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GEOLOGY OF THE HEALY A-3 QUADRANGLE, ALASKA

by

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[In pocket]

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By

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INTRODUCTION AND ACKNOWLEDGMENTS

The Healy A-3 Quadrangle straddles the southeastern Chulitna Mountains and part of the northeastern Fog Lake Upland of the northern Talkeetna Mountains (Wahrhaftig, 1965). This report summarizes results of geologic mapping conducted by Alaska Division of Geological and Geophysical Surveys geologists in 1973 and 1988. These studies extend westward previous geologic mapping by Smith (1981), Smith and others (1988), and Reger and Bundtzen (1990). This report was prepared in cooperation with the U.S. Bureau of Mines, which is conducting a mineral-resource evaluation of the Valdez Creek mining district. We gratefully acknowledge bedrock-mapping contributions by W. G. Gilbert and D. N. Solie.

BEDROCK GEOLOGY

Bedrock lithologies in the Healy A-3 Quadrangle range in age from Late Jurassic to middle (?) Tertiary. They are dominated by regionally metamorphosed rocks of the Maclaren metamorphic belt (Smith, 1981) and by complex, composite plutons mainly of early Tertiary age. In the extreme northwestern part of the quadrangle, Tertiary lavas overlie both Jurassic-Cretaceous Kahiltna flysch and early Tertiary granitic rocks.

KAHILTNA TERRANE

The oldest rock unit, the Kahiltna terrane (KJs), is a turbidite-dominated section of deformed argillite, siltstone, and lithic sandstone that crops out in the northern highlands of the map area (sheet 1). The unit is characteristically isoclinally deformed at scales of meters to kilometers and, where mapped, has been subjected to conditions of the zeolite and lower greenschist metamorphic facies. The Kahiltna terrane is part of a 50,000-km^2, turbidite-dominated basin that trends from the western Clearwater Mountains (Smith, 1981) at least 300 km west-southwest to the western Alaska Range (Eakins and others, 1978; Csejtey and others, 1986; Bundtzen and others, 1987). Fossil collections from the Kahiltna terrane in the Healy Quadrangle consist primarily of *Buchia* sp., indicating that the age of this terrane ranges from Late Jurassic (Kimmeridgian Stage) to Early Cretaceous (Valaginian Stage)(Csejtey and others, 1986). Kahiltna sedimentary rocks form the parent material of hornfels in the southeastern part of the quadrangle, and most geologists, including Csejtey and others (1978; 1986) and Smith (1981), regard much of it as the protolith of phyllite, schist, and gneiss of the Maclaren metamorphic belt, a zonational sequence of the Barrovian type.

MACLAREN METAMORPHIC BELT

Nearly 40 percent of the bedrock in the Healy A-3 Quadrangle consists of a progressive series of metamorphic rock units that increase in metamorphic grade from southeast to northwest. Lowest-rank lithologies are spotted phyllites and semischist (TKph) that have been gradationally transformed to biotite schist (TKs) and paragneiss (TKpgn) in the Deadman Creek drainage (sheet 1). The highest grade part of the belt consists of a complex series of orthogneiss and migmatite (TKgm), biotite schist (TKs), and

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foliated granodiorite (TKgd). Estimated width of the Maclaren metamorphic belt in the southeastern corner of the quadrangle is about 8 km; hence, the metamorphic gradient from zeolite or prehnite-pumpellyite facies to middle amphibolite facies is either very steep or is telescoped locally by thrust (?) faulting.

As noted by Smith (1981), the belt appears to be inverted, with facies representing higher T-P conditions overlying lithologies with mineral assemblages of lower T-P conditions. This relation indicates either that the entire metamorphic belt is overturned, or--more plausibly--that the belt represents a northeast-trending zone of ductile overthrusting (Smith, 1981).

In the southwestern corner of the map area, a foliated granodiorite sill (Tgdf) is encased in a complex zone of biotite-rich migmatitic schist and pelitic schist. Metamorphic mineral assemblages in garnet-bearing schist (TKas) west of the granodiorite sill (muscovite+actinolite+garnet+biotite+muscovite) indicate upper greenschist facies, whereas mineral assemblages immediately east of the sill (hornblende+almandine garnet+calcic plagioclase+muscovite+biotite), indicate lower amphibolite facies. This implies a sharp, possibly structural break in the metamorphic gradient. Furthermore, measurements of local overturned fold axes and rolled garnets indicate compressional movement eastward parallel to schistosity.

Hence, the granodiorite sill is postulated to have migrated upward along a low-angle ductile shear during waning stages of regional metamorphism. This syntectonic, foliated granodiorite-sill complex thrust within enclosing migmatitic schist and pelitic schist may be an example of melt-enhanced synmetamorphic deformation described by Hollister and Crawford (1986) in the Coast Range metamorphic complex in British Columbia and southeastern Alaska. These observations are consistent with the concept that lithologies in the Maclaren metamorphic belt are structurally juxtaposed, foreshortened, and inverted by ductile imbricate thrust faults (Smith, 1981; Turner and Smith, 1974). Smith (1981) also determined that regional metamorphism in the Maclaren metamorphic belt peaked in Late Cretaceous time and waning retrograde effects extended into early Tertiary time.

PLUTONIC AND VOLCANIC ROCKS

A complex series of intrusive rocks of various lithologies intrudes the metamorphic rocks and Jura-Cretaceous Kahiltna flysch. Composite stocks contain granodiorite, quartz monzonite, and granite as major phases; minor gabbro and diorite crop out locally (sheet 1).

The two major stocks north of Deadman Lake and in the west fork of Deadman Creek appear to be crudely zoned, with granite cores and quartz-monzonite rims. Smith and others (1988) described similarly zoned complexes in the Butte Lake area immediately east of the Healy A-3 Quadrangle. They are believed to be correlative with a 50-55 m.y. plutonic episode documented by Csejtey and others (1978) throughout the map area.

A distinctive dike swarm dominated by intrusions of numerous intermediate to felsic dikes trends N. 45 W. for at least 15 km across the central part of the quadrangle. This tensional zone extends northwestward into adjacent quadrangles.

A coeval series of basalt-to-rhyolite flows and pyroclastic deposits (Tvf, Tvfa) overlies plutonic rocks and older flysch in the Brushkana Creek drainage in the northwestern corner of the Healy A-3 Quadrangle. These volcanic rocks are probably equivalent in age and tectonic environment to the Teklanika Formation, which crops out west of the quadrangle in Denali National Park. The Teklanika Formation ranges in age from 55 to 60 m.y. (Gilbert and others, 1976).

ECONOMIC GEOLOGY

No mineral deposits are reported from the Healy A-3 Quadrangle. A poorly known placer-gold occurrence is located in Holocene alluvium in an un-named stream drainage immediately south of Sec. 23, T. 22 S., R. 5 W., in the southwestern corner of the map area. Units TKph and TKs in the southeastern of the quadrangle project northeastward into the "Valdez Creek trend", where metamorphic quartz and gold veins and intrusive-hosted gold deposits are currently being explored. Hence, careful exploration may reveal that these lithologies are also gold bearing in the Healy A-3 Quadrangle. Coarsely crystalline pegmatite veins with K-spar, quartz, and biotite books up to 8 cm long occur north of Deadman Lake. The economic potential of these occurrences is unknown.

QUATERNARY GEOLOGY

Based on photointerpretation verified by field examination, evidence for at least three Pleistocene glaciations and at least one glacial expansion of Holocene age is present in the Healy A-3 Quadrangle.

ILLINOIAN GLACIATION

Drift, colluviated drift, and ice-stagnation deposits of a pre-Wisconsin glaciation are recognized between 3,700 and 4,900 ft (1,120 and 1,485 m) elevation above the upper limit of late Wisconsin glaciation on the upland east of lower Brushkana Creek (where headless, ice-marginal-stream channels cut into bedrock as high as 5,200 ft (1,576 m) elevation), on the Deadman Mountain upland, and above 4,300 ft (1,300 m) on the upland in the vicinity of VABM Gold in the southeastern corner of the quadrangle (sheets 1 and 2). An ice cap of this age developed above 4,800 ft (1,455 m) on the northern part of the Deadman Mountain upland. In addition to widespread ice-scoured bedrock surfaces, which are littered with frost-rived debris representing local lithologies, and drift, this high-level ice-accumulation center is indicated by obviously glaciated valleys (without cirques) cut into northern and eastern upland margins where outlet glaciers formerly flowed. A valley glacier reoccupied and deepened the eastern valley in late Wisconsin time (sheet 2).

Based on similar landform preservation, deposits of the oldest recognized glaciation in the Healy A-3 Quadrangle correlate with pre-Wisconsin drift (unit Qdt1) mapped on the same highland in the adjoining Healy A-2 Quadrangle by Smith and others (1988)(fig. 1). They tentatively correlate with deposits of the Delta glaciation of Illinoian age in the Clearwater and Amphitheater Mountains farther east and in the southern Alaska Range to the north. At that time, thick piedmont ice sheets also formed in the northern Talkeetna Mountains just south of the Healy A-3 Quadrangle.

EARLY WISCONSIN GLACIATION

We map no glacial landforms or deposits of early Wisconsin age in the Healy A-3 Quadrangle. Nonetheless, a single infinite radiocarbon date for twigs in lacustrine-deltaic sand 15.5 m above till at map locality D (sheets 1 and 2, table 1) along middle Brushkana Creek indicates that the area was glaciated more than 37,000 y.a. and that an ice- or moraine-dammed lake existed. We acknowledge that some of the drift, moraines, and ice-stagnation deposits (especially the colluviated drift) we map as late Wisconsin (sheet 1) could be early Wisconsin in age as mapped by Woodward-Clyde Consultants (1982) and Smith and others (1988). However, stratigraphic evidence at Valdez Creek Mine 27 km east of this quadrangle indicates that the early Wisconsin glaciation, as it developed in both the southcentral Alaska Range and locally, was less extensive than either the Illinoian or late Wisconsin glaciations (Reger and Bundtzen, 1990). Therefore, we attribute the most extensive well-preserved moraines and associated landforms to the late Wisconsin glaciation.

STANDARD NORTH AMERICAN CHRONOLOGY	SOUTH FLANK ALASKA RANGE	AMPHITHEATER MOUNTAINS	WESTERN CLEARWATER MOUNTAINS		NORTHERN TALKEETNA MOUNTAINS				NW COPPER RIVER BASIN	
	Péwé (1961, 1965, 1968, 1975)	Péwé (1961, 1965, 1975) Péwé and Reger (1983)	Smith (1981)	Reger and Bundtzen (1990)	Welsch and others (1982); Thorson and others (1981)	Woodward-Clyde Consultants (1982)	Smith and others (1988)	This study	Thorson and others (1981)	Williams and Galloway (1986)
Holocene interglaciation	Several minor advances Summit Lake glaciation	Two advances Glaciation	Alpine Creek glaciation	Fourth glaciation			Rock glaciers Valley-mouth alpine advances	Rock glaciers Valley-head alpine advances		
Late Wisconsin glaciation	Donnelly glaciation	Denali II glaciation	Hatchet Lake glaciation	Third glaciation: Late phase	Butte Lake glaciation	Glaciation	Glaciation	Glaciation	Glaciation	Glacier-dammed lakes (glaciation)
Early Wisconsin glaciation		Denali I glaciation	Denali glaciation	Early phase	Clear Valley glaciation	Glaciation	Glaciation	Less extensive glaciation	Glacier-dammed lake (glaciation)	
Illinoian glaciation	Delta glaciation	Delta glaciation		Second glaciation	Thick piedmont glaciation	Glaciation	Glaciation	Glaciation		
Pre-Illinoian glaciation	Early glaciation	Darling Creek glaciation		First glaciation						

Figure 1. *Comparison of Quaternary glacial events in the southcentral Alaska Range, Amphitheater Mountains, western Clearwater Mountains, northern Talkeetna Mountains, and northwestern Copper River Basin, Alaska.*

LATE WISCONSIN GLACIATION

Till and other glacigenic deposits of the last major glaciation are widespread in lowlands of the Healy A-3 Quadrangle (sheet 1). These deposits were laid down by glaciers originating in the southcentral Alaska Range to the north, in the high Talkeetna Mountains to the south, and in local cirques. Interactions of different ice streams were complicated by different sizes and types of glacier systems and different response rates to climatic stimuli. The result is a complex pattern of crosscutting moraines that demonstrates activity of local ice sources before or after external glaciers reached this area, or both (sheet 2). Morainal relations in the valley of Brushkana Creek indicate that ice streams generated in the nearby northern Talkeetna Mountains reached maximum extents before piedmont ice from the Alaska Range entered the area. Then, as Alaska Range ice fluctuated in thickness and extent, glaciers in small upland valleys fluctuated in a complex manner--at times overriding moraines deposited by outside ice and at times being overridden by resurgences of the larger ice system. Along the eastcentral limit of the quadrangle, a short valley glacier from the east-facing cirque at the head of the northwest tributary of Butte Creek built late Wisconsin moraines that cut across lateral moraines built by a large valley glacier perhaps of local origin or derived from the higher Talkeetna Mountains to the south, indicating the small glacier in this tributary was still active after ice retreated from the main valley. This cirque is particularly interesting because its floor is offset along a northwest-trending photogeologic lineament and is deeply incised by postglacial stream erosion.

North- and northeast-facing cirques of late Wisconsin age have floors between 4,200 and 4,700 ft (1,270 and 1,425 m), indicating that late Wisconsin snowline was in this elevation range.

After Alaska Range ice crossed Monahan Flats north of the Healy A-3 Quadrangle, it entered the northern foothills of the Talkeetna Mountains, blocking and diverting established drainages. A series of glacier-dammed lakes formed at different levels (sheet 2). The highest recognized lake formed at 3,700 ft (1,120 m) elevation north of upper Brushkana Creek in the vicinity of Hill 3806. Waters of that temporary lake were dammed between Alaska Range ice to the northeast and the glacier that flowed eastward down the upper valley of Brushkana Creek. At that time, overflow through a low divide to the northwest carried lake waters into upper East Fork Jack River.

A slightly younger glacier-dammed lake of unknown duration reached an elevation of 3,650 ft (1,110 m) in the valley of upper Brushkana Creek during retreat of the glacier that previously occupied that valley (sheet 2). This lake drained westward through a narrow bedrock canyon down Soule Creek into upper Jack River. Meltwater streams from the nearby glacier occupying the valley of lower Brushkana Creek entered the lake from the north and built a distinctive hanging delta on the north valley wall (sheet 1). Crosscutting of locally-derived moraines by shorelines at and below the maximum elevation of the 3,650-ft (1,110-m) lake indicates that, during the existence of the lake, local ice streams had retreated at least to the mouths of their mountain valleys, even though ice from the Alaska Range remained nearby (sheet 2).

A little later, a distinctive shoreline was cut into late Wisconsin drift and moraines at 3,400 ft (1,030 m) elevation in the low divide between Brushkana Creek and upper Deadman Creek and along the walls of lower Brushkana Creek valley (sheet 2). Distribution of this and lower wavecut scarps in this area indicates that this large lake was impounded between Alaska Range ice, which probably occupied a terminal position just north of this quadrangle, and a glacier of local origin that flowed eastward down the upper valley of Deadman Creek, blocking the southward-diverted flow of Brushkana Creek (sheet 2). Woodward-Clyde Consultants (1982, fig. 3-4) concluded that the distinctive end moraine just north of the Healy A-3 Quadrangle is latest Wisconsin in age (9,000 to 11,000 y.o.). A radiocarbon date of basal peat at map locality C (sheet 2, table 1) indicates that the glacier dam on upper Deadman Creek had retreated before 9,900 y.a. Radiocarbon dates of allochthonous peat lenses in alluvium of a pitted stream terrace along middle Brushkana Creek at map locality B (sheet 2, table 1, fig. 2) supports drainage of the 3,400-ft (1,110-m) lake before 8,400 y.a. The presence of these pitted stream terraces also indicates that

Map Designation	Collection Site	Materials Dated	Radiocarbon Age (C14 years before present)	Laboratory Number	Significance of Date	Reference
A	63°12'45.3"N 148°20'25.7"W Slump exposure in 4-m-high palsa on low terrace near south bank of upper Brushkana Creek. Elevation 3,450 ft (1,045 m).	Twigs from upper 0.2 m of medium-gray lacustrine silt-clay	6,705 ± 280	GX-14434	Maximum age for deglaciation of Meadow Creek valley and nearby mountain valleys that drained into former shallow, local lake. Maximum age for drainage of lake.	Section A, this study
B	63°10'51"N 148°11'15.7"W Stream-cut exposure in 4.2-m pitted terrace in north bank of Brushkana Creek. Elevation 3,150 ft (955 m).	Allochthonous peat lenses in channel-fill alluvium	8,110 ± 140 8,360 ± 280	GX-14431 GX-14430	Confirms Holocene age of pitted stream terraces along upper Brushkana Creek. Distant minimum age for recession of ice from south flank of Alaska Range and drainage of glacier-dammed lake in upper Brushkana Creek area. Indicates buried glacial ice persisted several centuries after glacier receded northward.	Section B, this study
C	63°05'23.9"N 148°18'12.4"W Slump exposure in palsa	Peat in fine-grained ice-disintegration deposits	9,920 ± 265	GX-8062	Minimum age for last retreat of local glacial ice from upper valley of Deadman Creek.	Woodward-Clyde Consultants (1982, table 3-2, locality S54-1)
D	63°11'37.4"N 148°09'50.8"W North bank exposure of Brushkana Creek	Wood chips in lacustrine-deltaic sand 15.5 m above till	>37,000	GX-8057	Indicates pre-late-Wisconsin age for ice invading upper Brushkana Creek area from Monahan Flats to the north. Minimum age for underlying till.	Woodward-Clyde Consultants (1982, table 3-2, locality S12-2)

Table 1. *Significance of radiocarbon dating in the Healy A-3 Quadrangle, Alaska.*

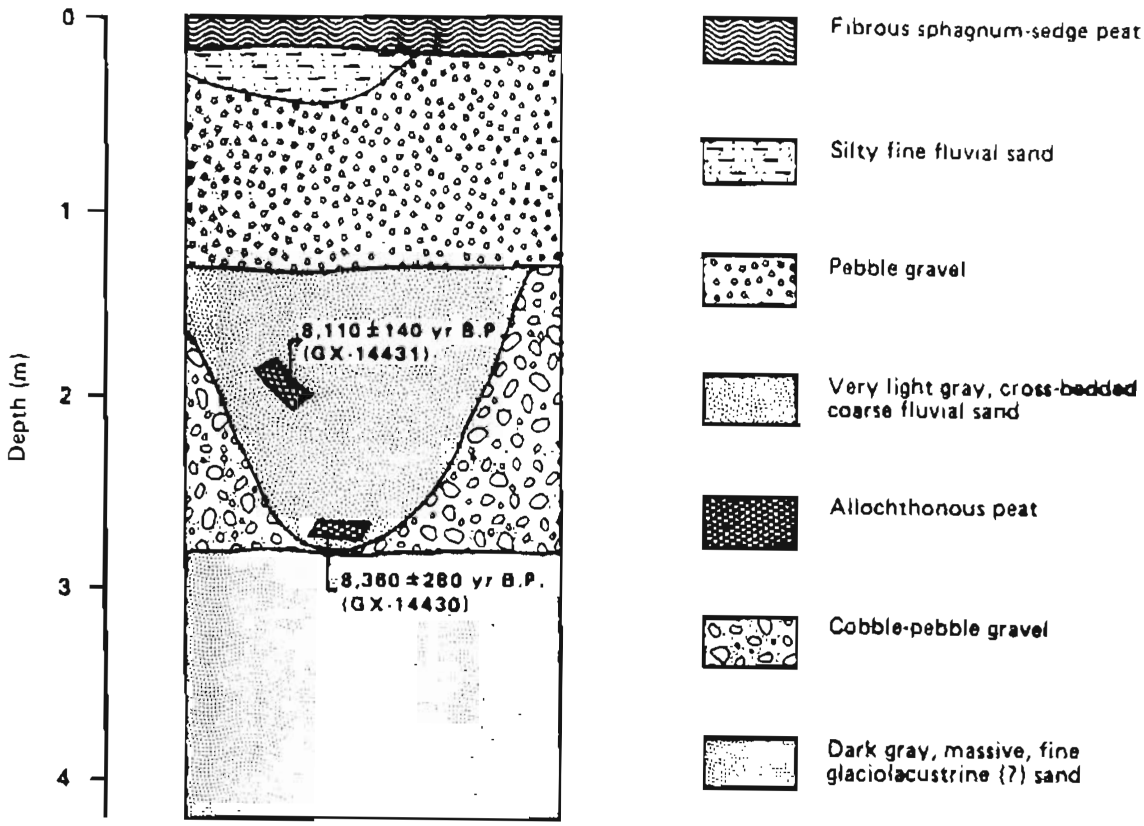

Figure 2. *Schematic diagram of section exposed in 4.2-m-high pitted stream terrace and associated radiocarbon dates, map locality B, Healy A-3 Quadrangle, Alaska. Elevation is 3,150 ft (955 m).*

buried glacial ice of late Wisconsin age persisted locally until after 8,400 y.a., even though cold, glacier-derived waters of ice-dammed lakes inundated the locality for an unknown length of time.

Based on radiocarbon evidence and similar preservation of landforms, the second-most-extensive glaciation of the Healy A-3 Quadrangle probably correlates with late Wisconsin glaciations recognized in the southcentral Alaska Range, Amphitheater Mountains, and northern Talkeetna Mountains (fig. 1). At that time, an extensive glacier-dammed lake also existed in the northwestern Copper River Basin. In Susitna River canyon, lake waters rose to a level of 2,840 ft (860 m) behind a dam of glacial ice from the Talkeetna Mountains as late as 9,400 y.a., according to a radiocarbon date of wood collected from frozen lacustrine silt and clay by Woodward-Clyde Consultants (1982; sample S42-1, table 3-2 and fig. 3-3) along upper Watana Creek in the northwestern Talkeetna Mountains D-2 Quadrangle.

HOLOCENE GLACIATION

Our brief investigation indicates that glacial expansions were generally confined to the heads of alpine valleys during Holocene time (sheet 2, fig. 1). Moraines there, many still ice cored, are associated with rock glaciers, protalus ramparts, and talus cones and aprons (sheet 1). Based on the distribution of moraines or drift sheets in eight valleys, lowest (probably early) Holocene equilibrium line was at about 4,700 ft (1,425 m) elevation (sheet 1). Termini of early Holocene glaciers reached elevations as low as 3,900 to 4,750 ft (1,180 to 1,440 m). The longest recognized glacier of early Holocene age extended 5 km down the valley of Meadow Creek. Stratigraphic evidence exposed in a 13-ft-high (4-m-high) palsa at map locality A (sheet 2, table 1, fig. 3) indicates that silt-laden meltwater from this and nearby glaciers drained into a shallow, local lake in the upper Brushkana Creek area until about 6,700 y.a. The palsa section also indicates that this lake became less silty and drained after 6,700 y.a. but before 3,650 y.a., when the Hayes tephra was deposited (Begét and others, in press).

A survey of 20 active rock glaciers in this quadrangle demonstrates that they range in elevation from 4,150 to 5,000 ft (1,260 to 1,515 m), averaging 4,550 ft (1,380 m)(sheet 1). With one exception, these permafrost indicators occur at the bases of northwest- and northeast-facing slopes and cirque headwalls, where incident solar radiation has low intensity.

NEOTECTONICS

In this quadrangle, several photogeologic lineaments transect or offset moraines and a cirque floor of late Wisconsin age (sheet 1). These features are likely candidates for active faults.

REFERENCES

Begét, J.E., Reger, R.D., Pinney, DeAnne, Gillespie, Tom, and Campbell, Kathy, in press, Correlation of the Holocene Jarvis Creek, Tangle Lake, Cantwell, and Hayes vent tephras in south-central and central Alaska: Quaternary Research.

Bundtzen, T.K., Kline, J.T., Smith, T.E., and Albanese, M.D., 1988, Geology of the McGrath A-2 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 91, 22 p., scale 1:63,360, 1 sheet.

Csejtey, Béla, Jr., Mullen, M.W., Cox, D.P., Gilbert, W.G., Yeend, W.E., Smith, T.E., Wahrhaftig, Clyde, Craddock, Campbell, Brewer, W.M., Sherwood, R.W., Hickman, R.G., Stricker, G.D., St. Aubin, D.R., and Goerz, D.J., III, '1986, Geology and geochronology of the Healy Quadrangle, Alaska: U.S. Geological Survey Open-file Report 86-396, 96 p., scale 1:250,000, 4 sheets.

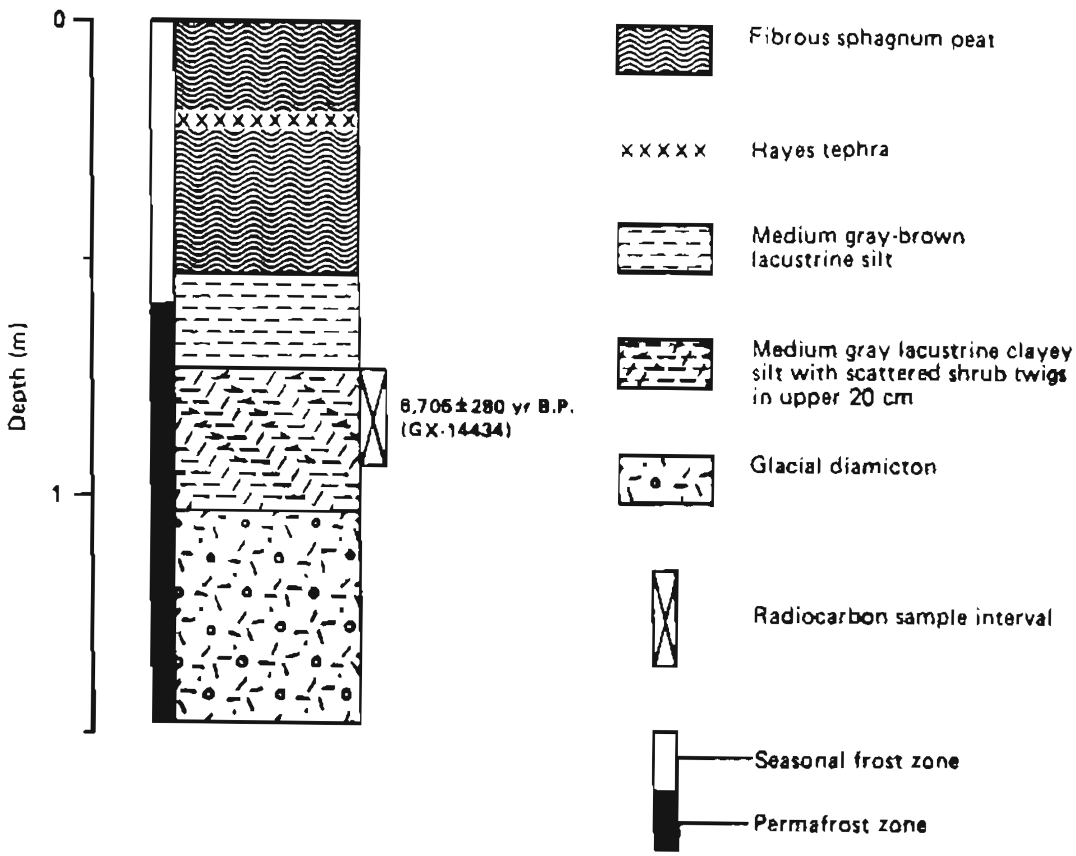

Figure 3. *Schematic diagram of section exposed in upper part of Holocene palsa, map locality A, Healy A-3 Quadrangle, Alaska. Elevation is 3,450 ft (1,045 m).*

Csejtey, Béla, Jr., Nelson, W.H., Jones, D.L., Silberling, N.J., Dean, R.M., Morris, M.S., Lanphere, M.A., Smith, J.G., and Silberman, M.L., 1978, Reconnaissance geologic map and geochronology, Talkeetna Mountains Quadrangle, northern part of Anchorage Quadrangle, and southwestern corner of Healy Quadrangle, Alaska: U.S. Geological Survey Open-file Report 78-558A, 60 p., scale 1:250,000, 1 sheet.

Eakins, G.R., Gilbert, W.G., and Bundtzen, T.K., 1978, Preliminary bedrock geology of west-central Lake Clark Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 118, 15 p., scale 1:63,360, 2 sheets.

Gilbert, W.G., Ferrell, V.M., and Turner, D.L., 1976, The Teklanika Formation--a new Paleocene volcanic formation in the central Alaska Range: Alaska Division of Geological and Geophysical Surveys Geologic Report 47, 16 p.

Hollister, L.S., and Crawford, M.L., 1986, Melt-enhanced deformation--a major tectonic process: Geology, v. 14, no. 7, p. 558-561.

Péwé, T.L., 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 424D, p. D200-D201.

_______1965, 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 and Geophysical Surveys).

_______1968, Loess deposits of Alaska: International Geological Congress, 23rd Session, Prague, 1968, Proceedings, v. 8, p. 297-309.

_______1975, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p.

Péwé, T.L., and Reger, R.D., 1983, 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 and Geophysical Surveys Guidebook 1, p. 47-135.

Reger, R.D., and Bundtzen, T.K., 1990, Multiple glaciation and gold-placer formation, Valdez Creek valley, western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., scale 1:63,360, 1 sheet.

Smith, T.E., 1981, Geology of the Clearwater Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 60, 72 p.

Smith, T.E., Albanese, M.D., and Kline, G.L., 1988, Geologic map of the Healy A-2 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 95, scale 1:63,360, 1 sheet.

Thorson, R.M., Dixon, E.J., Jr., Smith, G.S., and Batten, A.R., 1981, Interstadial proboscidean from south-central Alaska: Implications for biogeography, geology, and archeology: Quaternary Research, v. 16, no. 3, p. 404-417.

Turner, D.L., and Smith, T.E., 1974, Geochronology and generalized geology of central Alaska Range, Clearwater Mountains, and northern Talkeetna Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 72, 10 p., scale 1:250,000, 1 sheet.

Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

Welsch, Dennis, Goodwin, Robert, and Ten Brink, Norman, 1982, Late Quaternary glaciations of the Talkeetna Mountains, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 14, no. 6, p. 353-354.

Williams, J.R., and Galloway, J.P., 1986, Map of western Copper River Basin, Alaska, showing lake sediments and shorelines, glacial moraines, and location of stratigraphic sections and radiocarbon-dated samples: U.S. Geological Survey Open-file Report 86-390, scale 1:250,000, 1 sheet.

Woodward-Clyde Consultants, 1982, Quaternary geology, *in* Final report on seismic studies for Susitna Hydroelectric Project (Subtasks 4.09-4.15): Buffalo, Acres American Incorporated report, p. 3.1-3.20.