foot-thick (6 to 8 m) interval rich in inoceramus prisms (Inoceramus zone). White- to yellowish-brown-weathering soft bentonite occurs in beds as much as 6 inches (15 cm) thick as interbeds and partings in the formation. The tuff is interbedded with shale and is light gray, fine textured, hard, indurated, and thinly bedded; it weathers to red on rubble-covered hills (Refer to Molenaar and others, 1987).

TKc/Kh — This compound mapping unit comprises Canning Formation (Upper Cretaceous to Paleocene) and Hue Shale (Lower to Upper Cretaceous). The unit consists of undifferentiated lower part of Canning Formation and upper half of Hue Shale (see description of individual formations.). Unit is very poorly exposed. Exposures are mostly isolated, conspicuous, red-weathering, rubbly mounds (labeled tuff on map) separated by tundra-mantled low areas. Poor exposures in stream cuts suggest that most of the low-lying areas are underlain by shale and scattered turbidites. This unit may be as much as 1,000 feet (300 m) thick. The unit consists of shale, scattered turbidites, and tuff. The outcrop area is structurally intricate and the sequence making up the unit is repeated numerous times by thrust faults and detachment folds.

Kp — Pebble shale unit (Lower Cretaceous). This informal but widely recognized lithostratigraphic unit is between 200 and 300 feet (60 to 90 m) thick and is silty shale and siltstone in the lower part and grades upward to clay shale. Shale is dark gray to black, silty, nonfissile to poorly fissile, and noncalcareous. The unit contains ironstone concretions, scattered frosted quartz grains, and minor amounts of matrix-supported chert and quartzite pebbles and rare cobbles. Where the underlying Kemik Sandstone is thin or not present, the lower part of pebble shale unit is very silty and contains common beds of siltstone and common matrix-supported pebbles. Pebble zones are common at base of the unit. The unit is unfossiliferous, except for carbonaceous plant debris, palynoflora, and microfauna, which indicate Hauterivian to Barremian (Early Cretaceous) age. The lower contact is sharp but conformable with Kemik Sandstone. Where Kemik Sandstone is absent, contact is unconformable on underlying Jurassic and Triassic rocks in map area. The upper contact is gradational with overlying Hue Shale and is placed at the change from non-bentonitic shale below to bentonitic shale of gamma-ray zone of the Hue Shale above.

Kh/Kp — This compound mapping unit includes undifferentiated Hue Shale and pebble shale unit (see description of individual units). The unit includes between a 700 to 1,000 foot (215 and 300 m) thick sequence of mechanically incompetent and structurally complex shaly strata. The sequence is duplicated by unmapped folding and thrust faulting a number of times within the mapped distribution of the unit.

Kk — Kemik Sandstone (Lower Cretaceous). This formation is between 0 and 50 feet (15 m) thick and consists of predominantly light-gray, very fine to fine-grained, medium- to thick-bedded, locally cross bedded, hard, and indurated quartzose sandstone with abundant chert grains. Thin pebble conglomerate beds are common at or near base of the formation. The formation contains trace fossils, sparse bivalves, and in a nearby area, the ammonite *Simbirskites*of Hauterivian (Early Cretaceous) age. The lower contact is a regional unconformity along which subjacent rocks are progressively truncated to the north. The upper contact is sharp but conformable with pebble shale unit. The formation was probably deposited under shallow marine conditions.

KJk — Kingak Shale (Lower Cretaceous and Jurassic but probably only the Jurassic part is present in map area). Thickness of the formation in the map area is uncertain owing to limited exposure but probably is less than 300 feet (90 m). The formation is mostly dark-gray to black, fissile, noncalcareous, and clayey to silty shale with subordinate amounts of siltstone. Ripple-cross-bedded, burrowed siltstone is common in the outcrop in section 28, T.4N.,R.31E. Ironstone concretions are common to rare throughout the formation. The formation contains belemnites and less commonly ammonites. The Kingak Shale is unconformably overlain by Kemik Sandstone. Lower contact of the Kingak Shale is conformable. The Kingak Shale as included in this map unit occurs in a structurally uninterrupted sequence of Mississippian to Lower Cretaceous strata at Last Creek at the east end of the Sadlerochit Mountains. The Kingak Shale, in uncertain structural relations to older strata, also occurs in isolated outcrops northeast of the Sadlerochit Mountains.

Kp/Kk/KJk — This compound map unit comprises undifferentiated pebble shale unit (Lower Cretaceous), Kemik Sandstone (Lower Cretaceous), and Kingak Shale (Lower Cretaceous and Jurassic) (see individual unit descriptions for description of individual lithostratigraphic units in this map unit). The sequence occurs in structurally repeated and imbricate fault blocks made prominent by repetitions of the Kemik Sandstone. Repetitions within this map unit are shown on the map by distribution of the Kemik Sandstone, indicated by a dot pattern, and imbricate thrust faults.

Trk — Karen Creek Sandstone (Upper Triassic). The formation is sandstone and siltstone. Sandstone is gray, hard, resistant-weathering, very fine grained, and quartzose. The sandstone grades to siltstone. Bedding is thick to massive, commonly bioturbated, and locally contains small dark burrows. The formation is fossiliferous, mostly bivalves. The formation is 0 to 25 feet (0 to 8 m) thick in the northeastern Brooks Range; the only occurrence in the map area is a poorly exposed and probably very thin interval at Last Creek at east end of Sadlerochit Mountains.

Trs — Shublik Formation (Middle to Upper Triassic). The formation is between 0 and 500 feet (0 to 150 m) thick and consists of 3 members in ascending order: siltstone member, limestone member, and clay shale member. The siltstone member is dark-gray to black, sooty, calcite cemented, quartzose, organic, phosphatic, and regular bedded. The limestone and dolomite of the limestone member is very silty, sandy, thin-bedded to massive, and interbedded with sooty black to dark-gray shale. The carbonate layers include coquina intervals of flattened and typically phosphate-replaced bivalves. Weathered surfaces of the carbonate beds locally weather to pastel shades of yellowish-gray. The clay shale member is poorly exposed. Dark-grey to black sooty calcareous shale, siltstone, and fossiliferous limestone and dolomite best characterize most outcrops in the map area. The formation is exposed at Last Creek at the east end of the Sadlerochit Mountains were it is part of a structurally uninterrupted Mississippian to Lower Cretaceous sequence. The formation is also exposed in fault blocks along the foot of the northwestern Sadlerochit Mountains.

TrPs — Sadlerochit Group (Lower Triassic and Permian). The group comprises the Echooka Formation and overlying Ivishak Formation and is between 600 and 800 feet (180 to 240 m) thick. The Echooka Formation is predominantly sandstone and siltstone that is locally conglomeratic. Sandstone in the Echooka Formation is pyritic, reddish-brown-weathering, and greater than 100 feet (30 m) thick. Ivishak Formation consists of the Kavik and Ledge Sandstone Members. The Kavik Member consists of medium- to dark-gray silty shale and siltstone that grades into the overlying Ledge Sandstone Member. The Ledge Sandstone Member is predominantly fine- to medium-grained, hard, resistant-weathering, quartzose, pyritic, and reddish-brown-weathering sandstone. The Sadlerochit Group unconformably overlies Lisburne Group; abrupt contrast between underlying light-gray limestone and dolomite of the Lisburne Group and overlying dark-reddish-brown-weathering clastics of the Sadlerochit Group marks the contact.

PMl — Lisburne Group (Pennsylvanian and Mississippian). The group consists of the Alapah Limestone and overlying Wahoo Limestone and comprises about 1500 feet (460 m) of mainly carbonate strata. Light-gray-weathering, medium- to dark-gray, and locally cherty limestone, dolomitic limestone, and dolomite make up most of the section. The group includes small amounts of limy shale and shaly limestone. Specifically, Armstrong and Mamet (1977) report pelletoidal packstone and grainstone, bryozoan and pelmatozoan mudstone and wackestone, bryozoan and pelmatozoan packstone and wackestone, and oolitic packstone and grainstone from measured sections in the Sadlerochit Mountains. The weathering profile of the group commonly consists of a massive-weathering basal interval, a thick-bedded and positive weathering upper half, and a rubbly intervening interval between the two positive weathering intervals.

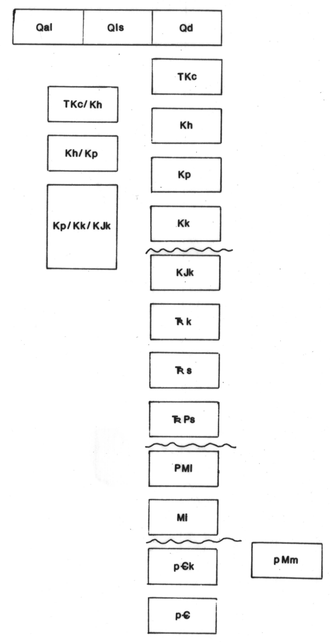
Ml — Itkillyariak Formation (Mississippian). This formation is as much as 150 feet (45 m) thick but not clearly recognized throughout the map area. The formation consists of reddish-brown to maroon limestone, shale, sandstone, conglomerate, breccia, greenish-gray shale, and quartzose sandstone. The Itkillyariak Formation grades into a thin Kayak Shale (not mapped) at base and into Lisburne Group at top.

pCk — Katakturuk Dolomite (Proterozoic ?). The formation consists of about 7,500 feet (2,500 m) of mostly dolomite and limy dolomite. The formation is probably Proterozoic in age; it lacks fossils other than algal structures and underlies a formation that includes Cambrian fossils in the Shublik Mountains (Blodgett and others, 1986). Dolomite is light medium gray to dark gray, light medium to light gray weathering, thin-bedded to massive but commonly laminated, cross-laminated, and algal-laminated, commonly vuggy, generally fine grained, and limy locally. Algal structures including stromatolites, pisolite beds, mud chip clasts, and silica-replacement are characteristic lithologic features of the formation. In thin section, dolomite, making up much of the formation, appears to have been pelletoidal limestone devoid of shelly debris. The formation is ubiquitously fractured on scales ranging from handspecimen to outcrop scale.

pC — Undivided Precambrian rocks. This unit includes mostly clastic rocks of probable Proterozoic age. As much as 2,000 feet (600 m) of these rocks may be exposed in the Sadlerochit Mountains; the base of the section is not exposed. The rocks of this unit possibly are structurally complex. The unit includes reddish-brown and greenish-gray argillite, orthoquartzite, and chert-quartz and quartzite conglomerate. The rocks are locally highly sheared. Pencil cleavage is present locally. Some fine-grained rocks have phyllitic sheens on cleavage surfaces, especially in association with shear zones. Other rocks appear little deformed and unrecrystallized and contain recognizable sedimentary structures such as dune and ripple cross-bedding, lamination, and mud cracks.

pMm — Mafic igneous rocks (Pre-Mississippian). This unit includes extrusive and/or intrusive, dark-brown-weathering basaltic and/or andesitic rocks.

CORRELATION OF MAP UNITS



MAP SYMBOLS

- Anticline showing trace of axial plane and plunge of axis. Dashed line indicates projected position of the axial plane in a thrust sheet removed by erosion and the anticline is not present in the lower sheet.
- Strongly asymmetrical anticline showing trace of axial plane and plunge of axis; double arrow indicates steeper limb. Dashed line indicates projected position of the axial plane in a thrust sheet that has been removed by erosion and the anticline is not present in the lower sheet.
- Overturned anticline showing trace of axial plane and plunge of axis. Arrows show dip direction of axial plane.
- Syncline showing trace of axial plane and plunge of axis.
- Strongly asymmetrical syncline showing trace of axial plane and plunge of axis; double arrow indicates steeper limb.
- Overturned syncline showing trace of axial plane and plunge of axis; arrows indicate dip direction of axial plane.
- Small asymmetrical anticlines and synclines; double arrows indicate the steeper limbs.
- Thrust fault; teeth indicate upper plate, arrow shows estimated dip of fault plane. Dashed where approximately located or obscure. (50)
- Fault; relative sense of movement along segments indicated by: U (up) and D (down) dip slip component, and arrows for strike-slip component. Dashed where location uncertain or obscure
- Approximately located detachment fault indicated by folding and/or imbricate faulting of one sequence of beds independently of adjacent and depositionally continuous strata but not resulting in superimposition of older strata on younger strata; teeth indicate upper plate.
- Unconformable contact with inferred detachment; detachment indicated by local brecciation and different structural fabric across contact but detachment not everywhere coincident with the stratigraphic contact.
- Location of rubble-obscured outcrop.
- Small anticlines and synclines showing traces of axial planes and plunges of axes.
- 17 — Strike and dip of bedding; measured
- 25 — Strike and dip of bedding; visually estimated.
- Direction of strike and dip of bedding; estimated from field observation or vertical aerial photographs.
- <10 — Direction of strike and dip of bedding estimated to be dipping less than 10 degrees.
- Trend of lineations in poorly exposed strata; approximate general strike of bedding and axial planes of folds.
- Contact; dashed where imprecisely located or obscure.

REFERENCES CITED

Armstrong, A. K. and Mamet, B. L., 1977, Carboniferous microfacies, microfossils, and corals, Lisburne Group, Arctic Alaska: U. S. Geological Survey Professional Paper 849, 144 p., 19 fig., 47 pl.

Blodgett, R. B., Clough, J. G., Dutro, J. T., Jr., Ormiston, A. R., Palmer, A. R., and Taylor, M. E., 1986, Age revisions for the Nanook Limestone and Katakturuk Dolomite, northeastern Brooks Range, *in* Bartsch-Winkler, Susan, and Reed, K. M., eds., Geologic studies in Alaska by the U. S. Geological Survey during 1985: U. S. Geological Survey Circular 978, p.5-10.

Kelley, J. S., and Molenaar, C. M., 1985, Detachment tectonics in the Sadlerochit and Shublik Mountains and applications for exploration beneath the coastal plain of the Arctic National Wildlife Refuge, Alaska (abs.): American Association of Petroleum Geologists Bulletin, v. 69, n.4, p. 667.

Kelley, J. S., and Foland, R. L., 1987, Structural style and framework geology of the coastal plain and adjacent Brooks Range, *in* Bird, K. J., and Magoon, L. B., eds., Petroleum geology of the northern part of the Arctic National Wildlife Refuge, northeastern Alaska: U. S. Geological Survey Bulletin 1778, chpt. 20, p.255-270, 12 fig., 1 pl.

Kelley, J. S., Foland, R. L., and Molenaar, C. M., 1987, Structural framework of the Sadlerochit Mountains and Shublik Mountains and adjacent Arctic Coastal Plain (abs.): Abstracts and Program; Symposium on the Petroleum Geology of the 1002 Area, ANWR Coastal Plain, Alaska, Nov. 16-17, 1987, Alaska Geological Society, Anchorage, Alaska.

Molenaar, C. M., Bird, K. J., and Kirk, A. R., 1987, Cretaceous and Tertiary stratigraphy of northeastern Alaska, *in* Tailleur, Irv, and Weimer, Paul, eds., Alaskan North Slope geology: Bakersfield, Calif., Society of Economic Paleontologists and Mineralogists, Pacific Section, v.1, p. 513-528

Reiser, H. N., Brosgé, W. P., Dutro, J. T., Jr., and Detterman, R. L., 1971, Preliminary geologic map, Mt. Michelson quadrangle, Alaska: U. S. Geological Survey Open-File Report 71-237, scale 1:200,000.

Reiser, H. N., Dutro, J. T., Jr., Brosgé, W. P., Armstrong, A. K., and Detterman, R. L., 1970, Progress map, geology of the Sadlerochit and Shublik Mountains, Mt. Michelson C-1, C-2, C-3, and C-4 quadrangles, Alaska: U. S. Geological Survey Open-File Report 70-273, 5 sheets, scale 1:63,360.

Geologic Map of the North Flank of the Sadlerochit Mountains, Mount Michelson C-1, C-2, and C-3 Quadrangles, Northeastern Alaska

By

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1988