FORMATION AND AGE \ CHARACTERISTIC	DEFINITION / TYPE SECTION LOCATION	RELATIONSHIP WITH BOUNDING UNITS	DISTRIBUTION	THICKNESSES AT VARIOUS LOCATIONS	LITHOLOGIES / GRAIN SIZES	DIAGNOSTIC LITHOLOGIC FEATURES	COLOR(S)
GRUBSTAKE (late Miocene–early Pliocene)	The interbedded dark-colored sediments making up the walls of the valley of Grubstake Creek and the banks of Totatlanika Creek north to the confluence with Hearst Creek. Exposures on Grubstake Creek.	The contact with the overlying Nenana Gravel varies---locally apparently conformable, elsewhere unconformable. Conformable with the underlying Lignite Creek Formation.	Local extent.	Type section, 1000 ft Grubstake Creek, 1000-1500ft North of Coal Creek, 1000-1500 ft Buzzard Creek, 500 ft	Claystone, sandstone, fine conglomerate, thin coal and bony coal beds. Ratios of rock types in Wood River field: Claystone...70% Sandstone...15% Conglomerate...15% However, sandstone may predominate in other sections of Grubstake Formation.	The distinctive greenish-gray shale and claystone occurs in the Healy Creek and Hosanna Creek fields. Locally reworked ash beds.	Sandstone---very dark gray to almost black Claystone---dark gray to greenish gray.
LIGNITE CREEK (middle Miocene)	Strata of the coal-bearing group above the No. 6 coal bed at the type section on Suntrana Creek. It extends to the base of the distinctive greenish-gray shale at the top of the coal-bearing group. Suntrana Creek	Usually conformably overlies the Suntrana Formation but locally unconformities exist.	The coal-bearing facies is exposed in the Healy Creek and Hosanna Creek coal fields and the southern part of the Tatlanika and Wood River fields. The non-coal-bearing facies is exposed in the northern and western parts of the basin.	Type section, 630 ft Northwest part of Hosanna Creek field, 500 ft East end of Healy Creek field, 1000 ft Tatlanika Creek field, 620 ft Wood River field, 800 ft	Coal-bearing facies: Pebbly sandstone and conglomerate...65% Claystone, siltstone, and interbedded fine sandstone...30% Coal...5%	Repetitive sequence of pebbly sandstone, claystone, and coal. However, each sequence is capped by several thin coal beds rather than the common thick one for each Suntrana Formation sequence. Arkosic sandstones and conglomerates, overall less resistant pebbles than in the Suntrana and Healy Creek Formations. Calcite-cemented concretions are present in the sandstones at certain locales. Other layers are cemented with iron oxide or iron carbonate. Pale blue vivianite masses (1/8 to 1/4 in diameter) occur in a green shaley claystone near the top of the Lignite Creek Formation (Wahrhaftig, 1958b). Vivianite is a hydrous iron phosphate $[Fe_3(PO_4)_2 \cdot 8H_2O]$, dimorphous with metavivianite, and sometimes is referred to as blue-iron earth or blue ocher. It is commonly found in monoclinic crystals, fibrous masses, and earthy forms, and often in association with clays and peats.	Sandstones typically buff rather than chalky white of Suntrana Formation.
SUNTRANA (middle Miocene)	Section between the top of the Sanctuary Formation and the top of the No. 6 bed at the old Suntrana Mine. Suntrana Creek	Conformably overlain by the Lignite Creek Formation. Locally unconformably overlies Sanctuary Formation.	Widely exposed in Healy Creek and Hosanna Creek coal fields; also occurs in Rex Creek, southern Tatlanika Creek fields, and probably underlies most of the Wood River field. Absent in the Western Nenana field.	Coal Creek tributary to Wood River...1000ft Coal Creek tributary of Healy Creek...1290 ft	Sandstone and conglomerate...70% Claystone...15% Coal...15% Summary of lithologic character of exposed and measured sections: Coal... %...............4-23 Avg. thkness...3-16 ft Max. thkness...5-60 ft Clay and silt... %..................8-25 Avg. thkness...5-16 ft Max. thkness...10-75 ft Sandstone... %..................52-84 Avg. thkness..30-93 ft Max. thkness..80-215 ft Number of repetitive sequences...5-12	Cyclic fining-upward sequences, many times repeated. Wahrhaftig (1958b) states that there are up to 10 or 12 in the Suntrana Formation alone. Buffler and Triplehorn (1976) cited evidence for at least 23 fining-upward cycles along Healy Creek and Suntrana Creek at Suntrana. Lithologically similar to Healy Creek Formation sands, but cleaner overall. Pebbles of conglomerates relatively more resistant than those in the arkosic Lignite Creek Formation. Pebbles less than 1 in diameter predominantly consist of the following rock types: A. Resistant rock types...65%: 1. Quartz 2. Chert 3. Quartzite 4. Argillite 5. Jasper B. Nonresistant rock types...35%: 1. Granitic rocks 2. Gabbro 3. Greenstone 4. Graywacke 5. Volcanic rocks	Sandstones---chalk white to very light buff. May be stained orange or red for up to several feet above a coal bed.
SANCTUARY (early–middle Miocene)	Shale between the top of the F bed and the coarse conglomerate beneath the G and No. 1 beds at locale of old Suntrana Mine. Exposures on the east bank of the Sanctuary River near the north boundary of Mt. McKinley National Park.	Locally its upper contact cannot be defined precisely because of interbedded coals. Predominantly a conformable contact with Healy Creek Formation but locally lies directly on schist or other basement rocks.	From Savage and Sushana Rivers to the Rex Creek and Wood River fields.	East end of Healy Creek field...350 ft South margin of Hosanna Creek field...less than 10 ft East of mouth of Popovich Creek... 200 ft Eastern end of Hosanna Creek field...150-200 ft Type locality... 90-130 ft	Shale/claystone. At type locality, silt is common in shale and thin sand beds are present. Locally, sand beds are common. Thin coal and bone.	Finely banded or varved with alternating dark-weathering and pale-weathering laminae. Where coal and bone are present (as on Coal Creek tributary to Wood River), it gives the formation a darker appearance.	Gray on fresh exposures, weathers to a characteristic chocolate or yellowish brown.
HEALY CREEK (late Oligocene–early Miocene)	All of coal-bearing group below F bed. Exposure on north-east wall of Healy Creek canyon at Suntrana from a few feet south of the old Usibelli tipple northward for approximately 1000 ft.	Conformable contact with overlying Sanctuary Formation. Lies unconformably on irregular, highly weathered Birch Creek Schist at type section. Elsewhere, the basement is Totatlanika Schist. Locally a basal conglomerate present on schist. If present, the underlying schist is less altered than sections of schist overlain by coal or clay.	Probably the most widely distributed of the formations of the coal-bearing group but occurs as isolated patches. Recognized from Sushana River on the west to the Jarvis Creek field on the east. Most of the scattered patches of coal-bearing rocks of somewhat questionable affinity north of the Alaska Range are probably correlatable with this unit.	Head of Davis Creek...1150 ft Mystic Creek field and head of Healy Creek field...approx. 1000 ft. Western Nenana field...550 ft Jarvis Creek field...approx. 2000 ft	Weakly consolidated sandstone, conglomerate. Siltstone and claystone...20-50% Coal Higher proportion of clay-size material than in the Suntrana or Lignite Creek Formations.	Lenticularity of beds; rapid lateral and vertical changes in lithology. Pebbles more resistant than those of the arkosic Lignite Creek Formation. Tendency toward mixed lithologic components in same bed, and indistinct separation. Claystones often contain pebbles and rock fragments and sandstones commonly have a clay binder. Claystones also often contain gray sideritic concretions up to several ft in diameter; these may weather to bright orange or deep red. Proportion of claystone increases upward.	Claystones---whitish, gray, brown, purplish-gray.

FORMATION AND AGE	WEATHERING FEATURES	SEDIMENTARY STRUCTURES	FOSSILS	COMPOSITION	HEAVY MINERALOGY	PROVENANCE	DEPOSITIONAL ENVIRONMENT
GRUBSTAKE (late Miocene–early Pliocene)	Badland exposures rare. Slumps and earthflows are common in the sandstones along the claystone beds. The sandstones weather to brownish red, and joints and cracks are stained orange by iron-oxide minerals. Claystones are poorly consolidated and disintegrate rapidly when wet, resulting in many large landslides.	Well developed trough cross-beds at several places in the sandstone.	Sandstones contain coalified logs and driftwood. The wood is partly replaced by iron carbonate. White-weathering fine vitric tuffs contain erect, coalified, rooted tree trunks.	A conglomerate bed in this unit north of the forks of Coal Creek shows the following pebble population: 1. Quartz pebbles...30% 2. Chert pebbles...35% 3. Schist and graywacke pebbles...15% each 4. Other rocks, mainly volcanic...5%	No data.	The pebble population of the fine conglomerate (milky quartz and dull black chert) indicates that the source of the sediments was to the south. Cross-current flow directions in sandstones indicate source areas to the south, opposite that for the Lignite Creek and Suntrana Formations.	Basin(s) of deposition alternating between broad shallow lakes and flat alluvial plains. Conditions too unstable for the accumulation of significant coal deposits. Locally, it appears that lacustrine deltas are splayed into the lakes of the formation.
LIGNITE CREEK (middle Miocene)	Badland outcrop features form by frost-spalling into sculptured regular forms.	Cross-bedded throughout with trough cross-beds the most common. Locally the cross-bedding is intricately contorted by deformation that was penecontemporaneous with deposition of the sands.	Preserved woody materials from the original coal-forming forest.	Sandstones: Quartz....................65-70% Plagioclase...............10-15% Orthoclase.................5-10% Chert and rock fragments..............10% Heavy minerals...........10%	Heavy-mineral fraction chiefly muscovite with minor: 1. Hornblende 2. Biotite 3. Epidote-clinozoisite 4. Chlorite 5. Pigeonite 6. Tremolite-actinolite 7. Garnet 8. Tourmaline 9. Opaque minerals	Current directions measured from the cross strata are almost uniformly to the south, with the source of clastic components to the north of the present Nenana basin.	The same basin(s) in which the Suntrana Formation accumulated continued to subside but probably at a faster rate. The growth of vegetation could not keep pace with subsidence, and the coal swamps were frequently inundated by flood waters forming large shallow lakes in which silt and clay accumulated.
SUNTRANA (middle Miocene)	Badland topography with gullies cut to concave theatres and intermediate narrow coxcomb sandstone ridges or pinnacles.	Strongly cross-bedded with trough cross-stratification and planar cross-stratification.	Fossilized leaves are best preserved in adjacent beds baked by the burning of coal beds. Schlaikjer (1937) found fossil fish of Miocene age in coal-bearing rocks near the old Suntrana coal mine. Coalified stumps, roots, leaves, and twigs.	Sandstones (light-meral fraction), avg. 93.5% of total: 1. Quartz...............70-75% 2. Orthoclase...........5-10% 3. Plagioclase...........1-5% 4. Chert and rock fragments.......5-10% 5. Heavy minerals.....6.5% Clay-mineral contents change from dominantly kaolinite below the Suntrana Formation to a higher proportion of montmorillonite in the Suntrana Formation and above (Dickson, 1981).	Sandstones (heavy fraction), avg. 6.5% of total: 1. Fine-grained sericite 2. Micaceous chlorite 3. Clinozoisite-epidote 4. Hornblende 5. Tremolite-actinolite 6. Biotite (stilpnomalane?) 7. Garnet 8. Zircon 9. Rutile 10. Magnetite-ilmenite	Resistant quartz, quartzite, and black chert pebbles of petromict conglomerates indicate that the most likely source area was the western end of the Yukon-Tanana upland to the north. Cross-bedding directions in sandstone indicate the source of the clastic components was to the north, probably derived from the southern Yukon-Tanana Upland.	Subsiding plain with scattered coal swamps. The relatively greater lateral continuity of individual coal beds indicates more uniform depositional conditions than elsewhere in the coal-bearing group. Depositional events were cyclic with alternation of uplift and subsidence 8-10 times during the deposition of the Suntrana Formation.
SANCTUARY (early–middle Miocene)	Breaks down quickly to a mass of flat chips; when saturated, forms masses of sticky mud. This results locally in large slumps and landslides, and rounded landforms.	None.	Coalified woody fragments.	Clay mineralogy: 1. Kaolinite................0-50% 2. Montmorillonite.....0-40% 3. Illite.......................20-50% 4. Chlorite..................10-50% Major-oxide analysis: 1. SiO_2............59.96-70.83% 2. Al_2O_3.........15.60-16.05% 3. Fe_2O_3...........7.05-7.51% 4. CaO...............0.80-1.00% 5. MgO..............1.61-1.76% 6. Na_2O............0.34-0.51% 7. K_2O.............2.86-3.46% 8. TiO_2............0.72-0.81% 9. LOI.............8.67-9.34%	No data.	Clays have a high content of silica (quartz). Wahrhaftig (1958b) found the content of kaolinite to be low at the type section, with high chlorite (or montmorillonite) and illite. Contrasted with the clay mineralogy of the Healy Creek Formation, this suggests a different provenance for the clay in this unit, possibly a basic-igneous rock source.	Large shallow ancient lake.
HEALY CREEK (late Oligocene–early Miocene)	Weathers to badland exposures, with more pronounced gullying than in Suntrana and Lignite Creek Formations. Outcrops are often coated with a thin veneer of fluffy clay.	Poorly developed cross-bedding, usually large scale with flat dips and not readily recognizable.	Coalified leaves and grasses in fissile claystones (shales).	Sandstones (light-mineral fraction): 1. Angular quartz.......70-85% 2. Orthoclase................5-20% 3. Plagioclase................1-5% 4. Chert and rock fragments...........1-5% Clay mineralogy: 1. Kaolinite..............40-100% 2. Montmorillonite......0-50% 3. Illite.........................0-30% 4. Trace of chlorite	Sandstones typically have less than 4% heavy minerals. The chief constituents are: 1. Iron-stained sericite with traces of pigeonite. 2. Clinozoisite-epidote 3. Chlorite 4. Tourmaline 5. Garnet 6. Zircon 7. Topaz 8. Rutile 9. Partially oxidized opaque iron ores	Mineralogies of the sandstones and conglomerates reflect those present in nearby basement rocks from which they were probably derived. Quartz pebbles poorly rounded and most likely derived from quartz veins in nearby metavolcanics. Current-direction measurements from locally developed cross-beds indicate multiple source areas for clastic components of sandstones.	Lowland alluvial plain with considerable local variations in conditions of deposition, but including densely vegetated coal swamps, relatively quiet muddy backwater ponds, and shifting, sinuous river channels cutting the sandy plains.

FORMATION AND AGE	CHARACTER OF COALS: PHYSICAL	QUALITY	THICKNESS RANGE	PERCENTAGE COAL IN SECTION	CONTINUITY	INTERBEDS	NUMBERED, LETTERED, OR NAMED BEDS	RESOURCES / RESERVES	COMMENTS
GRUBSTAKE (late Miocene–early Pliocene)	Thin, lenticular, and woody.	Poor.	Less than 1 ft. Seams unminable; essentially can be considered as part of overburden.	Minimal.	Thin and lenticular.	Claystone, siltstone, fine sandstone, and bony coal.	None.	Minimal.	Overall, this unit is lithologically more similar to the overlying Nenana Gravel than to the coal-bearing group.
LIGNITE CREEK (middle Miocene)	Coal beds break up into masses of long narrow flakes parallel to bedding. These flakes were probably formed from the intense compression of twigs and branches of the coal-forming forest. This is in contrast to the blocky fracture of most coals of the Suntrana Formation.	Subbituminous. Predominantly less than 10% ash, some less than 5%. Low sulfur content, nominally 0.2%. Heating values typically 8000-9500 Btu/lb.	Relatively thin.	Coal typically composes 5-10% of most sections.	Discontinuous. Correlation of coal beds is difficult.	Typically, thinner coal seams are interbedded with claystone. Sandstone, siltstone, and conglomerate are also common.	None.	Contains the third largest deposits of the coal-bearing group.	Wahrhaftig (1970a-h) often grouped the Lignite Creek and overlying Grubstake Formations together for mapping purposes. Locally the claystones contain pale blue vivianite masses up to 1/4 in diameter. Large coal fragments are included in certain sandstones of the unit; presumably these are redeposited rip-up peat bodies.
SUNTRANA (middle Miocene)	Predominantly blocky fracturing and well cleated. Upper portions of beds 5 and 6 are woody with interlocking mats of compressed branches and twigs, which weather to a loose network of thin flat laths.	Subbituminous. Ash content usually less than 10%. Typically, 50% durain and 50% vitrain with some beds having a layer of fusain at the top. Low sulfur content, nominally 0.2%. Heating values usually 8000-9500 Btu/lb.	Generally in beds 10-60 ft thick.	In typical sections, coal composes 15-20% of the total thickness.	Many of the coal beds are thick and comparatively continuous. Certain beds (as No. 6) are continuous along strike for over 10 mi. Generally, coal beds can be correlated more easily than those of other formations of the coal-bearing group.	Fine-grained sandstone, siltstone, and claystone.	G, 1, 2, 3, 4, 5, 6	Contains most of the coal resources of the Nenana basin.	Stripping conditions are very favorable in many areas.
SANCTUARY (early–middle Miocene)	Beds thin, lenticular, and bony. Typically, thin coal and bone coal interbedded with claystone.	Low quality.	Thin coal and bone layers.	Very low percentage of total section.	Poor continuity; thin beds pinch out quickly laterally.	Claystone and bone coal.	None.	Minimal. Beds unminable.	Useful marker bed throughout the Nenana basin.
HEALY CREEK (late Oligocene–early Miocene)	Most beds black with a dull luster, locally bright banded, and blocky fracture.	Subbituminous. Typically less than 10% ash, some less than 5%. Low sulfur content, nominally 0.2%. Heating values 8000-9500 Btu/lb.	Less than 1 in up to 60 ft. Many beds are too thin to be mined. Typical sections generally contain from from 25 to 100 ft of coal.	Sections of moderate thickness average 10-20% coal, but locally may be as low as 3-5%.	Lenticular and discontinuous. Upper coal beds of formation are thicker and more continuous.	Many of the coals are thin-bedded, lenticular, and bony. Claystone interbeds grade abruptly laterally to coarse-sand members. Carbonaceous claystone and bone interbeds are common.	A, B, C, D, E, F	Holds the second largest quantity of coal resources within the coal-bearing group, only surpassed by the Suntrana Formation.	Locally unusually thick coal beds rest directly on schist. Two of these thick beds occur within the formerly mined section at the old Arctic Coal Company mine on Hosanna Creek and at the old Diamond coal mine, southwest of Healy. These appear to have accumulated in small isolated basins or restricted lakes.

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SUMMARY CHARACTERISTICS OF TERTIARY COAL-BEARING STRATA IN THE NENANA BASIN

compiled by R.D. MERRITT

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