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Geologic Map of the Christian Quadrangle, Alaska

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INTRODUCTION

GEOLOGIC SETTING

Most of the Christian quadrangle is in the Porcupine Plateau; the northwestern part is in the southern Brooks Range, and the southern quarter is in the Yukon Flats. Outcrops of bedrock are poor or lacking, except in the Brooks Range. Although large valley glaciers have moved through the Porcupine Plateau, along the East Fork Chandalar and Vanticlese Creek, most of the upland areas in the Porcupine Plateau have not been eroded by ice. Consequently the rocks are deeply weathered and many outcrops in the low hills east of the East Fork are only soil and rubble. The southern quarter of the quadrangle in the Yukon Flats is covered with unconsolidated glacial and alluvial deposits.

The Christian quadrangle is at the east end of the southern Brooks Range schist belt. Here three geologic terranes that originate well south of the Brooks Range intersect the subterranes of the southern Brooks Range along northward-directed thrust faults and northeast-striking strike slip faults. The displaced terranes from the south have been mapped by Jones and others (1987), as the schist of the Ruby terrane, the mafic rocks and phyllite of the Tozitna terrane, and the graywacke of the Venetie terrane. The typical rocks of the southern Brooks Range Arctic Alaska terrane at this intersection are the carbonate and clastic rocks of the Hammond subterrane, and the schist of the Coldfoot subterrane. The Coldfoot schist ends at a probable strike-slip fault about 10 miles west of the Christian quadrangle. At that place the mafic rocks and phyllites of the Angayucham terrane that form the south flank of most of the Brooks Range veer sharply northeastward across the Coldfoot subterrane schist and terminate it (fig. 2). A small fragment of the Endicott Mountains subterrane of the Arctic Alaska terrane also lies within the Christian quadrangle, but the main body of this subterrane lies north of the quadrangle.

The schist of the Ruby terrane is distinguished from that of the Coldfoot subterrane by the high temperature metamorphic aureole characteristic of the Ruby terrane around the probably Cretaceous granite that intrudes it and by the small positive magnetic anomaly produced by that granite in contrast to the less magnetic Devonian granites of the Brooks Range.

Figure 2 shows schematically the map arrangement of the terranes and subterranes. The rocks themselves are discussed in the Description of Map Units.

GEOLOGIC MAPPING

J.B. Mertie, Jr. made the first geologic reconnaissance of this region in 1926 and 1927 (Mertie, 1930). Most of his mapping was in the Brooks Range north of the Christian quadrangle, but in 1926 he made a short trip up the lower Sheenjek River, and, in 1927, he, and topographer Gerald FitzGerald began their work by moving the summer's supplies northward through the quadrangle by way of the Christian and East Fork Chandalar Rivers, using dog team, canoe and backpack. At the end of the summer they canoed back to Fort Yukon on the East Fork. These trips along the rivers in the Christian quadrangle allowed Mertie to map and describe parts of most of the major rock units.

J.R. Williams in 1949 mapped the Yukon Flats from Circle to Beaver by boat and foot traverses along the Yukon and its tributaries (Williams, 1962). He extended his field map by interpretation of aerial photos. In addition to the alluvial and high terrace deposits of the Flats, he mapped the glacial deposits and moraines along the East Fork Chandalar River. The map and description of the unconsolidated deposits in the southern part of the quadrangle are largely from his work.

In 1959, Brosgé visited a few outcrops on the Christian River while enroute across the area. The next year, while mapping the adjacent southern Brooks Range from a base in Arctic Village, Brosgé and Reiser made a reconnaissance of the entire quadrangle and published an open-file map (Brosgé and Reiser, 1962). In 1963 they did more detailed work from camps at Vundik Lake in the Coleen quadrangle and on the East Fork Chandalar River. They described the ophiolite complex (Reiser and others, 1965), but did not publish a revised quadrangle map. Since then, brief investigations have been made by I.L.Tailleur in search of oil shale in 1966, by the authors for fossils in 1972 and 1979, and by Hawley and Garcia in search of minerals in 1976. The data from these years, beginning with 1963, are incorporated in the present map.

MINERAL AND GEOPHYSICAL INVESTIGATIONS

MINERALS

Gold.—A few ounces of placer gold have been mined from Crater Creek and Cornucopia Creek on the flank of the Ruby Terrane (Hawley and Garcia, 1976).

Chromium and Platinum Metals.—Traces of these metals have been found with the ultramafic rocks of unit Jou of the Tozitna terrane. Hawley and Garcia (1976) mapped and sampled these rocks on behalf of the Bureau of Indian Affairs and the Bureau of Mines. Nodules in peridotite soil contained 4.5% chromium and a trace of platinum. A mining exploration company also made a geochemical survey of part of the Venetie Indian Reservation. The company took up no claims, but suggested that the Natives prospect for chromite.

Oil Shale.—Small amounts of very rich oil shale occur as float in the Tozitna terrane, and are described with unit JMv. Mertie (1930) reported the analysis of a sample from the Christian River area given to him by a local resident. It contained 122 gallons of low-density oil per ton. In 1943 the Bureau of Mines trenched a site where float of this oil shale was most common according to the people on the Venetie Reservation, who apparently had been using float of oil shale as casual fuel. A trench through soil to mafic bedrock found no oil shale in place, only fragments in the soil and frozen to bedrock. Samples of the float assayed 60 to 123 gallons per ton of API 29.3 to 33.4 degrees oil (Ebbley, 1944). Analyses of samples collected at that site in 1976 by Hawley and Garcia were similar, but very little oil shale float could be found.

GEOPHYSICS

A reconnaissance aerial magnetic survey of most of the quadrangle was flown in 1965 along flight lines 5 and 10 miles apart, and at altitudes generally 5,000 feet above sea level. The sparse data have been interpreted by correlation of anomalies (Brosgé and others, 1970), and magnetic contour maps have been drawn at scales of 1:1,000,000 (Kirby *in* Brosgé and others, 1970) and 1:500,000 (Saltus and Simmons, 1997). Some major geologic features can be distinguished magnetically. Positive anomalies characterize the exposed mafic rocks of the Tozitna terrane, and a probable southward extension of the mafic rocks beneath the Yukon Flats. They also show the continuity northeastward across the Chandalar River of the metamorphic rocks of the Ruby terrane and the granite that intrudes them. Just to the west in the Chandalar quadrangle a continuous zone of negative anomalies characterizes the phyllite belt of the Angayucham terrane (see figure 2 for location of this belt).

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

The map of surficial deposits is based on interpretation of aerial photos by the authors, and on earlier photo interpretation by Williams (1962), and Coulter and others (1965). Descriptions are from Mertie (1930) and Williams (1962), and a few observations by the authors. Correlations are by Williams (1962) and Hamilton and Porter (1975).

Qu **Undifferentiated deposits (Quaternary)**--Glacial and alluvial deposits, and some colluvium. In Yukon Flats much yellow-weathering pebbly silt probably correlative with upper part of the terrace deposits Qt

Qal **Alluvium (Holocene)**--Coarse sand and rounded to subangular gravel, minor fine sand and silt, and some glacial boulders. On flood plains and low terraces. Covered by as much as 25 feet (8m) of stratified sand, silt and peat

Qg **Glacial drift undifferentiated (Pleistocene)**--Unsorted gravel, sand, silt and clay of terminal and ground moraine; some boulders 5 to 6 feet (2m) in diameter. Forms morainal ridges and boulder rapids, behind which are areas of kettle lakes and sluggish stretches on rivers. Hachured lines indicate prominent lateral or terminal moraines. Includes drift of three Middle(?) to Upper Pleistocene glaciations listed below. May include some drift of an earlier glaciation

Qg2 **Drift of Itkillik II glaciation (Upper Pleistocene)**--Mostly till and gravel. Terminal moraines of this glaciation enclose the 25 mile (40 km) long, flat-floored, lake-filled valleys of the Sheenjek and East Fork Chandalar that begin just north of the Christian quadrangle

Qg1 **Drift of Itkillik I glaciation (Middle to Upper Pleistocene)**--Till, gravel, sand and silt

Qgs **Drift of Sagavanirktok glaciation (Middle(?) Pleistocene)**--Till, gravel, sand and silt. May also include some drift of Lower Pleistocene glaciation

Qt **Terrace deposits (Pleistocene)**--Deposited as outwash fans of the Sheenjek, Christian and Chandalar rivers. Stratified layers and lenses of well-sorted sandy pebble-cobble gravel, with lenses of sand, silt, and peaty organic material. Mantled by 25 feet (8 m) of sand, silt and organic material. Forms many terraces, some at levels only a few feet apart. Older (upper) terrace deposits locally cemented by iron oxides. Lower terraces have thin oxidized zones. Unit may be as much as 500 feet (150 m) thick. Fragment of Early to Middle Pleistocene horse jaw found below terrace near Venetie (Williams 1962)

BEDROCK UNITS

The bedrock units occur in five different stratigraphic sequences that have been recognized by Jones and others (1987) as the Tozitna terrane, the Venetie terrane, Endicott Mountains and Hammond subterranes of the Arctic Alaska terrane, and the Ruby terrane. We follow Jones and others and Silberling and others (1994) in assigning the schist in the southwest part of the quadrangle to the Ruby terrane, rather than to the Coldfoot terrane as shown by Nokleberg and others (1994).

TOZITNA TERRANE

Ophiolitic sequence (Middle Jurassic)--Upper part mapped as layered leucogabbro Jol; lower part as ultramafic rocks, Jou. The contact with the immediately surrounding basalt, diabase and chert of unit JMv is obscure, but is probably a flat thrust fault.

Jol **Layered leucogabbro (Middle Jurassic)--**Mostly light gray hornblende anorthosite and pyroxene anorthosite, with dark layers of gneissic hornblende gabbro that contain minor clinozoisite. Some green hornblende in both the anorthosite and gabbro. The light and dark bands range from thin streaks to layers several inches thick. Layering on a larger scale is suggested by alternating bands of hillside rubble of leucogabbro, hornblende gabbro, and ultramafic rocks. At one locality the gneissic leucogabbro intrudes and replaces the ultramafic rocks. The leucogabbro there contains olivine xenoliths, and much of the adjacent massive peridotite remains only as a sponge-like matrix with the olivine and hornblende partly replaced by feldspar.

The hornblende gabbro is Middle Jurassic in age. A K/Ar age was measured on hornblende from gabbro interlayered with anorthosite on the highest hill in the main body. Originally calculated as l68+/- 8 Ma (Reiser and others, 1965), the age is here revised to 174 +/- 8 Ma using new K^{40} decay constants (Lanphere, M.A., written commun. 3/5/97)

Jou **Ultramafic rocks (Middle Jurassic)--**Orange-weathering peridotite and clinopyroxenite. Peridotite is partly serpentinized and is locally intruded and replaced by anorthosite. Pyroxenite is locally sheared and slickensided. Characterized by yellow and orange soil. The ultramafic rocks occur as narrow rubble traces between zones of anorthosite rubble, and also in larger mappable areas near the edges of the leucogabbro body. These were originally mapped by Hawley and Garcia, (1976). The location of these ultramafic rocks on the flanks of the synform suggests that most of them lie beneath the leucocratic rocks on the synform axis

Soil in the western area of ultramafic rocks contains metallic platinum, and small nodules containing 4.5% chromium (Hawley and Garcia, 1976)

JMv **Mafic volcanic rocks (Jurassic through Mississippian)--**Basalt, diabase, gabbro and diorite, rare dacite, rhyolite, and tuff in a synformal klippe near the center of the quadrangle. Described and mapped mostly from the characteristic red-brown color of the soil. Basalt and diabase make up most of the unit. Gabbro and diorite occur at about 1/3 of the exposures visited, commonly as the only mafic rock, but locally with basalt or chert. Unit also includes some unmapped chert and oil shale.

Although gabbro and diorite occur throughout the mapped area, about half of the known exposures are along the north and northwest margins of the unit, and along part of the southeast margin near White Snow Mountain, suggesting that the gabbro and diorite are low in the volcanic pile. Individual bodies could not be outlined; most of them are probably sills or dikes tens or hundreds of feet thick, but bodies a few thousand feet thick are possible. The gabbro and diorite intrude most of the associated units of sedimentary rocks; locally, they cross-cut the shale of the MzPzs unit, show chill zones at the contacts with chert and tuff of unit TrMc, and at one locality with a quartzite (Dsq?) like that in the adjacent Venetie subterrane. They have thermally altered the chert and quartzite. Basalt-gabbro contacts are rare, but locally gabbro sills are above the basalt, so they must have intruded it.

Gabbro is dark colored, coarse to very coarse crystalline, unfoliated, and composed of partly kaolinized plagioclase, with 20% to 30% clinopyroxene; hornblende, chlorite and minor biotite. Some is quartz-gabbro with 10% quartz-myrmekite and quartz. Chemical analysis for major elements shows it to be tholeiitic. Some has a bulk composition suitable for diorite, but is assigned to gabbro, because of the calcic composition of the plagioclase (see Streckeisen, 1976).

Diorite is dark, rusty weathering, medium to coarse crystalline, and is composed of 35% to 50% sodic plagioclase that is locally kaolinized, 30% to 45% clinopyroxene, as much as 25% chlorite, and minor ilmenite. Chemical compositions are tholeiitic and are suitable to gabbro, but assigned to diorite because of the sodic plagioclase. Quartz-diorite, found at one locality, is light colored and is about 60% andesine overgrown by 5% K-spar with chlorite and biotite after pyrabole, and minor quartz and epidote.

A potassium-argon age of 155 +/- 6 Ma has been measured on plagioclase from diorite southwest of the Christian River (Reiser and others, 1965). This age is here revised to 159+/-6 Ma (Late Jurassic) using new K^{40} decay constants (Lanphere, M.A., written commun., 3/5/97). The other indications of the age of the gabbro and diorite are: intrusive contacts with gray chert of probable Carboniferous age (TrMc) at three localities, and with shale of Mesozoic or late Paleozoic age (MzPzs) at one locality. We found no exposure where the gabbro is definitely older than the adjacent rocks. A Late Jurassic age is compatible with all these intrusive relations, but is not required by them. The various bodies of gabbro and diorite may be of many different Late Paleozoic or Early Mesozoic ages, because the relations between the different bodies are not known. Their map distribution suggests that many of them are in the lower layers of the synformal volcanic pile, but does not suggest when they were intruded.

Basalt and diabase occur throughout the area, usually together with bedded chert. The basalt is dark brown to green, weathers rusty orange to brick red, and is mostly preserved as rubble. It consists of plagioclase, clinopyroxene, chlorite and magnetite and is tholeiitic in major element composition. Except for one locality, no pillows were recognized, possibly because of the small size of the rubble. Layers with amygdules up to one half inch in diameter filled by chlorite and calcite or calcite and celadonite are present locally along the north margin of the mafic rocks in the area labeled Jmva.

The basalt is exposed in units 300 to 1,000 feet (100 to 300 m) thick that are interbedded with radiolarian chert in beds 2 to 3 feet (1 m) thick to 3 or 4 hundred feet thick. At one locality where curved weathering shells suggest pillows, the basalt contains small green chert inclusions that may be interpillow chert. Beds of mafic volcanic breccia and tuff up to 200 feet thick occur at two localities. Where the breccia rests on chert it contains rounded clasts of chert in addition to clasts of mafic rocks and crystals of euhedral plagioclase and clinopyroxene.

Diabase is gray-green to dark green, weathers reddish-brown with some manganese stain, and makes blocky rubble. It consists of labradorite, clinopyroxene and chlorite, with some magnetite, and is tholeiitic in major element composition. Quartz diabase at one locality contains about 5% quartz and minor biotite. The diabase is in sills from 25 feet (8 m) to about 500 feet

(150 m) thick most of which are in contact with bedded chert and argillite that commonly is red and green. The sills are above, below, and between the chert beds. At one locality dikes with chilled margins cut across the chert beds. At a few places, gabbro has intruded the diabase. At fossil locality 12 quartz diabase underlies (and probably has intruded) brown slate and chert that contains Mississippian radiolaria (see table I).

Oil Shale--Chips and slabs of very rich oil shale occur in residual soil in the area of volcanic rocks (JMv), and used to be common as surface float (Tailleur, 1967). Mertie (1930) described a sample of this shale that yielded 122 gallons of green, low-density oil per ton. The shale ignites easily and the Native Indians used the shale float as casual fuel. Apparently, most of the float has now been consumed. The two known occurrences are shown by symbol on the geologic map. In 1943, the Bureau of Mines investigated the site near the north edge of the volcanic rocks where float had been abundant 30 years before, but was then rare. Six trenches and three pits found bedrock of sandstone, greenstone, diorite and gray-green slate at depths of two to four feet, with abundant chips of oil shale in the overlying soil and in a thin layer of chips frozen to the bedrock in one trench (Ebbley, 1944; Hawley and Garcia, 1976). The shale yielded 60 to 123 gallons per ton of oil with API Gravity 29.3 degrees to 33.4.degrees. Surface samples taken from the same site in 1976 yielded 88 to 136 gallons per ton (Hawley and Garcia, 1976)

Most of the formerly productive sites to which we were guided during geologic mapping were barren, but at one site near the head of Kocacho Creek oil shale was found in ground squirrel diggings (Tailleur, 1967). The oil shale is gray to black, light in weight, soft, tough and leathery, burns readily and resembles slabs of wood. It probably occurs as small lenses. It seems identical to the more abundant high-yield oil shale called tasmanite that is found on the North Slope (Tailleur, 1964) where it is composed of the marine algae *Tasmanites* (Tourtelot and others, 1968). Tasmanite is deposited in quiet shallow marine waters (Hutton, 1986), and the North Slope tasmanite is closely associated with bedded chert. In the Christian area both oil shale and many small beds of chert lie within the mafic volcanic rocks. Although no chert occurs directly with the oil shale both kinds of sediment were probably deposited on the basalt during times of quiet water.

The Christian oil shale is probably Triassic or Permian in age. Clasts of the oil shale occur in a carbonaceous graywacke (Trgw) on Otter Creek that contains Triassic pollen (Scott, R.A., *in* Reiser and others, 1965). According to Scott, samples of the North Slope oil shale itself also contain Permian or Triassic pollen, although for stratigraphic reasons that oil shale is considered to be Jurassic(?) (Boneham and Tailleur, 1972)

JMvr **Rhyolite and dacite (Jurassic through Mississippian)--**Two isolated exposures of rhyolite have been mapped at the south edge of the outcrop area. Both are flows, one with quartz amygdules, and the other with layered nodules of orthoclase over plagioclase. Nearby exposures are basalt and diorite. On the Christian River between Otter and Timber Creeks an unmapped dacite dike cuts basalt. Because they are closely associated, these acidic rocks are correlated with the mafic rocks of unit JMv

JMg **Greenstone (Jurassic through Mississippian)--**Altered basalt and diabase composed of chlorite, clinopyroxene, and plagioclase with abundant kaolin and secondary quartz. Dense, fine crystalline, not foliated; weathers blocky. Contacts are indefinite

Trgw **Graywacke (Middle or Lower Triassic)--**Gray green medium-grained carbonaceous quartz wacke; overlies 30 feet (10 m) of gritty wacke with interbedded shale, coaly partings, and oil shale clasts. One small outcrop on a hilltop near upper Otter Creek. A 200 foot covered interval separates it from a small outcrop of underlying unit MzPzs. Contains Middle or Early Triassic pollen and spores (locality 13, table 1), and was probably deposited in brackish or marine water

TrMc **Chert and argillite (Triassic(?) through Mississippian)--**Black, white, gray and brown radiolarian chert with some beds of black siltstone; red and green chert interbedded with red and green partly silicified argillite. Forms conspicuous ridges and ledges because of its light weathering color and resistance to weathering. Chert is thick-bedded to laminated, is usually in beds 10 to 25 feet (3 to 8 m) thick, and, together with the argillite and siltstone, forms units from 100 to about 500 feet (30 to 150 m) thick. Some chert is silty; some is glassy with conchoidal fracture, and has been worked for tools. Chert commonly is in contact with gabbro or diabase intrusives, but it also lies on, below, and between layers of basalt; and, at one place, it is in thin beds within a basalt layer. At one locality, green chert and argillite grade upward within 100 feet (30 m) to interbedded chert, argillite, and crystal tuff overlain by green volcanic breccia.

Brown chert contains Mississippian radiolarians at one locality (locality 12, Table 1). An unusual layer of fine-grained limestone in black shale at locality 14 contains Early Mississippian conodonts. In the Venetie terrane, Permian and Mesozoic(?) microfossils also occur in similar rocks (TrMcs)

MzPzs **Shale (Mesozoic or Paleozoic)--**Black and gray shale and slate; black, gray and green-brown weathering partly silicified siltstone; minor maroon slate; and thin beds of black, gray and green chert grading into silicified slate. Shale commonly contains calcareous concretions or small lenses and nodules of gray-brown fine-grained limestone. Siltstone locally is pyritic or copper-stained. Unit is about 300 to 500 feet (100 to 150 m) thick. Age is uncertain., but is probably Triassic or Permian. Unit underlies the mapped outcrop of Triassic graywacke Trgw, and at one locality is overlain by andesitic flow breccia and intruded by a thin gabbro sill. Distribution of mapped outcrops along the axis of the synclinorium suggests that the shale is above most of the rocks of unit JMv

Dsl **Sandy limestone (Upper Devonian)--**Yellow-weathering, gray green fine-grained, thin-bedded sandy limestone; yellow-weathering fine-grained, massive to thin-bedded calcareous sandstone, and interbedded brown silty shale that grades into black chert, about 200 feet (60 m) thick. Intruded by diabase, overlain by basalt. Contains Late Devonian conodonts at Localities 15 and 16

VENETIE TERRANE

TrMcs **Chert and slate (Triassic(?) through Mississippian)--**Radiolarian and spiculitic chert interbedded with shale, siltstone and argillite in units 25 to hundreds of feet thick. Most chert is black, white or gray to brown, weathers white to rusty, is massive to laminated, and is interbedded with black, partly silicified, siltstone and shale. Red and green chert is also abundant, and is interbedded with red, gray-green and green argillite and slate that is hematitic, manganiferous and possibly tuffaceous. The chert forms conspicuous small ridges. Some have been worked for tools. Tan and gray chert contains Mississippian(?) radiolarians at localities 8 and 10 (table 1); green chert in red and green argillite contains Permian conodonts at locality 1, and olive chert in green argillite contains Mesozoic(?) radiolarians at locality 2

MzPzg **Greenstone (Triassic or Upper Paleozoic)--**Sills of slightly metamorphosed felsic rock interlayered in phyllite and quartzite. Sills are 15 feet to 150 feet (5 to 45 m) thick and occur through a zone more than 500 feet (150 m) thick. Most sills are diorite or monzonite. Some thin sills are of amygdaloidal andesite and quartz trachyte. Country rock at the contacts is thermally altered, and at the northwesternmost locality, the greenstone contains a xenolith of schist. The greenstone everywhere contains chlorite, and locally contains epidote, biotite after hornblende, or abundant tremolite. The southeasternmost exposure is schist. The greenstone intrudes phyllite and sandstone (Dpm) of probable Devonian age, and has been metamorphosed, probably during the Jurassic or Early Cretaceous, and so its age is probably Late Paleozoic or Triassic

Dsq **Quartzite and slate (Devonian)--**Interbedded quartzite, quartz wacke, lithic wacke and shale. Quartz wacke is common to all exposures; it is mostly gray to brown, fine- to medium-grained, thin- to medium-bedded, weathers yellow, brown and gray; it is composed of quartz, chert and mica clasts in a cherty to micaceous matrix. Thicker-bedded to blocky quartzite is fine- to medium-grained, locally ripple-marked, and at a few places, is gritty and contains chips of quartz, chert and slate. At one place, it contains rip-up clasts of shale and red argillite. Lithic wacke interbedded in most exposures is dark gray-green, weathers orange or brown, is fine-to medium-grained and locally contains slate pebbles. Black shale and gray-green to brown micaceous siltstone occur as thin partings or interbeds, and locally make up as much as half the thickness of the unit. At a few places, quartzite and wacke rest directly on the thick shale of unit Dhf. At most places, the quartzite and slate unit rests on, and probably grades into the fossiliferous Devonian lithic wacke Dw. Thickness is probably about 500 feet (150 m). Age is not known, but is probably Devonian, and equivalent to that of the quartzite member of the Kanayut Conglomerate of the adjacent Arctic quadrangle (Brosgé and others, in press)

Dhf **Hunt Fork Shale, shale member (Devonian)--**Mostly black shale, slate and siltstone with lesser amounts of sandstone; rare conglomerate in northernmost exposures. Slate weathers yellow to greenish gray; locally contains clay pebbles. Siltstone weathers greenish-gray, is thin-bedded, micaceous and partly manganese stained. Sandstone is gray, brown-weathering, fine-to very fine-grained, thin- to medium-bedded, contains slate chips, and is partly micaceous. Rare limonitic conglomerate of quartz and chert pebbles. Probably 500 to 1,000 feet (150 to 300 m) thick. No fossils found. Age inferred from position beneath Devonian quartzite and slate (Dsq), and by correlation with Hunt Fork Shale in adjacent Arctic quadrangle

Dw **Wacke (Devonian)--**Gray-green lithic wacke interbedded with lesser amounts of gray and brown quartz wacke and with black micaceous shale and silt shale. Faintly schistose in many exposures, particularly those south of Bob Lake. Lithic wacke is fine-to medium-grained, thin- to medium-bedded, weathers brown to rusty. It consists of quartz, chert, and some labile rock grains in a sericitic and chloritic matrix. Rare gritty beds contain chips of shale. The quartz wacke is also fine- to medium-grained and thin- to medium-bedded. Black shale occurs in thin partings and in beds as much as 25 to 50 feet thick (8 to 15 m) that may form 30 to 50% of the unit. The total thickness of the unit is uncertain, but is probably about 4,000 feet (1200m). The age is Devonian. Graywacke and shale on the upper Christian River contain Devonian plants and spores. Plants from locality 6 (table 1) are probably Late Devonian; spores from that locality are Middle or Late Devonian. Spores from nearby localities 3 and 7 are probably Early Devonian

Dmw **Metamorphosed wacke (Devonian)--**
WEST OF EAST FORK OF CHANDALAR RIVER: Mostly schistose lithic wacke; minor schistose quartz wacke and black phyllite. Lithic wacke is gray and brown, brown weathering, fine-to medium-grained and thin- to medium-bedded, with a few gritty beds that contain chips of quartz, mica and slate. Bedding is well preserved, but most beds are foliated, secondary mica is common, and some plagioclase has been altered to sericite. Quartz wacke is also gray and brown, fine- to medium-grained, and locally gritty. Thin beds of black phyllite occur at a few places, and locally make up as much as one half of the exposed rock in the lower part of the unit. Wacke contains quartz veins, is resistant, and forms rocky ledges rather than rubble. Probably is a slightly more metamorphosed facies of Devonian wacke Dw and quartzite and slate Dsq. About 1,000 to 2,000 feet (300 to 600 m) thick. Rests on, and probably grades into, phyllite and metamorphosed sandstone unit Dpm

EAST OF EAST FORK OF CHANDALAR RIVER: Schistose lithic wacke and minor quartzitic sandstone, black phyllite and siltstone. Lithic wacke is gray-green, partly limonitic, very fine- to fine-grained, rarely coarse-grained, and is strongly foliated, with secondary mica and partly recrystallized matrix. Quartzitic sandstone is gray to gray-green, very fine- to medium-grained, thin-bedded and slightly foliated. Southern part is very poorly exposed, and is mapped from rubble found in frost boils in the tundra

Dpm **Phyllite and metamorphosed sandstone (Devonian)--**
WEST OF EAST FORK OF CHANDALAR RIVER: Black phyllite interbedded with schistose sandstone. Phyllite, in zones up to 200 feet (60 m) thick, comprises about half the unit. Schistose sandstone is gray, limonitic, and weathers yellow and brown; most is fine- to medium-grained and thin-bedded

EAST OF EAST FORK CHANDALAR RIVER: Black phyllite and siltstone interbedded with schistose sandstone. Minor quartzite. Schistose sandstone is dark gray, very fine- to medium-grained, thin-bedded, foliated, and locally recrystallized to quartz and muscovite

Ds **Phyllite (Devonian)--**Mostly black phyllite with interbedded schistose gray-brown siltstone and very fine-grained schistose quartz wacke. Minor white to tan quartzite. Thickness not known. Age uncertain, but unit is probably lowest part of a shale and sandstone sequence (Dmw, Dpm, Ds) equivalent to the Devonian wacke Dw

ARCTIC ALASKA TERRANE

ENDICOTT MOUNTAINS SUBTERRANE

Dk **Kanayut Conglomerate (Upper Devonian)--**Siliceous conglomerate of chert and quartz pebbles, and gray, partly ferruginous fine- to medium-grained, thin- to medium-bedded quartzite. Present in northeast corner of Christian quadrangle.

Contains Devonian plants to the north in Arctic quadrangle (Brosgé and others, in press)

HAMMOND SUBTERRANE

Dkq **Kanayut Conglomerate, quartzite member (Upper Devonian)**—Massive, gray, fine- to medium-grained quartzite, laminated quartzite, and shale and ironstone in thinning and fining-upward cycles about 25 feet thick. Present in northeast corner of Christian quadrangle. Contains Late Devonian (Famennian) brachiopods to north in Arctic quadrangle (Brosgé and others, in press)

Dn **Noatak Sandstone (Upper Devonian)--**Sandstone and shale interbedded in units hundreds of feet thick. Sandstone is partly calcareous, medium-to dark-gray, ferruginous, medium-grained, thin-bedded; some is light gray and fine-grained. About 500 to 1,000 feet (150 to 300 m) thick. Tentatively recognized in northeast corner of Christian quadrangle. Contains Late Devonian (Famennian) brachiopods to north in Arctic quadrangle (Brosgé and others, in press)

Dg **Greenstone (Devonian and younger?)--**Sills of slaty to massive schistose, pyritic greenstone interlayered in Hunt Fork Shale and Beaucoup Formation. Sills, flows and volcanic conglomerate altered to greenstone occur in and on the Skajit Limestone. Locally the Skajit Limestone and the slates of the Beaucoup Formation are altered at the contacts. Weathers to green, gray and rusty slabs and blocks. In part of Devonian age, equivalent to greenstone Dv of the adjacent Arctic quadrangle (Brosgé and others, in press)

Dhf **Hunt Fork Shale, shale member (Upper Devonian)--**Black slate, phyllite, siltstone, and fine-grained partly schistose sandstone; with a basal sheared conglomerate. The slate and phyllite are commonly micaceous, and weather brown and yellow. Gray, fine-grained, thin-bedded sandstone is interbedded with the slate and phyllite, and, near Buffalo Mountain, sandstone forms most of the unit. Gray and white sheared conglomerate of quartz, chert and slate pebbles that are flattened parallel to the foliation occurs as lenses in some of the sandstone, and in many places, in beds as much as 200 feet (60 m) thick at the base of the formation. These beds are shown by pebble symbol on the geologic map. Little Rock Mountain seems to be entirely conglomerate. The Hunt Fork Shale rests unconformably on each member of the Beaucoup Formation and also on the Skajit Limestone, and at a few places the basal conglomerate contains some carbonate pebbles. The limestone and siltstone member of the Beaucoup (Dbls) contains Middle(?) and Late Devonian fossils (table 1), so the Hunt Fork is probably Late Devonian in age. The thickness is unknown, but is probably between 1,000 and 2,000 feet (300 m to 600 m)

Dvt **Volcanic rocks and tuff (Upper Devonian)--**Basaltic and andesitic flows, tuff, breccia, and volcanic conglomerate altered to greenstone, interbedded in the Hunt Fork Shale in the northeast corner of the Christian quadrangle. Conglomerate contains limestone clasts with Late Devonian (Frasnian) brachiopods and conodonts 7 miles north of the Christian quadrangle (Brosgé and others, in press)

Dbsg **Beaucoup Formation, siltstone, greenstone and wacke member (Upper and Middle(?) Devonian)--**Purple, green and black-banded siltstone. Calcareous brown, green, and orange siltstone interbedded with partly schistose brown, fine-grained to gritty quartz wacke and green fine-grained lithic wacke. Interlayers of greenstone, partly metamorphosed diorite and rare fresh andesite. Unit resembles the wackes and purple and green siltstones of the conglomerate and shale member in the adjacent Arctic quadrangle (Brosgé and others, in press), but lacks the characteristic chert-pebble conglomerate. Overlies the limestone and siltstone member (Dbls) which contains Late Devonian (Frasnian) fossils nearby in the Arctic quadrangle, and Middle(?) and Late Devonian fossils in the Christian quadrangle. Probably about 1,000 feet (300 m) thick

Dbls **Beaucoup Formation, limestone and siltstone member (Upper Devonian)--** Brown-weathering limestone and marble, brown-weathering calcareous slate and siltstone, and partly calcareous sandstone and grit. The limestone occurs in zones as much as 300 feet (100 m) thick, and most is shaley, and fine-grained to silty. The marble is micaceous, grading to calcareous schist. Locally, the basal part of the member is red and black, hematitic, fine-grained limestone. The calcareous siltstone, slate and sandstone are interbedded with the limestone and, locally, lie at the base of the unit. At a few places carbonate-pebble conglomerate also occurs near the base. The member rests on the Skajit Limestone, possibly unconformably. It is absent in the south where the Hunt Fork Shale rests unconformably on the Skajit. Where present in the north the member is probably more than 500 feet (150 m) thick

Dbl **Beaucoup Formation cherty limestone (Upper and Middle(?) Devonian)--** Fossiliferous cherty limestone present in a few places just above the base of the Beaucoup Formation. Middle(?) and Late Devonian fossils at locality 5, table 1

DOs **Skajit Limestone (Devonian through Ordovician)--**Gray weathering marble, dolomite and recrystallized limestone. Marble, common south of Wind River, is gray, fine-grained, slaty to massive. Dolomite is white to gray, medium- to coarse-crystalline, medium- to thick-bedded. Limestone is light to medium gray, very fine-grained, massive to slaty, and locally overlain by a few feet of orange weathering dolomite. Unit is commonly capped by bed of carbonate-pebble conglomerate that usually contains dolomite pebbles above dolomite and lime pebbles above marble. Capped by a bed of black chert at one locality. Thickness at least 500 feet (1500 m), probably about 2,000 feet (6000 m). Base not exposed. Contains corals of indeterminate age in the Christian quadrangle (table 1), but in the adjacent Arctic quadrangle contains Ordovician to Devonian corals, and Ordovician, Silurian(?) and Devonian(?) conodonts (Brosgé and others, in press). Contains Silurian brachiopods just to the northwest in Philip Smith Mountains Quadrangle (Brosgé and others, 1979). May include a few unrecognized Upper Devonian limestone beds of the Beaucoup Formation

RUBY TERRANE

Pzs **Quartz-muscovite schist (Lower Paleozoic)--**Gray quartz-muscovite schist with minor black phyllitic layers. Locally calcareous; locally pyritic

Pzbs **Biotite schist (Lower Paleozoic)--**Quartz-biotite schist with abundant andalusite; partly carbonaceous. Intruded by aplite near contact with granite Kgr. Ten miles to west in adjacent Chandalar quadrangle (Brosgé and Reiser, l964) this unit grades northward into quartz-mica schist (Pzs) through a 2-mile wide transition zone that has only minor biotite and no andalusite. In the Christian quadrangle, the contact of biotite-andalusite schist with the phyllite and metasandstone unit (Dpm) of the Venetie terrane is abrupt

Rocks that intrude Ruby terrane

Kgr **Granite (Cretaceous)--**Deeply weathered, medium crystalline, non-porphyritic granite exposed in this quadrangle as light tan gruss and boulders. Aplite dikes at contact with schist. In better exposures of the same pluton, just to the west in the Chandalar quadrangle, the granite contains biotite and is partly porphyritic, and it produces a small positive magnetic anomaly, unlike the non-magnetic Devonian plutons of the Brooks Range (Cady, 1978). Probably the same middle Cretaceous age as a similar pluton in the southern part of the Chandalar quadrangle dated as 101 Ma (K/Ar) or 140 +/- 20 Ma (Pb/alpha) (Brosgé and Reiser, 1964)

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