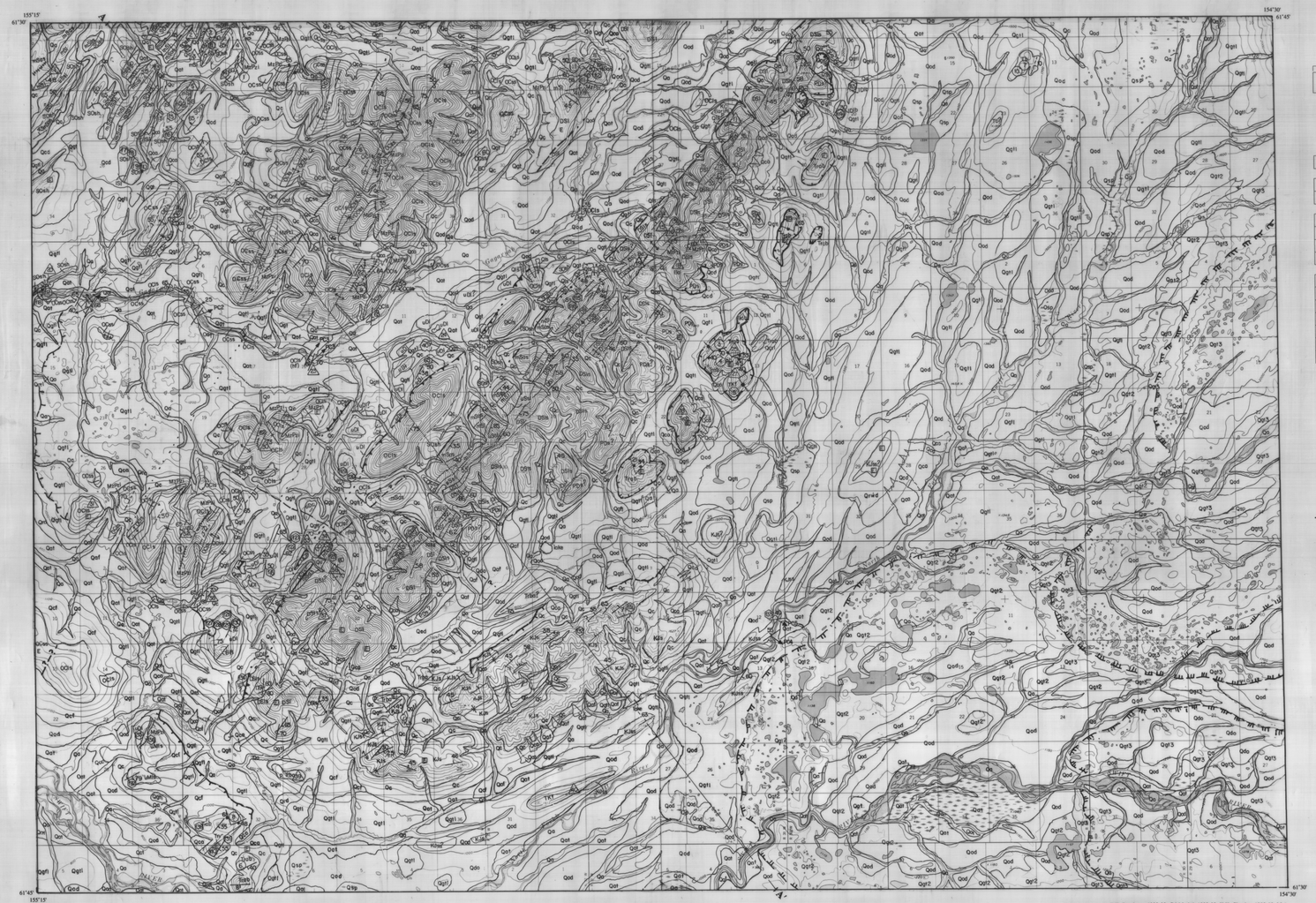


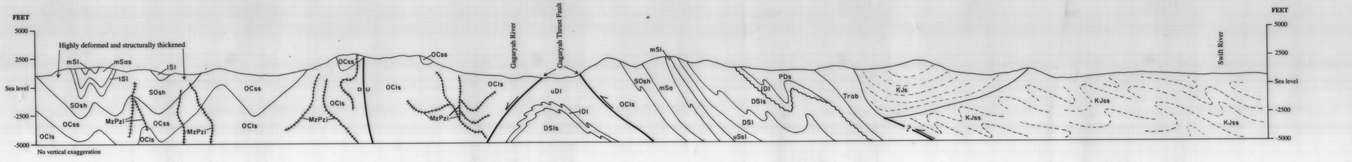
Base from U.S. Geological Survey, Lime Hills C-5 and C-6 Quadrangle, 1954
Universal Transverse Mercator projection, 1927 North American datum

Approximate mean declination, 1954

SCALE 1: 63,360

CONTOUR INTERVAL 100 FEET

Bedrock geology by T.K. Bundtzen, 1992-93, G.M Laird, 1992-93, K.H. Clautice, 1992-93, M.A. Wilbur, 1992, R.B. Blodgett, 1993, E.E. Harris, 1993, J.G. Clough, 1993 and B.M. Gamble, 1993; surficial geology by T.K. Bundtzen; graptolite identifications by Claire Carter; conodont identifications by Norm Savage and R. Stamm; invertebrate fossil identifications by R.B. Blodgett; palynomorph identifications by Hideyo Hagai; pelecypod identifications by Norm Silberling.



GEOLOGIC MAP OF THE GAGARYAH RIVER AREA LIME HILLS C-5 AND C-6 QUADRANGLES, SOUTHWEST ALASKA

By

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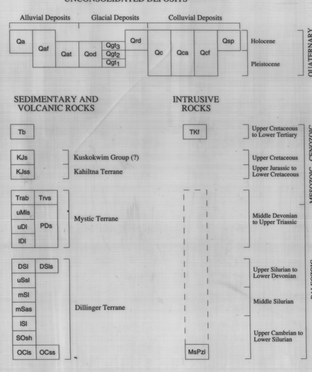
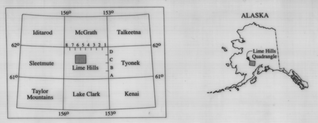
CORRELATION OF MAP UNITS



MAP SYMBOLS

- **Contact**—Queried where questionable
- **High angle fault**—Dashed where approximately located; queried where questionable; dotted where concealed; U=upthrown side; D=downthrown side; arrows show direction of relative movement
- **Thrust fault**—Sawteeth on upper plate; dashed where approximately located; queried where questionable; dotted where concealed
- **Anticline**—Showing trace of axial plane
- **Syncline**—Showing trace of axial plane
- **Strike and dip of beds**
  - **Inclined**
  - **Vertical**
  - **Horizontal**
  - **Overturned**
- **Secondary fold**
- **Strike and dip of joints**
  - **Inclined**
  - **Vertical**
- **Dikes**
- **Unconformity**
- **Bedding partings**
- **Major oxide analysis** (See text; table 1)
- **Fossil locality** (See text; table 2)
- **Paleocurrent direction** (See text; table 3)
- **Mineral occurrence** (See text; table 4)
- **Early Wisconsin ice limit**
- **Late Wisconsin ice limit**
- **Late Wisconsin or Early Holocene ice limit**
- **Glacial erratic**

LOCATION INDEX



DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

Qa **Alluvium**—Unconsolidated, generally well stratified, gray, fluvial silt, sand, and gravel deposited by modern streams. Forms floodplain, fan, and meandering to distributary stream channel deposits. Grain size, sorting, and degree of stratification vary according to stream size, bedrock source, gradient, and flow regime. Clasts of local and distal derivation indicate a mixture of local bedrock and glacial provenance. Qa unit ranges from a few meters thick in small gulches to 50 m in floodplain of Gagaryah River. Portions of Qa unit covered by pioneer vegetation such as alder, birch, aspen, and willow. Nonresistant.

Qaf **Alluvial fan deposits**—Poorly to moderately well sorted, gray to tan (oxidized), sand and gravel deposited where first and second order tributaries join third and fourth order streams. Smaller Qaf deposits originating in steep streams and gulches tend to be poorly sorted, whereas larger Qaf accumulations in second and third order valleys are better sorted and more mature. Age of Qaf in study area ranges from late Wisconsin to mid-Holocene(?), based on crosscutting relationships with unit Qgt_3 and stream dissection by unit Qa. Somewhat more resistant than units Qa or Qat due to calcareous cementation processes.

Qat **Terrace alluvium**—Moderately to well sorted, well stratified, gray to tan (oxidized), fluvial silt, sand and gravel of varying ages that occur on strath or fill terraces that form as a result of uplift, downcutting, and aggredation. Generally preserved in larger third and fourth order stream valleys, with grain size varying from silty sand to cobble rich gravel. Surfaces usually covered by climax to pioneer vegetation, dissected by Holocene streams, and mantled by eolian deposits. Qat deposits judged to be of Wisconsin to early Holocene age, based on relative relationships to other unconsolidated units. Ranges from 3 to 30 m thick in exposed stream cuts. Nonresistant.

Qod **Outwash and minor glacial till**—Poorly consolidated, fluvial sand and gravel deposited distally from glacial sources in the Revelation Mountains and western Alaska Range. Includes local patches of Early Wisconsin to Early Holocene ice contact deposits (till), the age of which is dependent on relationships to each of the three glacial drift units (Qgt_3, Qgt_2, Qgt_1). Qod unit on Gagaryah River drainage locally contains abundant, recycled, glacial erratic boulders. Qod ranges from 1 to 5 m thick. Older Qod somewhat resistant when subjected to calcareous cementation processes.

Qgt_3 **Late Wisconsin or Early Holocene till**—Unsorted to poorly sorted, clay, silt, sand and diamicton deposited by glacial ice. Polyhedral shaped granitic clasts derived from Revelation batholith are very abundant and largely unweathered. Qgt_3 contains from 12-30 kettles per km^2. Unit largely unmodified except incision by upward tributaries of Swift River. Reaches maximum thickness of 80 m in Swift River Canyon. Organic sediment collected from Qgt_3 in Swift River canyon yields radiocarbon age of 6,210 ± 90 yr BP; however, this may represent reworked till and not date primary age of unit Qgt_3. We correlate Qgt_3 with either a late stage of the Farewell II Glaciation (Kline and Bundtzen, 1986), or an unnamed, early Holocene advance originating in the Revelation Mountains. Generally nonresistant unit compared to Qgt_1 till, but similar in character to Qgt_2 till.

Qgt_2 **Late Wisconsin till**—Unsorted to poorly sorted, clay, silt, sand, gravel and diamicton deposited by glacial ice. Erratics are polyhedral, striated, and subrounded, relatively fresh granitic boulders derived from the Revelation batholith to the east of the study area. Prominent moraine not generally dissected by small streams, but cut by Swift River. Till ranges from 50 to 90 m thick in Swift River area, and 3-15 m thick in upland east of Gagaryah River, where Qgt_2 deposits are preserved in small cirque valleys. Contains from 7-15 kettles per km^2. Correlated with Farewell II Glaciation described by Kline and Bundtzen (1986) northeast of the study area. Generally less resistant than Qgt_1 deposits because of general absence of calcareous cementation processes.

Qgt_1 **Early Wisconsin till**—Unsorted to poorly sorted, clay, silt, sand, gravel and boulders deposited by glacial ice. Cobble and boulders are polyhedral, sometimes striated and subrounded or rounded. Granitic erratics exhibit frost-induced fracturing and weathering rinds, and probably derived from distal plutonic sources in the western Alaska Range or Revelation Mountains. Morainal deposits extensively dissected by Holocene streams and modified by hillslope erosion. Contains 2-7 kettles per km^2. Qgt_1 occurs as: (1) in a 50-70 m thick, prominent terminal moraine on lower Gagaryah River; (2) in highly modified, isolated, and eroded till sheets in major trunk valleys and (3) side glacial or lateral accumulations along the flanks of bedrock uplands. Judged to be of early Wisconsin age on the basis of correlation with Farewell I Glaciation defined by Kline and Bundtzen (1986) northeast of the study area. Resistant due to clay and calcareous cementation processes.

Qrd **Reworked glacial drift**—Poorly to moderately sorted, somewhat stratified sand, silt, and cobbles originally derived from glacial deposits. Forms elongate shaped deposits on moderate slopes in main Swift River valley and in areas of low relief north of lower Gagaryah River. Thought to be derived exclusively from Qgt_1 till, and hence, of post Early Wisconsin age. Moderately nonresistant, and only outcrops in stream canyons. Ranges from 2-5 m thick.

Qc **Colluvium, undifferentiated**—Unsorted to poorly sorted, fine to coarse grained, angular bedrock debris derived from frost riving followed by gravity transport down steep slopes, cirque headwalls, and gullies. Some colluvium in small cirques in north central portion of study area is transitional between coarse grained talus and rock glacier deposits. Thickness highly variable and reaches a maximum of 20 m in valley bottoms.

Qca **Colluvial-alluvial deposits**—Poorly to moderately sorted, silt, sand and gravel that occur at the intersection of first order tributary and second or higher order streams. Locally Qca deposits contain alternating stratified and unstratified zones or lenses in gullies or steep tributary valleys with intermittent drainage history. Qca fans are most active in spring when meltwater runoff takes place. Nonresistant unit. Ranges in age from Late Wisconsin to Holocene; Qca in some fans is currently forming.

Qcf **Colluvial fan and terrace deposits**—Composite unit containing poorly sorted, partially stratified silt, sand, gravel and colluvium that form broad, coalescing colluvial-alluvial fans and buried, ancestral(?) terrace deposits. May contain very minor patches of drift. Thought to postdate Early Wisconsin till (Qgt_1) in lower Swift River. Nonresistant and rarely exposed. Thickness varies from 2-15 m thick, but is highly variable.

Qsp **Silt and peat**—Poorly stratified, black to brown, organic rich, alluvial, lacustrine, and bog silt and peat. Qsp unit best exposed near two unnamed lakes and in upper reaches of North Fork of Swift River, all in northeast portion of study area. At these localities Qsp consists of several stacked palzas up to 5 m thick. Generally frozen except near stream cuts. Thought to be of Holocene age.

BEDROCK UNITS

MESOZOIC-CENOZOIC IGNEOUS ROCKS

Tb **Basalt**—Aphanitic to very fine grained, dark gray, olivine-augite, columnar jointed basalt. Zoned anorthite-labradorite phenocrysts make up to 15 percent of fabric; olivine grains occur in elongate clusters. The Tb unit is very similar both petrographically and chemically (table 1) to tholeiitic basalts of Trab unit of Mystic Terrane; however, a K-Ar whole rock age of 58.3 Ma (Gamble, U.S. Geological Survey) suggests early Tertiary age. Generally resistant and forms blocky outcrops where exposed.

TKf **Alaskite**—Light gray to, tannish weathered, bleached, very fine grained to porphyro-aphanitic, biotite bearing alaskite; color index less than 5. Resorbed quartz and feldspar phenocrysts locally comprise about 10 percent of fabric. Undated but similar to calc-alkaline, late Cretaceous or early Tertiary plutons reported elsewhere in region (Bundtzen and others, 1988; Gilbert and others, 1988; table 1, this study). Moderately resistant and forms coarse talus on steep slopes, but outcrops are rare.

KUSKOKWIM GROUP (?)

KJs **Coarse grained sandstone and conglomerate**—Medium gray to medium olive green, volcaniclastic, poorly sorted, subangular to subrounded, pebble to cobble conglomerate, and pebble sandstone. Sand layers lack graded intervals, exhibit distinctive large-scale foresets, and contain coalified layers, all of which collectively are suggestive of nonmarine or shallow marine environments. Fossil data is inconclusive; palynomorphs (table 1, no. 31, 32, 33) indicate either Cretaceous, Tertiary or indeterminate ages, and palynomorph contamination may be a problem. We tentatively correlate KJs to the Kuskokwim Group, which ranges in age from early Late to late Late Cretaceous in age (Cady and others, 1955; Miller and Bundtzen, 1994). KJs might be Tertiary or younger than either Mesozoic flysch basin. Moderately resistant and forms cobbly outcrops on ridgetops and steep scree-covered slopes.

KAHILTNA TERRANE

KJss **Fine grained sandstone, siltstone and minor conglomerate**—Medium to dark gray, fine grained, lithic sandstone, siltstone, and minor pebble conglomerate. Sandstone and conglomerate contain angular to subangular clasts of chert and quartz (45 percent), volcanic clasts (10 percent), lithic fragments (20 percent), feldspar (10 percent), granitic clasts (10 percent), and undetermined opagues and white mica. Clasts of OCls unit (crossbedded, silty limestone) from Dillinger Terrane recognized in outcrop. Flutes, ripple marks, and flame structures are locally abundant, and sandstones contain cyclic, graded Bouma "Tbcde" intervals, which indicate that KJss unit was deposited by turbidity currents. Age uncertain, but probably part of Kahiltna Terrane of Early Cretaceous age (Bundtzen and others, 1988). Unit apparently underlies KJs unit. Somewhat resistant where exposed in creek cuts of Swift River. Believed to be at least 300 m thick, based on correlation of limited outcrops in study area.

MYSTIC TERRANE

Trab **Pillow basalt, mafic sills and agglomerate**—Dark green-gray, massive, aphanitic to medium grained phaneritic, olivine-clinopyroxene rich, basalt, olivine diabase, gabbro, and mafic agglomerate, the latter largely derived from the two previous lithologies. Composition of mafic sills variable, but frequently composed of fresh, poikilitic to medium grained phaneritic, olivine-augite diabase, gabbro, and locally picrite with chemistry indicating titanium rich, tholeiitic compositions (table 1, no. 3, 4, 6, 8). Pillow structure locally very well developed in basalt flows, with rinds reaching up to 1 m in diameter, and indicating right-side-up in all localities (shown as "p" on plate one). Agglomerate and pillow basalt usually serpentinized with prehnite, pumpellyite, and chlorite alteration common. Late Triassic fossils found in interbedded volcaniclastic rocks (Trvs unit). Generally resistant where in outcrop, and forms rugged cliff faces and blocky rubble. Trab unit has minimum thickness of 400 m north of Swift River.

Trvs **Coarse sandstone and silty shale**—Tan to greenish gray, pebble rich, immature conglomerate, coarse sandstone, and distinctly brown silty shale. Sandstone (one thin section) contains abundant serpentinized mafic volcanic clasts. Shale at one locality (table 2, no. 40) contains abundant cephalopod and pelecypod fauna of Late Triassic age. Very nonresistant and rarely exposed. Trvs unit estimated to be 20-30 m thick, and is interbedded in Trab unit.

uMls **Limestone, conglomerate, shale and chert**—Brown to gray, layered to nodular limestone, calcareous siltstone, vari-colored chert, and limestone-chert conglomerate. Conglomerate contains rounded clasts of limestone (25 percent), chert, (25 percent), and silty sandstone (50 percent). Unusual limestone breccia rubble found, but not inplace. Micritic limestone contains abundant conodont fauna (table 1, no. 36). uMls unit is nonresistant, and forms rare rubble on vegetated slopes. Thickness not determined.

uDl **Massive to laminated, fossiliferous limestone**—Light to medium gray, massive to laminated, frequently fossiliferous with corals dominating, fetid limestone, and minor, black, carbon-rich shale. Presence of *Amphipora* sp. suggests lagoonal facies. Numerous fossil collections (table 2, no. 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 35) indicate Frasnian Stage, Late Devonian age. Strong, fetid odor locally developed. CAI (thermal maturation indices) in conodonts average 2.5, and are anomalously low compared to other Paleozoic carbonate units in western Alaska Range. Moderately resistant; massive beds form cliffs suitable for raptor nesting sites. Thickness roughly estimated at 500 m, 4 km south of Gagaryah River.

lDl **Micritic limestone and limestone breccia**—Dark gray, locally fossiliferous, micritic limestone, and lighter gray, oolite-rich limestone breccia. Has yielded rich brachiopod fauna of Emsian to Eifelian stages, or late Early to early Middle Devonian age (table 2, no. 13, 14, 34). Superficially similar to uDl unit and exhibits strong fetid odor. Nonresistant and rarely crops out; thickness roughly estimated at 150 m.

PDs **Sublithic sandstone and minor siltstone**—Tan to ferric brown, medium to coarse grained, calcareous, quartzose, sublithic sandstone, siltstone, and very minor black pebble conglomerate. Composed of subangular to subrounded chert (35 percent), quartz (25 percent), feldspar (15 percent), calcite as matrix (10 percent), mafic volcanic and felsic plutonic clasts (15 percent), and rarely white mica (<0.5 percent). Matrix debris constitutes less than 5 percent of fabric. Chert and igneous provenance and fabric character distinguishes these rocks from clastic lithologies (OCls, OCss, mSss and uSsl units) of Dillinger Group. PDs unit is nonfossiliferous, but overlies highest member of Dillinger Group and is tentatively correlated with Middle Devonian to Pennsylvanian Mystic Terrane clastic rocks in McGrath A-2 and Lime Hills D-4 Quadrangles (Bundtzen and others, 1988; Gilbert and others, 1990).

DILLINGER TERRANE

DSls **Calcarenite, calcareous siltstone and laminated limestone**—Thin to thick bedded, buff to orange weathered, light to medium gray, phyllitic calcarenite; thin bedded, orange to buff weathered, phyllitic calcareous siltstone, and light gray, silty limestone. Overall carbonate content comprises from 35 to 55 percent of total DSls unit. Contains channelized limestone breccia bodies (hr, plate 1) in two areas. Clastic units exhibit both stacked forset beds and minor graded Bouma "Tbcde" intervals. Believed to represent proximal turbidite or foreslope depositional facies. Fossils not found in study area, but overlies Late Silurian graptolite bearing beds of uSsl unit, and Late Silurian to Late Devonian conodonts of DSl unit (table 2, no. 16, 23). Blodgett and Gilbert (1993) report conodont fauna of Lochkovian to Pragian age (Early Devonian) from possible equivalent unit in Lime Hills D-4 Quadrangle. Deformation makes true thickness estimates difficult, but DSls is approximately 350 meters thick in the west-central part of study area. We correlate both DSls and DSl units with Barren Ridge Limestone Formation as defined by Churkin and Carter (in press) in the Terra Cotta Mountains.

DSl **Laminated limestone**—Light to medium gray, laminated to locally massive, micaceous silty limestone and very minor limestone conglomerate. Sometimes difficult to distinguish from lime rich portions of DSls unit, which it interfingers with. Conglomerates may suggest foreslope depositional environment. Contains conodont fauna ranging in age from Late Silurian to Late Devonian (table 2, no. 23) from study area; Bundtzen and others (1982) report Early Devonian conodont fauna from DSl unit in McGrath B-2 Quadrangle. Correlated with lower portion of Barren Ridge Limestone Formation as defined by Churkin and Carter (in press) in Terra Cotta Mountains. DSl unit estimated to be 350-400 m thick in northeast part of study area. Resistant and forms impressive, 35 km long, strike ridge in study area.

uSsl **Thin bedded calcareous sandstone, graptolitic shale and silty limestone**—Thin bedded, gray to tan micaceous sandstone, silty limestone and dark gray graptolitic shale and siltstone. Clast compositions of feldspathic litharenite, with up to 6 percent white mica content. Interstitial matrix component locally reaches 25 percent. Flute casts and ripples locally observed. Contains graptolites of Ludlovian stage, Late Silurian age, which are nearly identical to uSsl unit mapped in McGrath A-2 and B-2 Quadrangles (Bundtzen and others, 1982; 1988). We correlate uSsl unit with uppermost part of Terra Cotta Sandstone Formation as defined by Churkin and Carter (in press) in Terra Cotta Mountains. Unit estimated to be 75-100 m thick in study area.

mSl **Argillaceous limestone**—Medium to dark gray, laminated limestone, and brown weathered, graptolite bearing silty sandstone intervals. mSl limestone member forms distinctive rib-like outcrops throughout northwest corner of study area. Contains both conodonts and graptolites of Wenlockian age in study area (table 2, no. 3, 11, 12, 24); this prominent Wenlockian limestone crops out throughout the eastern McGrath Quadrangle (Bundtzen and others, 1982, 1988). Part of Terra Cotta Sandstone Formation defined by Churkin and Carter (in press). Estimated to be 40 to 65 m thick in study area. Resistant and forms linear outcrops traceable for many kilometers.

mSss **Lithic sandstone and minor limy siltstone**—Medium olive gray to terra cotta, thin to thick bedded, calcareous lithic sandstone with subangular to subrounded clasts of quartz (50 percent), feldspar (15 percent), white mica (4-5 percent), slate clasts (15 percent), and undifferentiated matrix (15 percent). Could be classified as a feldspathic litharenite after Folk (1968). Locally contains Bouma "Tabcd" graded intervals, and flutes suggestive of deposition by turbidity currents. Nonfossiliferous in study area, but overlies Llandoverian stage (upper Lower Silurian) graptolite horizons (table 2, no. 2) in northwest corner of study area. Correlated with lower part of Terra Cotta Sandstone Formation after Churkin and Carter (in press). Estimated to be 100-150 m thick in study area. Nonresistant and forms poorly exposed scree slopes.

lSl **Fetid limestone and black chert**—Very thin, dark gray, fetid, laminated, limestone and thin interbeds of black cherty argillite. Fossils were not positively identified in study area, but elsewhere, lSl yields the Early Silurian graptolite *Cyrtograptus centrifugus* (Bundtzen and others, 1982). Believed to be the lowest member of Terra Cotta Sandstone Formation after Churkin and Carter (in press). We have informally-referred to lSl as "Boundary Limestone", which marks base of Terra Cotta Sandstone Formation. Estimated to be 15-25 meters thick. Nonresistant and rarely outcrops.

SOsh **Graptolitic shale, siltstone and chert**—Medium to dark gray, fetid, fissile, isoclinally folded, carbonaceous shale, siltstone, and black, bioturbated, siliceous siltstone and chert. Very thin graded Bouma "Tcde" graded intervals in silts and very fine sands. Sulfurous plumes on joints and bedding partings distinguish SOsh from other Paleozoic shale-rich units. Contains Early Ordovician to upper Lower Silurian graptolites in study area (table 2, no. 2, 4, 5, 6, 7, 8, 9, 10, 17, 18). Correlated with upper part of Post River Formation, after Churkin and Carter (in press). Estimated to be 150 m thick in study area. Very nonresistant, despite distinctive rubble-crop character.

OCss **Thin bedded siltstone, shale and silty limestone**—Buff weathered, very light gray to light olive when fresh, thinly bedded, siltstone, shale and minor silty limestone, usually isoclinally deformed. Mapped as a more shale-rich variant of main OCls unit described below. Paleocurrents indicate northeast current directions. In study area, OCss underlies Argenian Stage, Lowest Ordovician graptolite zones (table 2, no. 17), and regionally, both OCss and OCls underlie Tremidocian Stage, Lowest Ordovician graptolite zones. Estimated to be 150-200 m thick in study area. Nonresistant, but well exposed in cuts along Gagaryah River.

OCls **Silty limestone and shale**—Rhythmically layered, thin-bedded, orange to buff weathered, light gray when fresh, silty, laminated to cross-bedded, limestone and silty shale. Individual limestone and shale partings range from 5-25 cm thick, and average about 15 cm thick. More thin-bedded than OCls unit mapped in McGrath Quadrangle by Bundtzen and others (1982, 1988) and Gilbert and others (1988, 1989). Shale and siltstone exhibit ripple-laminated structure with amplitudes of 5-70 cm. Some limestone interbeds contain graded "Tcde" intervals. Most distinctive sedimentary structure is stacked or wedge-shaped cosets 3-15 cm thick. Paleocurrents from OCls indicate strong northeast current directions. In study area, OCls underlies Areneigan stage (Early Ordovician) graptolite zones (table 2, no. 17). Churkin and Carter (in press) would regard OCls and OCss units as part of Post River Formation. We correlate OCls and OCss units with Rabbit Kettle Formation in Yukon and Northwest Territories, Canada, which ranges in age from Late Cambrian to Earliest Ordovician (Gordey and Anderson, 1993). Hence we separate OCls and OCss units or Rabbit Kettle equivalent units from SOsh, which is probably equivalent to base of Road River Group (Gordey and Anderson, 1993). We refer to OCls and OCss units as "Lyman Hills Formation" after extensive exposures in Lyman Hills north of study area. Estimated to be at least 650 m thick along lower Gagaryah River; the base is not exposed. Generally nonresistant, but forms distinctive orange-colored hillslopes throughout study area.

MzPzi **Gabbro and diorite dikes and sills**—Brownish weathering, to dark green-gray, very fine grained to medium grained phaneritic, uncommonly micro-pegmatoidal, olivine, aergerine-augite, gabbro, diorite, and uncommon alkali syenite. Quartz rare or absent. Color index = 45-65. Plagioclase twins suggest anorthite-labradorite compositions. Larger olivine and clinopyroxene grains remarkably fresh; groundmass is commonly altered. Larger sill bodies have produced zones of hornfels and uncommonly, calc-silicate skarn halos in host OCls lithologies. MzPzi is always olivine normative and sometimes nepheline normative and exhibits alkaline character (table 1). Radiometric age dating techniques have proven so far to be unsuccessful; however, because MzPzi exclusively intrude OCls and OCss units, an Early Paleozoic age for MzPzi seems likely. A plausible alternative is that MzPzi dikes and sills are feeders for Triassic volcanism in the study area (Trab unit). Resistant and forms blocky rubble standing in relief against host OCls and OCss units.

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