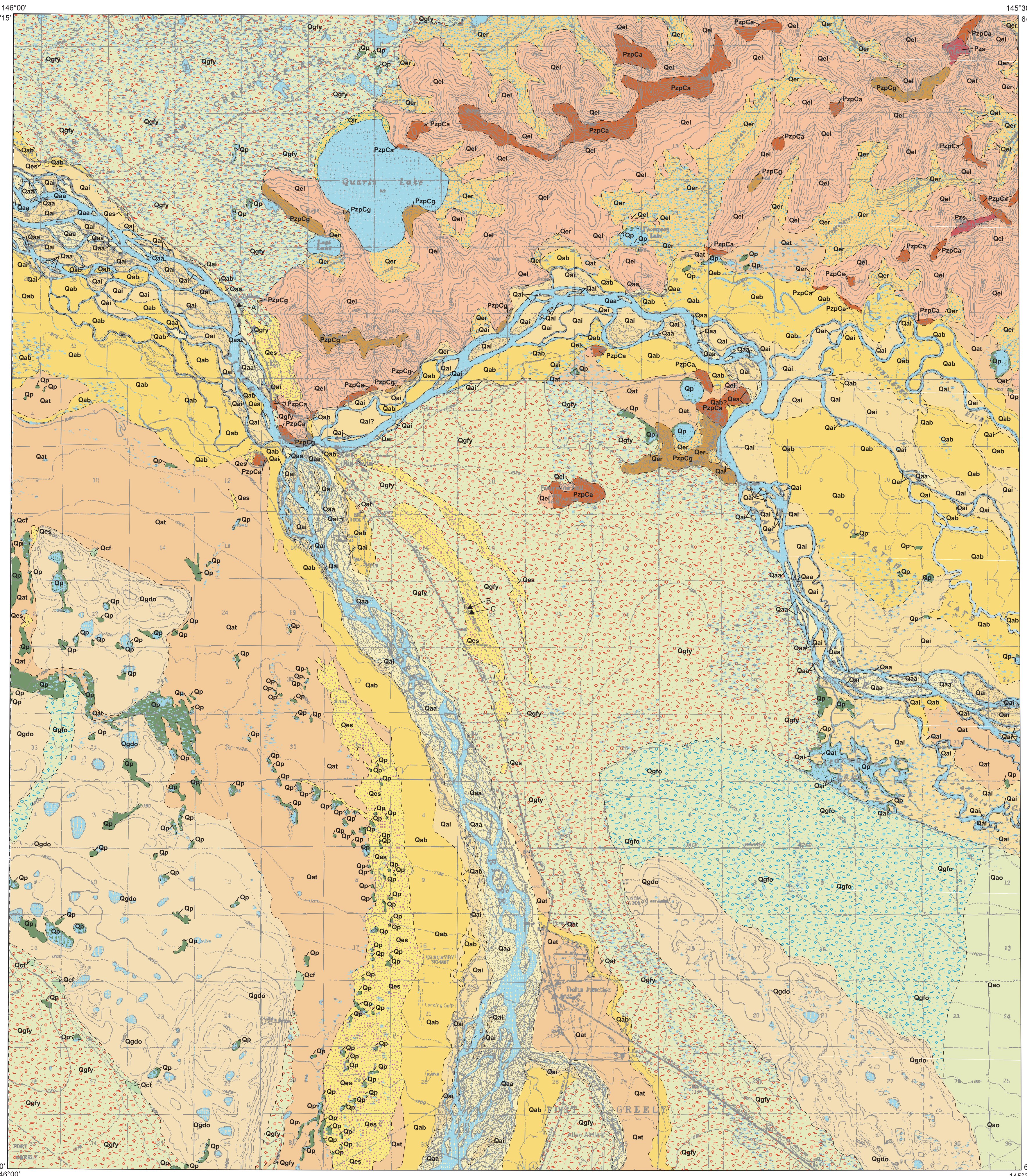
Alaska Division of Geological & Geophysical Surveys

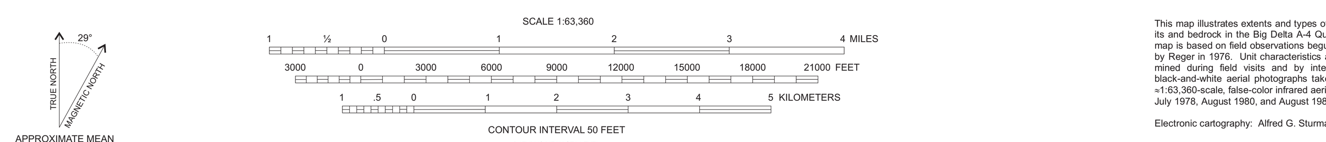
Report of Investigations 2002-2
Reger and Péwé

146°00′ 64°15′ — 145°30′ 64°15′



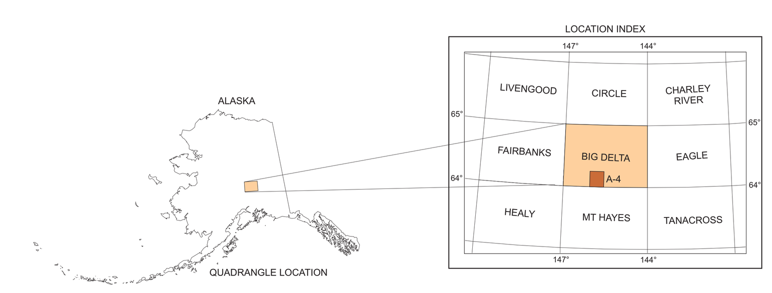
64°00′ 146°00′ — 64°00′ 145°30′

Base from U.S. Geological Survey topographic map Big Delta A-4 Quadrangle, Alaska (1950, with minor revision 1981).



This map illustrates extents and types of unconsolidated deposits and bedrock in the Big Delta A-4 Quadrangle, Alaska. This map is based on field observations begun by Péwé in 1949 and by Reger in 1976. Unit characteristics and extents were determined during field visits and by interpreting 1:40,000-scale black-and-white aerial photographs taken in August 1949 and 1:63,360-scale, false-color infrared aerial photographs taken in July 1978, August 1980, and August 1981.

Electronic cartography: Alfred G. Sturmann



Locality	Laboratory number	Material dated and stratigraphic context	Chronological significance	Radiocarbon age (^{14}C yr B.P.)	Calibrated mean age and 1 σ range[a] (cal. yr B.P.)	Source
A	GX-0255	Wood charcoal from depth of 4 ft near base of surface loess and above tan, cross-bedded eolian sand	Maximum age for initiation of loess deposition on this terrace. Minimum age for deposition of underlying eolian sand	8,040 ± 190	9,000 9,260–8,600	Péwé and Reger (1983a, p. 40)
B	GX-4293	Wood charcoal from top of 2.5-inch-thick pinkish paleosol at the top of the lower yellowish fluvial silt 8 inches above contact with underlying sand and gravel; overlain by 6 ft of yellowish fluvial silt	Dates pinkish paleosol; provides minimum age for deposition of lower fluvial silt and maximum age for deposition of the upper fluvial silt	8,125 ± 260	9,030 9,470–8,610	This study
C	GX-4292	Wood charcoal from pinkish paleosol at top of lower yellowish fluvial silt 12 inches above contact with underlying sand and gravel; overlain by 6 ft of yellowish fluvial silt	Dates pinkish paleosol; provides minimum age for deposition of lower fluvial silt and maximum age for deposition of the upper fluvial silt	8,150 ± 255	9,080, 9,060, 9,050, 9,030 9,470–8,640	This study

[a] Rounded to nearest 10 yr. Combines standard deviation in radiocarbon age and a conservative laboratory error multiplier, square root of (sample standard deviation squared plus curve standard deviation squared) (Stuiver and Reimer, 1993). Data set used in calibration can be found in Radiocarbon, v. 40, p. 1041-1083 (1998).

Table 1. *Summary of radiocarbon dates associated with late Quaternary deposits in the Big Delta A-4 Quadrangle, Alaska.*

Figure 1. *Oblique aerial photograph (looking north) showing clouds of silt being transported from the braided floodplain of the lower Delta River by strong east winds. Photograph taken by U.S. Navy in 1948 (Péwé, 1975a, fig. 21).*

GEOLOGIC MAP OF THE BIG DELTA A-4 QUADRANGLE, ALASKA

by

Richard D. Reger[1] and Troy L. Péwé[2]

2002

Affiliations

[1] Reger's Geologic Consulting, P.O. Box 3326, Soldotna, Alaska 99669

[2] Deceased November 21, 1999. Formerly Professor *Emeritus*, Department of Geology, Arizona State University, Tempe, Arizona 85287-1404

DESCRIPTION OF MAP UNITS

Unconsolidated Deposits

Qaa ACTIVE-FLOODPLAIN ALLUVIUM—Chiefly well-sorted and well-stratified layers and lenses of silt, sand, and polymictic gravel (pebbles and cobbles) comprising river bars subject to frequent inundations by streams; the mapped extent is a function of river level (stage) and reflects the transitory extent of exposed river bars at the time the photographs were taken; active alluvium underlies all active stream channels; composed dominantly of gravel and sand where stream is braided and sand and silt cover deposits and bars where meandering; generally unfrozen with shallow water table

Qai INACTIVE-FLOODPLAIN ALLUVIUM—Chiefly 10 to 20 ft of overbank silty sand and sandy silt overlying gravelly, polymictic riverbed sand and sandy gravel beneath surfaces subject to stream flooding at least as often as once or twice every century (Mason and Begét, 1991); may include more than one surface; surface peat generally absent; moisture contents range from 9 to 21 percent and average about 13 percent; generally unfrozen in younger areas and discontinuously frozen in older areas with low to moderate ice content; active channels are floored by 5 to 20 ft of sand and silty sand that are generally unfrozen; fills of inactive channels include 7 to 12 ft of discontinuously frozen organic silt with moderate to high ice content over sand and gravelly sand

Qab ABANDONED-FLOODPLAIN ALLUVIUM—Chiefly 10 to 20 ft of overbank sandy silt and silty sand overlying sandy, polymictic riverbed gravel beneath surfaces with widespread lowland loess and local sand dunes and subject to stream flooding about once every 500 to 1,000 years (Mann and others, 1995); may include several surface levels; overbank sequences contain organic-silt channel fills 7 to 20 ft thick; surface peat generally discontinuous to widespread; generally frozen with low to moderate ice content

Qao UNDIFFERENTIATED GLACIAL AND NONGLACIAL ALLUVIUM—Primarily coarse, polymictic gravel and sand deposited by former proglacial streams of the Delta glaciation and locally covered along courses of nonglacial streams by postglacial alluvium; may be terraced; locally mantled by loess and eolian sand; locally subject to seasonal stream icings; sporadically frozen with low ice content

Qat STREAM-TERRACE ALLUVIUM—Chiefly 4 to more than 20 ft of organic sandy silt and silty sand overlying well-sorted, polymictic sand and gravel beneath stream terrace treads no longer subject to inundations by the stream that deposited the alluvium (Kreig and Reger, 1982); may include several levels and incorporate outwash alluvium in highest terraces; locally covered by up to 15 ft of lowland loess and eolian sand-blanket and dune complexes; locally subject to seasonal stream icings; continuously to discontinuously frozen with low to moderate ice content

Qcf MIXED COLLUVIUM AND ALLUVIAL DEPOSITS—Primarily fan-shaped, massive to poorly stratified fine material mixed with polymictic pebble and cobble gravel laid down by small, ephemeral streams draining glacial and eolian-cover deposits; discontinuously to continuously frozen with moderate to high ice content

Qel LOESS—Silt with up to 15 percent very fine sand carried by winds and deposited as a blanket over the downwind topography (Péwé, 1951, 1955a); mixed with eolian sand on lower slopes and on lowland surfaces close to floodplain sources; thickness ranges from >20 ft close to Delta River to ≈2 ft elsewhere (Lindholm and others, 1959); organic rich on lower slopes and lowland sites; moderate to high moisture content (more than 15 percent moisture) in lowland sites; generally unfrozen, except discontinuously frozen and ice rich on some lower south-facing slopes and continuously frozen and ice rich on some lower north-facing slopes and lowland sites

Qer RETRANSPORTED LOESS AND LOWLAND SILT—Chiefly organic silt with variable amounts of sand and lenses of locally derived gravel that are deposited by slope runoff and seasonal streams draining bedrock slopes covered by upland silt; complexly mixed with primary airfall loess laid down on lowland sites and debris-flow deposits; subject to seasonal stream and slope icings; discontinuously to continuously frozen with moderate to high ice content

Qes DUNE SAND—Chiefly fine eolian sand with trace amounts (2 to 16 percent) of silt (Kreig and Reger, 1982, pl. 9); dunes stand 5 to 10 ft in relief; discontinuous with thicknesses up to ≈25 ft (Schoephorster, 1973); thicker and more extensive west of Delta River; generally covered by up to 2 ft of loess (Lindholm and others, 1959); moisture content is low (3 to 4 percent); discontinuously frozen

Qgdo TILL AND ASSOCIATED MORAINAL DEPOSITS OF DELTA GLACIATION—Heterogeneous, nonstratified, polymictic pebble–cobble gravel with some sand and silt and few to numerous subangular to subrounded boulders deposited by glacial ice; discontinuously mantled by eolian sand and loess; discontinuously to continuously frozen with low to moderate ice content (Péwé and Holmes, 1964; Holmes, 1965)

OUTWASH ALLUVIUM—Polymictic sand and gravel deposited by former proglacial streams; may be terraced; mantled by loess and eolian sand; locally subject to seasonal stream icings; sporadically to discontinuously frozen with low ice content

Qgfo OUTWASH OF DELTA GLACIATION (Péwé and Holmes, 1964; Holmes, 1965)

Qgfy OUTWASH OF DONNELLY GLACIATION (Péwé and Holmes, 1964; Holmes, 1965)

Qlr DEPOSITS OF ICE-SHOVED RAMPARTS—Chiefly well-sorted and complexly deformed polymictic pebble–cobble gravel with some medium to coarse sand pushed into a system of double 3- to 5-ft-high ridges around the northwestern margin of Quartz Lake by wind-driven, drifting lake ice (Péwé and Reger, 1983a, figs. 22A, B); contains numerous cobbles of Alaska Range lithologies that are faceted, grooved, and polished by windblown sand into ventifacts, many of which bear caliche rinds; discontinuously frozen with low ice content

Qp SWAMP DEPOSIT—Primarily fibrous and locally woody autochthonous peat with organic silt and sand deposited in lowland sites (Kreig and Reger, 1982); up to 8 ft thick; discontinuously to continuously frozen with moderate to high ice content

Bedrock

Pzs QUARTZITE AND SCHIST—Chiefly quartzite with common quartz–mica schist and lesser feldspathic quartzite; generally garnetiferous, locally actinolitic and gneissic (Weber and others, 1977, 1978)

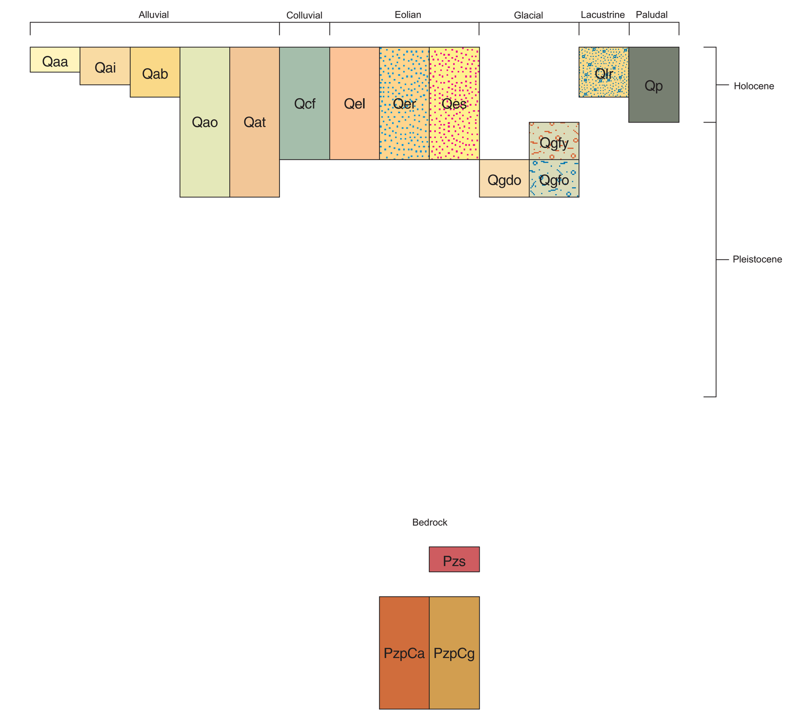
PzpCa AUGEN GNEISS AND BIOTITE GNEISS—Chiefly medium- to coarse-grained, foliated and typically mylonitic augen gneiss with subordinate augen schist and biotite gneiss of amphibolite metamorphic facies in bedrock uplands of southern Yukon–Tanana terrane (Weber, 1971; Weber and others, 1977, 1978; Foster and others, 1973; Aleinikoff and others, 1986); generally unfrozen on south-facing slopes, sporadically to discontinuously frozen on lower east- and west-facing slopes, and continuously frozen on north-facing slopes, all with low ice content

PzpCg QUARTZ–BIOTITE GNEISS—Medium-grained, well-foliated and banded to massive gneiss interbedded with quartzite in bedrock uplands of the southern Yukon–Tanana terrane (Weber, 1971; Weber and others, 1977; 1978; Foster and others, 1973; Aleinikoff and others, 1986); weathered as deep as 50 ft; generally unfrozen on south-facing slopes, sporadically to discontinuously frozen on lower east- and west-facing slopes, and continuously frozen on north-facing slopes, all with low ice content

Map Symbols

- - - - -	Approximate contact
?	Questioned identification
▲B	Field locality quoted in text

CORRELATION OF MAP UNITS



Discussion

The Big Delta A-4 Quadrangle is situated at the junction of the lower Delta River valley and the upper Tanana River valley. For millennia, people living in east-central Alaska have passed through this area on their journeys to the southern coast or farther into central Alaska. At the settlement of Delta Junction in the south-central part of the quadrangle is the junction of the Alaska Highway (commonly known as the "Alcan"), which has provided road access into Canada and the contiguous United States since the 1940s, and the Richardson Highway, a historic route between Fairbanks and Valdez on the shore of Prince William Sound. During the early 1970s the trans-Alaska oil pipeline (TAPS) was built through this area to carry petroleum from huge reservoirs beneath Alaska's North Slope to the southern shipping terminal at Valdez. A modest, state-supported agriculture effort, based mostly on the growing of feed crops, like barley, was begun in the area in the late 1970s and has marginally persisted. Currently, ambitious plans are being developed for an extension of the Alaska Railroad southeastward from Fairbanks to the Canadian border and for construction of a high-pressure natural-gas pipeline that closely follows the Alaska Highway. Just south of this quadrangle, the military facility of Fort Greely is being seriously considered for expansion as part of the strategic missile-defense system.

The climate in the Big Delta A-4 Quadrangle is continental, characterized by extreme temperatures ranging from the high 80s to low 90s°F in summer to as cold as -65°F in winter (Péwé and Holmes, 1964). Mean annual temperature at Delta Junction is about 27°F (de Percin and others in Péwé and Holmes, 1964). Permafrost is generally discontinuous. However, coarse-grained outwash alluvium away from modern streams contains relatively shallow, small bodies of modern permafrost (Wilcox, 1980), and at greater depths there are isolated masses of relict permafrost (Péwé, 1955b). In near-surface silty sand capping the outwash fan north of Delta Junction, where microclimates are exceptionally cold, small ice wedges are actively forming (Péwé and Reger, 1983a). In the northern third of the quadrangle, there are continuous, ice-rich masses in retransported organic silt and sand and in peat-rich bog deposits covering treads of higher terraces (Kreig and Reger, 1982).

Annual precipitation is ≈11 inches, two-thirds of which falls as rain, and average annual snowfall is ≈3 ft. Because of its location at the junction of two large topographic corridors, the Big Delta A-4 area is subject to considerable strong-wind activity in contrast to most of the Interior (Mitchell, 1956). During a 20-yr period between 1949 and 1969 and considering only winds blowing more than about 11 mph, about 70 percent of these strong winds come from the south down the Delta River corridor during the summer in contrast to 40 to >95 percent from the east–southeast in the winter (Wendler and others, 1980). Wind velocities in excess of 95 mph have been recorded at the FAA station just south of Delta Junction (Péwé and Holmes, 1964).

In the past, strong surface winds passing across the unvegetated fluvial bars and floodplain surfaces of the Delta River picked up and spread considerable sand and silt across leeward surfaces east and west of the Delta River (Péwé, 1951; fig. 1). Eolian deposits are much thicker and widespread west of the Delta River than to the east. Similarly, winds from the south deposited eolian sand in a narrow belt of cliffhead dunes along the east side of the Tanana River before 8,000 ^{14}C yr ago (Péwé and Reger, 1983a)(table 1, A) and in late Wisconsin time blanketed upland and lowland sites near the Tanana River with eolian sand and loess (Holmes, 1996; Holmes and others, 1996). Loess deposition continues today in the area (fig. 1). We speculate that a thin, white tephra near the base of thick loess sections along the eastern floodplain margin of the Delta River near its junction with the Tanana River is part of bed G of the Hayes tephra set H (Riehle and others, 1990; Riehle, 1994, fig. 1) [=Jarvis Ash Bed of Reger and others (1964) and Péwé (1975b) and Jarvis Creek Ash of Begét and others (1991)]. Although the Hayes tephra set has been radiocarbon dated at between 3,500 and 3,800 ^{14}C yr B.P. (Riehle and others, 1990), a series of dates in the central Alaska Range (Begét and others, 1991) places deposition of lobe G at close to 3,660 ± 125 ^{14}C yr B.P.

Major streams crossing the Big Delta A-4 Quadrangle are the Tanana River and the Delta River, which are large, glacier-fed, braided streams draining the eastern and central Alaska Range, respectively (Anderson, 1970; Dingman and others, 1971; Nelson, 1995). Active bars and the floodplain of the Tanana River are surfaced by silty sand, resulting in liquefaction conditions that necessitated the special elevated design of the Tanana River crossing (Péwé and Reger, 1983a). Based on the records taken from a single gage maintained by the U.S. Geological Survey from 1948 to 1957, the flow of the Tanana River at the highway and TAPS crossing ranged from 3,720 cfs to 62,800 cfs and averaged 14,950 cfs (Wilcox, 1980). The more intensively braided bars of the Delta River are composed of ≈60 percent gravel and ≈40 percent sand, although local surfaces are underlain by ≈90 percent sand and ≈10 percent silt (Péwé and Holmes, 1964). Periodic summer measurements of the discharge of the Delta River indicate considerable flow variation, from 24 to 9,930 cfs (Wilcox, 1980), and Dingman and others (1971) thought there was no surface flow for half the year. Jarvis Creek, a small, glacier-fed tributary stream, enters the Delta River just south of the Big Delta A-4 Quadrangle; it has a history of flooding in response to the buildup of winter icings on the floodplain. Flood waters formerly coursed down the obvious abandoned channel to enter the Delta River about 1 mi north of Delta Junction, and each spring floodwaters from ice-blocked Jarvis Creek flow along the base of the high escarpment 2 mi northeast of Delta Junction (Salcha–Big Delta Soil and Water Conservation District, 1985). Flooding in 1976 left mud rinds on tree trunks up to 3 ft above ground level along the base of the escarpment.

Widespread, coarse-grained outwash alluvium in the southern portion of the quadrangle provides excellent supplies of groundwater (Péwé, 1955b; Wilcox, 1980). The regional water table slopes gently northward toward the Tanana River beneath scattered permafrost bodies and is probably recharged by water from several surface streams (Wilcox, 1980). The high-discharge spring system feeding Clearwater Lake provides an important and dependable spawning and overwintering habitat for fish. Extensive areas of the floodplain of the Delta River are inundated by stream icings due to groundwater seepage each winter (Sloan and others, 1976).

Surface evidence of at least two major glaciations is preserved in the Big Delta A-4 Quadrangle. The type terminal moraine and associated outwash alluvium of the earlier Delta glaciation are breached by the Delta River. Till of this advance contains numerous rock types cropping out in the Alaska Range to the south. Cobbles of Alaska Range lithologies litter the surface of proximal outwash of Delta age beneath discontinuous, thin dunes of medium to coarse sand along Jack Warren Road (Péwé and Reger, 1983b), where they are pitted, faceted, grooved, and polished into classic ventifacts. A prominent linear scarp along the southern shore of Clearwater Lake between outwash of Delta age and modern floodplain deposits has been identified as a possible fault scarp by various workers in the past (for example, Weber, 1971; Carter and Galloway, 1978) but careful examination of extensive trench exposures and geophysical surveys across this lineament found no evidence of a fault (Alyeska Pipeline Service Company, unpublished data). Among others, Lindholm and others (1959, p. 40) concluded that the Clearwater Lake scarp was cut along the margin of the braided Tanana River.

Primary evidence in the Big Delta A-4 Quadrangle for the younger Donnelly glaciation is the extensive outwash fan and terrace system bordering the Delta and Tanana rivers. These glaciofluvial deposits can be traced southward up the Delta River to the type terminal moraine of the Donnelly glaciation in the Mount Hayes D-4 Quadrangle (Péwé and Holmes, 1964). A broad fan of outwash of Donnelly age and postglacial stream alluvium spreads northward from Delta Junction to the Tanana River. Abandoned channels of small meandering streams thread across this fan surface and pass beside and between two bands of postglacial sand dunes east of the Richardson Highway (Lindholm and others, 1959). To the northwest, lateral tracing indicates that coarse outwash alluvium, which is overlain by up to 14 ft of frozen, ice-rich silt and peat to form the extensive Shaw Creek Flats (Kreig and Reger, 1982), is Donnelly in age, not Delta in age as earlier proposed by Péwé in Péwé (1965a) and Péwé and Reger (1983a). This surface was the source of the sand swept by strong winds into the distinctive and episodically reactivated Rosa Creek dune field north of the Big Delta A-4 Quadrangle during the Donnelly glaciation (Kreig and Reger, 1982). During this time, the outwash alluvium beneath modern Quartz Lake was exposed, and the ventifacted cobbles now found in the ice-shoved ramparts bordering the lake were fashioned by windblown sand.

The age of the Delta glaciation has long been debated. Péwé and others (1953) initially assigned the Delta advance to the early Wisconsin glaciation, but later, on the basis of semiquantitative relative-age criteria, the Delta glaciation and its correlatives were reassigned to the earlier Illinoian glaciation (Péwé and Reger, 1983b, fig. 33). However, others working in valleys along the northern flank of the central Alaska Range and in the nearby Yukon–Tanana Upland have continued to advocate an early Wisconsin age for the Delta glaciation (Weber and others, 1981; Hamilton, 1982, 1994; Ten Brink, 1983; Weber and Hamilton, 1984; Thorson, 1986; Weber, 1983, 1986). More recent tephrochronological results provide important evidence to perhaps resolve this controversy. Reworked angular fragments of tephra at the base of unit 5 in the Canyon Creek section northwest of this quadrangle were initially and tentatively identified as the Dome Ash Bed of Péwé (1975a) by tephrochronologist John Westgate and determined to overlie (and therefore postdate) outwash alluvium assigned to the upper terrace of the Tanana River, which was correlated with the Delta glaciation (Weber and others, 1981, p. 177). The tephra in unit 5 of the Canyon Creek cut was later correlated with the Sheep Creek tephra in the Fairbanks area, not the Dome Ash Bed (Hamilton and Bischoff, 1984). A question unanswered by the evidence in the Canyon Creek section is how soon after its initial deposition was the Sheep Creek tephra retransported and redeposited in unit 5. Clearly, reworking occurred prior to deposition of unit 6, which is crosscut by ice-wedge casts and may represent cold conditions during the Donnelly glaciation (Weber and others, 1981, p. 177). Near Fairbanks the Sheep Creek tephra is found stratigraphically in the upper Gold Hill Loess beneath the Eva Forest Bed of the last interglaciation and beneath the widespread Old Crow tephra, which is dated by the fission-track method at 140,000 ± 10,000 yr B.P. (Péwé and others, 1997; Preece and others, 1999). Subsequently, the Sheep Creek tephra has been dated by the thermoluminescence method at 190,000 ± 20,000 yr B.P. (Berger and others, 1996), also confirming its deposition prior to the last interglaciation. In the western Yukon Territory, Hughes (1989) reported the Sheep Creek tephra overlying outwash attributed to the Reid glaciation and, as a result, correlated the Reid glaciation with the Delta glaciation. Therefore, both the Reid glaciation in the western Yukon Territory and the Delta glaciation must also predate the last interglaciation. In a recent paper, Westgate and others (2001) cite stratigraphic evidence in the central Yukon that indicates the Reid glaciation is at least as old as oxygen-isotope stage 8 (≈250,000 yr) and could be older. However, in most valleys beyond the heavy rain of eolian material from the lower Delta River, moraines of Delta and Donnelly ages have very similar morphologies and do not appear to be weathered much differently. Also, in the type area of the Delta glaciation, there is an inner and an outer moraine of Delta age (Péwé and Holmes, 1964). We speculate that the inner Delta-age moraine may represent a recessional moraine of late Illinoian age.

Although Péwé initially assigned the Donnelly glaciation to the late Wisconsin glaciation (Péwé and others, 1953), in subsequent papers (Péwé, 1961, 1965b, 1968, 1975a; Péwé and Holmes, 1964; Péwé and Reger, 1983b) he consistently proposed that the Donnelly and its correlatives spanned all of Wisconsin time, and Fernald (1965a, b), Holmes (1965), and Holmes and Foster (1968) concurred. However, others working in the region assigned the Donnelly glaciation and correlatives to the late Wisconsin time (Wahrhaftig, 1958; Ten Brink and Ritter, 1980; Hamilton, 1982, 1994; Ten Brink, 1983; Ritter and Ten Brink, 1986; Kline and Bundtzen, 1986; Weber, 1986). As first publicly reported in Weber and others (1981, p. 177), deposition of outwash gravels of Donnelly age on the large fan north of Delta Junction ended close to 18–20,000 yr ago. This age is based on three internally consistent radiocarbon dates from the upper part of the outwash gravel (Alyeska Pipeline Service Company, unpublished data). This outwash fan clearly relates to the culmination of the Donnelly glaciation (=McKinley Park stage I of Ten Brink, 1983) as represented by the type terminal moraine. Therefore, the Donnelly glaciation must be late Wisconsin in age. The small meandering channels crossing the outwash fan north of Delta Junction were still active after 8,100 ^{14}C yr B.P. (table 1, B and C).

References

Aleinikoff, J.N., Dusel-Bacon, Cynthia, and Foster, H.L., 1986, Geochronology of augen gneiss and related rocks, Yukon–Tanana terrane, east-central Alaska: Geological Society of America Bulletin, v. 97, no. 5, p. 626–637.

Anderson, G.S., 1970, Hydrologic reconnaissance of the Tanana basin, central Alaska: U.S. Geological Survey Hydrologic Investigations Atlas HA-319, scale 1:1,000,000, 4 map sheets.

Begét, J.E., Reger, R.D., Pinney, DeAnne, Gillispie, Tom, and Campbell, Kathy, 1991, Correlation of the Holocene Jarvis Creek, Tangle Lakes, Cantwell, and Hayes tephras in south-central and central Alaska: Quaternary Research, v. 35, no. 2, p. 174–189.

Berger, G.W., Péwé, T.L., Westgate, J.A., and Preece, S.J., 1996, Age of Sheep Creek tephra (Pleistocene) in central Alaska from thermoluminescence dating of bracketing loess: Quaternary Research, v. 45, no. 3, p. 263–270.

Carter, L.D., and Galloway, J.P., 1978, Preliminary engineering geologic maps of the proposed natural gas pipeline route in the Tanana River valley, Alaska: U.S. Geological Survey Open File Report 78-794, 26 p., scale 1:125,000, 3 map sheets.

Dingman, S.L., Samide, H.R., Saboe, D.L., Lynch, M.J., and Slaughter, C.W., 1971, Hydrologic reconnaissance of the Delta River and its drainage basin, Alaska: U.S. Army Material Command Cold Regions Research and Engineering Laboratory Research Report 262, 83 p.

Fernald, A.T., 1965a, Glaciation in the Nabesna River area, upper Tanana River valley, Alaska, in Geological Survey Research 1965: U.S. Geological Survey Professional Paper 525-C, p. C120–C123.

———1965b, Recent history of the upper Tanana River lowland, Alaska, in Geological Survey Research 1965: U.S. Geological Survey Professional Paper 525-C, p. C124–C127.

Foster, H.L., Weber, F.R., Forbes, R.B., and Brabb, E.E., 1973, Regional geology of Yukon–Tanana Upland, Alaska, in Arctic Geology: American Association of Petroleum Geologists Memoir 19, p. 388–395.

Hamilton, T.D., 1982, A late Pleistocene glacial chronology for the southern Brooks Range: Stratigraphic record and regional significance: Geological Society of America Bulletin, v. 93, no. 8, p. 700–716.

———1994, Late Cenozoic glaciation of Alaska, in Plafker, George, and Berg, H.C., eds., The geology of Alaska: Geological Society of America Decade of North American Geology, The Geology of North America, v. G-1, p. 813–844.

Hamilton, T.D., and Bischoff, J.L., 1984, Uranium-series dating of fossil bones from the Canyon Creek vertebrate locality in central Alaska, in Reed, K.M., and Bartsch-Winkler, Susan, eds., The United States Geological Survey in Alaska: Accomplishments during 1982: U.S. Geological Survey Circular 939, p. 26–29.

Holmes, C.E., 1996, Broken mammoth, in West, F.H., ed., American beginnings: The prehistory and palaeoecology of Beringia: Chicago, The University of Chicago Press, p. 312–318.

Holmes, C.E., VanderHoek, Richard, and Dilley, T.E., 1996, Swan Point, in West, F.H., ed., American beginnings: The prehistory and palaeoecology of Beringia: Chicago, The University of Chicago Press, p. 319–323.

Holmes, G.W., 1965, Geologic reconnaissance along the Alaska Highway, Delta River to Tok Junction, Alaska: U.S. Geological Survey Bulletin 1181-H, 19 p., scale 1:125,000, 1 map sheet.

Holmes, G.W., and Foster, H.L., 1968, Geology of the Johnson River area, Alaska: U.S. Geological Survey Bulletin 1249, 49 p., scale 1:63,360, 1 map sheet.

Hughes, O.L., 1989, Quaternary chronology, Yukon and western District of Mackenzie, in Carter, L.D., Hamilton, T.D., and Galloway, J.P., eds., Late Cenozoic history of the interior basins of Alaska and the Yukon: U.S. Geological Survey Circular 1026, p. 2–29.

Kline, J.T., and Bundtzen, T.K., 1986, Two glacial records from west-central Alaska, in Hamilton, T.D., Reed, K.M., and Thorson, R.M., eds., Glaciation in Alaska: The geologic record: Anchorage, Alaska Geological Society, p. 123–150.

Kreig, R.A., and Reger, R.D., 1982, Air-photo analysis and summary of landform soil properties along the route of the Trans-Alaska Pipeline System: Alaska Division of Geological & Geophysical Surveys Geologic Report 66, 149 p.

Lindholm, G.F., Thomas, L.A., Davidson, D.T., Handy, R.L., and Roy, C.J., 1959, Silts near Big Delta and Fairbanks, in Davidson, D.T., and Roy, C.J., eds., The geology and engineering characteristics of some Alaskan silts: Iowa Engineering Experiment Station Bulletin 186, p. 33–70.

Mann, D.H., Fastie, C.L., Rowland, E.L., and Bigelow, N.H., 1995, Spruce succession, disturbance, and geomorphology on the Tanana River floodplain, Alaska: Ecoscience, v. 2, no. 2, p. 184–199.

Mason, O.K., and Begét, J.E., 1991, Late Holocene flood history of the Tanana River, Alaska, U.S.A.: Arctic and Alpine Research, v. 23, no. 4, p. 392–403.

Mitchell, J.M., Jr., 1956, Strong surface winds at Big Delta, Alaska: An example of orographic influence on local weather: Monthly Weather Review, v. 84, no. 1, p. 15–24.

Nelson, G.L., 1995, Overview of environmental and hydrogeologic conditions near Big Delta, Alaska: U.S. Geological Survey Open File Report 95-180, 11 p.

Péwé, T.L., 1951, An observation on wind-blown silt: Journal of Geology, v. 59, p. 399–401.

———1955a, Origin of the upland silt near Fairbanks, Alaska: Geological Society of America Bulletin, v. 66, no. 6, p. 699–724.

———1955b, Middle Tanana Valley, in Hopkins, D.M., and others, Permafrost and ground water in Alaska: U.S. Geological Survey Professional Paper 264-F, p. 126–130.

———1961, Multiple glaciation in the headwaters area of the Delta River, central Alaska, in Short Papers in the Geologic and Hydrologic Sciences 1961: U.S. Geological Survey Professional Paper 424-D, p. D200–D201.

———1965a, Middle Tanana River valley, in Péwé, T.L., Ferrians, O.J., Jr., Nichols, D.R., and Karlstrom, T.N.V., Guidebook for Field Conference F, central and south-central Alaska, International Association for Quaternary Research, 7th Congress, Fairbanks, 1965: Lincoln, Nebraska Academy of Sciences, p. 36–54 (reprinted 1977, College, Alaska Division of Geological & Geophysical Surveys).

———1965b, Delta River area, Alaska Range, in Péwé, T.L., Ferrians, O.J., Jr., Nichols, D.R., and Karlstrom, T.N.V., Guidebook for Field Conference F, central and south-central Alaska, International Association for Quaternary Research, 7th Congress, Fairbanks, 1965: Lincoln, Nebraska Academy of Sciences, p. 55–93 (reprinted 1977, College, Alaska Division of Geological & Geophysical Surveys).

———1968, Loess deposits of Alaska: International Geological Congress, 23rd Session, Prague, 1968, Proceedings, v. 8, p. 297–309.

———1975a, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p.

———1975b, Quaternary stratigraphic nomenclature in unglaciated central Alaska: U.S. Geological Survey Professional Paper 862, 32 p.

Péwé, T.L., Berger, G.W., Westgate, J.A., Brown, P.M., and Leavitt, S.W., 1997, Eva interglaciation forest bed, unglaciated east-central Alaska: Global warming 125,000 years ago: Geological Society of America Special Paper 319, 54 p.

Péwé, T.L., and Holmes, G.W., 1964, Geology of the Mt. Hayes D-4 Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-394, scale 1:63,360, 2 map sheets.

Péwé, T.L., and Reger, R.D., 1983a, Middle Tanana River valley, *in* Péwé, T.L., and Reger, R.D., eds., Guidebook to permafrost and Quaternary geology along the Richardson and Glenn highways between Fairbanks and Anchorage, Alaska: Alaska Division of Geological & Geophysical Surveys Guidebook 1, pg. 5–45.

———1983b, Delta River area, Alaska Range, *in* Péwé, T.L., and Reger, R.D., eds., Guidebook to permafrost and Quaternary geology along the Richardson and Glenn highways between Fairbanks and Anchorage, Alaska: Alaska Division of Geological & Geophysical Surveys Guidebook 1, pg. 47–135.

Péwé, T.L., and others, 1953, Tentative correlation of glaciations in Alaska, *in* Péwé, T.L., and others, eds., Multiple glaciations in Alaska: A progress report: U.S. Geological Survey Circular 289, p. 12-13.

Preece, S.J., Westgate, J.A., Stemper, B.A., and Péwé, T.L., 1999, Tephrochronology of late Cenozoic loess at Fairbanks, central Alaska: Geological Society of America Bulletin, v. 111, no. 1, p. 71–90.

Reger, R.D., Péwé, T.L., Hadleigh-West, Frederick, and Skarland, Ivar, 1964, Geology and archaeology of the Yardang Flint Station: Anthropological Papers of the University of Alaska, v. 12, no. 2, p. 92–100.

Riehle, J.R., 1994, Heterogeneity, correlatives, and proposed stratigraphic nomenclature of Hayes tephra set H, Alaska: Quaternary Research, v. 41, no. 3, p. 285–288.

Riehle, J.R., Bowers, P.M., and Ager, T.A., 1990, The Hayes tephra deposits, an upper Holocene marker horizon in south-central Alaska: Quaternary Research, v. 33, no. 3, p. 276–290.

Ritter, D.F., and Ten Brink, N.W., 1986, Alluvial fan development and the glacial–glaciofluvial cycle, Nenana Valley, Alaska: Journal of Geology, v. 94, p. 613–625.

Salcha–Big Delta Soil and Water Conservation District, 1985, Report on comprehensive flood and erosion control plan of work for the Delta study area: Delta Junction, U.S. Department of Agriculture Soil Conservation Service, 72 p., scale 1:63,360, 10 map sheets.

Schoephorster, D.B., 1973, Soil survey of Salcha–Big Delta area, Alaska: U.S. Department of Agriculture Soil Conservation Service soil survey, 51 p., scale 1:31,680, 26 map sheets.

Sloan, C.E., Zenone, Chester, and Mayo, L.R., 1976, Icings along the trans-Alaska pipeline route: U.S. Geological Survey Professional Paper 979, 31 p.

Stuiver, Minze, and Reimer, P.J., 1993, Extended ^{14}C database and revised CALIB 3.0 ^{14}C age calibration program: Radiocarbon, v. 35, no. 1, p. 215–230.

Ten Brink, N.W., 1983, Glaciation of the northern Alaska Range, *in* Thorson, R.M., and Hamilton, T.D., eds., Glaciation in Alaska: Extended abstracts from a workshop: University of Alaska Museum Occasional Paper 2, p. 82–91.

Ten Brink, N.W., and Ritter, D.F., 1980, Glacial chronology of the north-central Alaska Range and implications for discovery of early-man sites [abs.]: Geological Society of America Abstracts with Programs, v. 12, no. 7, p. 534.

Thorson, R.M., 1986, Late Cenozoic glaciation of the northern Nenana Valley, *in* Hamilton, T.D., Reed, K.M., and Thorson, R.M., eds., Glaciation in Alaska: The geologic record: Anchorage, Alaska Geological Society, p. 99–121.

Wahrhaftig, Clyde, 1958, Quaternary and engineering geology in the central part of the Alaska Range: U.S. Geological Survey Professional Paper 293-A, p. 1–67, 2 plates, 6 map sheets, various scales.

Weber, F.R., 1971, Preliminary engineering geologic maps of the proposed trans-Alaska pipeline route, Fairbanks and Big Delta quadrangles: U.S. Geological Survey Open File Report 71-317, scale 1:125,000, 2 map sheets.

———1983, Glacial geology of the Yukon–Tanana Upland—a progress report, *in* Thorson, R.M., and Hamilton, T.D., eds., Glaciation in Alaska: Extended abstracts from a workshop: University of Alaska Museum Occasional Paper 2, p. 96–100.

———1986, Glacial geology of the Yukon–Tanana Upland, *in* Hamilton, T.D., Reed, K.M., and Thorson, R.M., eds., Glaciation in Alaska: The geologic record: Anchorage, Alaska Geological Society, p. 79–98.

Weber, F.R., and Hamilton, T.D., 1984, Glacial geology of the Mt. Prindle area, Yukon–Tanana Upland, Alaska, *in* Short Notes on Alaskan Geology, 1982–83: Alaska Division of Geological & Geophysical Surveys Professional Report 86, p. 42–48.

Weber, F.R., Hamilton, T.D., Hopkins, D.M., Repenning, C.A., and Haas, Herbert, 1981, Canyon Creek: A late Pleistocene vertebrate locality in interior Alaska: Quaternary Research v. 16, no. 2, p. 167–180.

Weber, F.R., Foster, H.L., and Keith, T.E.C., 1977, Reconnaissance geologic map of the Big Delta A-2 and A-3 quadrangles, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-869, scale 1:63,360, 1 map sheet.

Weber, F.R., Foster, H.L., Keith, T.E.C., and Dusel-Bacon, Cynthia, 1978, Preliminary geologic map of the Big Delta quadrangle, Alaska: U.S. Geological Survey Open File Report 78-529A, scale 1:250,000, 1 map sheet.

Wendler, G., Kodama, Y., and Eaton, F., 1980, On the frequency of strong winds in the Big Delta area: Fairbanks, University of Alaska Geophysical Institute Scientific Report UAF R277, 23 p.

Westgate, J.A., Preece, S.J., Froese, D.G., Walter, R.C., Sandhu, A.S., and Schweger, C.E., 2001, Dating early and middle (Reid) Pleistocene glaciations in central Yukon by tephrochronology: Quaternary Research, v. 56, no. 3, p. 335–348.

Wilcox, D.E., 1980, Geohydrology of the Delta–Clearwater area, Alaska: U.S. Geological Survey Water-Resources Investigations 80-92, 26 p.

Acknowledgments

This map has been completed in the absence of Troy Péwé, who has been gone 2 years now, but I must emphasize the very positive influence that he has had on my work in the Big Delta A-4 Quadrangle and elsewhere in Alaska during my professional career. Troy and I often reached different conclusions in the course of our many joint efforts, but we worked hard to resolve these issues in a professional manner by following the scientific method, which Troy emphasized in the many classes he taught over his long and distinguished career. Troy approached a geologic problem with bulldog tenacity and worked hard to assemble the evidence supporting his arguments. He challenged me and others to work just as hard to prove 'our case.' Troy began mapping the Big Delta A-4 Quadrangle 27 years before I started, and I first became interested in this area during the many field trips that he so ably led. He was a consummate leader in the field, and I miss his inspiration.

Another friend, who motivated me to continue thinking about Quaternary glaciations in central Alaska, is Florence Weber. Florence worked with Troy even longer than I and approached her profession with a questioning attitude that encouraged others to work harder. Although I examined many bedrock outcrops close to the Richardson Highway and Troy tramped along ridge crests away from the roads, Florence is the expert on the bedrock geology of the Big Delta A-4 Quadrangle, and I have extensively used her maps (as cited) to label bedrock outcrops that I identified on aerial photographs.

Rod Combellick (DGGS) provided the incentive and means for me to complete this map for publication 24 years after my field work was completed, and multi-talented Alfred G. Sturmann (DGGS) shepherded this map through the digitizing and layout processes to final publication. Able assistance in the field was provided by Jeffrey T. Kline (DGGS), who passed away much too soon.

Also, I want to gratefully acknowledge the encouragement and indispensable assistance provided by Michael C. Metz, formerly of the Geotechnical Section of Alyeska Pipeline Service Company, and Alyeska Pipeline Service Company for permission to examine their lengthy trenches and for providing access to their unpublished data.

Many thanks for helpful comments by Florence Weber and Rod Combellick during their excellent reviews of this map. Rod also kindly provided the calibrated radiocarbon ages in table 1.

This DGGS Report of Investigations is a final report of scientific research. It has received technical review and may be cited as an agency publication.