U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Surficial geologic map of the Anchorage A-8 NE quadrangle, Alaska

By

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Dr. Milton A. Wiltse
State Geologist and Director
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794 University Avenue, Suite 200
Fairbanks, AK 99709-3645

Dear Dr. Wiltse:

We are pleased to send you a copy of the latest in our series of surficial geologic maps of the Municipality of Anchorage, entitled "Surficial geologic map of the Anchorage A-8 NE quadrangle, Alaska" by Henry R. Schmoll, Lynn A. Yehle, and Ernest Dobrovolny. Published as USGS Open-File Report 96-003, the black-and-white map is at 1;25,000 scale and is accompanied by an illustrated text of 49 pages.

Sincerely,

Henry R Schmoll

Henry R. Schmoll
Scientist Emeritus

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SURFICIAL GEOLOGIC MAP OF THE ANCHORAGE A-8 NE QUADRANGLE, ALASKA

By

Henry R. Schmoll, Lynn A. Yehle, and Ernest Dobrovolny

INTRODUCTION

The Anchorage A-8 NE quadrangle is located in south-central Alaska and is one of a series of 1:25,000-scale maps in the upper Cook Inlet-Knik Arm region for which geologic or surficial geologic maps have been published (fig. 1; references given in caption). The quadrangle lies entirely within the Municipality of Anchorage and is centered about 10 km east of downtown Anchorage (fig. 2). Suburban Anchorage extends from the west into the map area in two prongs (fig. 3, areas labeled 1); the west-central prong is the more densely populated of the two and includes local commercial and educational centers, whereas the southwestern prong has more widely spaced homes and fewer businesses. Exurban residential development is present in the community of Basher, an isolated square-mile area in the south-central part of the map area. Between the two main urbanized areas lies a largely undeveloped area around Campbell Airstrip that includes public parks and various government facilities. Chugach State Park occupies the mountainous southeastern part of the map area, and military reservations occupy the remainder: Elmendorf Air Force Base in the northwest and Fort Richardson in the north and east. The Alaska Railroad traverses the northwesternmost part of the area and the Glenn Highway crosses most of the northern part.

Geology of the quadrangle was included in previous mapping at smaller scales by Dobrovolny and Miller (1950), Miller and Dobrovolny (1959), and Cederstrom and others (1964), and at slightly larger scale but in a generalized way without traditional geologic map units by Schmoll and Dobrovolny (1972a). Other workers who reported on the geology of the region without detailed geologic maps of this area include Karlstrom (1964) and Reger and Updike (1983, 1989). Bedrock crops out only in the eastern and southern marginal areas, and was not examined in detail in any of those maps and reports, but is included in the reconnaissance map of Clark (1972); that mapping serves as the basis for subsequent regional compilations of bedrock geology, for example, Magoon and others (1976) and Winkler (1992). Most of the map area is dominated by surficial deposits of glacial, glacioestuarine, and glacioalluvial origin, emplaced during and following the withdrawal of glacier ice from the area in the latter part of the last major (Wisconsinan) glaciation; they are now regarded as younger than they were by most previous workers. The interpretations given here also ascribe more importance to a glacioestuarine environment that was both coeval with and subsequent to withdrawal of the glacier as ancestral Cook Inlet invaded the area to levels higher than those of the present. In this process, moraine deposits were eroded and modified, and the resulting reworked deposits interfinger with, overlap, or even bury moraine and related deposits (Schmoll and Yehle, 1986). These interpretations were suggested in Schmoll and Dobrovolny (1972a) and support in part the earlier ideas of Karlstrom (1964); he, however, envisioned the water body as a lake rather than an estuary, and extended the duration of the process over a longer period of time.

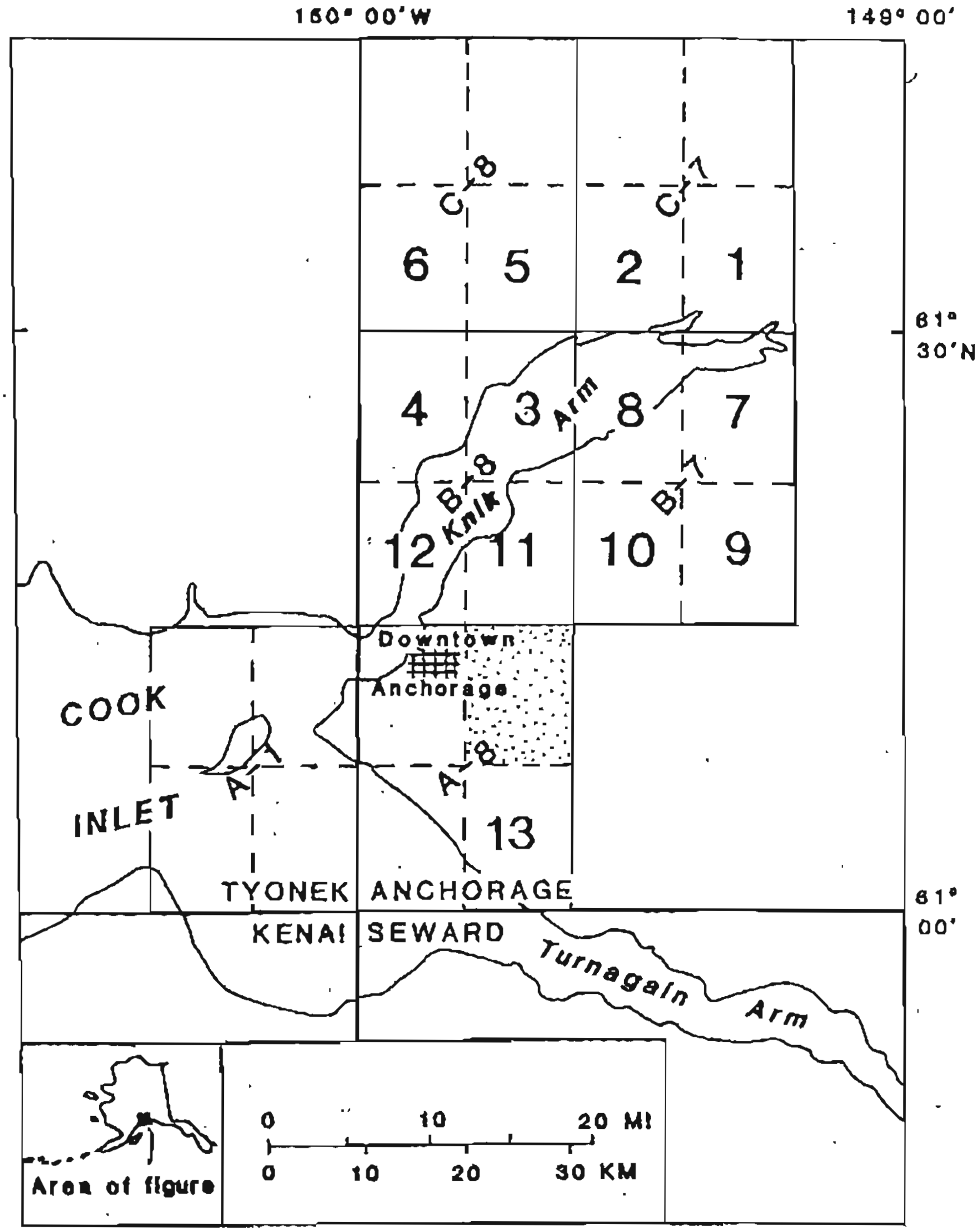


Figure 1. Index map showing location of geologic maps in the Anchorage-Knik Arm region published at 1:25,000 scale. Area of this report is indicated by stippled pattern. Previously published maps are as follows:

1. Daniels, 1981a
2. Daniels, 1981b
3. Reger, 1981a
4. Reger, 1981b.
5. Reger, 1981c
6. Reger, 1981d
7. Yehle and Schmoll, 1987a
8. Yehle and Schmoll, 1987b
9. Updike and Ulery, 1988, and Yehle and Schmoll, 1988
10. Yehle and Schmoll, 1989
11. Yehle and others, 1990
12. Yehle and others, 1991
13. Yehle and others, 1992

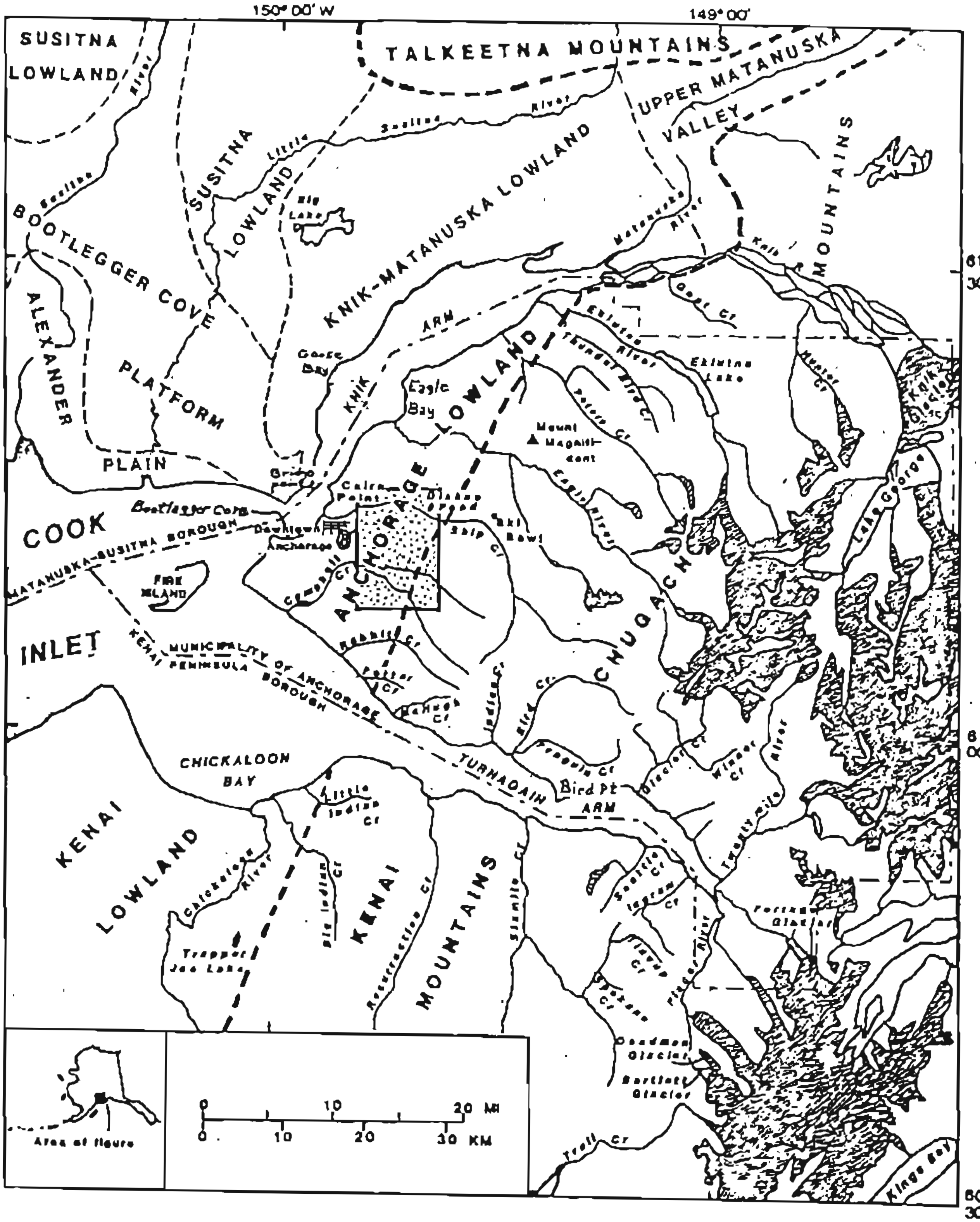


Figure 2. Location of map area (stippled rectangle) and major geographic features. Thick dashed lines indicate boundaries between major physiographic provinces of Wahrhaftig (1965): Talkeetna Mountains, Kenai-Chugach Mountains, and Cook Inlet-Susitna Lowland. The lowlands are subdivided informally into subprovinces separated by thin dashed lines and water bodies. Heavy pattern indicates glaciers. 8 , location of radiocarbon-dated sample, see table 2 and text.

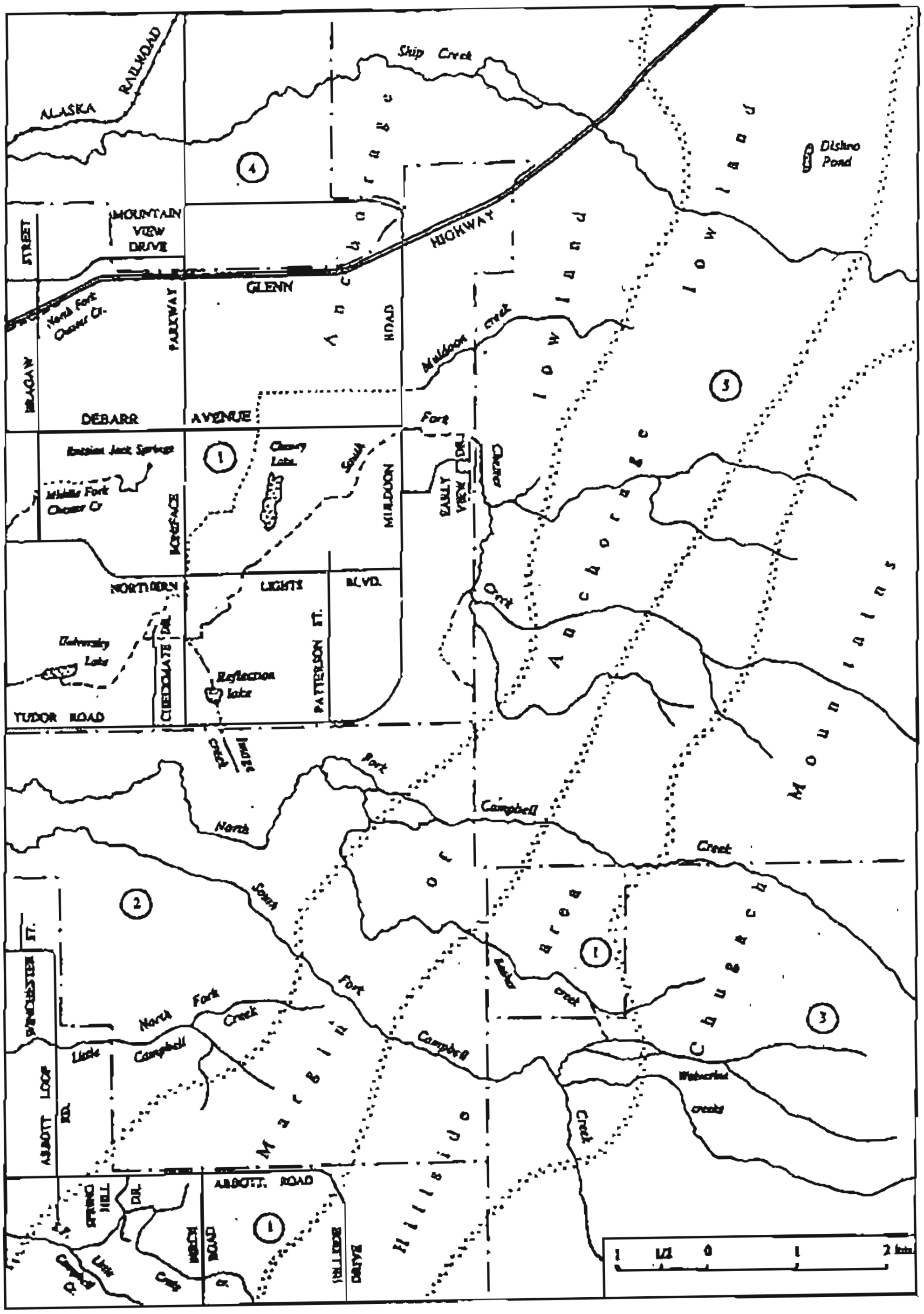


Figure 3. Selected physiographic, hydrologic, and cultural features of the Anchorage A-8 NE quadrangle, Alaska. Physiographic units are separated by stippled lines; streams are dashed where in anthropogenic channel and dotted where in a pipe; lakes are indicated by stippled pattern; dash-dot lines separate areas of major land holdings as follows: 1, mainly privately held residential and commercial areas; 2, government facilities and recreation areas; 3, Chugach State Park; 4, Elmendorf Air Force Base; 5, Fort Richardson Military Reservtion. Only major roads and those whose names are used for informal geologic units are shown.

The geology of the quadrangle presented here was mapped initially at 1:24,000 scale by Schmoll and Dobrovolny mainly between 1965 and 1971 by interpretation of 1:20,000-scale air photos taken in 1962 and by field investigations that continued intermittently through 1988. The original 1:24,000-scale mapping was reduced photographically to a scale of 1:25,000 and modified for the 1:25,000-scale base map, 1973 edition, by Yehle and Schmoll in 1991-1993, with further modifications for the 1993 revision of the base map in 1994. Most of the mountainous parts of the area were remapped by Yehle from examination of 1:24,000-scale air photos taken in 1972; additional interpretations were made by Schmoll from those photos and from 1:40,000-scale air photos taken in 1950. Selected data from earlier geologic maps by Dobrovolny and Miller (1950) and Miller and Dobrovolny (1959) also were utilized. Additional field investigations were undertaken in 1992-1994.

PHYSIOGRAPHY

The map area lies within two major physiographic provinces, the Cook Inlet-Susitna Lowland and the Kenai-Chugach Mountains (Wahrhaftig, 1965) which are subdivided informally as shown on figure 2. The Anchorage lowland occupies most of the map area, whereas the rugged Chugach Mountains dominate the southeastern part and extend north along the eastern fringe. Although a line separates the lowland and the mountains on figure 2, when viewed at larger scale (fig. 3), a transition zone straddles this line. This zone is referred to as the Hillside area, an extension of the name used locally for a major residential area located mainly to the south of the map area (Dearborn and Barnwell, 1975).

The Anchorage lowland (Schmoll and others, 1984) lies in a roughly triangular area between Knik Arm, Turnagain Arm, and the Chugach Mountains (fig. 2). Within the map area, the lowland terrain is marked by southwest-trending belts that rise in altitude and have successively greater relief toward the maintains to the southeast. In the northwestern part of the map area, the terrain is flattest: broad alluvial plains are incised slightly by wide channels and there is a single line of hills of low relief composed of glacial drift. In the central part, similar southwest-trending hills dominate the terrain, but many individual hills have a dominantly north-south alignment. These hills are interrupted by gently sloping alluvial fans formed by streams emanating from the mountains. Farther southeast as the land surface rises, the hills have greater relief and there are fewer and smaller intervening channels.

The Chugach Mountains consist of a central core of very steep mountains where peaks rise to more than 2,000 m and flanking regions where peaks and ridges are generally 1,000-1,500 m in altitude. Only a small part of the western flanking region is present in the map area where the highest peak, 1,167 m, not formally named, occurs along a ridge near the east edge; the second highest peak reaches 1,086 m at bench mark Rusty on the next ridge south. These ridges culminate about 1 km east of the map area in Wolverine Peak at 1,368 m (fig. 2). The Chugach Mountains are transected by a series of northwest-trending U-shaped valleys that merge with the Hillside area at their mouths and thus are hanging with respect to the Anchorage lowland. The prominent, generally sharp-crested ridges that separate the U-shaped valleys descend in altitude toward the northwest where many of them are relatively smoothed. Some ridges have gently sloping to nearly flat crests.

HYDROGRAPHY

The map area lies entirely in the drainages of Ship, Chester, and Campbell Creeks (figs. 2 and 3). Ship Creek flows across the northern part of the area in a well-developed stream course that emerges from a major valley in the mountains to the east. It is well incised where it crosses the narrow extension of the Hillside area in the northeastern part of the map area but is very little incised in the north-central part where it flows across a well-developed alluvial fan. To the west it gradually becomes more deeply incised again so that it occupies a wide, bluff-bounded channel in the northwestern part.

South of Ship Creek area lies an area drained by a complex series of tributaries that combine to form main Chester Creek about one kilometer west of the map area. Within the map area (fig. 3) these tributaries have been modified to a variable degree in the process of urban development and in places are no longer present at the ground surface. The North and Middle Forks extend only a short ways into the map area where they have local sources. Only the South Fork, the stem of Chester Creek with the largest discharge, extends to a valley in the Chugach Mountains. Several unnamed tributaries drain smaller mountain gullies. These streams are poorly defined in places as they cross the Hillside area and the margin of the Anchorage lowland.

The southern half of the map area is drained mainly by the North and South Forks of Campbell Creek which merge about 500 m west of the map area. Each of these forks emerges from a major mountain valley, is incised in a bedrock canyon crossing the Hillside area, and flows near the surface of an alluvial fan. The South Fork is the larger of the two forks, and has the larger fan. In the southeastern part of the map area, two unnamed tributaries of the South Fork drain the ridges dominated by Wolverine Peak; they are here informally termed Wolverine creeks and the three principal valleys that they drain are referred to as Wolverine valleys. The more northerly Wolverine creek may drain, perhaps by having been diverted to the North Fork Campbell Creek through informally-named Basher creek. In the southwestern part of the map area, the North and South Forks of Little Campbell Creek and a tributary to the latter informally named Craig creek dominate the drainage. They join Campbell Creek about 3 km to the west.

Parts of the Anchorage lowland are poorly drained and bogs and ponds were abundant before the onset of urban development. Although many of these features are no longer apparent and some may no longer exist, some peat still may be present in the shallow subsurface. The largest natural water body is Dishno Pond in the northeastern part of the map area. Several smaller ponds occur at widely scattered localities. In addition, several small bodies of water resulted from urban development. Among these are Cheney Lake, University Lake, and the informally named Reflection lake, occupying former gravel pits in the west-central part of the map area. Along Ship Creek in the northwestern part, a small ellipsoidal pond is confined by a low dam, and near the eastern edge of the map area the creek has been dammed for a water-supply intake.

SURFICIAL DEPOSITS

Surficial deposits within the map area comprise a northwest-thickening wedge mainly of Pleistocene-age glacial drift (Miller and Dobrovolny, 1959; Trainer and Waller, 1965; Dearborn and Barnwell, 1975; Freethey and Scully, 1980; Schmoll and Barnwell, 1984; Schmoll and others, 1986; Glass, 1988). The drift includes glacioalluvial and glacioestuarine deposits, ground-moraine deposits that probably were modified by glacioestuarine water, lateral-moraine and kame deposits, and glaciolacustrine deposits. Individual occurrences of nonglacial deposits are more restricted in areal extent, although some of them are widely distributed; mostly Holocene in age, they include alluvial, colluvial, pond and bog, and anthropogenic deposits. Glacial drift occupies the Anchorage lowland, including the Hillside transition zone that flanks the Chugach Mountains, and occurs in the lower parts of major valleys and in cirques along the front of the mountains. In addition there are a few small tracts of glacial till and alluvium on gently crested ridge tops within the mountains, indicating that at times glacier ice filled the Cook Inlet-Susitna Lowland to a sufficient altitude to overtop and erode parts of the adjacent mountains. Alluvial deposits occur along all the major streams. Colluvial deposits cover bedrock on most of the gentler mountain slopes throughout the area and border valleys cut into the glacial drift. Deposits of landslides and a possible rock glacier are present locally along the flanks of the mountains, and a few large areas of landslide deposits are tentatively identified within the glacial drift. Pond and bog deposits occur mainly in the numerous glacial meltwater channels in the Anchorage lowland. A ubiquitous mantle of organic and windblown materials, including minor amounts of tephra, covers all but the most recent deposits. This mantle varies widely in degree of development and preservation but is commonly less than a meter thick; it has not been mapped separately but is included with the underlying deposits. Mapped anthropogenic deposits include the more important areas of engineered fill and of extensively reworked ground in the lowland. Although not so mapped, most of the area of urban development (fig. 3) includes some modification of the deposits within a meter or so of the original ground surface.

GLACIAL DEPOSITS

Glacial deposits in the map area are the products of several advances of a trunk glacier from, and retreats into, distant mountains to the north and east, as well as the advance and retreat of local glaciers in mountain valleys. During each major episode of glacial advance, glaciers successively modified the terrain in the map area. In the mountainous part of the map area, however, evidence for older glaciations is based largely on relict landforms rather than on deposits in stratigraphic sequence. In general, the landforms resulting from the most recent glacier to occupy a given area are the most likely landforms to be preserved. Consequently, the oldest glacier advance for which there is evidence is probably the most extensive one, and successively younger advances from which landforms and their deposits still survive were successively less extensive. Landform evidence is lacking for intervening advances that are less extensive than following advances, because the succeeding more extensive advances tend to destroy previously existing landform evidence. Such intervening, but lesser, ice advances have been recorded in deep-sea drill holes, however, and they probably occurred here as well. In the lowland part of the map area, stratigraphic sequences known from subsurface investigations, mainly water-well logs, indicate a series of at least seven glacial advances separated by deposits indicative of ice withdrawal (Trainer and Waller, 1965; Schmoll and Barnwell, 1984). These sequences cannot, however, be correlated with confidence to deposits of glacial advance and retreat evidenced geomorphically.

The interplay between glaciers from distant and nearby sources varied, depending on a variety of climatic and geographic factors. Five generalized situations outlined below represent successively less extensive maximum advances of glacier ice that may have recurred throughout glacial time. The full sequence occurred only when glaciation was most extensive. At perhaps more common times of less extensive glacial advance, there would have been shorter sequences of only the higher-numbered situations:

1. The most widespread glaciers to reach the map area from distant sources overwhelmed valley glaciers flowing out of the Chugach Mountains, filling the Cook Inlet-Susitna Lowland and covering parts of the adjacent mountains with ice. Local valley glaciers were separately identifiable only at very high levels in the mountains. This situation is represented in the map area by scattered glacial deposits at high levels on some mountain ridges.
2. When glaciers from the distant sources were less extensive, glaciers occupied local valleys in the mountains and joined the major trunk glacier in the Anchorage lowland, the combined glacier flowing southwestward down the Cook Inlet-Susitna Lowland. This situation is attested to by glacial deposits lower on mountain ridges and along the mountain front.
3. At times, as represented in the map area by deposits where valleys reach the mountain front, glaciers in the local mountain valleys did not reach far enough downvalley to join the lowland ice, and the lower parts of these valleys were free of glacier ice. When drainage in such local valleys was blocked by the lowland glacier or its lateral moraines, lakes formed between the lowland glacier and the mountain-valley glaciers. The local glaciers then either terminated directly in lake water, or were separated from lake water by tracts of outwash that formed deltas into the lakes. Except along Ship Creek, however, such local lake deposits are poorly represented in the map area, and valley streams more commonly may have drained through and (or) around the trunk glacier. Similar relations between trunk glaciers and glacier-free tributary valleys along other mountain margins are described by Booth (1986) and Sturm and others (1987).
4. When glacier advances were still less extensive, ice reached only into the northern part of the map area. The remainder of the Anchorage lowland was probably occupied by glacioestuarine water of an ancestral Cook Inlet with relative water levels substantially higher than at present. The level of such inlet water relative to the land surface at any given time is the product of worldwide eustatic sea level and local isostatic adjustments to glacier loading and unloading of the area, compounded by ongoing tectonic activity. Action of this water reworked the moraine and related deposits, modifying the higher-lying moraines and kames and depositing somewhat better sorted deposits around them, with finer-grained materials accumulating at lowest levels. This situation is represented by a major northeast-trending belt of glacioestuarine deposits extending from the southwest corner to the central part of the map area. Stream flow in the mountain valleys was probably not blocked but flowed into the high-level inlet, locally forming well to poorly defined deltas and fan-deltas.
5. When glacier ice was present only in areas north of the map area in the Anchorage lowland, inlet water extended only into the northwestern and western parts of the map area. Subsequently, the water receded and outwash from the glacier plus alluvium from Eagle River and local valleys dominated the area.

Glacial deposits at the land surface make up landforms of various kinds; the types and spatial relations of the landforms serve as guides to mapping the type of deposit inferred to be present and to interpreting the relative ages of the deposits. The four principal types of glacial deposits mapped in this area are (1) moraine deposits--materials deposited directly by glacier ice and that occur in end, lateral, and ground moraines; (2) glacioalluvial deposits--materials deposited by running water within, around, and draining away from the ice and that occur mainly in kames, meltwater-channels, small outwash plains, and broad alluvial channels and fans; (3) glaciolacustrine and kame-fan deposits--materials deposited in lakes or fans in valleys dammed by glaciers; and (4) glacioestuarine deposits--materials deposited in ancestral Cook Inlet when it was bordered in part by glacier ice; many of the glacioestuarine deposits in the map area represent reworking of other drift.

Glacial deposits vary greatly in texture, both in grain size and degree of sorting, and range within the map area from large areas of coarse-grained deposits like gravel and sand to relatively smaller areas of finer-grained silt and clay. They also include large areas of thinly interbedded deposits of those grain sizes as well as a poorly sorted mixture of them known as diamicton.

Most glacial deposits, especially those of moraines and the closely related glacioalluvial deposits, are further subdivided and relative ages determined with reference to informally named lateral and end moraines, as discussed by Schmoll and Yehle (1986). Glacioestuarine deposits and those glacioalluvial deposits not directly related to named moraines, however, are informally named separately. Schmoll and Yehle (1986) also discuss difficulties in using the glaciation terminology developed by Karlstrom (1957; 1964) in classifying glacial deposits in the Anchorage area and used with some modification by Miller and Dobrovolny (1959) and most later workers. The localities from which Karlstrom's terminology is derived are located to the north and northeast of this map area in the Anchorage lowland and to the south in the Kenai Lowland (fig. 2). Because most of the typical deposits are not well dated and successive deposits are neither in stratigraphic or geomorphic contiguity, there are many uncertainties in correlations of those deposits throughout the Cook Inlet-Susitna Lowland. Furthermore, it is no longer certain that each named glaciation or moraine system necessarily corresponds to a separate major episode of glaciation; instead, some of the named units probably represent either recessional or relatively minor readvance phases of the same glaciation. Thus Schmoll and Yehle (1986) did not use the term glaciation but instead correlated both named moraines and associated glacioestuarine deposits throughout the region by grouping them into "glacioestuarine association." Here, we also do not use Karlstrom's terminology, but rely on local terminology and relate deposits directly to the widely used chronology for the Quaternary of Bowen and others (1986). We apply this chronology without using queries, but recognize that the age of many deposits in the region is still uncertain.

Moraine deposits

Moraine deposits are subdivided according to their occurrence in lateral, end, and ground moraines, all of which are found in the map area (map-unit symbol *m* followed by a letter designating moraine type [*-l*, *-e*, *-g*] and preceded by a letter for moraine name). Well-formed lateral moraines dominate the Hillside transition zone along the front of the Chugach Mountains and are present as scattered remnants along the sides of mountain valleys. Small end moraines are found in the easternmost part of the map area near the heads of small mountain valleys. Ground-moraine deposits occur locally near the mouths of mountain valleys where they emerge onto the Hillside area and are present on several mountain ridgecrests. Extensive deposits in the central part of the map area that might otherwise be regarded as ground-moraine deposits are mapped separately because they were modified (eroded and reworked) in a glacioestuarine environment. These modified deposits are discussed with the glacioestuarine deposits, but some of them are mentioned and their relationship to moraine deposits is discussed here. Moraine deposits consist of till that is composed mainly of diamicton (a poorly sorted mixture of clay, silt, sand, and gravel) and poorly sorted silty to sandy gravel; some sand and gravel are present locally, as are lesser amounts of silt and clay.

Table 1. Characteristic altitudes of moraines along the Chugach Mountain front, Anchorage A-8 NE quadrangle, Alaska

[Ranges given in meters above mean sea level; where no range is given, only single moraine deposit present; range values in parentheses are interpreted, as deposits are lacking. Leaders (--), moraine does not occur in this area]

Moraine system	Range in altitude			General characteristic altitude
	South of Ship Creek	Near North Fork Campbell Creek	Near South Fork Campbell Creek	
Dishno Pond	150-250[1]	--	--	200
Fort Richardson	250-400	250-375	200-350	325
Rabbit Creek	425-500	375-475	350-450	425
Little Rabbit Creek	550-575	475-525	425-(475)	500
Ski Bowl	600-750	550-700	(500-650)	650
Glen Alps	(750-825)	725-800	(675-750)	750
Mount Magnificent	850-950	850-900	950	900
Older moraine deposits	--	--	1,050	1,050

[1]Values mainly for moraines north of Ship Creek.

The deposits of eight named moraine systems are identified in this map area. Six of these were included in the discussions by Schmoll and Yehle (1983, 1986) and two others occur principally and were named in the map area to the south (Yehle and others, 1992). Correlations of seven of these moraine systems, each descending southwestward in altitude along the Chugach Mountain front, have been aided by graphically determined gradients. Each system occurs within characteristic altitudinal ranges in and upslope from the Hillside area; these ranges are presented for three selected areas in table 2. A generalized single characteristic altitude is also given for each system, to provide a more readily visualized approximation of the altitudinal distribution of the moraine systems.

The Elmendorf Moraine (a named geographic feature), the deposits of which comprise the youngest of the eight moraine systems, is not present along the mountain front within the map area; this system terminates in a large end moraine that transects the map area to the north (Yehle and others, 1990). It is represented within the present map area only by narrow belts of outwash deposits. However, deposits of a small end moraine and related features in the largest of the Wolverine valleys in the southeastern part of the map area are thought on sequential evidence to be an equivalent of the Elmendorf Moraine and are so mapped (symbol *e-*).

Of the seven systems that occur along the mountain front, only one, comprising deposits of the Fort Richardson moraines and related kame fields and meltwater channels, is represented by well-formed, nearly continuous, lateral moraines in the Hillside area. The younger Dishno Pond moraines dominate the northern part of the Hillside area; here the morainal ridges are more discontinuous. The older Rabbit Creek moraines form a narrow belt upslope from the Fort Richardson moraines only in the southern part of the map area. All of the other moraine systems are represented only discontinuously on mountain ridges in the east-central and southeastern parts of the map area. Each system is discussed briefly below from youngest to oldest.

The deposits of the Dishno Pond moraines (map symbol *d-*) (Schmoll and Yehle, 1983, 1986) descend along the Chugach Mountain front in the northeastern part of the map area. The name is derived from Dishno Pond which occupies a low-lying channel cut into ground-moraine deposits. The typical locality for these deposits is here designated as the mapped area of the deposits in sec. 3, 4, 8, 9, and 10, T. 13 N., R. 2 W. The best exposure of these deposits occurs on the north side of Ship Creek in the SE 1/ SW 1/4 sec. 9, where about 13 m of diamicton with minor interbeds of gravel have been observed. It is not clear, however, how much of the exposed material corresponds to Dishno Pond moraines rather than older moraines such as the Fort Richardson. The Dishno Pond moraines correspond to the Knik moraines of Karlstrom (1964), that name derived from exposures of diamicton along the northwest shore of Knik Arm about 15 km to the north with which the deposits in the moraines were correlated. Although the correlation might be reasonable, we prefer to follow our system of naming the deposits after the moraine in which they occur. The Dishno Pond moraines were not mapped separately from what are here termed Fort Richardson moraines by Miller and Dobrovolny (1959) who used the term Knik to identify those moraines as well. The substantial areal and altitudinal separation of the Dishno Pond moraines from the Fort Richardson moraines, and the possible association of the Dishno Pond moraines with an end moraine north of Knik Arm (Karlstrom, 1965, fig. 9-47; Schmoll and Yehle, 1986, fig. 5) has lead us, like Karlstrom, to identify them separately.

South of Ship Creek the arcuate trend of the Dishno Pond lateral moraines is represented mainly by an extensive kame field that probably owes is existence to penetration of the glacier by an ancestral Ship Creek. The kames extend about 3 km southwestward from Ship Creek before losing their characteristic form (pl. 1A). At altitudes below about 140 m, drumlinoid ridges are more subdued than similar ground-moraine ridges to the northeast; deposits in the subdued ridges are mapped as Russian Jack deposits and those of the surrounding, smoother terrain as Abbott Road and Muldoon Road deposits. No end-moraine equivalent of the Dishno Pond lateral and ground moraines is evident here or to the southwest. The glacier is interpreted to have terminated in inlet water near here, and as the glacier front withdrew, the water covered previously formed morainal ridges and they were modified by wave and tidal action. The recognition of the downglacier transition from unmodified to modified landforms in this vicinity is complicated by the possiblity of a large landslide, as discussed later under colluvial deposits.

Deposits of small end moraines and related landforms in the largest of the Wolverine valleys in the southeastern part of the map area are identified as Dishno Pond deposits. The correlation of these deposits with those of the Dishno Pond moraines in the northeastern part of the map area is tentative and is based largely on their position in the sequence of moraines in that valley.

The Fort Richardson lateral moraines (map symbol *f-*) are the principal moraines of the Hillside area and extend southwesterly throughout the eastern part of the map area from just south of Ship Creek, continuing into the map area to the south. They consist of a set of three to five parallel ridges commonly separated by meltwater channels. The ridges occur *en echelon*; no single ridge can be traced for the entire length of the set. The typical locality for the deposits of these moraines is regarded as the reach of terrain from the SW 1/4 sec. 20, T. 13 N., R. 2 W., to the SW 1/4 sec. 13, T. 12 N., R. 3 W.; this set of lateral-moraine ridges is continuous except where transected by Chester Creek and the North and South Forks of Campbell Creek. The name is derived from the Fort Richardson Military Reservation where they occur in its southern part. The Fort Richardson moraines extend from the Eklutna River about 30 km northeast (fig. 1; Yehle and Schmoll, 1987a) to Potter Creek about 7 km southwest (fig. 1; Yehle and others, 1992). These moraines were identified as Eklutna moraines by Karlstrom (1964), and as part of the Knik moraines by Miller and Dobrovolny (1959).

Individual moraine ridges, and to some extent the belts of kames as well, descend southwestward in elevation and gradually lose their identity because of burial by glacioestuarine deposits. Because of this burial, and because no Fort Richardson end moraines associated with the lateral-moraine complex have been identified, the moraines are interpreted as the product of a glacier that terminated in glacioestuarine water and that receded northeastward.

Deposits in end and lateral moraines and related features in some of the mountain valleys within the map area are included with the Fort Richardson deposits. In Chester Creek valley and in the southernmost mountain valley, deposits can be correlated with some confidence to the lateral moraines along the mountain front by direct tracing of related deposits. Correlations of deposits in the Wolverine valleys with Fort Richardson deposits in the Hillside area are more tentative, however, and are based mainly on position in the sequence of moraines. The Rabbit Creek moraine deposits (map symbol *r-*) occur mainly in lateral moraines next upslope from the Fort Richardson moraines. They are well developed in the map area to the south where their typical locality occurs (Yehle and others, 1992) and extend northeastward into this map area as far as the North Fork Campbell Creek. Farther northeast, deposits are mainly erratics on glacially eroded bedrock surfaces. Northeastward from the map area such remnants occur as far as the Eklutna River (fig. 1; Yehle and Schmoll, 1987a). Rabbit Creek moraines may represent the greatest extent of the glacier of which the Fort Richardson and Dishno Pond moraines represent largely recessional phases.

Ground-moraine deposits in the Chester Creek and North Fork Campbell Creek valleys mapped as Rabbit Creek deposits are nearly continuous with Rabbit Creek deposits along the mountain front and thus are correlated readily with them. In the Wolverine valleys, however, the correlation with Rabbit Creek deposits in the Hillside area is based largely on their position in the sequence of moraines in those valleys.

Deposits of the Little Rabbit Creek moraines (map symbol *l-*) are found in a discontinuous set of lateral- and ground-moraine remnants that lie about 75 higher on the slope than deposits of the Rabbit Creek moraines. The most prominent occurrences (and typical locality of these deposits) are near Little Rabbit Creek in the map area to the south (Yehle and others, 1992); they extend into this map area as far northeast as the Wolverine valleys. Farther northeast, glacially eroded bedrock surfaces are considered equivalent to these deposits on the basis of their altitude. Because deposits of the Little Rabbit Creek moraines are areally restricted and not far upslope from the Rabbit Creek moraines, their existence was formerly acknowledged only as a subunit within the Rabbit Creek deposits. However, both the lack of continuity of these moraines and their more subdued nature relative to the Rabbit Creek moraines suggest that deposits of the Little Rabbit Creek moraines might be substantially older than those of the Rabbit Creek moraines; therefore, they are now regarded as the deposits of a separate, older glacial event.

Deposits of the Ski Bowl moraines (map symbol *s-*) are restricted to the southeastern part of the map area where they occur as fairly extensive ground moraine on broad surfaces and as very small lateral-moraine remnants in a few mountain valleys. North of the Wolverine valleys scattered erratics are found on the glacially smoothed crests of most mountain ridges; judging by their altitudes, these smoothed surfaces probably were developed by Ski Bowl glaciers. Such surfaces can be traced discontinuously to the typical locality of Ski Bowl deposits about 11 km northeast of the map area (Yehle and Schmoll, 1989) where they occur in well-developed but subdued lateral moraines.

Glen Alps moraine deposits (map symbol *g*-) are found on glacially smoothed bedrock knobs and ridgecrests as variably thick patches of glacial drift, in places limited to scattered erratics. The typical locality for these deposits occurs in the map area to the south (Yehle and others, 1992) where they were first recognized. These deposits occupy a level at least 50 m higher than most of the Ski Bowl deposits and about 150 m lower than most Mount Magnificent deposits and are restricted mainly to the area of the Wolverine valleys. Three very small lateral-moraine remnants, two in the mountain valley in the southeastern corner of the map area and one in the valley of North Fork Campbell Creek, are also regarded as containing Glen Alps deposits. No deposits have been recognized farther northeast than those mapped here.

At still higher altitudes on mountain ridges patches of drift or mixed gravel and bedrock rubble containing numerous erratics are thought to correlate with the Mount Magnificent moraine deposits (map symbol *m*-) about 22 km to the northeast (Yehle and Schmoll, 1989). They occur on mountain ridges north and south of the North Fork Campbell Creek valley.

Glacioalluvial and related alluvial deposits

Alluvium is represented among the surficial deposits of all ages from the oldest recognized to that of the lowest terraces and streams of the present day. It includes deposits clearly influenced by the proximity of glaciers, those for which the glacial influence is less direct, and those formed in the absence of glaciers. Thus, glacioalluvial and related alluvial deposits are discussed together here. The oldest deposits are fragmentary in both space and time, and are presumed by their location at high altitudes to be mainly glacioalluvial. Most of the alluvium within the map area, however, can be regarded as representing a near-continuum of successively lower-level water courses developed as the lowland glacier retreated through the phases marked by successively younger moraines, and finally, by the Elmendorf Moraine in the map area to the north. Subsequent alluvium was less directly influenced by glacier ice. Analysis of the gradients of these deposits indicates that about 30 levels of alluviation can be differentiated. Some moraine-associated meltwater-channel deposits appear to lie along the same gradient as other deposits some distance downgradient, but it is not certain that they necessarily were formed by a coeval, once continuous stream. Because of various uncertainties, the narrow, commonly short meltwater channels associated with lateral moraines in the Hillside area have been designated only by the moraine names, whereas the larger channels and fans that dominate the lowland are separately named, commonly in groups. Eventually the continuum extended to alluvial deposits commonly associated with present-day streams.

The alluvial deposits of this continuum record changes in the pattern of alluviation as the drainage from mountain valleys within and north of the map area reacted to the change in environment from glacial to glacioestuarine to the subaerial regime of most of postglacial time down to the present day. The presence of a trunk glacier and succeeding glacial landforms in the Anchorage lowland generally forced the drainage from the northwest-trending valleys to take a southwesterly course as it entered the Hillside area, and only gradually did the drainage achieve the northwest-trending course across the lowland characteristic of most streams of the present.

Glacioalluvial deposits in the map area related to moraines are further subdivided into (1) deposits of kames and minor eskers that formed mainly by running water within the glacier during the early stages of stagnation when large amounts of glacier ice were still present; (2) kame-terrace deposits that formed similarly but adjacent to the glacier; (3) meltwater-channel deposits that formed in channels developed either adjacent to the glaciers or within morainal areas during the waning stages of glacier stagnation or perhaps just after the ice was no longer present; (4) outwash deposits that formed at the margin of the glacier by drainage from within it and channel deposits that lead away from the glacier margin.

Kame deposits (map symbol *-k*) occur in locally prominent landforms that include irregular hills and areas of hummocky terrain mainly within the Dishno Pond and Fort Richardson moraines. They are especially prevalent downslope from relatively narrow lateral-moraine ridges where they occur as a broader band of hills and small ridges that lack the continuity of the moraine ridges. Dishno Pond kame fields are best developed downglacier from (southwest of) Ship Creek; Fort Richardson kame fields are continuous downglacier from the valleys of Chester Creek and the North and South Forks of Campbell Creek. These relationships suggest that the deposits formed when streams in tributary valleys entered the margin of the lowland trunk glacier. Some kames, however, may have formed at least partly from drainage within the glacier that had a more northeasterly source. Only one kame deposit is mapped within the small mountain valleys. Some kames of especially high relief are mapped separately (*-kh*), but the significance of differences in relief is not evident. Other deposits that may have been deposited originally in kames apparently were reworked by the activity of glacioestuarine water and are discussed with those deposits. The kames consist mostly of gravel and sand, but also include varying amounts of diamicton and finer-grained deposits; some of the higher kames may include substantial cores of diamicton. In a few places within the map area, kame deposits have been utilized as major sources of sand and gravel; this utilization has altered the original landforms; in places, they are no longer recognizable.

Kame-terrace deposits (*-kt*) are mapped in a few places in belts parallel to the kame fields. They differ from the kames in having broad, smoothly sloping tops and in having prominent scarps on their ice-proximal (northwestern) sides developed when the adjacent glacier melted.

Meltwater-channel deposits (*-c*) occur extensively in the Hillside area. They are associated mainly with Fort Richardson lateral moraines except in the northeastern part of the map area where they are part of the Dishno Pond moraine system. In the southeastern part a few meltwater-channel deposits parallel the Rabbit Creek lateral moraines, and small remnants of higher-level channels are also present. The only representatives of glacial drift at levels higher than the Mount Magnificent drift are a few tentatively identified channel deposits just east of the peak at benchmark Rusty near the southeastern corner of the quadrangle. Most of the meltwater channels are narrow, separating well developed lateral-moraine ridges. Some channels occur in broader complexes, however, and especially in these areas some deposits are separately identified as kame-channel deposits (*-kc*). These deposits have a slightly hummocky surface, perhaps influenced by the lingering presence of glacier ice during and shortly after deposition. The meltwater-channel deposits consist mainly of gravel and sand, but in some channels peat may be common at the surface; locally, diamicton or bedrock may be present at shallow depths.

Deposits mapped as glacial outwash (*-o*) are restricted to those in close association with or directly traceable to end moraines; these deposits have only limited distribution within the map area. Small outwash deposits are mapped in terrace remnants that extend downvalley from end moraines, mainly in the Wolverine and Chester Creek valleys. These deposits probably consist of gravel and sand, but no exposures of them have been observed. Outwash deposited by streams emanating from the Elmendorf Moraine in the map area to the north (Yehle and others, 1990) are closely associated with glacioalluvium of other sources; they are discussed below with them, and likewise are separately named.

The separately-named glacioalluvial deposits are extensive throughout the lowland part of the map area and include both deposits with sources farther northeast within the lowland as well as those with more local sources in mountain valleys within and to the east of the map area. The deposits can be divided into three groups that range in geographic occurrence from southwest to north and in age from older to younger, but with considerable overlap among the groups. (1) Deposits in the southwestern part of the map area have sources either in lowland moraines, in the local mountain valleys, or perhaps both. These deposits trend southwestward mainly in channels that lead to deltaic deposits west and southwest of the map area. (2) Deposits with probably glacial sources in local mountain valleys within and to the east of the map area trend generally westward or northwestward, cutting across the map area in channels and major alluvial fans. (3) Deposits that dominate the northern and west-central parts of the map area have sources mainly in the map area to the north (Yehle and others, 1990) but derive partly from Ship Creek valley as well.

All of the separately-named alluvial deposits consist dominantly of gravel that becomes finer and includes an increasingly higher proportion of sand southwestward or downstream. Some of these deposits were used extensively as sources of sand and gravel in earlier stages of urban development, and in places the present ground surface lies at the level of originally adjacent lower-lying surfaces. In some places lakes now occupy former excavations. Particularly in the western part of the map area, grain-size distribution of some deposits was such that pit-run material was useful for construction purposes. These sources of sand and gravel are now largely exhausted, developed upon, or otherwise unavailable, and most of the formerly extensive gravel pits are no longer in operation, and for some, their former identity is not even evident.

The glacioalluvial deposits in the southwestern part of the map area occur at four levels. The deposits of the three highest levels are termed Klatt Road deposits, whereas deposits of the lowest level are designated Spring Hill deposits. The main (intermediate level) Klatt Road (*kc*) and the Spring Hill (*sh*) deposits each occupy a major channel, whereas the other Klatt Road deposits occupy smaller channels or occur as terraces along the major channels. The name was first used in the map area to the south (Yehle and others, 1992), where the deposits appear in the northwestern part, but they are more extensively developed in this map area. They lead southwestward to large areas of deltaic deposits in map areas to the west (Schmoll and Dobrovolny, 1972a, map unit *af*). Their name derives from the deltaic deposits that are traversed by Klatt Road, the eastern extension of which also traverses the channel deposits in the map area to the south. The typical locality for the three levels of Klatt Road channel deposits lies within this map area, however, and is regarded as the channel that extends from the NW 1/4 sec. 12 to the SW 1/4 sec. 14, T. 12 N., R. 3 W. The Spring Hill deposits take their name from Spring Hill Drive (fig. 3) which crosses the best-developed channel in the NW 1/4 sec. 15, T. 12 N., R. 3 W; this area constitutes the typical locality. Exposures of all of these deposits are poor, and the thickness of the gravel and sand is not known. In places, the channels may be floored by finer-grained materials or by peat deposits.

Klatt Road and Spring Hill deposits are incised into the surfaces of the Abbott Road glacioesturaine deposits and are graded in turn to successively lower levels of ancestral Cook Inlet. The higher-level Klatt Road deposits (*kch*) occupy a shallow, poorly preserved system of possibly anastomosing channels evidenced at present mainly by terrace remnants. Although the deposits appear related to the lowermost levels of Fort Richardson moraines, they may also represent streams from both the North and South Fork Campbell Creek valleys that flowed through these moraines after both retreat of the ice and recession of ancestral Cook Inlet from its highest levels. The main-level deposits (*kc*) occupy a remarkably well developed and straight channel that carried copious quantities of water judging by the size of both the channel and the deltas to which it leads. Much of this water may have come from the South Fork of Campbell Creek valley, possibly from the breakout of a glacier- or moraine-dammed lake. The lower-lying Klatt Road deposits (*kcl*) occupy smaller channels through which water flowed perhaps for only a short period of time to a lower-level delta in the vicinity of Klatt Road. The main channel floored by Spring Hill deposits apparently was developed first by lower-level Klatt Road water, but the Spring Hill channel is deeper and broader, the Klatt Road deposits occurring only as terrace remnants. Spring Hill streams apparently developed shorter courses to still lower-level deltas directly west of the map area. Spring Hill deposits can be traced only as far northeast as South Fork Campbell Creek, but on the basis of similarity of gradient they have been extended up the South Fork, although this correlation is tentative.

Eastern-source glacioalluvium includes mainly deposits of ancestral Ship and Chester Creeks and the North and South Forks of Campbell Creek. These deposits occur in terrace remnants mainly within their respective mountain valleys and in prominent alluvial fans with northwest-trending axes. The alluvial fans lie downslope from the Hillside area which the streams cross in deep, narrow canyons, some incised into bedrock. The deposits occur at several levels, but few deposits can be traced with confidence either upvalley to glacial sources or downvalley to identifiable levels of ancestral Cook Inlet. It is thought, however, that upvalley the terraces lead to moraines, and that downvalley base levels were controlled by water levels higher than that of present-day Cook Inlet. These relationships are clearest in the South Fork Campbell Creek drainage, but probably obtain in the other valleys as well. Correlations between the valleys are also difficult, but it appears that the main Ship Creek deposits are somewhat younger than the correspondingly major deposits in the more southerly valleys. This is reasonable because the Dishno Pond glacier was still blocking Ship Creek after the Fort Richardson glacier was no longer in existence to block the more southerly valleys. Furthermore, most levels of the southern valley sequences grade to glacioestuarine base levels whereas all but the two highest levels of the Ship Creek sequence are graded to, or are lower than, the generally younger northern-source alluvium. Because of difficulties in correlation, most of the deposits are separately identified in each major valley except that of Chester Creek. The correlations shown on the correlation of map units (Pl. 1B, in pocket) are thus tentative.

Alluvium of South Fork Campbell Creek is subdivided into five map units that include deposits in the main alluvial fan (*sf*), in terrace remnants at two levels higher than that of the main fan (*sft* and *sfth*), and in two levels cut below the main fan (*sfn*, *sfs*). As noted above, Spring Hill deposits are also mapped in the South Fork valley, at a level above that of the main fan deposits. Thus, there are deposits at six levels above that of the present stream along South Fork. The two highest-level deposits, which occur only in small remnants, might correlate with Klatt Road deposits, or alternatively could be fan-delta remnants related to the highest levels of ancestral Cook Inlet. The Spring Hill deposits and those of the main fan occupy the two lower terraces along the uppermost reach of South Fork within the map area and are traceable to deposits mapped as alluvial terrace deposits in the map areas to the south (Yehle and others, 1992). Following deposition of the main fan, South Fork alluvial deposits at the next lower level are traceable to North Fork Campbell Creek as well, suggesting that for a time the two forks joined farther upstream than at present. During at least part of this time, they may have flowed northward to join a stream in Nunaka valley (ancestral Eagle River combined with Ship Creek) by way of grosssly underfit "Image creek" (fig. 3). Later, in shifting back to a more westerly course, the two forks followed the present pattern of maintaining separate courses for a few kilometers before joining. Still later, South Fork followed an entirely separate course along the south side of the main fan, which was then abandoned when the stream returned to its present position on the north side of the fan, but still in a stream separate from North Fork. The abandoned southern channel at present contains only a small flow of water, North Fork Little Campbell Creek, which probably derives from the South Fork by underflow. However, because the upstream end of this south-side channel lies less than a meter above the present level of South Fork, this abandoned channel could again become the main channel; such a shift in stream course could result in flooding along North Fork Little Campbell Creek.

Alluvium of North Fork Campbell Creek is subdivided in three map units, including deposits of the principal fan along the North Fork (*nf*), of one level cut below that (*nfl*), and of a few remnants of higher-level deposits (*nfh*). The deposits of the main fan of the North Fork may be slightly older than those of the South Fork, but the evidence is not conclusive. North Fork deposits are also mapped in two levels along Chester Creek where the higher-level deposits are the more extensively preserved.

Alluvium of Ship Creek is subdivided into six units, comprising deposits of the prominent alluvial fan and deposits at two levels higher than, and at three extensively developed levels lower than, the fan. The two highest deposits (*sct* and *scth*) are restricted to small occurrences upvalley from the fan. They might be fan-deltas graded to high levels of ancestral Cook Inlet. The deposits of the alluvial fan and those at lower levels are more appropriately discussed below with northern-source deposits into which they grade or are incised.

The alluvial deposits that dominate the northern and west-central parts of the map area are divided into eleven map units; these deposits are derived from two different northern sources as well as from Ship Creek valley. Three deposits of relatively limited extent trend southerly and, with varying degrees of certainty, are interpreted to have formed as outwash from the Elmendorf Moraine a few kilometers north of the map area (Yehle and others, 1990). Deposition of the outwash was apparently interrupted, and the two older deposits substantially eroded, as the area became overwhelmed by incursions of streams that laid down the principal deposits in the two southwest-trending alluvial systems that transect the outwash. The large-scale Nunaka Valley and Mountain View deposits (four map units) resulted from the seeming breakout of Eagle River drainage (fig. 2) that had been blocked by the Elmendorf glacier and its massive moraine; those features, however, forced the water to take a southwesterly course into this map area. It is likely that the four deposits formed in a relatively short time, perhaps in a series of catastrophic events. Subsequently, the Eagle River cut a more westerly course across the moraine and, since then, has not entered this map area. Ship Creek could then dominate the northern part of the map area as it does at present. The Ship Creek deposits are mapped in four units of which the deposits of the lower-lying three are incised into the Eagle-River-source deposits.

The two highest-lying outwash deposits occur only as remnants, mainly in the west-central part of the map area. They cannot be traced directly to the Elmendorf Moraine and hence are separately identified. Their orientation and gradients strongly suggest, however, that they once were continuous with Elmendorf outwash that is now truncated by Eagle-River-source alluvial deposits in the map area to the north. This outwash is divided into Patterson Street deposits (*ps*) and Cheney Lake deposits (*ch*). The Patterson Street deposits are slightly higher in level and lie to the southeast of the Cheney Lake deposits. The Patterson Street deposits are named here for the first time; the typical locality occurs along that street in the NW 1/4 sec. 25 and the NE 1/4 sec. 26, T. 13 N., R. 3 W. The best exposures, however, were in former gravel pits in the NW 1/4 sec. 35 of the same township where about 4 m of gravel with minor sand beds were observed overlying fine-sandy diamicton. The Cheney Lake deposits, also named here for the first time, occur in more restricted remnants; furthermore, they have been removed in large part from their principal area of occurrence in the former gravel pit in the E 1/2 sec. 23, T. 13 N., R. 3 W., now occupied by the artificial lake from which they take their name.

Nunaka Valley channel deposits (*nc*) constitute the higher-lying and more southeasterly of the two alluvial systems derived from Eagle River. These deposits occur in a broad, somewhat anastomosing channel that apparently has been partly buried by late-phase deposits of the Ship Creek alluvial fan. This channel system splits into two main channels of which the more southeasterly is presently occupied in part by the underfit course of South Fork Chester Creek. These deposits take their name from the Nunaka Valley subdivision (in the vicinity of Nunaka Valley School) in the west-central part of the map area. The name was first used to denote subsurface occurrences illustrated in Schmoll and Barnwell (1984). The most complete exposure of the deposits was observed along the east wall of an excavation in the SW 1/4 sec. 27, T. 13. N., R. 3 W. This exposure is designated the typical locality, although it is now only partially visible along the east side of University Lake. Here, the deposit consists of 12 m of pebble to small cobble gravel, well bedded and sorted, and including only relatively minor beds of sand. The base of the deposit is not exposed.

In much of the stretch of the Nunaka Valley channel now occupied in part by South Fork Chester Creek, the surface of the channel is marked by numerous boulders, some as much as 3 m in long dimension. In this part of the deposit, gravel may be thin or lacking, and the surface may have been underlain in part by peat deposits. Most of such peat has been removed in the processes of urbanization, however, and the boulders have been placed decoratively within residential lots. It is thought that this area represents erosion of diamicton, silt, and fine sand of the Muldoon Road and perhaps Russian Jack deposits, which formerly extended across the area of the channel and which were themselves reworkings of preëxisting moraine deposits. The boulders thus represent at least a second generation lag concentrate of older deposits. This distinctively characterized area is mapped separately as the Checkmate phase of Nunaka valley deposits (*ncc*), named for Checkmate Drive (fig. 3) in the SE 1/4 sec. 27, T. 13 N., R. 3 W., where the boulders are extensively displayed. Many of the boulders are granitic with distinctive, large feldspathic phenocrysts, and are similar to those found in lateral moraines along the Chugach Mountain front; the boulders are especially prominent in the Mount Magnificent ground moraine to the northeast. They are believed to have a source in the Alaska Range, as discussed briefly by Schmoll and Yehle (1986, p. 199), and may represent a lag concentrate that has been recycled through deposits of more than one glacial episode, as well as the glacioestuarine deposits from which they were most recently reworked, to appear now on this alluvial surface.

Deposits of the Mountain View alluvial fan (*mvf*) comprise the lower-lying and more extensive of the two Eagle River channel and fan systems. Only the southeastern part of this large alluvial fan lies within the map area, dominating its northwestern part. Here, the fan is dissected into long and relatively narrow southwest-trending remnants. Among these remnants are deposits that occur at two levels slightly higher than that of the main fan (*mvl* and *mvh*); these remnants were identified previously as East High alluvial deposits in Schmoll and Barnwell (1984), a name now abandoned. The Mountain View deposits are more extensive in the map area to the north where the head of the alluvial fan complex is located (Yehle and others, 1990), but the higher-lying remnants were not differentiated there. To the west, the deposits underlie much of downtown Anchorage. The typical locality extends from downtown to the N 1/2 sec. 10, T. 13 N., R. 3 W, in this map area where the community of Mountain View is located. The name was first used in Bartsch-Winkler and Schmoll (1984) and the deposits shown in Schmoll and Barnwell (1984). Previously, the deposits were identified as map unit *an* (Schmoll and Dobrovolny, 1972a) and map unit *Qo*, Naptowne outwash (Miller and Dobrovolny, 1959). Near Mountain View, about 6.5 m of gravel and sand have been exposed from time to time, and the deposits are well known from numerous shallow bore holes in the downtown area where as much as 14 m has been reported (Schmoll and Barnwell, 1984). The deposit is underlain by the Bootlegger Cove Formation or by an intervening sand deposit directly overlying the Bootlegger Cove Formation. The Mountain View surface apparently was covered more consistently than most deposits in the map area by about a meter of silt and fine sand of probable eolian origin; much of this material has been removed or obscured, however, in the process of urbanization.

The lowest-lying and youngest of the Elmendorf outwash deposits occupy a shallow channel cut slightly below the surface of the Mountain View alluvial fan deposits in the northwesternmost part of this map area. This outwash is termed Bluff Road deposits and the map-unit symbol (*ecb*) carries an Elmendorf channel designation because in the map area to the north the outwash can be traced to the younger phase of the Elmendorf Moraine. West of the map area, the channel deepens and deposits are graded to two levels above that of the higher-level Chester Creek alluvial deposits of Ship Creek source. The deposits are better developed there and take their name from occurrences near Bluff Road along the north rim of Ship Creek valley, the typical locality. The deposits are poorly exposed but probably consist of gravel and sand that overlie (and might be difficult to distinguish from) Mountain View alluvial fan deposits.

The deposits of the prominent alluvial fan of Ship Creek (*scf*) are graded mainly to Mountain View deposits, but some may be graded to the older Nunaka Valley channel deposits; they are recognized only within the fan itself. The three later channel deposits of Ship Creek lie only slightly lower than the level of the alluvial fan, and at their upstream ends are virtually indistinguishable in level from each other as well. The two highest channels descend in altitude with slightly different gradients, and at the west edge of the map area both are well incised beneath the Mountain View surface. The deposits in these two channels are here termed Chester Creek deposits for their occurrence in this valley through which present-day Chester Creek flows to Cook Inlet west of the map area. There, the higher-level deposits (*sch*) occur in terrace remnants and the lower-level deposits (*scc*) form the floor of the valley. Eventually, Ship Creek flowed in a new valley farther north, the one in which the creek presently flows. The deposits of this valley are here termed lower Ship Creek deposits (*scl*). In the north-central part of the map area, Ship Creek and its modern alluvium lie about a meter lower than the level of these deposits. The valley becomes increasingly more incised to the west, however, and there the lower Ship Creek deposits occupy a terrace a few to several meters higher than the level of Ship Creek and its still lower terraces.

Kame-fan and glaciolacustrine deposits

In major mountain valleys where the drainage was blocked by glaciers, generally fine-grained deposits formed in lakes dammed by the glaciers; coarser-grained materials accumulated as deltas at the upvalley ends of the lakes. Only the fine-grained deposits occur within the map area, however. In smaller valleys and gullies, delta-like kame fans formed next to the glacier; open bodies of water may have been present only intermittently, if at all. Other glaciolacustrine deposits may be present within the Anchorage lowland, as postulated, for example, by Karlstrom (1964), but because they are not distinguishable with certainty from glacioestuarine deposits, they are discussed together with the latter deposits.

Kame-fan deposits (*-kf*) occur near the mouths of mountain valleys in association with the Dishno Pond and Fort Richardson moraines, and at scattered localities higher on mountain valley slopes in association with marginal positions of older glaciers. These deposits are poorly exposed, but are thought to be typically coarse grained and moderately well to poorly sorted; they may include diamicton.

Glaciolacustrine deposits (*-gl*) are best developed within the map area near its eastern edge on the south side of Ship Creek valley. These deposits occur in two levels of which the higher appears graded to Fort Richardson lateral moraines and the lower to Dishno Pond lateral moraines; the deposits are designated accordingly. Smaller areas of such deposits are identified in the valley of North Fork Campbell Creek in association with the Fort Richardson moraines. If glaciolacustrine deposits were present along the reach of the South Fork within the map area, they may have been restricted to the area now occupied by the canyon of the creek and thus would not have been preserved. Glaciolacustrine deposits are not well exposed within the map area, but deposits to the east along Ship Creek include silt, clay, and fine sand at stratigraphically lower levels; coarser sand is found near the surface. By implication, these deposits could be as much as 120 m thick.

Glacioestuarine deposits

Deposits interpreted to be mainly glacioestuarine in origin dominate a northeast-trending belt within the the Anchorage lowland extending from the north-central to the southwestern parts of the map area between the Hillside area (to the southeast) and the glacioalluvial channel and fan deposits (to the northwest). Miller and Dobrovolny (1959) regarded these deposits as glacial, mainly ground-moraine and kame deposits, although they recognized some glaciolacustrine deposits as well. In concurrent work however, Karlstrom (1964) expanded the glaciolacustrine concept so that large parts of the upper Cook Inlet region (including the Anchorage lowland) were thought to have been occupied by glacial lake Cook, mainly to explain the large areas of rather subdued topography and the lack of well formed end moraines where they otherwise would be expected. These relationships are similar to those in the Copper River basin about 250 km to the east where a large glacial lake exerted a dominating influence on the nature of the glacial deposits (Ferrians and Schmoll, 1957; Ferrians and Nichols, 1965; Nichols and Yehle, 1969). In the upper Cook Inlet region, however, subsequent work discussed in more detail below, has indicated that the presumed glaciolacustrine deposits are mainly glacioestuarine, that is, deposited in water open to the marine environment of the Pacific Ocean. They are termed glacioestuarine rather than marine or glaciomarine by analogy to present-day upper Cook Inlet, an estuary the upper end of which is some 250 km from the open ocean, as discussed in Bartsch-Winkler and Schmoll (1984) and Schmoll and others (1984). The occurrence of widespread glacioestuarine deposits in the region was suggested in the generalized mapping of Schmoll and Dobrovolny (1972a) and discussed more fully by Schmoll and Yehle (1983, 1986).

The only unambiguously documented glacioestuarine deposit within the Anchorage lowland is the Bootlegger Cove Formation (map unit *bc*). It consists of silty clay and clayey silt with minor interbedded silt, fine sand, fine to medium sand, and thin beds of diamicton; scattered pebbles and cobbles are present in widely varying concentrations. It was originally named Bootlegger Cove Clay (Miller and Dobrovolny, 1959) from exposures along Knik Arm west of the map area (fig. 2) and considered to be glaciolacustrine in origin. Karlstrom (1964) recognized one relatively thin horizon as glacioestuarine ("marine"). In Karlstrom's interpretation, the formation encompassed both glacial and interglacial aspects. However, the occurrence of brackish marine microfossils at many stratigraphic levels within the formation (Schmidt, 1963; Smith, 1964), as well as revised dating (Schmoll and others, 1972), has lead to reinterpretation of the formation as mainly, and perhaps entirely, glacioestuarine. In recognition of there being at least as much silt- as clay-size material in most fine-grained beds, as well as the inclusion of numerous, probably lenticular beds of sand, the stratigraphic unit was subsequently redesignated "Formation" (Updike and others, 1982). Present knowledge of the distribution and age of the Bootlegger Cove Formation is well summarized by Reger and others (1995).

The Bootlegger Cove Formation is present in the subsurface in the northwestern part of the map area but is not known to crop out there. However, blue-gray silty clay thought to be Bootlegger Cove Formation was observed in a now-concealed highway excavation at the intersection of the Glenn Highway and Boniface Parkway and it is mapped as anthropogenically disturbed there. It is also thought to be present, although concealed by overlying colluvium, in the lower part of bluffs along Ship Creek valley in the northwestern part of the map area. Its crucial role in that geomorphic setting in the development of major earthquake-induced landslides is discussed with colluvial (including landslide) deposits.

The identification of other deposits as glacioestuarine is less well documented and is based largely on types of geologic materials and their geomorphic relationships, together with the certainty of a glacioestuarine environment established by the presence of the Bootlegger Cove Formation. Some microfossil evidence from similar deposits in the map area to the south (Bartsch-Winkler and Schmoll, 1984; Yehle and others, 1992) support this interpretation, but such evidence has not been found in the poorly exposed deposits within the map area. Glacioestuarine deposits overlap moraine deposits, yet in places only partly conceal moraine-like landforms. They may be divided into two categories: (1) those that consist largely of substantially reworked materials newly deposited in better sorted, well-defined beds, commonly obliterating the original landform; and (2) those in which material originally deposited by glaciers or glacier-related streams may have been reworked only minimally, the original landform either largely preserved or substantially altered in form because of erosion by wave, tidal, or other current action within the glacioestuarine environment.

The deposits in the first category were included in map unit *mg* (marine, glacial, and (or) lacustrine deposits) in the generalized geologic map of Schmoll and Dobrovolny (1972a). We, however, subdivide these deposits into five informally named units that occur in belts generally at successively lower altitudes or successively farther southwest; they are named in descending order after Birch Road, Abbott Road, Muldoon Road, Early View Drive, and Winchester Street. All but the first-named of these deposits have typical localities in this map area. Although the altitudinal demarcation of the various deposits is consistent across the map area, it is not certain that such limits necessarily mark shoreline levels of substantive duration, and no prominent evidence of former shorelines at any of these levels has been found. Each of these deposits differs from the others in one or more characteristics, including texture, thickness, moraine association, landform, or certainty of identity.

Birch Road deposits (*br*) are best developed in the map area to the south where their typical locality occurs (Yehle and others, 1992). They extend into this map area to about North Fork Campbell Creek and occupy a narrow, irregularly sloping bench-like area that lies between about 140 and 200 m in altitude. At the typical locality they consist mainly of fine sand and silt; diamicton or gravel and sand may be dominant locally; most exposures in this map area, however, are poor. Birch Road deposits may have formed in the glacioestuarine water in which the Fort Richardson glacier terminated and that modified the Fort Richardson moraine deposits. However, because of the altitude to which the deposits extend and because no estuarine microfauna have been found in the deposits, it is possible that they were deposited instead in glaciolacustrine water. Such a lake could have been either (1) a relatively restricted lake impounded between a glacier in the Anchorage lowland and one emanating from Turnagain Arm, or (2) glacial lake Cook as postulated by Karlstrom (1964). Although we do not support Karlstrom's interpretation of low-lying glaciolacustrine deposits in the Anchorage area, we cannot rule out Karlstrom's concept, and the Birch Road deposits could be the product of such a regional lake at a higher level; Birch Road deposits lie well within the altitudinal range of the lake he postulated.

Abbott Road deposits (*ar*) occur within the map area in a narrow belt that extends northeasterly from the southwestern corner to near Ship Creek in the northeastern part. They range in altitude between about 110 and 140 m. Their typical locality occurs along Abbott Road between about 1 km east of Abbott Loop Road and Birch Road, mainly in the SE 1/4 sec. 10 and the NE 1/4 sec. 15, T. 12 N., R. 3 W. The deposits are poorly exposed, but appear to include mainly silt, fine sand, and diamicton. In the vicinity of the typical locality they characteristically contain a high proportion of cobble-size rubble in shallow, near-surface exposures, including mainly metagraywacke and other rocks that crop out in the mountains to the east; the rubble may be the product of a localized landslide and not be typical of the deposit as a whole. Such a landslide could have originated in the SE 1/4 sec. 5, T. 12 N., R. 2 W., and the debris transported by the Fort Richardson glacier before being reworked into the Abbott Road deposits. Abbott Road deposits occupy a broad but dissected surface of subdued relief downslope from Birch Road deposits and, farther northeast, a narrower, more bench-like surface subjacent to modified Fort Richardson kame deposits. At their northeastern extremity, the deposits impinge upon Dishno Pond moraine deposits and probably represent the estuarine water that extended successively farther northeastward as the Fort Richardson glacier receded and as the Dishno Pond glacier subsequently may have readvanced.

Muldoon Road deposits (*mr*) occupy a broad northeast-trending belt in the southwestern and central parts of the map area where they range in altitude between about 70 and 110 m. The name was first used and the deposits illustrated in Schmoll and Barnwell (1984). Their typical locality lies in the vicinity of Muldoon Road. The locality from which the deposits were initially described (but not designated as the typical locality) was in the SW 1/4 sec. 25, T. 13 N., R. 3 W.; however, it was subsequently destroyed during work for the extension of Muldoon Road in the broad curve connecting it with Tudor Road. Similar but less well exposed deposits east of Muldoon Road in the SE 1/4 sec. 13, T. 13 N., R. 3 W., are here designated as the typical locality. The deposits include well bedded fine sand, silt, silty sand, and silty to fine-sandy diamicton that is in part less distinctly bedded. Elsewhere the deposits may be less well sorted and bedded. They occur commonly in a smoother, lower-lying zone adjacent to and in places completely surrounding higher hills mapped as Russian Jack deposits (discussed below). Less commonly, the deposits occur in low hills surrounded by broad glacioalluvial channels; these hills are probably remnants of previously more extensive Muldoon Road deposits much of which have been eroded in the process of channel formation.

Early View deposits (*ev*) lie mainly in a relatively narrow, low-lying sector within the central part of the map area east of Muldoon Road. This sector previously was thought to be a peat-surfaced alluvial channel (Schmoll and Dobrovolny, 1972a). Constructed drainage channels and several excavations subsequently revealed the extensive presence of blue-gray clay and silt beneath the peat in this area. These deposits are here termed Early View deposits after Early View Drive (fig. 3), a residential street that borders the western side of part of the typical locality in the NE 1/4 sec. 24, T. 13 N., R. 3 W. Although possibly the deposits of a local lake blocked perhaps by the South Fork Campbell Creek alluvial fan, the similarity of the material to that of the Bootlegger Cove Formation suggests instead the likelihood that the deposits represent a stage in the sequence of successively lower-level glacioestuarine deposits. Conceivably they are equivalent to the Bootlegger Cove Formation, but pending the establishment of such identity, they have been separately identified. The Early View clay and silt deposits are bordered in many places by slightly higher-lying and better-drained areas that are mapped separately (*evc*). Here the deposits are thought to be coarser grained, probably including sand and perhaps fine gravel, but exposures are poor. The clay and silt deposits are commonly surfaced by a meter or less of peat; where the peat is thought to be thicker in the central parts of some areas of the deposits, a separate map unit (*evp*) is used. Early View deposits are also shown in small areas south of the South Fork Campbell Creek alluvial fan, largely on the basis of similar geomorphic position. If the Early View deposits originated in glacioestuarine water of wide extent, they may be coeval with those lower-lying Muldoon Road deposits mapped in the northwestern and west-central parts of the map area.

Winchester Street deposits (*ws*) are restricted to the west-central part of the map area where they seem to be a finer-grained, downstream equivalent of the lower-level South Fork Campbell Creek alluvial deposits into which they appear to grade. Their broad form, very gentle gradient, and poorly drained surface suggest that they represent a marginal facies of the glacioestuarine environment. The deposits range in altitude between about 50 and 75 m. The typical locality is in a small residential neighborhood centered around Winchester Street (fig. 3) in the NE 1/4 sec. 4, T. 12 N., R. 3 W. Exposures are very poor, but the deposits probably consist mainly of fine sand commonly overlain by peat. Where the peat is thicker than about 1 m a separate map unit (*wsp*) is used. In a few places the Winchester Street deposits are bordered by better-drained areas that consist of coarser sand and fine gravel; these areas are mapped separately as *wsc*.

The Winchester Street deposits may be underlain by the Bootlegger Cove Formation at least in the western part of their occurrence. The lower part of the Winchester Street may have an interfingering relationship with the upper beds of the Bootlegger Cove which contain more interbeds of fine sand than is characteristic of the lower part of the formation (Updike and others, 1988). Thus, Winchester Street may represent a marginal, extensively developed sand facies of the upper part of the Bootlegger Cove.

The glacioestuarine deposits in the second category appear to preserve their presumed origin as glacial deposits more than do the more modified deposits of the first category, in that the landforms are similar to ground moraine and kames and the respective deposits are likewise similar to their glacial counterparts. However, the landforms are somewhat more subdued, and a thin cover of bedded, finer-grained material blankets the modified landform in many places. At least some of the deposits could have accumulated entirely in the glacioestuarine environment, in sectors of especially rapid deposition near glacier fronts. These deposits are divided into three map units, the Russian Jack deposits, primarily diamicton, and the Boniface Parkway and O'Malley Road deposits, mainly gravel and sand.

The Russian Jack deposits (*rj*) were mapped previously by symbol *gm* (glacial and (or) marine deposits, Schmoll and Dobrovolny, 1972a). The name was first used and the deposits illustrated in Schmoll and Barnwell (1984). They occur extensively in the central and west-central parts of the map area in isolated hills that are elongated in a dominantly north-south direction. Some of the hills appear to have an elliptical, somewhat drumlinoid form, but most are too irregular in shape to be classified as drumlins, although some possibly originated as such. The present form of some of the hills is the product of erosion, especially by Eagle River water as it coursed through the area. The deposits take their name from Russian Jack Springs Park where a characteristic hill containing the deposits occurs. The typical locality is designated as the good exposure in a sidehill excavation for a trailer park about 1 km east of the park in a similar hill in the NW 1/4 sec. 14, T. 13 N., R. 3 W. Here, about 16 m of mainly gray, fine-sandy diamicton is present in both north- and west-facing cut slopes; the base of this unit is not exposed. Summary subsurface data (Schmoll and Barnwell, 1984) indicate thicknesses ranging from about 6 to 25 m. At the typical locality faint bedding was visible in places within otherwise massive-appearing diamicton; at some horizons such bedding seemed to mark a subtle change in the color or texture of the diamicton. About 4.5 m above the base of the exposure a zone about 4 m thick was observed that included predominantly better sorted material including stony sand, fine sand, and gravel. In the upper part of the exposure as much as 4 m of well bedded sand was observed in some places. Pebbles and cobbles are well scattered throughout the diamicton, but boulders are rare. Additional detailed observations were made in a series of trenches in the hill in the SE 1/4 sec. 26, T. 13 N., R. 3 W., where minor bedding was observed within fine-sandy matrixed diamicton. The bulk of the diamicton could reasonably be till, but an alternate possibility is that the diamicton was deposited entirely in a glacioestuarine environment. These exposures resemble in a general way exposures of rudely bedded diamicton with interbedded gravel, sand, and silt observed at several places in the Copper River basin, especially at the mouth of the Gakona River (Mendenhall, 1905, p. 66; Ferrians, 1963) where a glaciolacustrine origin for the deposit seems very likely.

The hills of Russian Jack deposits are commonly surrounded by lower-lying terrain with a smooth to very slightly irregular surface underlain by Muldoon Road deposits; the geomorphically expressed contact between the two is rarely sharp, however. Efforts to see the relationship between the more clearly bedded Muldoon Road and the obscurely bedded Russian Jack deposits have proved futile; in a few poor exposures, however, there seems to be an interfingering, in the sense of seeing a gradual change in the number of identifiable beds from few (Russian Jack) to many (Muldoon Road), but elsewhere the Muldoon Road appears to lap onto the Russian Jack.

If the Russian Jack deposits do represent till for the most part, it is not clear to which of the named lateral moraines they are related. At the northeastern end of the area of occurrence, the Russian Jack hills seem to lie in continuity with moraine hills at slightly higher altitude that constitute somewhat drumlinoid Dishno Pond ground moraine. In the central part of the map area, Russian Jack hills more likely could be regarded as modified Fort Richardson ground moraine, but the positional distribution of the hills is less than optimal for that interpretation. An alternate possiblilty is that the deposits formed when the Dishno Pond glacier fronted in glacioestuarine water and that the diamicton represents subaqueous slumping of unstable, but perhaps better sorted, material deposited near the terminus of the glacier. Such an interpretation has been made for diamicton and better sorted and bedded deposits well exposed on Fire Island (fig. 1) (Schmoll and Gardner, 1982; Schmoll and others, 1984, p. 69-81), but it is not certain from the limited exposures in this map area that a similar interpretation can be made here. The southernmost mapped Russian Jack deposits occur in hills with a northwest-trending orientation, and here the identity of the deposits is tentative. It is possible that these deposits are related to an otherwise unrecognized, outer, modified ridge of the Potter Creek moraines, and in that case it would be more appropriate to identify the deposits as DeArmoun Road deposits; both of these deposits occur in the map area to the south (Yehle and others, 1992).

The other two deposits of the second glacioestuarine category both appear to be modified kame deposits. They occur in irregularly shaped hills that consist mostly of gravel and sand with only minor finer-grained or less well sorted materials; some have been used as sources of gravel. However, the hills tend to be isolated, or occur in small groups that do not otherwise resemble the kame fields characteristic of the Hillside area, for example.

The Boniface Parkway deposits (*bp*) are restricted to the north-central and west-central parts of the map area where they occur in a southwest-trending alignment associated with hills of Russian Jack deposits. They take their name, used here for the first time, from an occurrence that straddles Boniface Parkway in the NE 1/4 sec. 22 and the SW 1/4 sec. 14, T. 13 N., R. 3 W. which constitutes the typical locality. In an abandoned gravel pit in sec. 14, about 5 m of gravel with minor sand was formerly exposed; a greater thickness appeared to have been removed. Muldoon Road deposits appeared to lap onto the gravel in a rare view of such a relationship. Like the Russian Jack deposits, the Boniface Parkway deposits have uncertain affinity to named moraines, but could represent drainage, perhaps into glacioestuarine water, from within the Dishno Pond glacier.

The O'Malley Road deposits occur only in the southwestern part of the map area; they are somewhat more extensive in the map area to the west where their typical locality was located in a kame-like hill observed by the first author with T.N.V. Karlstrom and O.J. Ferrians, Jr., in 1957. At that time about 10 m of gravel was exposed, overlain by a thin cover of finer-grained deposits thought by Karlstrom to be glaciolacustrine in origin. By 1965, however, the deposit had been totally excvated. The deposits could be associated with either the Potter Creek or Fort Richardson moraines that subsequently were modified by glacioestuarine water. The hills are near broad areas of deltaic deposits, however, and could represent high-level remnants of the deltaic deposits, most of which are related to the Klatt Road glacioalluvial deposits in this map area.

Chronology

The age of the deposits described above is known in a relative way but is not well established in an absolute sense. Previous workers (Miller and Dobrovolny, 1959; Karlstrom, 1964) have differed, and we have been uncertain (Schmoll and Yehle, 1986) as to which deposits should be regarded as late Pleistocene in age, that is, part of the Wisconsin glaciation (Bowen and others, 1986). In the map area to the south (Yehle and others, 1992), however, we have concluded that the Rabbit Creek and younger moraines are probably all late Pleistocene in age, and that the higher-level remnants of glacial deposits are of unknown earlier Pleistocene age. In the map area to the north, the Elmendorf Moraine has a relatively well established age of about 14,000 radiocarbon years, that is, very late Pleistocene (Schmoll and others, 1972; Yehle and others, 1990, 1991). Alluvial deposits in the northern part of the present map area related to the Elmendorf Moraine are thus somewhat similar in age.

Radiocarbon ages have been determined on samples from several sites within the map area (table 2), but they mainly provide minimum ages that are consistent with the above interpretations (localities 4-7). The most meaningful minimum age is from locality 8 (in the map area to the west; fig. 2) where peat overlying or within the youngest Chester Creek alluvium has an age of about 10,000 years. On this basis, deposits as young as the Chester Creek are regarded as late Pleistocene in age, and thus, of the major alluvial deposits, only the lower Ship Creek alluvium is of Holocene age. The two dates at locality 2, however, indicate that at least locally more alluviation was occurring within the Holocene than is indicated by the alluvial map units. For this reason, several late Pleistocene alluvial deposits are indicated on the correlation of map units (pl. 1B, in pocket) as being at least allowably of Holocene age in their upper parts.

The radiocarbon dates thus do not help in determining the ages of the morainal and related deposits within the late Pleistocene. Since it is thought likely, however, that the Rabbit Creek moraines represent a maximum glacial advance of late Pleistocene age, and that it is probably coeval with such maximum advances in other parts of the world (Bowen and others, 1986), it might have occurred in the period between about 18,000 and 25,000 years ago. If so, the Fort Richardson and Dishno Pond moraines then represent deposition during a gradual downmelting and retreat of ice from the Rabbit Creek position concurrent with advance of glacioestuarine water as the ice front retreated. In this interpretation, all of the surface deposits in the map area from the Fort Richarsdon moraines in the south and east to (but not including) the Nunaka Valley and Mountain View deposits in the north and west may range in age between about 20,000 and 15,000 years, whereas the major alluvial deposits formed between about 12,000 and 10,000 years ago.

COLLUVIAL DEPOSITS

The term colluvial deposits (colluvium), as used here, includes those deposits that occur on a slope and that have accumulated primarily through the action of gravity and secondarily with the aid of running water. Colluvium is broadly subdivided into deposits that have accumulated particle by particle over a long period of time (for example, talus) and deposits that have moved *en masse* (mass-wasting deposits), either rapidly, such as debris avalanches, or slowly, such as by solifluction. The deposits that accumulated particle by particle commonly underlie relatively smooth, mostly concave-upward slopes, whereas mass-wasting deposits, including rock-glacier deposits, are generally characterized by sloping topography that is irregularly lumpy to hummocky.

Most colluvial deposits contain minor admixtures of organic-rich soil and windblown material, and can be derived either directly from bedrock, from unconsolidated surficial deposits, or from a combination of these materials. Colluvium generally is poorly sorted, ranges widely in grain size, and is only somewhat compact. Good exposures of colluvial deposits are uncommon, and our descriptions are based largely on inference from exposures in similar landforms elsewhere in the region.

Smooth-surfaced colluvium occupies large areas on mountain slopes, commonly thickest in the middle part of the slope, and is derived mainly from bedrock and mapped as undivided colluvium (map unit *c*). Other types of colluvium that accumulated particle by particle have more specialized characteristics and are mapped separately. Talus deposits (*ct*) generally occur high on the slopes and along the upper courses of tributary valleys, usually downslope from prominent bedrock outcrops. Only a few of these deposits occur within the map area, in the southeastern part. On slopes on which remnants of lateral- and ground-moraine deposits are mapped or are thought to be present at depth, colluvium contains material derived from glacial deposits as well as from bedrock (*cg*); some of these slopes have an irregular surface and only partly conceal in-place morainal deposits. On slopes below the proximal (toward-ice) side of some lateral moraines, colluvium is derived largely from morainal deposits (*cm*) and is similar to ground moraine except that it has been subjected to some mixing during its downslope movement. Colluvium that is mixed with alluvium (*ca*) occupies small areas generally restricted in width and commonly in gullies and small ravines

Table 2. List of radiocarbon dates in and near the Anchorage A-8 NE quadrangle, Alaska

[Localities 1 through 7 shown on plate 1A; locality 8 shown on figure 2. Samples collected by Dobrovolny and Schmoll and reported here for the first time except as noted. W-, data from Meyer Rubin, U.S. Geological Survey radiocarbon laboratory, Washington, D.C. (now Reston, Virginia). Ages given in years before present (1950) as reported by laboratory]

Locality number and name	Location	Date of collection	Material	Lab number	Radiocarbon age
1. Ship Creek	NE1/4SE1/4 sec. 1, T. 13 N., R. 3 W.	August 24, 1971	Wood	W-2935	90±250
2. Reflection lake[1]	SW1/4SW1/4 sec. 26, T. 13 N., R. 3 W.	August 14, 1971	Wood Wood	W-2910 W-2909	3,100±250 4,650±250
3. South Fork Campbell Creek	SW1/4NW1/4 sec. 7, T. 12 N., R. 2 W.	September 13, 1965[2]	Peat	W-1807	5,960±250
4. 18th Avenue and Valarian[3]	SE1/4NE1/4 sec. 21, T. 13 N., R. 3 W.	August 12, 1971	Peat	W-2939	7,990±300
5. Debarr and Pine	SW1/4SE1/4 sec. 15, T. 13 N., R. 3 W.	July 18, 1968	Peat	W-4472	9,290±70
6. Sixth Avenue west of Boniface	NE1/4SE1/4 sec. 15, T. 13 N., R. 3 W.	September 5, 1983[4]	Peat	W-5786	9,440±200
7. Tudor-Muldoon	NE1/4NW1/4 sec. 36, T. 13 N., R. 3 W.	August 8, 1970	Peat	W-2918	9,800±360
8. Chester Creek at Ingra	SW1/4NW1/4 sec. 20, T. 13 N., R. 3 W.	August 4, 1970	Peat	W-2916	10,800±350

[1]Collected in gravel pit before creation of lake.

[2]Marsters and others (1969).

[3]Approximate location; collected in gravel pit before development of streets.

[4]Collected by Schmoll and A.H. Richardson.

The steep walls of valleys that are incised into surficial deposits are particularly subject to instability and renewed stream erosion. These valley walls commonly are veneered by a downslope-thickening wedge of colluvium (*cw*) derived mainly from material into which the wall was cut during the last episode of erosion. Such erosion is likely to recur at any place along the wall when the stream renews its lateral attack, removes at least part of the colluvium, and erodes anew the underlying material. Valley-wall colluvium commonly forms long, narrow belts on terrace and channel escarpments; some of these bluffs are too narrow to map separately, but occur commonly where alluvial deposits of different ages are in contact. Some of the small bluffs are indicated by linear scarp symbol. In the northwestern part of the map area valley-wall colluvium probably conceals the Bootlegger Cove Formation in the lower part of the valley wall. Because there is some potential for large-scale landsliding to occur here especially during large-magnitude earthquakes (Dobrovolny and Schmoll, 1974), these deposits are mapped separately (*cwb*).

Colluvial deposits that have formed *en masse* include mainly landslide deposits. These are among the most important of the colluvial deposits in terms of their potential impact on human activity. They vary from individual earthflows and slumps in surficial deposits and (or) bedrock to huge retrogressive block failures developed entirely in bedrock. Deposits of all but one of these landslide types, common mainly within the mountains, are included in an undivided map unit (*cl*). Earthflows larger than about 100 m in length, however, are mapped separately (*cle*); most of these occupy pre-existing gullies and ravines. Solifluction deposits (*cs*) accumulated more slowly than landslides, generally by creep, and occupy small to fairly large areas on broad mountain slopes.

The widespread occurrence of landsliding in the area is facilitated by (1) the structural complexity and highly fractured or sheared nature of bedrock in a locality; (2) occurrence of fine-grained deposits, mainly silt and clay; (3) steepness of slopes, caused in part by glacial erosion, and (4) slope orientation. In the Anchorage lowland west of the map area, large landslides occurred during prolonged ground shaking produced by the 1964 Alaska earthquake (Hansen, 1965). All of these landslides resulted from failures within the Bootleger Cove Formation where it was exposed in valley walls and sea bluffs that provided a free face from which the destabilized material could move. Older landslides of similar form and location are thought to have been formed similarly (Miller and Dobrovolny, 1959; Schmoll and Dobrovolny, 1972a). Only one such older landslide deposit is tentatively identified within the map area, along Ship Creek in the northwestern part, and is mapped separately (*clb*). Other large landslides are inferred to have occurred within the map area, possibly under somewhat similar conditions, and these also are mapped separately. In the central part of the map area, several postulated landslides may have resulted from failures in fine-grained glacioestuarine deposits (*clg*). In the northeastern part of the map area south of Ship Creek, a large landslide is inferred to have developed in Dishno Pond lateral-moraine deposits (*cld*), possibly shortly after the glacier melted down and when glacioestuarine water may have been present. As was the case with the lower part of the extensive 1964 Turnagain Heights landslide west of downtown Anchorage (Hansen, 1965), the lower part of the slide may have entered the estuary and the deposits become substantially modified (*clm*).

In many places landslides can be readily identified on the basis of surface morphology visible on air photos. In other places, however, surface morphology is merely suggestive that landslide deposits might be present. The substantial number of suspected landslide deposits are indicated by query on the map. Detailed investigation may suggest alternate interpretations for these features and some of them, for which alternate origins can be confirmed, would be relegated to the category "pseudo-landslides" (Shlemon and Davis, 1986).

Rock-glacier deposits are the products of rock glaciers that are no longer active. These deposits are transitional in nature between colluvial and glacial deposits, although recent evidence suggests that rock glaciers probably have a closer affinity to true glaciers than previously thought (Moore and Friedman, 1991). Within the map area, deposits comparable to the older rock-glacier deposits (*rdo*) discussed by Yehle and Schmoll (1988) have been identified only in the most northerly Wolverine valley. These deposits are probably similar to ground-moraine deposits, but at least near the surface may be more bouldery and the surface morphology is generally more massive and uniformly hummocky in appearance than is true of most ground moraine.

A special type of slope process that occurs on some steep mountain slopes and on ridge crests but which commonly does not give rise directly to colluvium, is inferred from small, narrow, bedrock-flanked trenches which we interpret as sackung features. The trenches occur along or just downslope from and subparallel to the crests of a few high-mountain ridges. *Sackung features* are thought to have formed through gravitational spreading of a ridge by gradual displacement along a series of disconnected planes or by deep-seated plastic deformation of the rock mass without formation of a through-going discrete slide surface (Radbruch-Hall, 1978; Savage and Varnes, 1987; Varnes and others, 1989). Although the process is not fully understood, conditions especially conducive to sackung formation are thought to include oversteepened valley walls left unsupported after retreat of a glacier. Earthquake-shaking and tectonic- or glacio-isostatic uplift might enhance or accelerate development of the sackung features, but are not regarded as the primary cause. All these conditions obtain in the Chugach Mountains where we recognize sackung features. A few of these features are present in the east-central and southeastern parts of the map area; others are well exhibited farther to the east (Schmoll and Dobrovolny, unpublished mapping) and northeast (Updike and Ulery, 1983; Yehle and Schmoll, 1987b, 1988, 1989).

OTHER DEPOSITS

Other surficial deposits mapped include alluvial, pond and bog, and anthropogenic deposits. The alluvial deposits are subdivided into stream alluvium and fan alluvium. Stream alluvium (map unit *al*) has been mapped along the main streams that cross the Anchorage lowland and in the narrow inner valleys within the major mountain valleys, as well as along a few small streams where they drain the lateral moraines and related kame fields. In the central and west-central parts of the map area, alluvium is mapped along several tributaries of Chester Creek where the streams have been diverted to ditches or pipes; in many of these places the presence of alluvium has been obscured in the process of urbanization. Alluvium also occurs along a few small streams in areas that are too narrow to map separately. Fan alluvium (*af*) is deposited where steeply-graded tributary valleys enter a larger valley of substantially lower gradient or the lower-lying parts of the Anchorage lowland.

In places, alluvial deposits thought to be significantly older are mapped separately (*alo*). These older alluvial deposits generally occur in small channels within the moraines, but are thought to post-date the influence of the glaciers. Older alluvium also occurs in generally small, high-level fans (*afo*) that have been incised by streams which in many places subsequently developed modern fans near present stream levels. The deposits of large, still older alluvial channels and fans within the map area were discussed above with related glacioalluvium.

Alluvial deposits consist mostly of sand and gravel. Locally, alluvium both along small streams and in fans is finer grained, mainly fine sand and silt; some of these occurrences are mapped separately as *alf* and *aff*, respectively.

Pond and bog deposits (*p*) are mapped mainly in small poorly drained areas within moraines and kame fields, in glacial meltwater channels, and in a few areas of glacioestuarine deposits. Within the lowland, there are a few large bogs that originally may have been lakes. Other areas with peat at the surface are mapped with the glacioalluvial deposits that they overlie; these bogs probably did not originate as lakes. Deposits consist largely of peat of varying degrees of compaction, including some woody horizons. Minor amounts of silt and sand, especially in the basal parts of large bogs, and thin lenses of tephra also are present. The pond and bog deposits grade laterally into, but are thicker than, the mantle of organic and eolian deposits that overlie most other deposits, but that is not mapped separately.

Anthropogenic deposits are those that have been emplaced or significantly disturbed by the activities of man. Much of the urbanized area (fig. 3) is covered by varying thicknesses of fill that is not mapped. Engineered fill (*f*) has been mapped mainly where the Alaska Railroad, the Glenn Highway, and other major streets cross low, poorly drained areas or traverse between ground surfaces of significantly different level, and the fill is more than about a meter thick. A large area of fill is associated with an airfield in the northwestern part of the map area. Other areas of fill, some not necessarily engineered, are mapped where significant landforms have been created as landfills. In numerous areas, naturally occurring materials have been extensively reworked, or, as in some major gravel pits, entirely removed, commonly destroying original landforms. Such areas include both cut and fill and are shown by underscored map-unit symbols.

PERMAFROST

Permafrost is defined as "soil or rock material, with or without included moisture or organic matter, that has remained at or below 0° C. [32° F.] for two or more years" (Muller, 1945, cited in Ferrians, 1994). The lowland part of the Anchorage area is included within a region that is generally free of permafrost (Ferrians, 1965). Most surficial deposits do appear unfrozen during midsummer when they are most readily observed. However, permafrost has been reported or is suspected at three sites within the map area, encountered in the process of ground disturbance while undergoing urban development. These areas have been identified by diagonal ruling on the geologic map (Pl. 1A, in pocket). They all lie within a few kilometers of each other in places of relatively thick peat accumulation in low-lying areas in the central to west-central parts of the map area, and are within the broad zone of possible permafrost conditions shown on a map published by the Municipality of Anchorage (1980).

The best known area of permafrost lies in the SW 1/4 sec. 25, T. 13 N., R. 3 W., and was encountered during preconstruction bore-hole drilling in 1962 at the broad curve connecting Tudor Road and Muldoon Road (J.R. Williams, written commun., 1979, cited in O.J. Ferrians, Jr., written commun., 1993). Here, there is "a large, oval-shaped, tree-covered palsa [peat-covered frost mound indicative of permafrost conditions]. This palsa, approximately 150 m by 60 m in plan and 3.5 m in height, is underlain by an irregularly shaped core of perennially frozen peat and silt up to 7.5 m thick. Numerous lenses of segregated ice are present in the silt. The surface peat layer ranges from 1.5 to 3 m in thickneess." The area of the palsa was bypassed by subsequent construction and remains mostly undisturbed; the proposed highway alignment was altered slightly to avoid the site. In spite of much development and concomitant excavation in the vicinity, no other such characteristic ground has been found nearby.

Another area in the SE 1/4 sec. 27, T. 13 N., R. 3 W., about 3 km to the west, was identified only after a residential building suffered severe differential settlement a few years after its construction. The building subsequently was demolished and the area is now a small municipal park. It is likely that the building was situated on a small tract of ground underlain by peat that previously was not recognized or was regarded as too small to portray at the 1:63,360-scale of geologic mapping of Miller and Dobrovolny (1959) or at the degree of generalization used by Schmoll and Dobrovolny (1972a) on their geologic map. Although at about the lower limit of detail that is shown on our geologic map, we portray this area at slightly exaggerated size on Plate 1A.

The third and largest area is in the NE 1/4 sec. 26, T. 13 N., R. 3 W., northeast of Baxter Bog Municipal Park, and is suspected of containing permafrost on the basis of apparent measures being undertaken to monitor ground conditions at the site. Pre-development appearance of the site on 1950 and 1972 air photos indicates some irregular ground in this otherwise bog-like area, but the photo appearance was not sufficiently diagnostic to unequivocally indicate the presence of permafrost.

It is possible that similar low-lying areas, particularly where peat is relatively thick, may contain permafrost, but they are likely to be relatively small, perhaps confined to the general vicinity of the identified occurrences.

Within the Chugach Mountains, isolated masses of permafrost are likely to exist in selected areas (Ferrians, 1965). Their location is hard to predict because of the variability in material type, orientation of the ground slope, and microclimatic factors responsible for mean annual air and ground temperatures at any given site. The presence of solifluction deposits is suggestive of permafrost conditions, but no firm conclusions in this regard can be drawn without detailed investigations to determine whether permafrost, melting of seasonal frost, or some other lubricating mechanism is responsible for apparent downslope movement of the material.

SUBSURFACE DATA

There are few good exposures of surficial deposits within the map area, and those rarely reveal more than one stratigraphic unit each, commonly without extending to the base of the unit. Consequently, little stratigraphic information can be gained from study of surface exposures. There is, however, a large body of subsurface data, mainly in the form of water-well logs; some of these have been summarized by previous workers as parts of more regional studies (Miller and Dobrovolny, 1959, pl. 6; Trainer and Waller, 1965; Freethey and Scully, 1980; Schmoll and Barnwell, 1984). A detailed log of a 230-m deep drill hole, substantially deeper than any of the water wells, exists about 0.5 km west of the map area in Tikishla Park near the center of sec. 21, T. 13 N., R. 3 W. (fig. 2; Yehle and others, 1986). Most of these data, however, are so variable in quality that interpretations of both material type and genesis derived from them are subject to a high degree of uncertainty. Nevertheless, some estimate of the nature of the stratigraphy can be ascertained.

A summary of subsurface stratigraphy along DeBarr Avenue is presented as cross section A-A' on figure 4; its location and other subsurface information are shown on figure 5. This version is modified slightly from that given in Schmoll and Barnwell (1984). Geologic units mapped at the surface along the line of the cross section are shown in its near-surface part, as inferred both from lithologies given in the well logs and from inferred relationships among the mapped units. Lower in the cross section the limited data do not allow presentation in similar detail. However, the depositional model developed for this part of the Cook Inlet basin envisions a series of glaciations, as noted above, and it thus is reasonable to assume (1) that deposits at depth should bear a similarity to those that occur near the surface, and (2) that the entire sequence of deposits should be repetitive in character. Indeed, most of the data bear this out. The depositional units developed by Schmoll and Barnwell (1984) are shown as recurring throughout the depth of the cross section, implying the recurrence of similar environments of deposition within each of several succeeding glaciations. These units are given here, together with selected equivalent units mapped at the surface:

A. Alluvial gravel and sand	Mountain View and Nunaka Valley deposits; Ship Creek and Campbell Creek alluvial-fan deposits
B. Bootlegger Cove Formation and similar but older deposits dominantly of silt and clay	Bootlegger Cove Formation; Early View deposits
M. Silty fine sand and fine sandy silt	Winchester Street deposits; coarser beds within the Bootlegger Cove Formation
S. Stony silt and clay	Muldoon Road and Abbott Road deposits
D. Diamicton	Russian Jack deposits; Dishno Pond ground-moraine deposits

In the interpretation of these subsurface data, A-units function as marker horizons. They probably are the deposits of glacial retreat that mark a nonglacial interval at their upper boundary; thus, the tops of these units are analogous to the present surface. These marker horizons are not recognized in all well logs, just as the mapped alluvial units of the present surface are not a totally continuous blanket, but they appear to align with sufficient consistency for the interpretation to be valid. As many as seven such A-unit horizons have been identified, including the one at the present ground surface which is numbered 1. A practical consequence of the widespread if not universal presence of the A horizons is that they have served as dependable sources of ground water. The horizons closer to the surface, 2 and 3, have been particularly important in this regard as the process of urbanization proceeded and additional water supplies were needed (Cederstrom and others, 1964; Barnwell and George, 1968; U.S. Geological Survey, 1987).

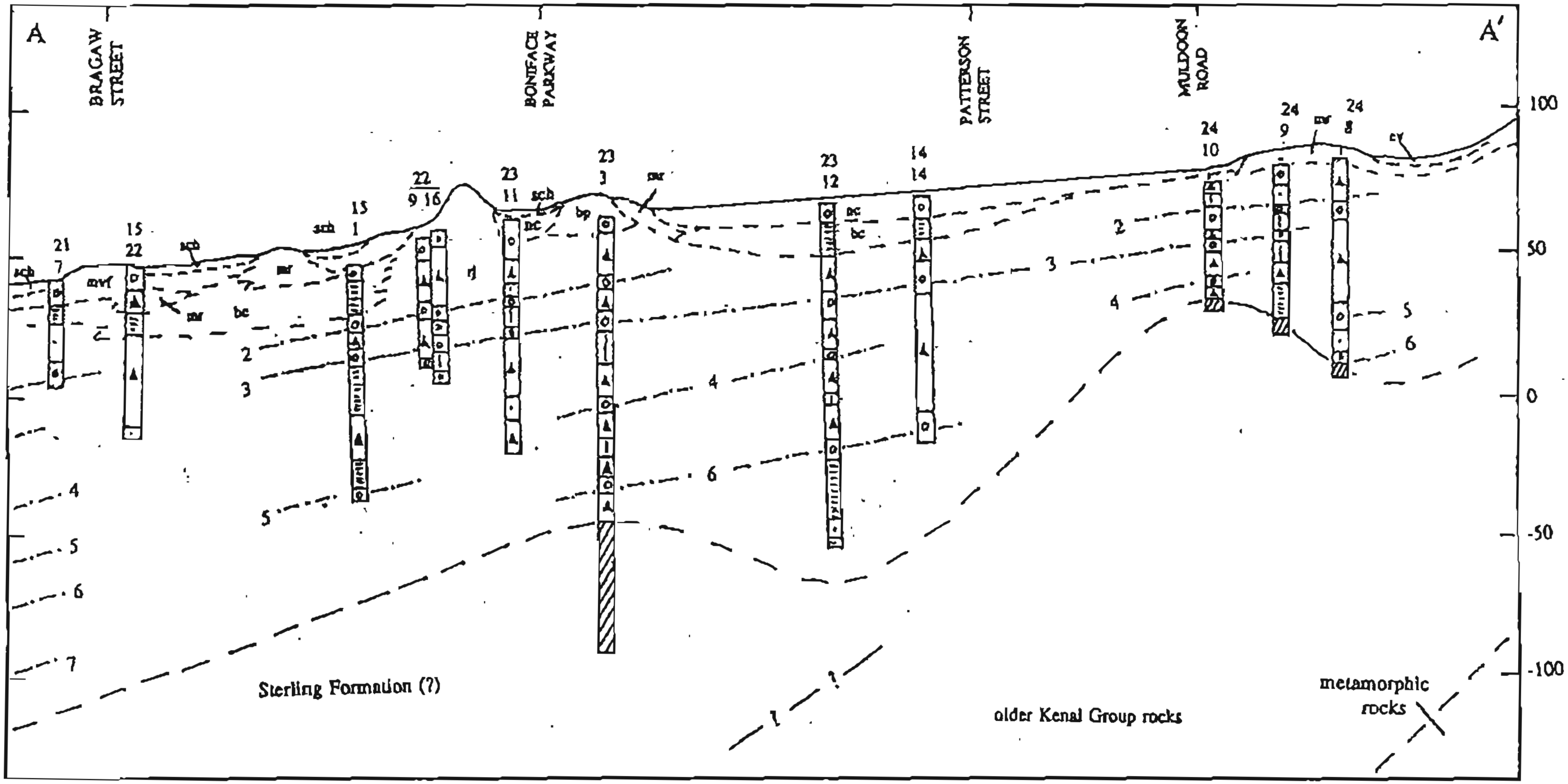


Figure 4. Cross section A-A' showing subsurface data along Debarr Avenue, Anchorage A-8 NE quadrangle, Alaska. Near-surface geologic units are those used on the geologic map (pl. 1A, in pocket). Water-well identification numbers are given at the top of each well. Lithologies derived from well logs, described more fully in the text, are shown as follows:

A, alluvial gravel and sand	open circles	S, stony silt and clay	vertical line
B, Bootlegger Cove Formation and other units of similar lithology	short horizontal lines	D, diamicton	solid triangle
M, silty fine sand and fine sandy silt	single dot	K, siltstone, claystone, sandstone and coal of the Kenai Group.	diagonal ruling

Correlation of alluvial units (A-lines as discussed in the text), shown by numbered dash-dot lines. Vertical scale in meters above and below mean sea level. Modified from Schmoll and Barnwell (1984).

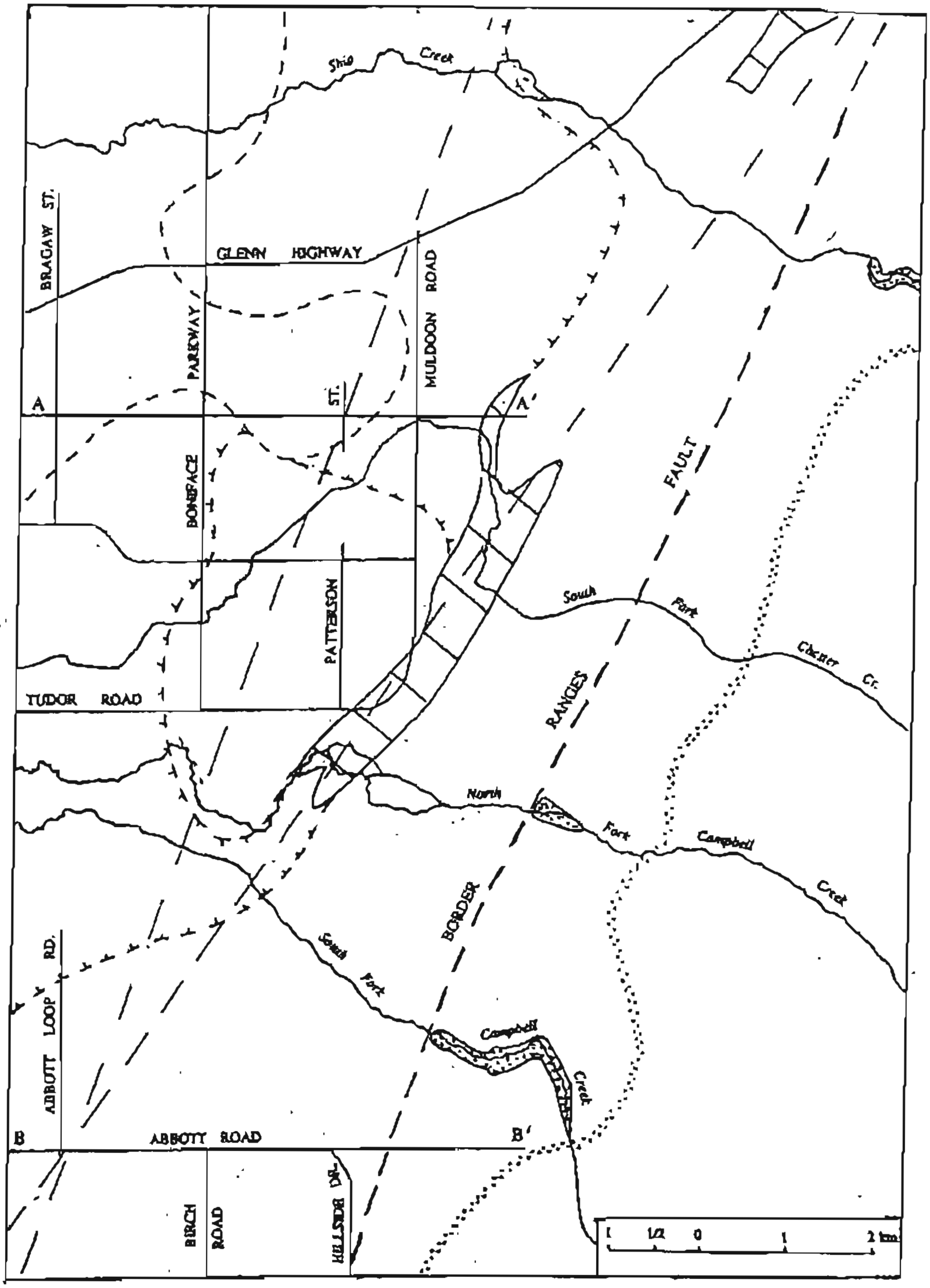


Figure 5. Map showing selected subsurface and related surface features of the Anchorage A-8 NE quadrangle, Alaska. Line A-A', cross section along Debarr Avenue, shown on figure 4; B-B', line of seismic profile shown on figure 6. Short dashed line, inferred southeastern limit of Bootlegger Cove Formation; ticked short dashed line, inferred southeastern limit of silt and sand deposits marginal to Bootlegger Cove Formation. Light dashed lines delimit area of possible extension of Abbott Loop fault as discussed in the text. Diagonal ruling, selected poorly drained areas. Stippled units, bedrock exposed in creek canyons; wide stippled line, Chugach Mountain front (from fig. 3).

The generalized picture thus presented suggests that the total prism of "surficial" deposits in the subsurface includes those of seven glacial sequences. In reality, however, the relationships of the deposits preserved are likely to be more complicated, and the deposits may be only fragmentary remnants of an even larger number of glacial events. The deposits between the A horizons include B, M, S, and D units, of which the finer-grained and better sorted B and M units are somewhat more prevalent in the western part of the map area, the D units are more common nearer the mountain front, and the S units occur in a somewhat intermediate position, a distribution rather like that exposed at the present surface. This distribution is by no means regular, however, indicating great variablilty both in the deposition and differential erosion of the various deposits. Minor unconformities and perhaps even major intervals of erosion are difficult to detect.

The cross section along DeBarr Avenue can be regarded as representative of the northwestern half of the quadrangle, but elsewhere in the lowland details of Quaternary stratigraphy are less well known. An attempt is made in figure 5, however, to show the distribution of both the Bootlegger Cove Formation and coarser-grained deposits marginal to it as known from well logs in addition to those used in the Debarr cross section.

BEDROCK

Bedrock is exposed within the map area only in the Chugach Mountains and in narrow canyons where major creeks cross the Hillside area just northwest of the Chugach Mountain front (fig. 5). Bedrock of the Chugach Mountains consists of structurally complex and variably metamorphosed sedimentary and igneous rocks (Capps, 1940; R.G. Gastil, U.S. Army Corps of Engineers, written commun., 1956; Clark, 1972; Clark and others, 1976; Updike and Ulery, 1988; Nelson and Blome, 1991; Winkler, 1992; Madden-McGuire and Winkler, 1994; Burns and Winkler, 1994; Plafker and others, 1994). Most of these are rocks of the Chugach tectonostratigraphic terrane, but rocks of the Peninsular terrane occupy the northern or inland side of the mountains and rocks of the Prince William terrane are found to the south near the coast (Coney and Jones, 1985; Jones and others, 1987; Silberling and others, 1994). All of the rocks in the mountainous part of the map area (map unit *b*) are part of the Chugach terrane and are assigned entirely to the McHugh Complex (Clark, 1973) that is Cretaceous and Jurassic in age of assemblage but includes protoliths as old as Late Triassic (Plafker and others, 1989).

Bedrock beneath the Anchorage lowland is concealed by the northwest-thickening wedge of glacial and related deposits discussed above. The nature of and depth to various bedrock units can be inferred, however, from several water wells and drill holes that reach or penetrate bedrock, and from outcrops nearby and in map areas to the northeast and south. In most of the Hillside area surficial deposits are thin and the underlying bedrock probably comprises rocks of the McHugh Complex similar to those that crop out in the mountains and canyons nearby. Additional inferences can be drawn from an east-west seismic refraction line along Abbott Road in the southern part of the map area (Harvey Johnson, Western Geophysical Corp., written commun. to W.W. Barnwell, 1967), from which the cross section shown in figure 6 is derived.

The boundary between the Chugach and Peninsular rocks is marked by the Border Ranges fault (MacKevett and Plafker, 1974), known locally as the Knik fault (Clark, 1972; Dearborn and Barnwell, 1975; Magoon and others, 1976); the Border Ranges terminology, however, is now in more common use (for example, Winkler, 1992). The precise location of this fault within the map area is unknown; its inferred position is shown in figures 5 and 6. The single line shown actually marks the approximate southeastern limit of the Border Ranges fault zone, a major tectonic feature perhaps 12 km in width that extends across southern Alaska (Winkler, 1992, cross section B-B'; Burns and Winkler, 1994); thus, all of the map area northwest of the delineated fault may lie within the Border Ranges fault zone. Most of the rocks within this zone in the map area are probably metamorphic rocks of Permian to Jurassic age similar to those known to crop out about 10 km south of the map area (Clark, 1972; Clark and others, 1976; Yehle and others, 1992). However, a body of gabbroic and (or) ultramafic rocks similar to other such bodies that lie along the trend of the Border Ranges fault zone is inferred to lie just west of the map area in the vicinity of the Abbott Road cross section, and may underlie the northwesternmost part of the map area (Burns and Winkler, 1994). All of these metamorphic and igneous rocks are identified on the seismic profile (fig. 6) as those characterized by a seismic velocity of about 5,800 m per second.

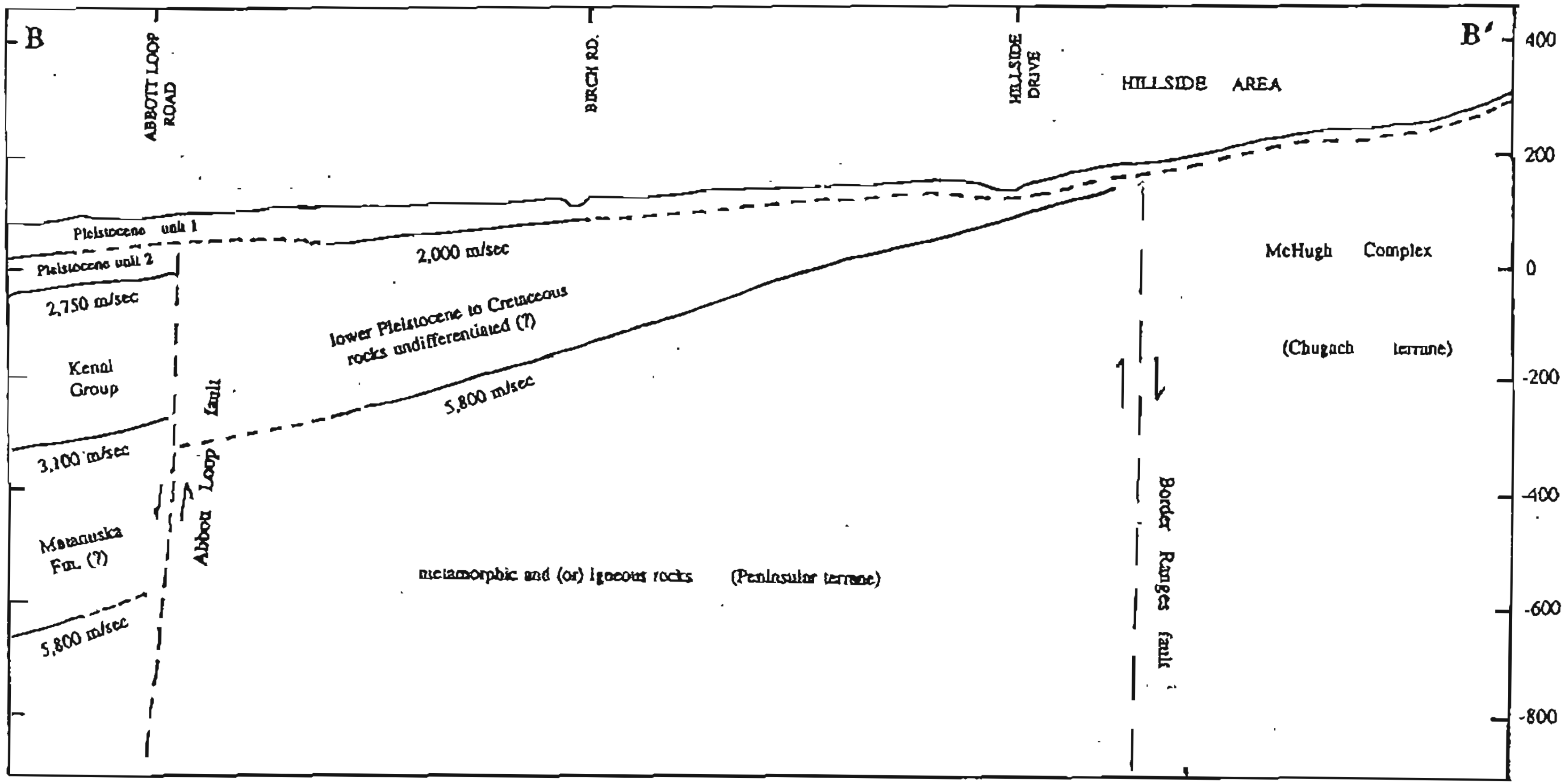


Figure 6. Cross-section B-B' along Abbott Road, Anchorage A-8 NE quadrangle, Alaska. Bedrock formations and two units of Pleistocene deposits are inferred from part of a seismic refraction line. Solid lines, position inferred from data, seismic velocities shown at the top of each unit of which they are characteristic; short dashed lines, position inferred in the absence of data. Abbott Loop fault inferred from data; position of Border Ranges fault inferred from fig. 5 and from Winkler (1992). Vertical scale in meters above and below mean sea level. Modified from Harvey Johnson, Western Geophysical Corp. (written commun. to W.W. Barnwell, 1967).

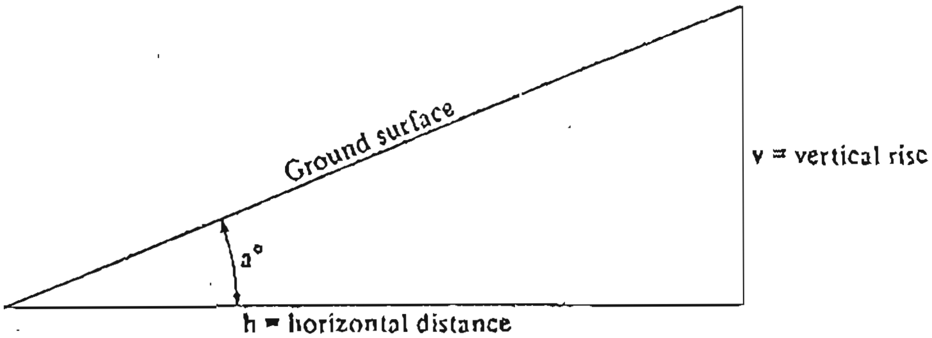
Overlying the metamorphic and igneous rocks in the western part of the seismic profile within the map area are two units of rocks characterized by substantially lower velocities. The lower of these units is identified as possibly Matanuska Formation, mainly marine sedimentary rocks of Cretaceous age. These rocks are shown in a comparable position on a cross section about 30 km south of the map area (Plafker and others, 1982), but their identity here is speculative. The upper of the two units is identified as including rocks of the Kenai group, relatively soft, easily eroded continental sedimentary rocks of Tertiary age (Calderwood and Fackler, 1972). These rocks are known to underlie the glacial deposits at depth as shown in figure 4, and their identity here is reasonably certain. They probably occur in the central part of the profile as well, even though their characteristic velocity was not obtained there. In the Debarr cross section the rocks in the upper part of the Kenai Group penetrated in the Tikishla Park test hole just west of the map area (Yehle and others, 1986) are identified as Sterling Formation (Stricker and others, 1988) but the extent of that formation in the subsurface within the map area is not known.

Quaternary deposits in the western part of the seismic profile are divided into two units on the basis of a seismic velocity of about 2000 m/sec inferred to lie at a depth of about 110 m. The nature of such a seismic discontinuity is not further elucidated in the profile. In the Tikishla Park test hole (Yehle and others, 1986), however, a change in the signature of the resistivity and other geophysical logs occurs at a depth of about 80 m, a position within the Quaternary sequence relatively similar to that of the 2000 m/sec line in the profile. At Tikishla Park this change corresponds to the top of a sequence of diamicton beds, and could correlate with the increased velocity reported in the seismic profile. It is thus possible that the lower units within the glacial deposits, perhaps those below A-line 5 of figure 4, are somewhat more indurated and perhaps significantly older than the upper beds, and that this horizon marks an erosional interval within the sequence.

High-angle faulting is characteristic of the Border Ranges fault zone (Burns and Winkler, 1994). That such faulting might bound Cook Inlet basin on its southeast margin along the Chugach Mountain front has been suggested by the steepness of the front northeast of the map area (Yehle and others, 1990). The presence of a high-angle fault has been interpreted from the Abbott Road seismic line to occur at about the intersection with Abbott Loop Road; this postulated fault here is called informally the Abbott Loop fault. The trend of this fault is unknown, but it is likely to occur within the area bounded by light dashed lines on figure 5 if, like the Border Ranges fault zone within which it occurs, it is somewhat parallel to the mountain front. The limits of this trend have been determined in part by the relatively steep rise in the top of the Tertiary rocks shown in the Debarr cross section in the vicinity of Patterson Street, and by aligned poorly drained areas shown on figure 5 that could reflect faulting at depth. Neither of these features require faulting for their cause, nor does the postulated Abbott Loop fault necessarily extend as a single feature across the map area. Instead, the Aboott Loop fault identified on the seismic profile may be one of several such faults of relatively restricted length. It apparently offsets rocks of the Kenai Group, and perhaps beds as young as older glacial deposits, but it apparently does not offset younger glacial deposits. None of the known or inferred faults are known to offset glacial or younger deposits within this map area, and thus there is presently no known evidence of late Pleistocene or Holocene faulting here.

DESCRIPTION OF MAP UNITS

Characteristics of the geologic materials delineated by the units of the surficial geologic map (plate 1A) described here are based primarily on field observations; they are supported in part by laboratory analyses, especially of grain size, the description of which follows the modified Wentworth grade scale (American Geological Institute, 1989). Slope information is derived from or based on geomorphic analogy to estimates presented in Schmoll and Dobrovolny (1972b), whose slope categories are used (fig. 7). Standard age designations are omitted from map symbols because all units except bedrock are of Quaternary age. The correlation of map units is shown on plate 1B (in pocket). The units described here may be overlain by as much as one meter of organic and windblown materials as discussed above.



Diagrammatic representation of slope-measuring terms

Slope in percent = v/h × 100

Slope angle in degrees = a°

Slope ratio = h:v (h to v) where v is equal to 1 unit of measurement

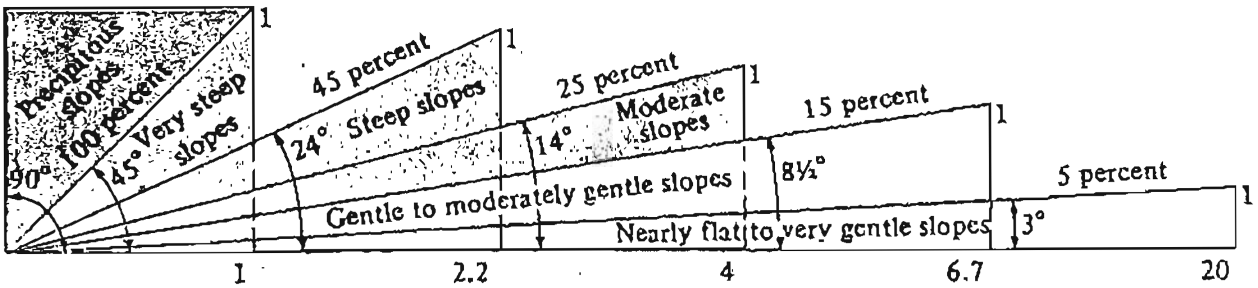


Figure 7. Diagram illustrating slope categories used on this map. Modified from Schmoll and Dobrovolny (1972b).

SURFICIAL DEPOSITS

Moraine deposits

Subdivided according to type of moraine (end, lateral, and three types of ground moraine) and according to correlations with named end and lateral moraines along the Chugach Mountain front. The till that composes most moraine deposits is chiefly a diamicton consisting of massive, unsorted to poorly sorted mixtures of gravel, sand, silt, and relatively minor amounts of clay; in places may consist of poorly sorted silty sandy gravel; includes scattered large boulders; generally moderately to well compacted.

End-moraine deposits--Thickness poorly known, probably about 10 m or less. Contacts well defined. Topography irregular; slopes gentle to moderate in small areas on some ridge tops, steep on ridge sides; occur near east edge of map area in small mountain valleys

eme **Deposits of Elmendorf moraines (late Pleistocene)**--Occur only in largest Wolverine valley

dme **Deposits of Dishno Pond moraines (late Pleistocene)**--Occur in Chester and Wolverine valleys

fme **Deposits of Fort Richardson moraines (late Pleistocene)**--Occur in Chester and Wolverine valleys

rme **Deposits of Rabbit Creek moraines (late Pleistocene)**--Occur in Wolverine valleys

lme **Deposits of Little Rabbit Creek moraines (Pleistocene)**--Occur in Wolverine valleys

Lateral-moraine deposits

eml **Deposits of Elmendorf moraines (late Pleistocene)**--Thickness poorly known, probably less than 10 m. Contacts well defined. Single ridge with steep sides. Occur only in largest Wolverine valley

dml **Deposits of Dishno Pond moraines (late Pleistocene)**--Thickness probably 10 to 15 m. Contacts well defined. Moraine ridges elongate with moderately irregular topography; slopes gentle to moderate on small areas on some ridge tops, steep on ridge sides. Occur mainly in northeastern part of map area along the Chugach Mountain front, with a single occurrence in the largest Wolverine valley

fml **Deposits of Fort Richardson moraines (late Pleistocene)**--Thickness probably 10 to 15 m. Contacts well defined. Moraine ridges generally well formed; slopes moderate to steep. Occur throughout the map area along the Chugach Mountain front

rml **Deposits of Rabbit Creek moraines (late Pleistocene)**--Thickness probably several to 10 meters. Contacts relatively well defined. Moraine ridges well formed to moderately irregular; slopes generally moderate, locally steep on ridge sides. Occur mainly along the Chugach Mountain front near South Fork Campbell Creek; widely scattered occurrences farther northeast

lml **Deposits of Little Rabbit Creek moraines (Pleistocene)**--May be more oxidized than younger lateral-moraine deposits. Thickness probably a few to several meters. Contacts moderately well defined to gradational. Moraine ridges moderately irregular; slopes generally moderate, locally steep. Occur discontinuously in southeastern part of map area, with single occurrence in Chester Creek valley

sml **Deposits of Ski Bowl moraines (Pleistocene)**--Probably more compacted and oxidized than younger lateral-moraine deposits. Thickness poorly known, probably several meters. Contacts mostly gradational. Topography includes remnant ridges and irregular ground; slopes generally moderate to steep. Occur locally on slopes of major mountain valleys mainly in southeastern part of map area

gml **Deposits of Glen Alps moraines (Pleistocene)**--Probably well compacted and oxidized. Thickness poorly known, probably a few to several meters. Contacts gradational. Topography includes remnant ridges and irregular ground; slopes moderate to steep. Occur high on wall of North Fork Campbell Creek valley and near southeastern edge of map area

Ground-moraine deposits

emg **Deposits of Elmendorf moraines (late Pleistocene)**--Thickness poorly known, probably a few meters. Contacts fairly well defined. Topography smooth to very gently hummocky, slopes gentle. Single occurrence in the largest Wolverine valley

dmg **Deposits of Dishno Pond moraines (late Pleistocene)**--Thickness poorly known, probably several meters; may be difficult to differentiate from underlying moraine deposits. Contacts generally well defined. Topography smooth to gently hummocky, slopes generally gentle to moderate. Occur only in northeastern part of map area dmk **Deposits that include some kame deposits**--More likely to include gravel and sand deposits than other ground-moraine deposits. Thickness not well known but may be several meters. Contacts relatively well defined except gradational with other ground-moraine deposits. Topography irregular to hummocky, slopes gentle to moderate, locally steep. Occur only in northeasternmost part of map area

fmg **Deposits of Fort Richardson moraines** (late Pleistocene)--Thickness poorly known, probably a few to several meters. Contacts generally gradational with lateral-moraine and colluvial deposits. Topography generally smooth, slopes moderate. Occur mainly downslope from lateral moraines along Chugach Mountain front and locally in Chester Creek valley and in southeastern part of map area

rmg **Deposits of Rabbit Creek moraines** (late Pleistocene)--Thickness poorly known, probably only a few meters. Contacts gradational with lateral-moraine and colluvial deposits. Topography smooth, slopes gentle to moderate. Occur extensively in Chester Creek valley and locally in southeastern part of map area

rmb **Deposits that thinly mantle bedrock**--Thickness poorly known but may be about a meter. Bedrock outcrops may be present; include admixed bedrock rubble. Contacts gradational with bedrock. Topography smooth, slopes gentle. Single occurrence in northeastern part of map area

lmg **Deposits of Little Rabbit Creek moraines** (Pleistocene)--May be more oxidized than younger lateral-moraine deposits. Thickness poorly known, probably only a few meters. Contacts gradational. Topography smooth, slopes gentle to moderate. Occur locally in southeastern part of map area

lmb **Deposits that thinly mantle bedrock**--Thickness poorly known but may be about a meter. Bedrock outcrops may be present; include admixed bedrock rubble. Contacts gradational. Topography smooth, slopes gentle to moderate. Occur in several places on bedrock ridges in the east-central and southeastern parts of the map area

smg **Deposits of Ski Bowl moraines** (late Pleistocene)--Probably more oxidized than younger ground-moraine deposits. Thickness poorly known, probably a few to several meters. Contacts gradational. Topography smooth, slopes moderate. Occur mainly in broad areas in southern part of map area where South Fork Campbell Creek valley merges with the upper Hillside area; locally on mountain ridges to the northeast

smb **Deposits that thinly mantle bedrock**--Thickness poorly known, probably one to a few meters; small bedrock outcrops probably common; admixed with or consisting mostly of bedrock rubble. Contacts gradational. Topography smooth, slopes gentle to moderate. Occur near the northwestern ends of mountain interfluve ridges in east-central and southeastern parts of map area

gmb **Deposits of Glen Alps moraines that thinly mantle bedrock** (Pleistocene)--Thickness quite variable, probably a few meters or less, bedrock outcrops common; admixed with or consisting mostly of bedrock rubble. Contacts gradational. Topography somewhat more irregular than in areas of younger ground moraine, slopes gentle to moderate, locally steep. Occur locally on major interfluve ridges in east-central and southeastern parts of map area

mmg **Deposits of Mount Magnificent moraines** (Pleistocene)--Probably more oxidized than younger ground-moraine deposits. Thickness poorly known, no more than a few meters. Contacts gradational. Topography smooth to slightly irregular, slopes gentle. Occur only high on ridge between Forks of Campbell Creek in the east-central part of map area

mmb **Deposits including mainly bedrock rubble**--Thickness poorly known, probably a meter or little more; only widely scattered erratics may be present; bedrock outcrops common. Contacts gradational. Topography fairly smooth, slopes gentle. Occur high on bedrock ridges in east-central and southeastern parts of map area

Glacioalluvial deposits associated with moraines

Subdivided into (1) kame deposits and (2) kame-terrace deposits, both of which are dominantly gravel and sand but locally include diamicton, silt, and clay; and (3) kame-channel, (4) meltwater-channel, and (5) outwash-train deposits, all of which consist dominantly of gravel and sand.

Kame deposits (late Pleistocene)--Chiefly pebble and cobble gravel and sand, moderately to well bedded and sorted; some silt, and, especially in the cores of hills, diamicton; locally may include large boulders. Include deposits of small eskers. Moderately loose, but compact in cores of some hills. Contacts generally well defined; merge with lateral-moraine deposits. Topography sharply hilly to hummocky with some local depressions; slopes moderate to steep, except gentle to nearly flat in minor channels, on depression floors, and on some small areas on tops of hills

dk **Deposits of Dishno Pond moraines**--Thickness a few to a few tens of meters. Occur in northeastern and east-central parts of map area, especially in a prominent kame field south of Ship Creek

dkh **Deposits that exhibit high relief**--Probably thicker than other kame deposits, and topography more bold. Occur within kame field south of Ship Creek

fk **Deposits of Fort Richardson moraines**--Thickness probably a few to a few tens of meters. Occur mainly in a prominent kame field that dominates the Hillside area from the east-central to the southwestern parts of map area

fkh **Deposits that exhibit high relief**--Probably thicker than other kame deposits. Contacts gradational with them. Occur locally within kame field

Kame-terrace deposits (late Pleistocene)--Chiefly pebble and cobble gravel and sand, moderately to well bedded and sorted; locally may include boulders. Moderately loose. Thickness poorly known, probably a few to several meters. Contacts generally well defined. Topography smooth, slopes gentle except steep at terrace edge

dkt **Deposits of Dishno Pond moraines**--A single bilevel occurrence in northeastern part of map area

fkt **Deposits of Fort Richardson moraines**--Occur in a single dissected terrace in central to south-central parts of map area

Kame-channel deposits (late Pleistocene)--Chiefly pebble and cobble gravel and sand; locally may include some finer materials; may include pitted outwash and (or) meltwater-channel deposits. Thickness poorly known but probably at least a few meters. Contacts well defined. Topography slightly hummocky in channel-like landforms of generally low relief some of which lie within broad areas of kame deposits of high relief; slopes typically gentle; locally steeper where hummocks well developed

dkc **Deposits of Dishno Pond moraines**--Occur in major channels that extend discontinuously from northeastern to central parts of map area

fkc **Deposits of Fort Richardson moraines**--Occur in a few isolated channels in the south-central part of map area

Meltwater-channel deposits--Chiefly gravel and sand, well bedded and sorted; at the surface may include some finer-grained material with thin organic accumulations. Thickness poorly known, probably one to a few meters. In places channel deposits may be very thin or absent and ground-moraine deposits or, mainly within the mountains, bedrock may floor the channel or lie at shallow depth. Contacts well defined. Topography smooth, slopes gentle

dc **Deposits of Dishno Pond moraines (late Pleistocene)**--Extend from northeastern to central parts of map area

dcl **Lower-level deposits**--Occur in a few places in northeastern and central parts of map area

fc **Deposits of Fort Richardson moraines (late Pleistocene)**--Occur in numerous places from the east-central to south-central parts of map area, mainly in association with lateral-moraine deposits

fcl **Lower-level deposits**--Occur in a few places in central and south-central parts of map area

rc **Deposits of Rabbit Creek moraines (late Pleistocene)**--Occur in scattered localities in the east-central and southeastern parts of map area lc **Deposits of Little Rabbit Creek moraines** (Pleistocene)--May be somewhat more oxidized than younger channel deposits. Single occurrence in the southeastern part of the map area south of North Fork Campbell Creek

sc **Deposits of Ski Bowl moraines** (Pleistocene)--Probably more oxidized than younger channel deposits. Occur in several isolated places on mountain ridges in east-central part of map area

gc **Deposits of Glen Alps moraines** (Pleistocene)--Probably more oxidized than younger channel deposits. Occur at a few localities north and south of North Fork Campbell Creek in east-central part of map area

mc **Deposits of Mount Magnificent moraines** (Pleistocene)--Probably more oxidized than younger channel deposits. May include much bedrock rubble. Occur high on a few mountain ridges in east-central and southeastern parts of map area

oc **Older deposits** (Pleistocene)--Gravel and sand of these deposits may be less well bedded and sorted, thinner, and probably more oxidized than other channel deposits; may include much bedrock rubble and some small bedrock outcrops. Tentatively identified at a few places on highest ridge in southeasternmost part of map area

Outwash-train deposits--Chiefly pebble and cobble gravel and sand, well bedded and well sorted, that accumulated mainly in front of and downstream from valley glaciers in the large mountain valleys and that now occur mainly in terraces and channels. Contacts well defined. Topography smooth, slopes gentle except steep at terrace edges

eo **Deposits related to Elmendorf moraines** (late Pleistocene)--Single occurrence as outwash plain in largest Wolverine valley in southeastern part of map area

do **Deposits related to Dishno Pond moraines** (late Pleistocene)--Occur in a single dissected terrace in Chester Creek valley in east-central part of map area

fo **Deposits related to Fort Richardson moraines** (late Pleistocene)--Occur in Chester Creek and Wolverine valleys and in valley in southeasternmost part of map area

ro **Deposits related to Rabbit Creek moraines** (late Pleistocene)--Occur only in Wolverine valleys in southeastern part of map area

lo **Deposits related to Little Rabbit Creek moraines** (Pleistocene)--Mapped only at two places in the largest Wolverine valley; elsewhere in this vicinity included with map unit *lkf*

Other glacioalluvial and related alluvial deposits

Dominantly gravel and sand, well bedded and sorted, that occur mainly in major channels and alluvial fans. Thickness variable, but about 10 m common and a few tens of meters possible in some places. Contacts well defined. Topography smooth, slopes gentle to very gentle. Widespread mainly in northwestern third of map area.

Channel deposits in southern part of map area (late Pleistocene)--Occur in major channels graded to deltaic deposits which are a few kilometers southwest of map area

sh **Spring Hill deposits**--Occupy channel system in southwestern part of map area that splits near Service High School into a more deeply incised channel to the southwest and a shallower channel to the northwest. Also mapped in South Fork Campbell Creek valley in intermediate-level terrace remnants

kcl **Lower-level Klatt Road deposits**--Occur mainly in terraces at levels higher than Spring Hill deposits and in channels graded thereto; mapped also in a channel that probably carried water from North Fork Campbell Creek toward the southwest

kc **Main-level Klatt Road deposits**--Occupy major channel system extending from South Fork Campbell Creek to deltas southwest of map area that front at a level of about 65 m in altitude

kch **Higher-level Klatt Road deposits**--Occur in terrace remnants at levels higher than the main channel and in shallow channels graded thereto. Graded to deltas that front at a level of about 110 m in altitude

Deposits of South Fork Campbell Creek--

Lower-level deposits--Occupy relatively narrow channels on either side of main alluvial fan

sfs **Deposits on south side of main alluvial fan (Holocene? and late Pleistocene)**--Occur in channel that carried South Fork water at one or more times after deposition of main fan and that now contains underfit flow of North Fork Little Campbell Creek originating as underflow from South Fork Campbell Creek; that creek could reoccupy this channel

sfn **Deposits on north side of main alluvial fan (late Pleistocene)**--Occupy channel and smaller alluvial fan that could have carried some South Fork water northward into what was then combined ancestral Ship Creek and Eagle River

sf **Deposits of main alluvial fan (late Pleistocene)**--Occupy prominent alluvial fan in southwestern part of map area; extend upvalley as low-level terrace deposits

sft **Terrace deposits (late Pleistocene)**--Occur only at scattered localities in upper South Fork valley at intermediate terrace levels

sfth **Highest-level deposits**--Occur only in upper South Fork valley

Deposits of North Fork Campbell and Chester Creeks (late Pleistocene)--

nfl **Lower-level deposits**--Occur in channels on both sides of main alluvial fan of North Fork Campbell Creek that were not necessarily occupied contemporaneously

nf **Main alluvial-fan deposits**--Occur in prominent North Fork Campbell Creek fan in central part of map area and in smaller fan of Chester Creek; also mapped in low terrace remnants in North Fork Campbell Creek valley

nfh **Higher-level deposits**--Occur mainly in alluvial fan of Chester Creek; also in single high-terrace remnant along North Fork Campbell Creek

nfhf **Fine-grained deposits**--Probably sand and silt with peat at surface. Occur in single channel north of Chester Creek

Deposits of northern source (late Pleistocene)--

ecb **Bluff Road deposits**--Occur in shallow channel in northwesternmost part of map area; originated as outwash from younger part of Elmendorf Moraine in map area to north

ch **Cheney Lake deposits**--Occur in terrace remnants in west-central part of map area; principal deposit largely removed by excavation. Possibly originated as outwash from Elmendorf Moraine

ps **Patterson Street deposits**--Occur in channel remnants in west-central and north-central parts of map area. Probably originated as outwash from Elmendorf Moraine

Deposits related to the Eagle River (late Pleistocene)--

mvf **Mountain View alluvial-fan deposits**--Occur in north-central and northwestern parts of map area as part of southern edge of large, dissected alluvial fan

mvi **Deposits at intermediate level**--Occur in north-central part of map area in relatively small remnant of slightly higher part of main alluvial fan

mvh **Deposits at highest level**--Extend discontinuously from northeastern to west-central parts of map area as remnants of highest part of alluvial fan

nc **Nunaka Valley channel deposits**--Occupy major channel that extends from northwestern to west-central parts of map area at level higher than Mountain View Deposits

ncc **Checkmate boulder-rich sector**--Occurs in west-central part of map area in southeast part of main channel where erosion of channel was not followed by major deposition of gravel and sand as elsewhere. Instead, deposits include reworked finer-grained or more poorly sorted material; numerous boulders present on ground surface are part of lag concentrate resulting from erosion of earlier morainal and (or) glacioestuarine deposits; locally, peat deposits may have accumulated at surface, but most have been removed during urbanization

Deposits related to Ship Creek--

scl **Lower-level deposits (Holocene)**--Extend across entire northern part of map area along Ship Creek, mainly in extensive low terrace that to the west gradually becomes higher above stream

scc **Chester Creek deposits (late Pleistocene)**--Occur in north-central and northwestern parts of map area in channel that formed when ancestral Ship Creek flowed through valley of lower reaches of Chester Creek sch **Deposits at higher level**--Occur mainly in northwestern part of map area in broad channel occupied when ancestral Ship Creek first flowed through valley of lower reaches of Chester Creek where deposits now occur in terraces

schp **Deposits at higher level with peat at surface**--Occur locally in poorly drained parts of the channel; most areas have been drained and most peat removed during urbanization

scf **Alluvial-fan deposits (late Pleistocene)**--Occur in prominent fan in northeastern part of map area that apparently was graded to various levels of Eagle-River-source deposits and subsequently was dissected by Ship Creek

sct **Terrace deposits (late Pleistocene)**--Occur in northeastern part of map area in remnants of small, higher-level alluvial fan, or fan-delta graded to glacioestuarine level of Muldoon Road deposits

scth **Highest-level deposits)**--Occur in remnants of probable fan-delta graded to glacioestuarine level of Abbott Road deposits

Kame-fan and glaciolacustrine deposits

Kame-fan deposits are transitional in origin between glacioalluvial and glaciolacustrine deposits. Like kame-terrace deposits they were deposited along the margin of a glacier, but their main source valleys were mainly perpendicular to and blocked by the glacier. In part, the blockage may have resulted in small ice-dammed lakes, but at least within this map area most deposits seem to have more the character of alluvial fans, implying that lakes, if any, were short-lived, and that drainage was able to enter the glacier, probably resulting in the extensive kame fields associated with the lateral moraines. Glaciolacustrine deposits accumulated when more permanent lakes did form in valleys blocked by the glacier.

Kame-fan deposits--Mainly gravel and sand that is well to poorly bedded and sorted and that may include beds of fine sand, silt, and some clay, as well as some diamicton. Thickness poorly known, possibly as much as a few tens of meters. Contacts fairly well defined. Topography generally smooth, slopes moderately gentle to moderate, locally steep at eroded margins

dkf **Deposits related to Dishno Pond moraines (late Pleistocene)**--Occur at two levels near Ship Creek in northeastern part of map area

fkf **Deposits related to Fort Richardson moraines (late Pleistocene)**--Occur at mouths of all major mountain valleys along Chugach Mountain front

rkf **Deposits related to Rabbit Creek moraines (late Pleistocene)**--Occur only in association with Wolverine valleys in southeastern part of map area

lkf **Deposits related to Little Rabbit Creek moraines (Pleistocene)**--Occur in Chester Creek valley in east-central part of map area and in the two more northerly Wolverine valleys in southeastern part of map area where they extend upvalley to include outwash deposits

skf **Deposits related to Ski Bowl moraines (Pleistocene)**--Probably more oxidized than younger kame-fan deposits. Single occurrence in northernmost Wolverine valley in southeastern part of map area

gkf **Deposits related to Glen Alps moraines (Pleistocene)**--Probably more oxidized than younger kame-fan deposits. Single occurrence in northernmost Wolverine valley in southeastern part of map area

Glaciolacustrine deposits (late Pleistocene)--Interbedded clay, silt, and sand; may include some gravel and diamicton in varying proportions; well to somewhat poorly sorted. Thickness poorly known, probably 10 to possibly more than 100 m. Contacts relatively well defined. Topography generally smooth, slopes gentle, but steep at valleyward margins. Moderately stable except near contact with valley-wall colluvium where susceptible to stream erosion, earthflowage, or other landslide processes

dgl **Deposits related to Dishno Pond moraines**--Occur only along south side of Ship Creek valley near east edge of map area

fgl **Deposits related to Fort Richardson moraines**--Occur in Ship Creek valley at higher level than the Dishno Pond deposits, and in North Fork Campbell Creek valley near Chugach Mountain front

Moraine and kame deposits modified in a glacioestuarine environment (late Pleistocene)

Occur in relatively prominent hills in lowland part of map area. Formed either as ground moraine and associated kames and subsequently modified by wave and tidal action in a glacioestuarine environment, or by redeposition of glacial deposits by much subaqueous slumping. Most likely some combination of these processes was involved in producing the deposits, but the relative importance of each is uncertain and may vary both within the same deposit and among the deposits included in this group. Only locally appear to be a continuous mantle.

rj **Russian Jack deposits**--Mainly diamicton, with some interbedded silt, fine sand, and sand and gravel both in well defined zones and as obscurely bedded, discontinuous horizons. Thickness as much as 25 m. Contacts fairly well defined but gradational with Muldoon Road deposits in many places. Occur in well-defined hills of smooth topography with gently to moderately gently sloping tops and moderately to steeply sloping sides. Widespread from the north-central to southwestern parts of map area

Modified kame deposits--Mainly gravel and sand, well to moderately poorly bedded and sorted; include some interbedded fine sand, silt, and diamicton which also may occur at the surface of the hills; diamicton may be dominant in cores of hills. Contacts well defined. Topography commonly sharply hilly to hummocky; slopes generally moderate to steep

dkm **Deposits related to Dishno Pond moraines**--Occur in central part of map area at southwestern extremity of Dishno Pond kame field where it was encroached upon by glacioestuarine water; hills somewhat more subdued than in main part of kame field

fkm **Deposits related to Fort Richardson moraines**--Extend discontinuously from central to southwestern parts of map area where lowest-lying edges of Fort Richardson kame field are more subdued but identifiable separately from glacioestuarine deposits

bp **Boniface Parkway deposits**--Extend mainly from north-central to west-central parts of map area in association with Russian Jack deposits; may represent more gravelly phase of those deposits or perhaps are remnants of a once more continuous esker system originally part of Dishno Pond moraine system. In central part of map area occur mainly in small hills that may be partly buried kames and similar to deposits mapped as *fkm*

or **O'Malley Road deposits**--Occur in southwestern part of map area where relationships to moraines or kame fields is more obscure. Could represent more gravelly phase of glacioestuarine deposits or partly buried kames that were initially part of Fort Richardson or even Rabbit Creek ground or medial moraines

Glacioestuarine deposits (late Pleistocene)

Accumulated in an ancestral Cook Inlet that probably differed from the present-day inlet in configuration and in level with respect to the present land surface. Several different water levels inferred from deposits at recognizably different, somewhat terrace-like, levels, but no shorelines recognized. The land-water interface may have fluctuated repeatedly through time as glacier fronts withdrew and readvanced and as world-wide sea level also fluctuated, and as the land surface responded to local tectonism. Inlet water was at least partly in contact with glacier ice, as reflected in both volume and variety of material types, especially in their relative coarseness and poor sorting. Consist of variously interbedded diamicton, stony silt, fine-grained sand, silt, and silty clay. Well to obscurely bedded; individual beds commonly well sorted; in gross aspect the deposits appear rather poorly sorted because of the interbedding of thin beds of materials with widely disparate sizes. Thickness poorly known and probably quite variable, probably a few to more than 15 m; thinner in higher parts of slopes and near morainal deposits. Contacts generally well defined; contacts between adjacent glacioestuarine deposits may be located only approximately but deposits probably not in gradational contact. Topography commonly smooth but marked locally by subdued hills or minor irregularities; slopes gentle to moderate.

br **Birch Road deposits**--Extend discontinuously from central to southwestern parts of map area on relatively smooth to slightly hummocky bench-like terrain between about 140 and 200 m in altitude, downslope from Fort Richardson kame deposits. May in part resemble deposits of map unit *fkm* and include more gravel than other units in this group especially near kame field. May be in part or entirely glaciolacustrine in origin bc **Bootlegger Cove Formation**--Silty clay and clayey silt with minor interbedded silt, fine sand, fine to medium sand, and thin beds of diamicton, and with scattered pebbles and cobbles in widely varying concentrations. Occurs in subsurface in northwestern part of map area and is mapped only in now-concealed anthropogenic exposure there; also concealed beneath deposits of map units *cwb* and *clb*

mr **Muldoon Road deposits**--Widespread in occurrence between the north-central and southwestern parts of map area, commonly in lower terrain surrounding hills of Russian Jack deposits into which they may grade or onto which they mainly may lap. May contain higher proportion of better bedded and sorted material, commonly fine sand and silt, than Abbott Road deposits. Commonly lower than about 110 m in altitude

ar **Abbott Road deposits**--Extend in a relatively narrow belt from the central to southwestern parts of map area at altitudes between about 110 and 140 m, just downslope from Birch Road deposits. In belt about 1 to 2 km wide along Abbott Road in southwestern part of map area contain high proportion of bedrock rubble

ws **Winchester Street deposits**--Probably include higher proportion of sand, fine sand, and silt than other deposits of this group. Occur only in west and southwestern parts of map area, mainly near west edge. May represent marginal facies of estuary that had less contact with glacier ice than older estuaries in which other deposits of this group accumulated

wsc **Coarse-grained deposits**--Dominantly sand and gravel. A few occurrences in west-central part of map area

wsp **Deposits with peat at surface**--May include finer-grained material than elsewhere within these deposits. Single occurrence at western edge of west-central part of map area

ev **Early View deposits**--Dominantly silt and silty clay. May be equivalent to part of Bootlegger Cove Formation or, alternatively, have accumulated in fairly large local lake. Occur in low-lying terrain in central part of map area, commonly downslope from adjacent Muldoon Road deposits

evc **Coarse-grained deposits**--Probably contain higher proportion of sand, and perhaps some gravel as well, than remainder of deposit to which they are mainly marginal. Also mapped in southwestern part of map area where finer-grained deposits are lacking and identity is based mainly on relationship to adjacent higher-lying Muldoon Road deposits

evp **Deposits with peat at surface**--A few occurrences in central part of map area apparently less well drained than surrounding areas

Alluvial deposits

Generally well bedded and sorted, clasts commonly rounded to well rounded. Thickness variable, probably a few to several meters, and thickest in large valleys. Contacts well defined. Topography smooth, slopes nearly flat to very gentle.

al **Alluvial deposits along modern streams and in lowest terraces (Holocene)**--Chiefly gravel and sand. Generally at or no more than a few meters above stream level. Include material of active flood plains still partly in transport mode

alf **Fine-grained deposits along some minor streams (Holocene)**--Chiefly silt and fine-grained sand; may include some peat deposits near surface. Occur in central part of map area where streams cross low-lying Early View deposits and at widely scattered localities elsewhere

alo **Older alluvial deposits (Holocene and late Pleistocene)**--Chiefly gravel and sand, in channels abandoned by streams that formed them; occupied, if at all, by underfit water courses. Occur only in east-central part of map area

Alluvial-fan deposits (Holocene)--Formed mainly in moderate to small fans where small tributaries enter larger streams of lower gradient. Graded to or just above modern stream levels. Materials commonly less well sorted than other alluvium. Slopes moderate to moderately gentle, steeper near heads of fans

af **Coarse-grained deposits**--Chiefly gravel and sand; may include some silt and thin diamicton beds resulting from minor mudflows. Occur mainly in mountain valleys and along Chugach Mountain front in eastern part of map area aff **Fine-grained deposits**--Chiefly fine sand and silt. Occur in only a few scattered places along Chugach Mountain front

afo **Older alluvial-fan deposits (Holocene and late Pleistocene)**--Gravel and sand, possibly admixed with some finer-grained material and thin diamicton beds. Deposits typically less well sorted and more steeply sloping than those in other alluvial units. Occur on lower parts of mountain-valley walls and at a few places along Chugach Mountain front commonly as remnants associated with younger alluvial fans, but graded to levels above modern streams

Pond and bog deposits (Holocene and late Pleistocene)

p **Pond and bog deposits**--Chiefly mosses, sedges, and other organic material in various stages of decomposition; includes organic-rich silt, minor woody horizons, and a few thin interbeds of mainly ash-sized tephra. At shallow depth may include silt, clay, marl, or fine-grained sand. Accumulated mainly in small former lakes or in former stream channels which are now bogs. Soft and moist. Thickness as much as 4 m; adjacent mapped deposits extend beneath these deposits. Contacts well defined. Surface smooth, slopes less than one percent. Poorly drained. Occur in numerous small areas in lateral moraines and kame fields downslope from Chugach mountain front, in a few large areas in west-central part of map area, and at widely scattered localities elsewhere

Colluvial deposits

c **Colluvial deposits on mountain slopes (Holocene and Pleistocene)**--Mainly apronlike deposits of loose, sandy to rubbly diamicton derived directly from weathering of bedrock upslope; include some sheetwash deposits. Thickness poorly known, probably less than one to several meters, thicker on lower parts of slopes. Contacts gradational. Topography smooth, surface gently concave, slopes generally steep to very steep, but usually not in excess of 70 percent; some instability likely. Occur throughout mountainous part of map area in belt downslope from mapped bedrock

ct **Talus deposits (Holocene)**--Cone-shaped to apronlike deposits on valley walls within rugged mountains. Mainly loose, coarse rubble and rubbly diamicton derived directly from weathering of bedrock upslope. Thickness variable, generally thickest in middle to lower parts of cones and aprons, probably several to a few tens of meters, thinning gradually upward toward apexes and more abruptly downward near toes. Contacts generally gradational, to bedrock at apex, and to other map units at toe; individual cones commonly have well-defined boundaries. Talus deposits too small to map separately are included in bedrock map unit. Topography smooth, slopes steep to very steep, as much as 100 percent near apex, rarely less than 35 percent near toe. Commonly free of even low vegetation and subject to continuing deposition from upslope, including rockfalls and debris-laden snow avalanches; slopes generally unstable. Occur only on valley wall in southeasternmost part of map area

ca **Colluvial and alluvial deposits (Holocene and late Pleistocene)**--Areas of colluvium and alluvium too small to map separately. Chiefly moderately loose, sandy to rubbly diamicton, poorly sorted sand and gravel, and some organic debris. Thickness poorly known, probably a few meters. Contacts generally gradational. Topography irregularly gullied, slopes steep to very steep, generally ranging between 35 and 70 percent. Commonly covered by at least low vegetation, active deposition occurring in many of these gullies. Some instability of slopes likely. Occur in many small valleys and gullies in mountainous part of map area; many deposits too small to map separately

cg **Mixed colluvial and glacial deposits (Holocene and Pleistocene)**--Diamicton; may include chiefly gravelly to rubbly sand, with some silt and clay; locally bouldery. Derived from both bedrock and glacial deposits, either of which may be present in areas too small to map separately. Poorly bedded and sorted. Loosely to moderately compacted in most places. Thickness varies from a few to several meters. Contacts gradational. Slopes smooth to slightly irregular, steep to very steep. Common along middle slopes of most major mountain valleys and along Chugach Mountain front cm **Colluvial deposits derived mainly from moraines (Holocene and Pleistocene)**--Diamicton similar to that of adjacent upslope moraines, but less compact; include minor amounts of better sorted sand, silt, and gravel that occur in irregular beds and that may have been derived from better-sorted glacial deposits and moved partly with the aid of running water. Commonly a few meters thick. Contacts generally gradational, especially upslope. Slopes generally moderate and moderately stable. Commonly associated with lateral moraines along the Chugach Mountain front and in a few places in mountain valleys

cw **Colluvial deposits on walls of stream bluffs (Holocene and late Pleistocene)**--Loose accumulations derived from adjacent, upslope surficial deposits that form a veneer on bluffs after active stream erosion has ceased. Chiefly diamicton consisting of pebbly silt and sand with some clay, cobbles, boulders, and a variable amount of organic material. Massive to poorly bedded; poorly sorted. Generally a few meters thick, thinner at the upslope part; usually thicker downslope. Contacts generally well defined. Slopes steep to precipitous. Although stabilized locally by vegetation, subject to instability because of renewed stream erosion and accompanying mass-wasting processes. Common along inner valleys cut lower than the floors of major mountain valleys and extending northwestward across the Anchorage lowland; occur locally bordering deeper and wider channels within lateral moraines along Chugach Mountain front and in southwestern part of map area; present also in numerous narrow gullies along the south side of North Fork Campbell Creek in the southeastern part of map area

cwb **Deposits that conceal Bootlegger Cove Formation (Holocene)**--That formation itself likely to be present behind lower part of valley wall. Possibly subject to development of large landslides especially during great earthquakes, although no such landslides developed within this map area during the 1964 Alaska earthquake. Occur only in northwestern part of map area in bluffs bordering Ship Creek valley

cs **Solifluction deposits (Holocene and Pleistocene)**--Chiefly loose, organic-rich, sandy to rubbly diamicton, commonly lacking clasts larger than pebbles; generally derived from weathering of easily frost-shattered bedrock directly upslope, seasonally moving very slowly down broad mountain slopes either with the aid of interstitial or underlying ice (solifluction in a strict sense) or of water derived largely from snowmelt. Thickness poorly known, probably one to a few meters. Contacts gradational to (1) very thinly covered bedrock, (2) other colluvium, and (3) thicker accumulations of material that has moved downslope by landsliding; include some landslide deposits too small to map separately. Topography generally fairly smooth, but with many minor irregularities especially in the form of small lobes with flatter upper surfaces and steeper fronts. Slopes steep to moderately steep. Generally unstable. Occur mainly in a north-south trending zone near east edge of map area south of North Fork Campbell Creek

cl **Landslide deposits, undivided (Holocene and late Pleistocene)**--Include a wide variety of materials, chiefly diamicton, with lesser gravelly silt and sand, and relatively minor amounts of clay and organic material; include some large masses of bedrock and earthflow deposits too small to map separately. Nonbedded; nonsorted to poorly sorted. Relatively loose. Thickness poorly known, probably several meters to possibly several tens of meters locally. Contacts moderately well to poorly defined. Topography irregular to slightly hummocky, slopes moderate to steep. Queried where identity uncertain; these deposits alternately may be rock-glacier, moraine, or other colluvial deposits, or even in-place bedrock. Occur in many places on mountain slopes throughout map area

cle **Landslide deposits resulting from earthflows**--Similar to other landslide deposits but interpreted on the basis of landform to have been emplaced in a probably more fluid state and therefore may include a higher proportion of finer-grained material. Contacts generally well defined. Occur mainly in mountainous part of map area

cld **Landslide deposits related to Dishno Pond moraines (late Pleistocene)**--Identity postulated largely on basis of landforms similar to but more subdued than adjacent lateral moraines and kames, the continuity of which are lacking in area of these deposits. Mainly diamicton, gravel, and sand. Occur in northeastern part of map area south of Ship Creek

clm **Deposits possibly modified in a glacioestuarine environment**--Landforms even more subdued in this lower-lying area clb **Landslide deposits involving Bootlegger Cove Formation (Holocene)**--Probably gravel, sand, silt, and clay partly mixed to form poorly compacted diamicton. Single occurrence postulated in northwestern part of map area along south side of Ship Creek valley

clg **Landslide deposits involving glacioestuarine deposits (Holocene and late Pleistocene)**--Identity postulated largely on basis of irregularly lumpy, crudely lobate topography in areas of channels adjacent to higher-lying glacioestuarine deposits

Rock-glacier deposits (Pleistocene)

rdo **Older rock-glacier deposits**--Accumulations of mainly angular to subrounded rock fragments derived from upslope talus or landslide deposits, or directly from bedrock, and transported very slowly downslope in a rock glacier. Upper surface dominated by angular to subangular cobble- and boulder-size fragments; at depth, substantially more fine-grained material probably present to form coarse, rubbly, diamicton. Thickness poorly known, probably several to a few tens of meters. Contacts fairly well defined. Surface gently bummocky to smooth; slopes moderate to gentle. Almost certainly not moving as an active rock glacier nor containing any glacier ice

Anthropogenic deposits (latest Holocene)

f **Engineered fill**--Chiefly compacted pebble gravel probably underlain by poorly sorted sandy to silty gravel. Includes some areas where a more heterogeneous assemblage of material may have been emplaced without engineering specifications. Mapped mainly at Glenn Highway interchanges and along the Alaska Railroad in northern part of map area, where principal streets cross low-lying areas, and locally elsewhere throughout the urbanized area. Thickness as much as several meters. Contacts well defined, width shown on map may be exaggerated to accommodate linear base-map symbols for roads and the railroad

BEDROCK

b **Bedrock (Mesozoic)**--McHugh Complex of the Chugach terrane, including principally variably metamorphosed graywacke, argillite, phyllite, and conglomeratic graywacke. Occurs only in mountainous eastern part of map area and in canyons along Ship Creek and North and South Forks of Campbell Creek

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