GENERALIZED GEOLOGIC MAP OF THE CHANDLER LAKE QUADRANGLE, NORTH CENTRAL ALASKA

By

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INTRODUCTION

This map is the areal geologic base for the resource assessment of the Chandler Lake quadrangle under the Alaskan Mineral Resource Assessment Program (AMRAP). Emphasis is on structural patterns and depositional continuity at a scale and simplicity compatible with the areal density of geochemical and geophysical sampling for AMRAP assessment. The map is reduced, simplified, and interpreted from previous maps, principally Kelley (1988).

The map attempts to emphasize aspects of the areal geology relevant to the structural framework of the Chandler Lake quadrangle. Thin and contiguous stratigraphic units are combined. Where combination of map units does not obfuscate structural and stratigraphic relations, contiguous map units with similar geochemical signatures are combined to enhance the usefulness of the map in interpreting geochemical data. Assemblages of lithologically diverse but spatially associated rocks, of which the limited and scattered exposures were mapped at a scale of 1:125,000 (Kelley, 1988), are also combined to emphasize the distribution of assemblages; depiction of the inferred distribution of assemblages rather than isolated elements of assemblages better shows the association of geochemical and geophysical signatures with particular rock assemblages. Structural geologic information from Kelley (1988) was selected to emphasize continuity and major structural features.

Differing degrees of interpretation are involved in compiling different parts of the map. The northern and southern parts of the geologic map are compiled from mapping of areas in which structural and stratigraphic continuity were mapped at a scale of 1:125,000 (Kelley, 1988). The intervening central part of the map is greatly generalized from isolated outcrops of the same assemblage of rocks also mapped at a scale of 1:125,000 (Kelley, 1988).

Near-continuous outcrop from the range front, which is part of the Arctic Mountains province of Wahrhaftig (1965) south to the quadrangle boundary, affords interpretation of structures and map units with considerable objectivity. Generally thin Quaternary colluvium consisting of locally derived rock debris and tundra-covered solifluction deposits are not shown on lower slopes and in larger valleys. Small faults are selectively omitted, whereas larger through-going structures are emphasized.

There is limited outcrop in the northern Arctic Foothills of Wahrhaftig (1965) north of Hatbox Mesa, Tuktu Bluff, Gunsight Mountain, Banded Mountain, and Table Top mountain (Tuktu escarpment). Structural patterns are clear, however, from exposures of resistant-weathering sandstone and topography controlled by resistant-weathering sandstone.

North of the Tuktu escarpment, the present map attempts to emphasize stratigraphic continuity. Age-equivalent and age-transgressive formations, members, and tongues are combined to form map units on the basis of overall lithology, mainly units of principally sandstone and units of principally shale. Strata north of the Tuktu escarpment are complexly intertonguing nonmarine and marine strata, mostly shallow marine strata. Detterman and others (1963) used a complex stratigraphic-nomenclature based on rock type, depositional environment, and age ranges of transgressive and regressive depositional units; additionally Detterman and others (1963) dealt with stratigraphy in detail whereas, Molenaar (1985) dealt with the stratigraphy in a regional stratigraphic context.

Because of limited outcrop and structural complexity, considerable subjective interpretation is needed to generalize the geology within the southern Arctic Foothills of Wahrhaftig (1965). The area between the Tuktu escarpment and the range front encompasses isolated and commonly poor outcrops. This involved extrapolation from individual outcrops mapped at a scale of 1:125,000 (Kelley, 1988).

Two systems of thrust sheets are found in the southern Arctic Foothills. The lower system is inferable from recognition of a poorly exposed but widely distributed, areally persistent, and thin stratigraphic sequence consisting of chert, basalt, and clastic strata repeated by imbricate faults. The upper system is found as erosional remnants of sandstone and conglomerate overlying the lower system. The upper system is better exposed and structurally more simple than the underlying system. West of the Anaktuvuk River, the upper system comprises structurally simple sheets overlying complexly imbricated blocks of the lower system. East of the Anaktuvuk River, the upper system comprises imbricate blocks above the lower system of thrust sheets.

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The writer wishes to acknowledge the contribution of previous mappers. Although the present map is a distillation of concepts and syntheses generated from Kelley (1988), compilation of Kelley (1988) relied heavily on previously published maps. Detterman and others (1963), Brosgé and others (1960; 1979) were especially important map contributions. Patton and Tailleur (1964), Bowsher and Dutro (1957), and Porter (1966) also made important map contributions to Kelley (1988).

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DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unit comprises various unconsolidated debris including boulders, gravel, sand, silt, clay, and humic material. Unit includes sediments in river channels, active flood plains, bogs, and swamps. See Hamilton (1979) for detailed map and descriptions of Quaternary deposits

Qs **Surficial deposits (Quaternary)**—Widely inclusive unit that comprises undivided unconsolidated deposits, including glacial drift, outwash, and high-level terraces, mostly boulders, gravel, sand, silt, and clay. See Hamilton (1979) for detailed map and descriptions of Quaternary deposits

Ksb **Schrader Bluff Formation (Upper Cretaceous)**—Three members make up the Schrader Bluff Formation; they are, in ascending order, the Rogers Creek, Barrow Trail, and Sentinel Hill Members. All three members are found in Chandler Lake quadrangle but are not discriminated herein. Detterman and others (1963) reported about 550 m of the Schrader Bluff Formation at Race Track Basin syncline.

The Schrader Bluff Formation consists of shale, claystone, sandstone, and bentonite. Shale is medium to light gray, bentonitic, clayey, fissile, and includes tuff beds. Claystone is medium gray, commonly well indurated, and probably at least in part tuffaceous. Sandstone is light gray to light brown, fine grained, laminated, and micaceous. Bentonite beds consist of medium- to light-grayish-green bentonite that are locally silty and grade to gray tuffaceous siltstone. Formation includes shell fragments, identifiable megafossils, and coalified wood debris

Kp Prince Creek Formation (Upper Cretaceous)—Only the Tuluvak Tongue of the Prince Creek Formation is recognized in the Chandler Lake quadrangle. Detterman and others (1963) reported 175 m of the Tuluvak Tongue at type locality at Schrader Bluff about 24 km north of Race Track Basin. The Tuluvak Tongue appears to thicken radically in northeastern part of the Chandler Lake quadrangle where outcrop widths and dips infer thicknesses approaching 610 m (Kelley, 1988)

Character of the Prince Creek Formation changes from southwest to northeast. In northeastern part of quadrangle, it is principally sandstone, siltstone, mudstone, coal, and tuff. Sandstone is medium to light medium gray, yellowish gray, brownish gray, thin to medium bedded, fine to coarse grained, locally conglomeratic, and tuffaceous in part. Sandstone is locally conglomeratic and includes conglomerate beds composed mostly of small pebbles of black chert and white quartz and quartzite. Mudstone, siltstone, and shale are end members of a continuum of lithologies that are typically medium gray to dark gray, fissile in part, and bentonitic in part. Formation includes plant fragments, identified leaf fossils, tuff beds, coal, and ironstone nodules.

In northwestern part of quadrangle, formation comprises conglomerate, sandstone, siltstone, and shale. Conglomerate is basal in formation. Conglomerate is as much as 12 m thick and composed of well-rounded pebbles of white to light-gray quartz, orthoquartzite, and medium- to dark-gray chert. Conglomerate has sandstone matrix and prominent quartz cement that shines in direct sunlight. Conglomerate produces prominent positive-weathering topographic features such as cuestas and rimrock. Sandstone, siltstone, and shale in upper part of unit are very poorly exposed. Sandstone is gray, probably mostly quartz and chert, and prominently cross bedded. Siltstone and shale are gray, brownish gray, and poorly indurated

Ks Seabee Formation (Upper Cretaceous)—Formation consists of the Shale Wall Member and overlying Ayiyak Member in Chandler Lake quadrangle. Detterman and others (1963) reported about 550 m of the Shale Wall Member along Nanushuk River at Rooftop Ridge. Detterman and others (1963) also reported 110 m of the Ayiyak Member at type locality along Ayiyak River and generally uniform thickness in map area. Outcrop widths and dips suggest that the Seabee Formation is about 425 m thick and probably thins to south, probably at expense of the Shale Wall Member (Kelley, 1988). Differences in reported thicknesses probably are caused by structural complications in tuffaceous and shaly Shale Wall Member. Members of the Seabee Formation are not discriminated in mapping.

Shale Wall Member consists mostly of medium-gray shale. Shale is typically bentonitic, clayey, and includes bentonite beds, laminated siltstone interbeds, and limestone concretions. Member includes dark-gray to black organic shale locally, clayey limestone concretions as thick as 2.4 m, and marine fossils. Medium- to medium-light-gray, fine-grained to very fine grained sandstone and siltstone locally are present in member. Calcite cement is common.

Ayiyak Member is mostly greenish-gray and olive-gray siltstone. Siltstone is typically shaly and grades to mudstone. Brownish- and greenish-gray mostly fine-grained thin- to medium-bedded sandstone is also present in member. Locally, sandstone is coarse grained, conglomeratic, and includes thin lenticular beds of conglomerate composed mostly of black chert and white quartz pebbles. Member also includes impure limestone, shale, and both ironstone and calcareous concretions

Knc Ninuluk and Chandler (part) Formations, undivided (Upper Cretaceous)—Unit includes the Niakogan Tongue of the Chandler Formation, which is principally nonmarine sandstone that interfingers with the laterally equivalent and principally marine sandstone of the Ninuluk Formation. The Ninuluk Formation crops out northeast of the Niakogon Tongue and comprises strata deposited in progressively deeper water to northeast. Detterman and others (1963) reported 355 m of the Ninuluk Formation on east fork of upper Tuluga River. Outcrop widths and dips suggest that 355 m is maximum thickness for the undivided Niakogon Tongue and Ninuluk Formation (Kelley, 1988); both units are locally absent either because of erosion along unconformity at base of the Seabee Formation or abrupt depositional wedge out.

The Niakogon Tongue comprises sandstone, siltstone, and mudstone.

Sandstone is light olive gray, greenish gray, medium gray, fine to coarse grained, thin bedded to massive, well indurated, and locally limonite cemented. Sandstone typically weathers light gray with a "salt-and-pepper" appearance or buff and yellowish red where exposures are iron oxide stained. Ironstone concretions and beds of granule conglomerate and conglomeratic sandstone are present locally. Granules in conglomerate and conglomeratic sandstone are mostly dark-gray chert and quartz. Siltstone and mudstone may form as much as half of tongue. Plastic grayish-green bentonite beds are present in upper part of tongue.

The Ninuluk Formation is mostly sandstone, siltstone, and shale. Sandstone is greenish gray to brownish gray, thin bedded to massive, laminated in part, cross bedded, friable to moderately indurated, and fine to very fine grained. Sandstone grades to siltstone. Conglomeratic sandstone in part includes beds and lenses of granule conglomerate comprising framework clasts of varicolored chert and white quartz. Ripple marks, carbonaceous debris, marine fossils, and thoroughly carbonate-cemented lenses grading to sandy and silty limestone are found locally in sandstone. Across map area, sandstone beds become progressively finer grained, thinner bedded, more clayey, and more commonly carbonate cemented in northeasterly direction. Greenish-gray hard and hackly weathering shaly siltstone and dark-bluish-gray clay shale are present. Both siltstone and shale are laminated. Formation also includes soft shale exposing weathered surfaces that commonly have a yellowish-gray or light-gray bloom. Siltstone and shale contain ironstone concretions. Beds and partings of grayish-green plastic claystone, probably bentonite, are present in shale

Kc **Chandler Formation (part) (Upper and Lower Cretaceous)**—Consists of the Killik Tongue of the Chandler Formation. Detterman and others (1963) reported thicknesses of 785 and 865 m from measured sections in Chandler Lake quadrangle where the Killik Tongue is not interfingered with other map units. Mapped outcrop widths and dips suggest that the Killik Tongue is about 790 m thick, but thins dramatically to the northeast (Kelley, 1988)—possibly because of truncation under unconformity at base of the Seabee Formation or possibly facies transition into marine map units.

The Killik Tongue comprises sandstone, conglomerate, siltstone, shale, and coal. Sandstone and conglomerate are light olive gray, greenish gray, and medium gray but typically weathers light gray with "salt-and-pepper" color patterns caused by dark-gray chert and aphanitic rock fragments in contrast to very light gray weathering quartz and light-gray chert grains. Sandstone is medium grained to fine grained and characteristically cross bedded. Conglomeratic sandstone and conglomerate beds include clasts of mostly chert and quartz. Conglomerate is frame-work supported. Coal beds as much as 3 m thick are present in upper part of tongue and together with siltstone and shale are not resistant to weathering and generally poorly exposed. Ironstone concretions are common in coal-bearing part of tongue. Sandstone and conglomerate are very prominent ledge-forming strata

Ktg **Tuktu and Grandstand Formations, undivided (Lower Cretaceous)**—The Tuktu and Grandstand Formations constitute the basal (sandstone) part of the Nanushuk Group. Basal sandstone is time transgressive to north; age of the Grandstand Formation is equivalent to that part of the Killik Tongue of the Chandler Formation that overlies the Tuktu Formation along Tuktu escarpment. Both formations are mapped as undivided unit here, although the Grandstand Formation is younger than the Tuktu Formation, because (1) both formations occupy same stratigraphic position at base of the Nanushuk Group, (2) units are chronologic end members of time-transgressive depositional unit, and (3) a widespread structural detachment is present below the undivided Tuktu and Grandstand Formations. Combination of map units helps demonstrate fundamental transition from sandstone to shale, which is coincident with a regional structural discontinuity.

Detterman and others (1963) reported thickness of the Tuktu Formation from measured sections to range from 285 to 315 m and 435 m of the Grandstand Formation at type section on Anaktuvuk River. Outcrop widths and dips suggest that undivided Tuktu and Grandstand Formations attain thicknesses as much as 455 m (Kelley, 1988).

The Tuktu Formation and Grandstand Formation are principally grayish-green to greenish-gray sandstone. Sandstone is typically medium light gray to buff gray weathering, medium to very fine grained, shaly in part, and cross bedded in part. Ripple marks, wood debris, marine fossils, conglomerate beds comprising granules and small pebbles of mostly chert and quartz, and bioturbations are present locally. Greenish-gray siltstone and mudstone make up small part of formations. Undivided Tuktu and Grandstand Formations are resistant to weathering and together with overlying nonmarine sandstone form prominent ridges

Fortress Mountain Formation (restricted) (Lower Cretaceous)—Unit consists of 2 lithofacies: (1) nonmarine conglomerate and associated marine sandstone (Kfc), which is found west of Anaktuvuk River, and (2) turbidite sandstone and conglomerate (Kft) east of Anaktuvuk River. Patton and Tailleur (1964) reported between 760 and 3050 m of the Fortress Mountain Formation at Fortress and Castle Mountains. Crowder (1987, p. 454–455) reported 3,660 m of the Fortress Mountain Formation at Castle Mountain. Outcrop widths and attitudes suggest that the Fortress Mountain Formation, shown west of Anaktuvuk River on this map, is probably between 215 and 610 m thick in Castle Mountain and Fortress Mountain area and thins to east (Kelley, 1988). Sandstone and conglomerate east of Anaktuvuk River is possibly about 305 m thick; structural complexity, however, limits confidence in this estimate (Kelley, 1988).

Previous workers (Patton and Tailleur, 1964, p. 458) consider stratigraphic relations between the Fortress Mountain and Torok Formations and Nanushuk Group uncertain, but state that the Fortress Mountain Formation is unlikely as young as middle Albian or age equivalent to the Nanushuk Group. Other workers (Gryc, 1956; Patton, 1956; Jones and Gryc, 1960, p. 151; Detterman and others, 1963, p. 230; Chapman and others, 1964; Molenaar, 1981, p. 26; Molenaar and others, 1981, p. 3; Mull, 1979, p. 5; Ahlbrandt and others, 1979, p. 14; and Crowder, 1987, p. 451) describe the Fortress Mountain Formation as laterally equivalent to or lying stratigraphically below the Torok Formation, which underlies the Nanushuk Group. Fossils in marine sandstone interbeds, enclosed within predominantly nonmarine strata of the Fortress Mountain Formation in Chandler Lake quadrangle (Kelley, 1988), include middle to late Albian bivalves (J.W. Miller, written commun., 1983), which are same age as those within lower part of the Nanushuk Group.

Assignment of strata to the Fortress Mountain Formation in this report differs from previous reconnaissance mapping (Patton and Tailleur, 1964) in Chandler Lake quadrangle. Patton and Tailleur (1964) included 2 sets of outcrops within the Fortress Mountain Formation. First set includes prominent erosional remnants of conglomerate and sandstone lying on complexly deformed rocks and melange and includes type section of the Fortress Mountain Formation. The other set of outcrops consists of sandstone and minor conglomerate that are resistant lenses within strata largely indistinguishable from the Torok Formation. In this report, term "Fortress Mountain Formation" is restricted so as to apply to only to first set of exposures, which consists of Lower Cretaceous sandstone and conglomerate that lie on structurally complex Upper Jurassic and Lower Cretaceous clastic rocks, radiolarian ribbon chert, and mafic igneous rocks.

West of Anaktuvuk River, the Fortress Mountain Formation (as used in this report) comprises chiefly nonmarine strata that are found in unimbricate shallow-dipping slablike structural blocks that lie on complexly imbricated blocks of Mississippian to Lower Cretaceous strata, melange, and, locally, the Torok Formation. Outcrops are mostly massive-weathering nonmarine conglomerate and sandstone but locally include marine sandstone, especially in lower part of section. Most outcrops are erosional remnants of broad basin-shaped synclines comprising ridges underlain by beds of erosion-resistant conglomerate and sandstone arranged in circular or ellipsoidal pattern and dipping toward central point. Outcrops are remnants of more extensive structural sheets in probable fault contact, probably fault superimposed along a preexisting unconformity, with underlying older rocks including graywacke, ribbon chert, mafic igneous rocks, and melange.

West of Anaktuvuk River, the Torok Formation is found below the Fortress Mountain Formation and crops out on north flank of Fortress Mountain and east of Fortress Mountain in T. 10 S., R. 2 W.

Isolated exposures of the Fortress Mountain Formation probably are present outside mapped areas of the Fortress Mountain Formation, especially west of Anaktuvuk River. Mudstone and sandstone that probably would be assigned to the Fortress Mountain Formation if relations with underlying rocks were exposed are mapped as Arctic Foothills assemblage. These strata are depositionally consanguineous with the Fortress Mountain Formation but where structurally detached and intermixed with older underlying graywacke and mudstone are very difficult to discriminate from older strata, Because of their similar lithology and paucity of fossils in both older strata and the Fortress Mountain Formation.

Strata mapped as the Fortress Mountain Formations west of Anaktuvuk River, especially in larger exposed areas, probably include some older rocks. There probably are unrecognized erosional breaches in the Fortress Mountain Formation, breaches that expose underlying older rocks. The Fortress Mountain Formation is locally very thin and infolded and possibly imbricated to undetermined degree with underlying rocks, which increases the difficulty in discriminating the Fortress Mountain Formation from older strata.

The Fortress Mountain Formation east of Anaktuvuk River differs in some respects from the Fortress Mountain Formation west of the Anaktuvuk River. Submarine gravity-flow deposits, rather than interfingering nonmarine and marine deposits, cropout along upper Cobblestone and May Creeks. The Torok *Formation is* not recognized beneath the Fortress Mountain Formation along upper Cobblestone and May Creeks, although the Torok Formation lies adjacent to the Fortress Mountain Formation and rocks that underlie the Fortress Mountain Formation along May Creek. Along upper Cobblestone and May Creeks, the Fortress Mountain Formation is found in imbricate south-dipping blocks in contrast to extensive shallow dipping slablike blocks west of Anaktuvuk River.

However, exposures of the Fortress Mountain Formation on both sides of Anaktuvuk River are broadly similar. In both areas, *formation* lies in fault contact on mostly structurally complex ribbon chert, mafic igneous rocks, Mesozoic clastic rocks, and melange. Exposures on both sides of Anaktuvuk River contain wood debris and framework compositions rich in chert clasts.

In this area, the Fortress Mountain Formation is divided into:

Kfc **Conglomerate and sandstone**—Nonmarine and marine deposits, mostly found west of Anaktuvuk River, which consist principally of conglomerate and sandstone. Pebble conglomerate is mostly light-greenish-gray weathering, greenish gray, and framework supported that characteristically is found in beds that range from 0 to 1.2 m thick. Beds are lenticular and cross bedded. Pebble imbrication is locally prominent. Rip-up clasts, scarce mudcracks in thin and discontinuous mudstone intervals, and plant debris ranging from small carbonized wood debris to coalified logs are found in predominantly conglomeratic strata. Conglomerate clasts include greenish-gray, bright greenish-gray, gray, reddish-brown, and light-gray translucent varieties of chert, greenish-gray aphanitic, porphyritic vesicular, and nonvesicular mafic igneous rocks, light-gray to medium-light-gray limestone and dolomitic limestone, silicified argillite, organic shale, and granitic rocks. Although most conglomerate clasts are well rounded, clasts of sedimentary rock are typically elongate parallel to bedding. Conglomerate is interbedded with bioturbated marine sandstone and sandstone that contains local ripple and wave cross bedding, gravel lenses containing abundant wood debris, and locally, marine mollusks.

Conglomerate at Castle Mountain overlies and may grade abruptly to marine sandstone including fine- to coarse-grained thin-bedded to laminated sandstone with very prominent parting lineation and flaggy weathering character. Sandstone includes scarce shell and wood debris, some of which are present in small accumulations with current crescents about them

Kft **Turbidite sandstone and conglomerate**—Turbidite sandstone and conglomerate not associated with recognized shallow-marine or nonmarine deposits are found east of Anaktuvuk River. Sandstone is medium greenish gray, fine to very coarse grained, and granular. Most sandstone is fine to medium grained but grades to very coarse grained, sandy to granule conglomerate. Sandstone beds are as thick as 1.5 m, but most beds range from 0.3 to 0.6 m. Thicker sandstone intervals are generally composed of amalgamated beds. Sandstone beds are massive, graded, laminated, and locally wispy cross bedded. Sole marks on sandstone beds include flute casts and tool marks. Sandstone locally includes much carbonized wood debris some as long as 0.3 m. Most larger sand grains and granules are chert including light-gray, light-greenish-gray, dark-gray, and very light gray tripolitic chert. Sandstone is interbedded with siltstone and silty mudstone

Kto **Torok Formation (Lower Cretaceous)**—Detterman and others (1963) reported 1865 m of the Torok Formation in type section along Torok Creek north-northeast of Castle Mountain. Monotonous character, obscure imbrication, mechanical incompetence, and incomplete exposure of unit make estimates of thickness, based on outcrop width and dip alone, unreliable.

Assignment of strata to the Torok Formation in this report differs from previous usage in reconnaissance mapping in Chandler Lake quadrangle (Patton and Tailleur, 1964). Previous workers recognized two map units, the parts of which are here reassigned to the Torok Formation. Patton and Tailleur (1964, pl. 50) recognized a unit composed of undivided Torok Formation and Fortress Mountain Formation and a set of prominent outcrops of sandstone in shale that they recognized as the Fortress Mountain Formation. Kelley (1988) and this report discriminate sandstone and shale in both units of Patton and Tailleur (1964)—sandstone is here reassigned as informal subunit within lower part of the Torok Formation and the shale is here reassigned to the Torok Formation.

The Torok Formation comprises shale, mudstone, siltstone, and sandstone. Formation is mostly and characteristically bluish-gray, dark-greenish-gray, medium-dark-gray, and dark-gray shale, mudstone, and clayey siltstone. Shale is fissile in part, mostly very thin bedded, and includes partings and thin interbeds of siltstone and fine-grained sandstone. Sandstone is medium light gray and greenish gray, very fine to very coarse grained, silty and shaly, and in part conglomeratic. Sandstone also includes lenses of granule conglomerate, most granules of which are chert

The Torok Formation is locally, divided into:

Ktoc **Cobblestone sandstone unit**—Informal name here applied to mappable and discrete bodies of sandstone and conglomerate found within lower part of the Torok Formation. Unit comprises lenticular and discontinuous bodies of sandstone and conglomerate that are present in structurally complex and south-dipping imbricate fault blocks. Outcrops are discontinuous in trend that parallels and lies south of Tuktu escarpment.

Recognition of (informal) Cobblestone sandstone unit refines previous stratigraphy. Previous workers (Patton and Tailleur, 1964, pl. 50) mapped strata—which are herein referred to the Cobblestone sandstone unit and enclosing shale—as the Fortress Mountain Formation. Cobblestone sandstone unit as proposed here discriminates coarse-grained submarine gravity-flow deposits from fine-grained strata, shale, mudstone, siltstone, and fine-grained sandstone. Fine-grained strata are here mapped within undivided part (Kto) of the Torok Formation. Cobblestone sandstone unit also discriminates gravity-flow deposits within lower part of the Torok Formation from strata of the Fortress Mountain Formation strata used in this report.

Strata of Cobblestone sandstone unit are probably older than those of the Fortress Mountain Formation exposed west of Anaktuvuk River. Cobblestone sandstone unit is present within lower part of the Torok Formation, whereas the Fortress Mountain Formation locally overlies Torok strata exposed on north flank of Fortress Mountain and east of Fortress Mountain in T. 10 S., R. 2 W. Additionally, fossils near base of the Fortress Mountain Formation in T. 12 S., R. 2 W. are middle and late Albian in age (J.W. Miller, written commun., 1983) and equivalent to fossils in strata of the Nanushuk Group, which overlies the Torok Formation along Tuktu escarpment.

Previous workers (Gryc, 1956; Patton, 1956; Jones and Gryc, 1960, p. 151; Detterman and others, 1963, p. 230; Chapman and others, 1964; Patton and Tailleur, 1964, p. 458; Molenaar, 1981, p. 26; Molenaar and others, 1981, p. 3; Mull, 1979, p. 5; Ahlbrandt and others, 1979, p. 14; and Crowder, 1987, p. 451) recognized continuity between strata referred herein to Cobblestone sandstone unit and the Fortress Mountain Formation by assigning both units to the Fortress Mountain Formation. Present mapping and nomenclature point out: (1) discontinuous nature of tongues of sandstone within lower part of the Torok Formation, (2) diachronous relations between sandstone in lower part of the Torok Formation and the Fortress Mountain Formation, and (3) restriction of the Fortress Mountain Formation to conglomerate and sandstone overlying complexly deformed Mississippian to Lower Cretaceous rocks (including the Torok Formation). Present work does not preclude depositional consanguinity between strata referred to Cobblestone sandstone unit and the Fortress Mountain Formation; if consanguinity exists however, present work suggests structural telescoping of younger and more proximal facies over older more distal facies west of Anaktuvuk River.

The map pattern suggests that sandstone bodies of Cobblestone sandstone unit range between 0 and 305 m thick and from 0.6 km to more than 16 km in lateral continuity (Kelley, 1988). Structural complexities too small to be shown at a scale of 1:125,000 and likely to produce repeated section suggest that estimated thickness is maximum value.

Cobblestone sandstone unit comprises sandstone, siltstone, mudstone, and conglomerate. Sandstone is mostly yellowish-brown-weathering, olive to greenish gray, coarse to very fine grained, very thin to massive bedded, partly laminated, and partly small scale and wispy cross bedded. Sandstone includes locally abundant small carbonized plant debris, carbonaceous films, flute marks, load casts, and tool marks. Sandstone beds typically include incomplete turbidite sequences and are locally organized into thinning-upward cycles consisting of amalgamated sandstone and gritty sandstone progressively overlain by thinner and fewer amalgamated sandstone beds interbedded with siltstone and mudstone. By hand-specimen inspection, sandstone comprises moderately sorted subangular to subrounded clasts of chert, quartz, and rock fragments. Siltstone is yellowish-brown-weathering, olive to greenish gray, mostly thin bedded to laminated, and grades to very fine grained sandstone. Siltstone includes locally common plant debris. Mudstone is medium dark gray to medium greenish gray, mostly thin bedded, very silty and very sandy in part, and locally includes sandstone partings. Conglomerate is framework supported and consists mostly of well-rounded clasts that range from granule to cobble size but are mostly pebble size. Clasts making up conglomerate are mostly chert but include common various silicified aphanitic rock fragments, mafic igneous rock fragments, and carbonate-rock fragments.

Cobblestone sandstone unit includes distinctive iron-stained and granule- to small-pebble-bearing shale, mudstone, and siltstone. Some outcrops of pebbly strata are deeply iron stained with goethite coatings that give some beds a metallic appearance. Clasts in pebbly beds are scattered, well rounded, percussion marked and mostly chert and mafic igneous rock. Iron-stained and pebbly units include ironstone lenses. Unit includes some thin beds that are tough, fissile, and carbonaceous

KMaf Arctic Foothills Assemblage (Lower Cretaceous to Mississippian)— Assemblage comprises seven previously recognized map units (Kelley, 1988) that are found in Arctic Foothills (Wahrhaftig, 1965) of central Brooks Range. Assemblage consists of coquinoid limestone (Lower Cretaceous), undivided Upper Jurassic and Cretaceous strata, mafic igneous rocks (Jurassic), Permian and Triassic chert, the Nuka Formation (Mississippian and Pennsylvanian), marble, and melange.

Fragmentary evidence provides basis for inferring stratigraphic and structural relations within Arctic Foothills assemblage in Chandler Lake quadrangle. Contacts between units within assemblage are not extensively exposed in Chandler Lake quadrangle. However, distribution over an area greater than 2,590 km^2 of assemblage that comprises units that collectively may be as thin as 610 m infers shallow dip or structural repetition; steep dips and fold- and thrust-belt setting of the Arctic Foothills makes latter interpretation more likely.

Stratigraphic relations between all of units within Arctic Foothills assemblage in Chandler Lake quadrangle are not clear. Most of the Arctic Foothills assemblage probably is structurally repeated complexly deformed and tectonically disrupted depositional sequence consisting of

Permian to Triassic chert containing intrusions and possibly interbeds of mafic igneous rocks overlain by Upper Jurassic to Lower Cretaceous strata. Stratigraphic relations between this depositional sequence and the Nuka Formation, marble, coquinoid limestone, and melange are to differing degrees uncertain. The Nuka Formation and marble could be metamorphic equivalents of one another. Melange consists of structural blocks of Arctic Foothills assemblage in sheared matrix of Upper Jurassic to Lower Cretaceous strata, mostly shale. Most of melange is extreme case of structural disruption of depositional sequence that makes up most of Arctic Foothills assemblage but locally blocks of coquinoid limestone are found in the melange.

Blocks of coquinoid limestone unit probably are tectonically derived from strata adjacent to Arctic Foothills assemblage. Arctic Foothills assemblage structurally overlies Upper Devonian to Lower Cretaceous sequence of strata that is not intruded by mafic igneous rocks that are found in overlying Arctic Foothills assemblage. Along upper Peregrine, Cobblestone, May, and Tiglukpuk Creeks, blocks of coquinoid limestone in Arctic Foothills assemblage crop out within 0.6 km and less than 150 m structurally above strata from which blocks were likely derived.

Structural and stratigraphic relations of units of Arctic Foothills assemblage exposed in Killik River quadrangle adjoining to west support inferred stratigraphic and structural relations in Chandler Lake quadrangle. Contacts between equivalents of Permian to Triassic cherts and Upper Jurassic to Lower Cretaceous clastic rocks in Chandler Lake quadrangle are exposed in Killik River quadrangle. Chert, locally extensively intruded by mafic igneous rocks in the Chandler Lake quadrangle, unconformably underlies Upper Jurassic and Lower Cretaceous clastic rocks. A regional sole thrust underlies chert and mafic igneous rocks; subsidiary thrusts produce imbricate blocks of both (1) chert and mafic igneous rocks and (2) chert and mafic igneous rocks and Upper Jurassic to Lower Cretaceous clastic rocks.

Tectonic blocks of coquinoid limestone unit (Lower Cretaceous-Valanginian) are present in melange in Arctic Foothills assemblage. Coquinoid limestone is found as slabbly blocks indicated by on geologic map in highly sheared and disrupted Upper Jurassic and Cretaceous shale and sandstone. Blocks are typically brownish gray and reddish-brown-weathering limy siltstone, mudstone, and impure limestone including abundant bivalves, typically *Buchia sublaevis*, algae, and shell hash. See description of coquinoid limestone unit (Kcl) for additional lithologic description.

Undivided Upper Jurassic and Cretaceous strata (Kelley, 1988) unit consists of variety of bedded clastic rocks of uncertain aggregate thickness. Patton and Tailleur (1964, p. 447) reported between 550 m and possibly 670 m of Berriasian and Valanginian strata in undivided Cretaceous and Upper Jurassic strata unit used here. Unmapped structural complexity, generally poor and discontinuous exposure, lack of reliable marker beds, and poor biostratigraphic control limit accurate estimation of thicknesses.

Upper Jurassic and Cretaceous strata (Kelley, 1988) consists of four recognizable facies, which are: (1) sandstone and shale, (2) conglomerate, (3) tuffaceous sandstone, and (4) volcaniclastic breccia. Sandstone and shale facies makes up the bulk of the unit and ranges from shale with subordinate turbidite sandstone to amalgamated turbidite sandstone with subordinate shale. Sandstone and shale facies includes the Okpikruak Formation (Patton and Tailleur, 1964). Undivided Upper Jurassic and Cretaceous strata unit probably includes unrecognized exposures of the Torok Formation and Fortress Mountain Formation that probably unconformably overlay Okpikruak Formation and other elements of the Arctic Foothills assemblage; structural mixing and poor exposure make these outcrops difficult to recognize. Undivided Upper Jurassic and Cretaceous strata unit as used herein also probably includes tectonically detached and unidentified shale and sandstone that was originally in depositional continuity with coquinoid limestone unit.

Sandstone and shale facies is mostly light-olive-gray and greenish-gray sandstone, siltstone, mudstone, and shale. Sandstone is mostly medium to fine grained subangular to subrounded and composed of quartz, feldspar, chert, and greenish-gray rock fragments in chloritic matrix. Grain boundaries are typically obscure in more matrix-rich sandstone. Graded bedding and incomplete turbidite sequences are common. Wood debris, prod marks, flute casts, and load casts are common. Sandstone is locally conglomeratic with granules of mainly chert and aphanitic rock fragments. Facies includes medium-greenish-gray siltstone, mudstone, and shale.

Conglomerate facies includes framework-supported conglomerate typically found as beds and lenses in association with turbidite sandstone. Conglomerate is composed of well-rounded to subangular granules and small pebbles of quartz, chert, and rock fragments. Chert includes greenish-gray, light-gray, and dark-gray varieties. Most rock fragments are greenish gray to dark gray, aphanitic, and silicified. Framework-supported conglomerate is also typically found in isolated bodies, some of which appear to fill channels cut in sandstone and shale. Isolated outcrops of heterolithic conglomerate include subrounded to subangular pebbles of greenish-gray and various-colored chert, yellowish-gray-weathering silicified limestone or mudstone, and organic shale.

Tuffaceous sandstone facies is mostly grayish-green fine- to coarse-grained tuffaceous sandstone and interbedded siltstone and shale. Most grain boundaries in tuffaceous sandstone are indistinct. Sandstone is typically very chloritic. Sandstone includes chloritized rock fragments and locally relict glass-shard textures in thin section. Bedding ranges from 0.15 to 0.3 m thick and is commonly graded but also massive or obscure. Chlorite development and grain obliteration is especially prominent along broken and slickensided surfaces. Tuffaceous sandstone is interbedded with greenish-gray to olive-gray to medium-dark-gray siltstone and shale.

Volcaniclastic breccia facies includes grayish-green breccia and grayish-green graywacke. Breccia is composed of mostly granule to pebble-size clasts of greenish-gray rock fragments in grayish-green chloritic matrix. Breccias are both framework and matrix supported. Volcanic rock fragments are mostly chloritized aphanitic rock fragments, but some fragments include fine-grained plagioclase laths. Few clasts are of vesicular and amygdaloidal mafic igneous rocks. Scattered chert clasts are found locally in breccias. Matrix of most breccias is typically dense felted mass of chlorite.

Mafic igneous rocks (Jurassic) (Patton and Tailleur, 1964) locally make up large part of Arctic Foothills assemblage. Some are sills, although most are podlike masses in structurally disturbed contact with their host rock; undisturbed chilled margins are rare. S.W. Karl (oral commun., 1986) reports observing pillow structures in mafic igneous rocks on Tiglukpuk Creek. Outcrops of mafic igneous rocks are typically poor and scattered and indicated on the map by an within Arctic Foothills assemblage.

Mafic igneous rocks include dark-greenish-gray, olive-gray, and light-olive-gray rocks with a variety of textures. Most rocks are fine grained and equigranular, but the unit also includes aphanitic, porphyritic, and coarse-grained varieties. Porphyritic varieties include plagioclase laths in a grayish-green groundmass of chloritized mafic minerals, mostly pyroxene. Some varieties have diabase texture. Some are amygdaloidal and vesicular. Some are autoclastic, consisting of fine-grained to aphanitic clasts in crystalline groundmass of similar apparent composition.

Permian and Triassic chert is widely distributed within Arctic Foothills assemblage in Chandler Lake quadrangle. Patton and Tailleur (1964, p. 439) reported ribbon chert bodies as thick as 90 m in Chandler Lake quadrangle. Although structural complexity, poor and discontinuous outcrop, and general lack of stratigraphic control from outcrop to outcrop, limit confidence in estimating thickness of Permian and Triassic chert unit, chert appears to be as much as 150 m thick east of Anaktuvuk River and appears in general to thin eastward toward Cobblestone Creek area (Kelley, 1988). Chert is present as structural blocks that range from hand-specimen-size clasts in melange to large blocks that probably include original depositional thickness of chert. Localities are indicated by a ∧ within Arctic Foothills assemblage on map.

Chert found within Arctic Foothills assemblage is radiolarian ribbon chert. It is medium light gray, grayish green, very light gray, and moderate yellowish green to grayish green, very finely laminated in part, locally obscurely graded, evenly parallel bedded, and found in beds that range from 2.5 to 15 cm thick with most beds between 5 to 6 cm thick. Radiolarians are locally abundant and especially conspicuous in light-greenish-gray chert. Siliceous shale and black-carbonaceous shale partings, some of which are locally deeply iron stained on weathered surfaces, are present between chert beds. Chert is locally very limy suggesting alteration from carbonate protolith

The Nuka Formation (Mississippian and Pennsylvanian) (KMaf, part) is found within the eastern part of Arctic Foothills assemblage. Formation consists of sandstone and limestone. Sandstone is light gray to yellowish gray, and fine to very coarse grained but mostly coarse to very coarse grained. Sandstone is composed mostly of subangular quartz and feldspar, most of which appears to be microcline. Glauconite is abundant accessory mineral locally. Limestone is light to light medium gray, very coarse grained to fine grained, and composed mostly of crinoid debris and lime mud. Limestone is thin bedded and cross bedded. Outcrops of the Nuka Formation are small, poor, and typically rubbly.

Marble is found in a few isolated and scattered outcrops within western part of Arctic Foothills assemblage. Marble is light gray to light yellowish gray, mostly coarsely crystalline, but grades to medium-grained limestone. Relict thin bedding locally present. Outcrops are friable weathering, highly fractured, and rubbly. Some parts of this unit consist of friable-weathering mixtures of large single-crystal calcite grains in recrystallized finer grained matrix, possibly recrystallized encrinite limestone.

Melange is found extensively within Arctic Foothills assemblage and consists of blocks of Permian and Triassic ribbon chert, mafic igneous rocks, Jurassic and Cretaceous sandstone, coquinoid limestone, and probably marble in thoroughly sheared and disrupted matrix of greenish-gray and olive-gray shale and mudstone. Matrix and sandstone blocks are indistinguishable from strata elsewhere assigned to the undivided Upper Jurassic and Cretaceous strata map unit

Kcl **Coquinoid limestone unit (Lower Cretaceous, Valanginian)**—In the Chandler Lake quadrangle, Unit is found in depositional contact with the Otuk Formation (J♄os, part) and the undivided Otuk and Shublik Formations (J♄os), and also as tectonic blocks in melange in Arctic Foothills assemblage. These blocks are likely stripped from depositional sequence with the Otuk Formation and the undivided Otuk and Shublik Formations.

Unit is typically brownish-gray and reddish-brown-weathering limy siltstone, mudstone, and impure limestone comprising abundant bivalves (typically *Buchia sublaevis*) algae, and shell hash. Outcrops typically weather to slabby blocks. Surfaces perpendicular to bedding have distinctive plicate differential-weathering pattern reflecting deposition as shell and algal mats.

Bedding surfaces commonly have orbicular weathering patterns reflecting large number of whole or nearly whole bivalve valves that made up algal and shell mats from which rock likely formed

J♄os **Otuk (Jurassic and Triassic) and Shublik (Triassic) Formations, undivided**—Unit is equivalent to three map units used by Kelley (1988)—the Otuk Formation (see also Mull and others, 1982), the Shublik Formation (see also Patton and Tailleur, 1964), and the "Otuk and Shublik Formations undifferentiated." Probable overall thickness of unit, based on outcrop width and dip as measured on the map and sections of the Otuk Formation measured by Bodnar (1984, fig. 10), is about 130 m. Unit includes structurally induced variations in thickness.

Map units recognized in previous mapping but combined here have restricted distributions (Kelley, 1988). The Shublik Formation as used in this report is restricted to outcrops east of the Anaktuvuk River. The "Otuk and Shublik Formations, undifferentiated" crops out along range front between Anaktuvuk River and Cobblestone Creek. The Otuk Formation as used in this report crops out along range front west of Anaktuvuk River and in isolated outcrops along Ekokpuk Creek in southwestern part of quadrangle.

The Otuk Formation(J♄os, part) consists of (ascending) shale, chert, and limestone members, and the Blankenship Member. Shale member comprises dark-gray, grayish-black, and greenish-gray shale and mudstone, thin beds of dark-gray limestone, and dark-gray to black chert. Much of shale member has sooty appearance in outcrop and is locally phosphatic. Chert member is characterized by dark-gray to black chert, silicified micritic limestone, and dark-gray to black, soft, sooty, silty shale. Chert in chert member is rhythmically bedded, thin bedded, laminated in part, and locally fossiliferous containing abundant *Halobia* and *Monotis*. Limestone member is mainly rhythmically interbedded yellowish-gray, light-brownish-gray, and tan-weathering, dark-gray, fine-grained and very impure limestone with partings and interbeds of dark-gray and black shale. Limestone member includes coquina composed mostly of *Monotis* and *Halobia*. The Blankenship Member is mostly dark-gray to black carbonaceous shale with brownish-gray-weathering pliable laminated oil shale and thin chert interbeds.

The Shublik Formation (JTRos, part) is mostly shale and impure limestone. Shale is mostly dark to very dark gray, soft, sooty, and fissile in part with paperlike weathering character. Shale is in part calcareous, and includes apatite concretions. Limestone is dark gray, medium dark gray, and brownish gray. Limestone typically resistant to weathering and lighter shades of gray than associated shale and includes abundant thin-shell bivalves including *Halobia* and *Monotis*. Unit includes ferruginous-weathering shale and mudstone, and yellowish-gray-weathering silicified beds that grade into the Otuk Formation (JTRos, part).

Ps **Siksikpuk Formation of Mull and others (1987) (Permian)**—The Siksikpuk Formation of Mull and others (1987) used in this report is consistent with type section of Patton (1957), usage of Patton and Tailleur (1964), and age of Siok (1985) and Mull and others (1987). Patton (1957) first suggested name "Siksikpuk Formation" for outcrops of Lower(?) Permian strata along Skimo and Tiglukpuk Creeks in central Chandler Lake quadrangle. Patton and Tailleur (1964) subsequently traced their Siksikpuk Formation across Chandler Lake quadrangle referred to formation as Permian(?) in age. Mull and others (1982, p. 357) stated that the Siksikpuk Formation is Pennsylvanian, Permain, and Early Triassic in age based on fossil collections from widely scattered localities. Siok (1985, pl. 7) reported Early Permian fossils in two measured sections of his Siksikpuk Formation along range front between Confusion and Firestone Creeks in Chandler Lake quadrangle. Mull and others (1987) stratigraphically restricted their Siksikpuk Formation to Permian strata in Killik River quadrangle adjacent and west of Chandler Lake quadrangle.

The Siksikpuk Formation of Mull and others (1987) is between 61 and 175 m thick. Patton and Tailleur (1964) reported between 61 to 107 m of unit in Chandler Lake quadrangle, where Siok (1985) reported 175 and 145 m from measured sections. Top of the Siksikpuk Formation of Mull and others (1987) is not exposed in either section measured by Siok (1985) but outcrops of overlying Otuk Formation are found near top of both measured sections.

The Siksikpuk Formation of Mull and others (1987) in Chandler Lake quadrangle consists of three lithofacies (Kelley, 1988). These lithofacies are end members of continuum partially obscured by erosion. Lithofacies 1 is found along range front between west boundary of map area and Anaktuvuk River. Lithofacies 2 is present east of Nanushuk River along range front. Lithofacies 3 is found near head of Ekokpuk Creek in southwestern area of map.

Lithofacies 1 is mostly mudstone and siltstone with smaller amounts of shale, and limestone. Mudstone and siltstone are variegated reddish brown, grayish red, light to dark greenish gray, and medium dark gray to black, laminated in part, thin to medium bedded, calcareous in part with gradational relations to very silty and shaly limestone, locally reddish orange weathering, and locally pyritic. Mudstone and siltstone includes barite veins and nodules, carbonate nodules, and reddish-orange claystone partings and thin interbeds. Limestone is medium dark gray to black, very impure, very shaly and silty, and locally fossiliferous. Shale is black to dark gray, fissile, and sooty in part. Shale includes siltstone and mudstone partings. Lithofacies includes medium-dark-gray to black and greenish-gray to dark-greenish gray, wispy, laminated, and resistant siliceous mudstone resistant to weathering.

Lithofacies 2 is mostly shale and mudstone with smaller amounts of very impure limestone. Shale and mudstone is medium gray, black, dark greenish gray, fissile in part, silty in part, and calcareous in part. Lithofacies includes soft fissile dark-gray to black shale and sooty silty mudstone with obscure bedding. Mudstone and shale includes prominent barite nodules with radiating crystal structure and barite veins. Limestone makes up very small part of section and typically is very impure, mostly shaly, and nodularform. Some of *limestone beds* are ferruginous weathering. Siok (1985) reports *Zoophycos* on bedding surfaces near base of section.

Lithofacies 3 is siltstone and shale. Siltstone is light gray, dark to very dark gray, and brownish gray and is characteristically, hard, siliceous, very uniform in texture but with faint color laminations, conchoidal fracturing but bocky weathering, thin to medium bedded, and partly rhythmically bedded. Siltstone grades to porcelaneous chert. Shale is dark gray to black, soft, sooty in part, and poorly exposed. Barite concretions and veinlets as much as 75 mm in greatest dimension are rare

Psl **Sadlerochit Group (Permian)**—Only the Permian (including the basal) part of the Sadlerochit Group is present in map area. Slablike bodies of Sadlerochit strata as thick as 15 m thick are found within imbricate fault blocks composed mostly of carbonate strata of the Lisburne Group east of and adjacent to head of Nanushuk River. Strata in the Sadlerochit Group are mostly siltstone, sandstone, and mudstone. Siltstone and mudstone are reddish brown, iron oxide cemented, and deeply iron stained on weathered surfaces. Greenish-gray varieties of siltstone and mudstone without much iron stain also are present in group. Sandstone is very fine to fine grained, ripple-scale cross bedded, and grades to siltstone. Group includes coquina of brachiopods, gastropods, echinoderm debris, bryozoans, and shell debris. Large *Zoophycos* are present

Lisburne Group (Mississippian)—Map unit only discriminates two of three map units previously recognized in Chandler Lake quadrangle by Kelley (1988). Previous mapping showed distribution of (1) platform carbonate rocks of the Alapah and Wachsmuth Limestones, (2) prominent shaly intervals within platform carbonate strata, and (3) chert replacement of greatly thinned section of platform carbonate strata.

Strata of the Lisburne Group in Chandler Lake quadrangle are herein mapped as undivided Alapah and Wachsmuth Limestones. The Lisburne Group here also includes two facies that Mull and others (1982) previously identified as part of the Kuna Formation. These shale and chert facies were identified—but not assigned to the Kuna Formation—in previous mapping (Kelley, 1988). In this report, chert facies is shown as separate map unit (**Mawc**) within the Lisburne Group and shale facies is described, but not differentiated from, undivided Alapah and Wachmuth Limestones (**Maw**).

Chert facies (**Mawc**), whose strata are here geographically restricted from the Kuna Formation is regarded as part of undivided Alapah and Wachsmuth Limestones because bedding characteristics and likely protolith of these strata are more akin to platform carbonate strata than strata assigned elsewhere to the Kuna Formation. Chert facies is commonly massive bedded, whereas very prominent bedding, ranging from rhythmic to uneven, is characteristic of the Kuna Formation. Protolith in chert facies at least in part is very coarse grained grainstone more typical of platform carbonate strata than the fine-grained clastic strata, possibly mudstone turbidites, the most likely protolith of much of the Kuna Formation.

Although not included within the Kuna Formation, chert facies in Chandler Lake quadrangle is probably part of regional transition from the Alapah and Wachsmuth Limestones to the Kuna Formation. Transition is from shelf carbonate rocks on northeast to chert and possibly to the Kuna Formation on southeast and takes place across linear zone that extends southeast from range front in Outwash Creek area about 80 km west of Chandler Lake quadrangle, through Ekokpuk Creek area in southwestern Chandler Lake quadrangle, and thence south of Doonerak Mountain, about 16 km south of Chandler Lake quadrangle. In transition zone, the Lisburne Group is anomalously thin. Chert replaces grainstone and wackestone in Outwash Creek area, especially silica-spiculitic limestone, and grainstone and wackestone in the Ekokpuk Creek area. Bedded chert of the Kuna Formation is found on upper Otuk Creek, about 24 km west of Outwash Creek at range front, and probably is facies southwest of chert facies in Chandler Lake quadrangle.

Strata comprising shale facies (Kelley, 1988) are here geographically restricted from the Kuna Formation as previously assigned (Mull and others, 1982) because exposures of facies lack lateral persistence, consistent stratigraphic position, or unique lithology. In extensive exposures of the Lisburne Group northwest of Anaktuvuk Pass, two intervals of shaly facies are found, separated by as much as 120 m of the Alapah Limestone. Upper interval is transitional into Permian shale of the Siksikpuk Formation of Mull and others (1987) and lower interval was previously identified as black chert and shale member of the Alapah Limestone (Patton and Tailleur, 1964, p. 419). Lower interval, which is locally phosphate bearing, does not have locally persistent stratigraphic position probably due to intertonguing of subtle facies. Not all workers recognize interval in lower part of the Alapah Limestone lithologically distinctive enough to be indicated in measured sections; along Skimo Creek, Patton and Tailleur (1964) reported lower shaly interval within the Alapah Limestone, whereas Armstrong and Mamet (1977, pl. 40 and A1) failed to recognize same interval as distinctive in measuring the same section

The Lisburne Group in Chandler Lake quadrangle consists of:

Maw **Alapah and Wachmuth Limestones, undivided (Mississippian)**—Mostly light-brownish-gray packstones and wackestones composed of bioclastic framework clasts and interstitial lime mud; abundantly fossiliferous including brachiopods, foraminifers, echinoderms, corals, bryozoans, and gastropods. In most places, clastic character of limestone is apparent, but dolomitization obscures grain fabric. Bedding ranges from thin to massive and includes cross-bedded and cross-laminated beds. Dark-gray shale, carbonaceous limestone, shaly limestone, and limy shale make up between 10 and 30 percent of section. Dark-gray to light-medium-gray chert is present as nodules and nodularform beds. Ferruginous-weathering and especially fossiliferous beds crop out near base of the Wachsmuth Limestone (Maw, part). Undivided Alapah and Wachsmuth Limestones is about 1018 m thick (Bowsher and Dutro, 1957; Armstrong and Mamet, 1977; and Armstrong and Mamet, 1978) throughout quadrangle except in Ekokpuk Creek area, southwest of confluence of Ekokpuk Creek and John River, and between John River and upper Inukpasugruk Creek where Lisburne strata are hundreds rather than thousands of feet thick.

Very dark gray to medium-dark-gray argillaceous limestone, limy shale, and nodular chert are found in lower part of the Alapah Limestone (Maw, part). Beds include abundant phosphatic nodules and (or) ooids. Most of limestone and limy shale is fine-grained, carbonaceous, thin bedded to laminated, and platy weathering. Carbonaceous shale partings are common. Some outcrops have sooty carbonaceous bloom on weathered surfaces. Facies grades to medium-gray bioclastic limestone and dolomitized limestone. Mull and others (1982) previously assigned shale facies described in this report to easternmost tongue of black chert and shale facies of the Kuna Formation

Locally, this undivided unit is divided into:

Mawc **Chert facies**—Unit comprises mostly very dark gray to black chert. Chert is dense, nearly opaque, mostly massive, and conchoidal fracturing. Outcrops of chert are typically highly fractured and white quartz veined. Chert includes locally abundant medium-light-gray dolomitized micrite to very coarse grained grainstone in lenses, layers of dark to very dark gray argillaceous siltstone and medium-gray limestone, and faint wispy structures, which may be relict bedding. Chert facies is replacement feature of anomalously thin parts of undivided Alapah and Wachmuth Limestones

Mk **Kayak Shale (Lower Mississippian)**—Formation is predominantly shale with interbedded bioclastic limestone and finely crystalline limestone. Shale is dark gray to grayish black, carbonaceous, generally micaceous and fissile, clayey to very silty, and soft to brittle. Formation is not resistant to weathering in comparison to overlying and underlying formations. Shale grades to mudstone and siltstone and includes thin quartz-rich and commonly bioturbated sandstone beds near base of formation. Bioclastic limestone beds are generally less than 1.8 m thick and composed of reddish- and yellowish-brown-weathering accumulations of megafossil hash including abundant crinoid parts with smaller amounts of brachiopod, bryozoan, and coral debris. Argillaceous limestone consists of fine-grained crystalline limestone that is dark-gray to grayish-black, carbonaceous, and generally resistant to weathering. Reiser and others (1979) report beds of andesitic tuff and volcanic conglomerate in the Kayak Shale at the head of Inukpasugruk Creek. Formation ranges in thickness from 82 to 265 m thick. The Kayak Shale is a regional decollement zone (Kelley and Bohn, 1988) and ranges radically in apparent rather than true depositional thickness. Where the formation is best exposed and least disturbed, it is about 171 m thick

MDku Kanayut Conglomerate (upper part) (Lower Mississippian? and Upper Devonian)—Unit consists of the Stuver Member (Upper Devonian and Lower Mississippian) (Bowsher and Dutro, 1957; Nilsen and Moore, 1982, 1984; Nilsen and others, 1980, 1981; and Porter, 1966), the Shainin Lake Member (Upper Devonian) (Nilsen and Moore, 1982, 1984; Nilsen and others, 1980, 1981; Nilsen, 1981;), and strata mapped as the "upper part of the Kanayut Conglomerate" (Mississippian? and Devonian) by Kelley (1988). Thickness of unit in map area is uncertain but probably ranges between 760 and 305 m.

The Stuver Member (**MDku**, part) of the Kanayut Conglomerate extends from Chandler River to east boundary of quadrangle and from Toyuk Mountain thrust to range front (Kelley, 1988). The Stuver Member changes facies in south and southwest part of quadrangle. Laterally equivalent map unit, which includes the underlying Shainin Lake Member, is about 305 m thick in southeastern part of quadrangle (Kelley, 1988).

The Stuver Member comprises sandstone, siltstone, conglomerate, and shale. Variously iron-stained sandstone ranging from very fine grained to very coarse grained and conglomeratic, orthoquartzite to quartz-rich sandstone is principal rock type. Sandstone consists of very light gray quartz, chert, and siliceous rock fragments. Sandstone beds are as thick as 1 m thick and typically are found as elements of fining-upward cycles. Cross bedding is common in the sandstone. Member includes conglomerate consisting of granules and small pebbles of chert, quartz, and siliceous rocks typically in a matrix of quartz sandstone. Member also includes dark-gray to grayish-black shale and argillaceous siltstone which are micaceous, very silty, and sandy. Siltstone and shale grade to silty sandstone. The Stuver Member contains Devonian and Early Mississippian(?) plant fossils.

The Stuver Member locally includes Lower Mississippian(?) grayish-black to dark-gray shale in its uppermost part (Kelley, 1988). Lower Mississippian(?) shale is carbonaceous and includes plant debris, local ironstones and partings of siltstone, and very fine grained quartzose sandstone. Dark-gray commonly carbonaceous shaly quartz sandstone beds are found as weathering-resistant tabular bodies in Lower Mississippian(?) shale. Lower Mississippian(?) shale is exposed along outcrop belt of the Stuver Member extending from T. 15 S., R. 7 E. west across Nanushuk River and head of Alapah Creek to Kanayut River. Other outcrops are present in T. 13 S. , R. 6 E. between Erratic Creek and Nanushuk River and T. 15 S., R. 7 E.

The Shainin Lake Member (**MDku**, part) of the Kanayut Conglomerate underlies the Stuver Member and has similar areal extent to the Stuver Member. The Shainin Lake Member extends from east side of Chandler River to east boundary of quadrangle and from Toyuk Mountain thrust to range front (Kelley, 1988). The Stuver Member changes facies in south and southwest parts of quadrangle, at least in part by wedge out. Locally, southward thinning in the Shainin Lake Member is abrupt (Kelley, 1984b). Mapping further suggests that the Shainin Lake Member thins and probably wedges out in northeast part of quadrangle.

The Shainin Lake Member comprises mostly conglomerate and sandstone. Conglomerate is as much as half of member. Conglomerate is principally framework supported and composed of generally well-rounded pebbles and cobbles of mostly chert, quartz, and quartzite. Matrix of conglomerate consists of quartz- and chert-rich sandstone and granules. Conglomerate crops out in hard and resistant intervals as thick as 4.5 m. Conglomerate is typically silica cemented although calcareous and iron oxide cements are present. Sandstone is hard, resistant, cemented to varying degrees with silica, carbonate, and iron oxide, and composed of moderately to poorly sorted quartz, chert, and silicified rock fragments. Sandstone beds are commonly cross bedded, moderately to poorly sorted, conglomeratic in part, and include pebble trains. Much of conglomerate and sandstone is organized into recognizable fining-upward sequences. The Shainin Lake Member includes reddish-brown, greenish-gray, and dark-gray to grayish-black, silty, sandy shale, siltstone, and argillaceous sandstone in various amounts.

Resistant to erosion and cliff-forming character of the Shainin Lake Member contrasts sharply with relative recessive outcrops of overlying and underlying members of the Kanayut Conglomerate. Additionally, alternating recessive and resistant weathering character of the shale and sandstone making up members of the Kanayut Conglomerate that overlie and underlie the Shainin Lake Member, contrasts with the massive-weathering character of the Shainin Lake Member.

The "upper part of the Kanayut Conglomerate" of Kelley (1988) (**MDku**, part) crops out in mountains east of Chandler River and south of Toyuk Mountain thrust. Upper part of the Kanayut Conglomerate is laterally equivalent to the Stuver and Shainin Lake Members of the Kanayut Conglomerate.

The "upper part of the Kanayut Conglomerate" as used in Kelley (1988) comprises sandstone, conglomerate, and shale. Sandstone is light brownish gray, reddish brown, and light olive gray. Sandstone is typically iron stained to various degrees, cross bedded, very fine grained to very coarse grained but mostly coarse grained, and granular conglomeratic in part. Sandstone grains are mostly chert, quartz, and silicic rock fragments. Conglomerate is framework supported and mostly consists of granules and small pebbles of chert, quartz, and siliceous rock fragments. Sandstone and conglomerate organized into fining-upward sequences. Shale is dark gray, carbonaceous locally, very silty, sandy, and iron stained in part. The "upper part of the Kanayut Conglomerate" is characterized by iron-stained outcrops of differentially weathering sandstone-conglomerate intervals and shaly intervals. One or more massive-weathering intervals consisting of amalgamated sandstone and conglomerate are present, but generally less than 60 m thick and probably discontinuous

Dkln **Kanayut Conglomerate (lower part) and Noatak Sandstone, undivided (Upper Devonian)**—Unit consists of the Ear Peak Member of the Kanayut Conglomerate (Nilsen and Moore, 1982, 1984; Nilsen and others, 1980, 1981; and Nilsen, 1981) and the Noatak Sandstone. Map information (Kelley, 1988) suggests undivided unit may be as much as 760 m thick and thins abruptly to northeast.

The Ear Peak Member (**MDku**, part) of the Kanayut Conglomerate is mostly shale, mudstone, sandstone, and conglomerate. Shale is reddish brown, grayish green, brownish gray, and grayish black, typically very silty and micaceous, and grades to siltstone. Sandstone is quartz rich and ranges between orthoquartzite and quartz-rich sandstone with various amounts of silica, carbonate, and iron oxide cements. Sandstones are granule to pebble conglomeratic in part and grade to conglomerate. Cross bedding is common in sandstone beds and ranges from large scale to ripple laminae. Conglomerate is framework supported with framework clasts consisting of granules, pebbles, and cobbles of mostly quartz and chert. Sandstone consisting principally of quartz and chert make up the matrix in conglomerates. Principal rock types of the Ear Peak Member typically are organized into fining-upward cycles with conglomerate or massive sandstone at base grading upward to finer grained and cross-bedded strata.

Lithology of the Ear Peak Member varies across map area. Sandstone is most abundant in north and east parts of its outcrop area, mostly north of the Toyuk Mountain thrust. Dark-gray shale is most abundant south of the Toyuk Mountain thrust fault.

The Noatak Sandstone (**Dkln**, part) is principally sandstone and mudstone. Pinkish-gray, light-brownish-gray, and light-gray calcareous-cemented sandstone is typical. Sandstone is mostly fine to coarse grained with scattered granules and small pebbles of quartz and chert locally. Sandstone is laminated in part, ranges from thin to thick bedded and in part cross bedded. Load casts, marine fossils, and scattered plant debris are present locally in sandstone. Mudstone is dark gray and brownish gray. Principal distinguishing characteristics of the Noatak Sandstone include; pinkish-gray-weathering outcrops, continuous and tabular-weathering beds, moderate or good sorting, and carbonate cement.

In Thibodeaux Mountain area, the Noatak Sandstone is coarser grained than elsewhere in map area and includes possible evidence of nonmarine sedimentation. The Noatak Sandstone is highly iron stained, granular conglomeratic containing granules of quartz, chert, and ironstone, and includes conglomerate beds and lenses in Thibodeaux Mountain area. Formation includes deeply iron-stained shale partings, prominent cross bedding, and marine fossils in deeply iron-stained lenses. It also includes possible paleosols, rain-print structures, and mud-cracks structures. Conglomerate and conglomeratic sandstone are common in Thibodeaux Mountain area. Sandstone/shale ratio decreases to south and west of Thibodeaux Mountain area.

The Noatak Sandstone is found discontinuously in map area and probably interfingers with the Hunt Fork Shale locally, but structural detachment (Kelley and Bohn, 1988) and thrusting greatly obscure the interfingering

Dkn **Kanayut Conglomerate (part) and Noatak Sandstone, undivided (Upper Devonian)**—Thickness of this map unit is very poorly constrained but probably around 760 m.

Unit comprises sandstone, shale, and conglomerate. Sandstone is typically reddish brown weathering, reddish brown to brownish gray, iron stained, thin to medium bedded, and prominently cross bedded. Most sandstone is fine to coarse grained, moderately to poorly sorted, and granule conglomeratic locally. Ferruginous, silica, and carbonate cements are present in sandstones in various amounts in different localities. Reddish-brown and dark-gray shale is very silty, sandy in part, carbonaceous in part, and ferruginous in part. Conglomerate is framework supported, granule to pebble in size, and composed of chert, quartz, and silicic rock fragments. The Stuver, Shainin Lake, and Ear Peak Members of the Kanayut Conglomerate are obscure, if present. Dark-gray Lower Mississippian(?) shale is not present, or else unrecognized. Much of this unit appears transitional into the Noatak Sandstone as mapped elsewhere in this part of Brooks Range, especially in southwestern part of map area

Dh **Hunt Fork Shale (Upper Devonian)**—Unit consists of undivided wacke and shale members (units **Dhw** and **Dhs**, respectively, which are mapped separately locally). Thickness of undivided unit is uncertain.

Undivided unit comprises mostly shale and sandstone. Shale is medium dark gray and olive gray. Unit includes argillite with poorly developed cleavage. Most fine-grained and argillaceous rocks have poorly developed phyllitic sheen on partings and include sandstone partings and interbeds. Sandstone is grayish green and greenish gray, mostly fine to medium grained, micaceous, and ripple cross bedded in part. Sandstone beds are locally graded. Much of outcrop, in which the wacke and shale members are undiscriminated, is shaly strata (indicated by short-dashed-line pattern on map). Unresolved structural complication precludes determining whether shale member thickens or wacke member wedges out to southwest; shaly strata are more prominent in southeastern parts of map area

On map, exposures of especially shaly strata (shale? member) are indicated by same map pattern as for shale member (**Dhs**) of the Hunt Fork Shale, but without contact boundaries or map-unit symbols

Locally divided into:

Dhw **Wacke member**—Outcrop widths and dip from previous mapping (Kelley, 1988) suggest that wacke member is around 760 m thick. Wacke member appears to thin to northeast.

Member consists of siltstone, mudstone, and sandstone. Siltstone and mudstone are greenish gray, brownish gray, olive gray, and medium dark gray. Siltstone and mudstone are typically brownish gray, yellowish brownish gray, and hackly weathering. Manganiferous films on weathered surfaces are common on siltstone and mudstone. Siltstone is very shaly and mudstone grades to siltstone. Sandstone is light to medium olive gray, fine to medium grained, and conglomeratic locally. Sandstone is also commonly limonitic, ferruginous weathering in part, and locally fossiliferous. Conglomeratic sandstone includes small pebbles and granules of chert, argillite, and ironstone. Fossils typically are found in conglomeratic lenses containing plant debris. Sandstone beds are as thick as 0.9 m and ranges from wackes containing quartz, chert, mica, and aphanitic rock fragments to quartzites composed of quartz and chert. Unit highlighted by small dot pattern on map. Load casts and bioturbation are locally common. Wacke member locally interfingers with overlying Noatak Sandstone (**Dkn**, part), but structural complexities obscure gradational relations between wacke member and the Noatak (Kelley and Bohn, 1988)

Dhs **Shale member**—Outcrop widths and dips suggests that shale member attains maximum thickness of 610 m and probably thins to northeast (Kelley, 1988).

Member comprises mudstone, shale, and sandstone. Mudstone and shale are medium to medium dark gray, very silty, fissile, and interbedded with sandstone. Mudstone and shale grade to siltstone, argillite, and slate. Sandstone is brownish gray and greenish gray, fine to medium grained, mostly fine grained, laminated, low-angle cross bedded, and wavy laminated in part. Sandstone beds include ripple marks, load casts, and a few rip-up clasts of dark-gray shale. Sandstones consist of generally well-sorted grains of quartz, chert, argillite(?), feldspar, and white mica. Sandstone/shale ratios range from 1:5 to 2:3. Unit is structurally thickened and locally repeated by imbricate fault blocks.

Member appears to be slightly metamorphosed. Mudstone and shale commonly have a poorly developed axial-plane cleavage in cores of mesoscopic folds. Bedding and cleavage surfaces have micaceous sheen and shale and mudstone are gradational to slate and argillite