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Geologic map of the Anchorage B-8 SE and part of the Anchorage B-8 NE quadrangles, Alaska

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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GEOLOGIC MAP OF THE ANCHORAGE B-8 SE
AND PART OF THE ANCHORAGE B-8 NE QUADRANGLES, ALASKA

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INTRODUCTION

The area of this map (pl. 1A, in pocket) includes all of the Anchorage B-8 SE quadrangle and that part of the Anchorage B-8 NE quadrangle that lies along the southeast side of Knik Arm, one of the two upper extensions of Cook Inlet (fig. 1). The map area is located in south-central Alaska mainly within the Municipality of Anchorage and centered about 15 km northeast of downtown Anchorage. The northwestern part of the map area, entirely within Knik Arm, is part of the Matanuska-Susitna Borough. Knik Arm, together with a broad embayment, Eagle Bay, occupies about one quarter of the map area. The Alaska Railroad and the Glenn Highway traverse the southern part of the map area from southwest to northeast. Except for these rights-of-way all of the land area is included within either Fort Richardson or Elmendorf Air Force Base. This map is one of a series in the Anchorage-Knik Arm region for which geologic maps have been completed recently at a scale of 1:25,000 (Daniels, 1981a,b; Reger, 1981a,b,c,d; Updike and Ulery, 1988; Yehle and Schmoll, 1987a,b; 1988; 1989; fig. 2). The map of the Anchorage B-8 NE quadrangle by Reger (1981a) does not show any geology for that part included in our map.

The geology of the map area south of latitude 61° 20' N. was mapped at 1:24,000 scale by H.R. Schmoll and Ernest Dobrovolny between 1965 and 1971 by interpretation of 1:20,000-scale airphotos taken in 1962 and by field investigations; a generalized version of that mapping was included in Schmoll and Dobrovolny (1972a). The northern part of the map area was similarly mapped but at 1:63,360 scale using 1:40,000-scale airphotos taken in 1957. The mapping of these two parts of the area subsequently was photographically reduced and enlarged, respectively, to a scale of 1:25,000 by L.A. Yehle and H.R. Schmoll in 1988 and 1989; various modifications were made to accommodate the change in base map and considerable additional detail, especially in the northern part of the map area, was derived from interpretation of 1:24,000-scale airphotos taken in 1972. Selected data from earlier geologic maps of parts of the area by Dobrovolny and Miller (1950) and Miller and Dobrovolny (1959) were also utilized.

PHYSIOGRAPHY

The land area shown on this map lies entirely in the Anchorage lowland (fig. 1; Schmoll and others, 1984), an informal subdivision of the Cook Inlet-Susitna Lowland (Wahrhaftig, 1965) that lies southeast of Knik Arm. A few hundred meters southeast of the southeast corner of the map area lies the boundary with the Kenai-Chugach Mountains physiographic province, and here the rugged Chugach Mountains rise abruptly from the Anchorage lowland along the Chugach Mountain front. The highest point in the map area, about 180 m in altitude, lies at this southeast corner near the base of the Chugach Mountain front.

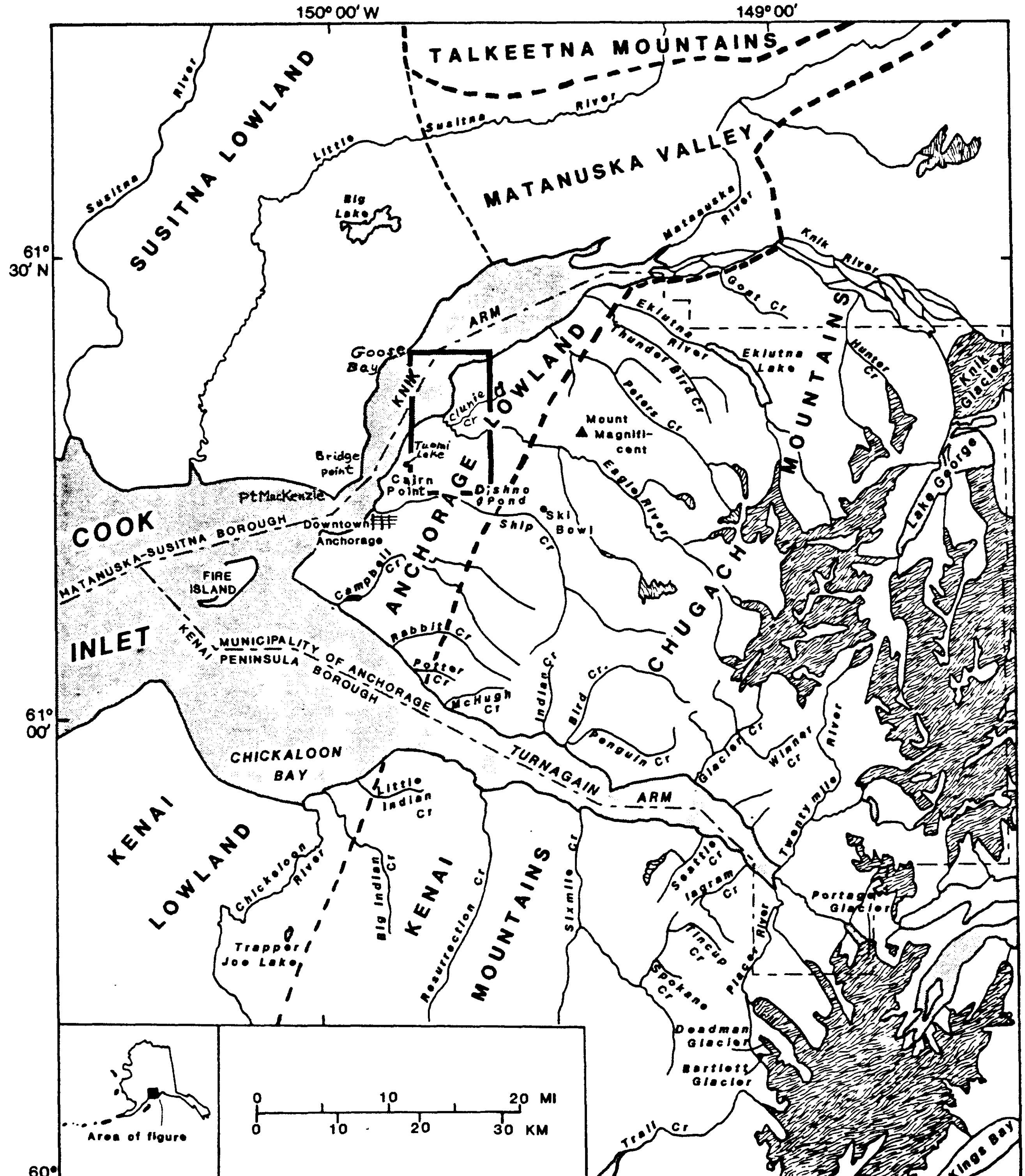


Figure 1.--Location of map area and major geographic features. Thick dashed line indicates boundary between major physiographic provinces, Talkeetna Mountains, Kenai-Chugach Mountains, and Cook Inlet-Susitna Lowland, of Wahrhaftig (1965); thin dashed line and water bodies separate physiographic subprovinces of informal usage. Heavy pattern indicates glaciers.

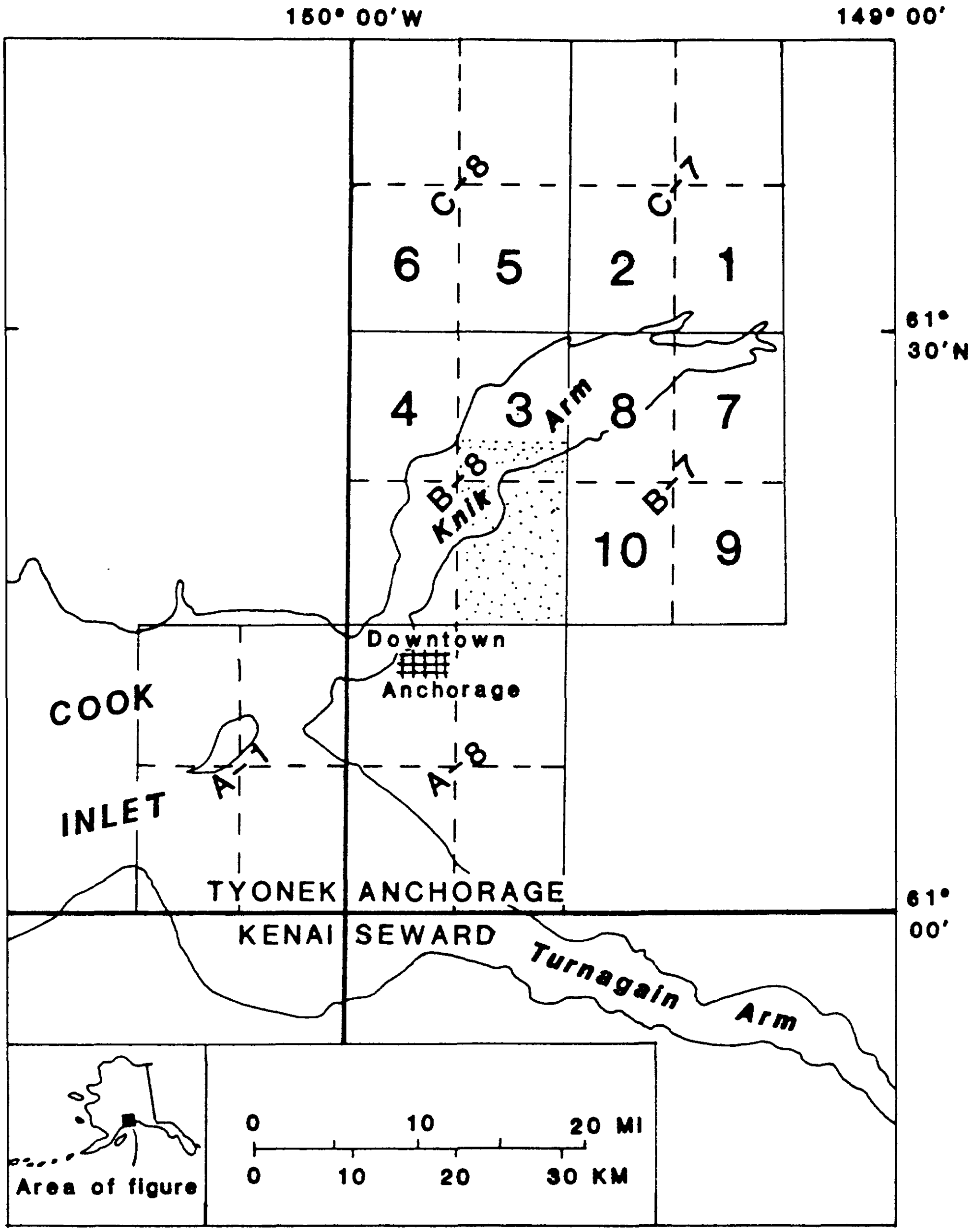


Figure 2.--Index map showing location of geologic maps in the Anchorage-Knik Arm region published at 1:25,000 scale (1, Daniels, 1981a; 2, Daniels, 1981b; 3, Reger, 1981a; 4, Reger, 1981b; 5, Reger, 1981c; 6, Reger, 1981d; 7, Yehle and Schmoll, 1987a; 8, Yehle and Schmoll, 1987b; 9, Yehle and Schmoll, 1988; 10, Yehle and Schmoll, 1989). Area of this report is indicated by stippled pattern.

The Anchorage lowland within the map area includes the following five principal sectors:

1. The northern and west-central parts of the map area are characterized mainly by elongate hills of glacial drift that trend north-northeasterly and that are separated in part by intervening meltwater channels some of which are surfaced by boggy ground. The hills range in altitude from 50 to 80 m in the north to 40 to 60 m in the south, and have local relief of about 20 to 30 m. The land is continuously separated from Knik Arm by steep bluffs that generally are about 30 m high but that rise to as much as 43 m in places. A narrow beach borders the base of the bluffs except during highest tides when water impinges directly on the base of the bluffs.
2. A system of northeast- and northwest-trending channels dominates the central part of the map area. These channels are about 300 to 500 m wide and are incised about 25 to 35 m below the surface of the glacial hills. The channel of the Eagle River is the lowest-lying, and the channels of Fossil Creek to the south and of Clunie Creek to the north of the Eagle River are hanging with respect to the Eagle River. The channel that extends from Otter Lake to Sixmile Lake (here called the Otter-Sixmile channel) appears to be a beheaded former continuation of the Eagle River channel. The channels all probably mark courses of the ancestral Eagle River during glacier retreat and are occupied now by underfit streams. In its lowermost, northwest-trending reach, the Eagle River drains through the Eagle River Flats (pl. 1A), a filled embayment which broadens to nearly 3 km in width where it merges with Eagle Bay. The embayment is part of a larger feature that also includes a similar embayment at Goose Bay on the northwest side of Knik Arm (fig. 1). We refer to the larger feature as the Goose-Eagle alignment.
3. The Elmendorf Moraine (Miller and Dobrovolny, 1959) is a prominent, sharply hummocky ridge only about one kilometer in width that trends in a west-southwesterly direction across the entire southern part of the map area and beyond to the west, descending in altitude from about 150 m on the east side to about 100 m on the west side; local relief is as much as 80 m, but more commonly ranges from 30 to 50 m.
4. South of the moraine and in sharp contrast to its irregular form is the smooth-surfaced, gently west-southwest sloping Mountain View alluvial fan that also extends across the entire map area, descending in altitude from about 130 m in the east to about 55 m in the west where it is about 3 km wide.
5. In the southeast corner of the map area are a few morainal hills that are related to the extensive belt of lateral moraines that lie along the Chugach Mountain front and that are more fully developed both to the east (Yehle and Schmoll, 1989) and south of the map area. These hills rise from about 20 m to as much as 70 m above the surface of the Mountain View fan.

The Eagle River is the only large stream within the map area and flows across the central part from east to west. It drains from a lake at an altitude of 267 m that formed in historical time at the foot of the receding Eagle Glacier about 35 km to the southeast. Clunie Creek and Fossil Creek are both small tributaries to the Eagle River whereas drainage in the Otter-Sixmile channel flows directly into Knik Arm through Sixmile Creek just west of the map area.

The two largest lakes in the map area, Otter Lake and Sixmile Lake, both occupy the otherwise bog-floored Otter-Sixmile channel. Sixmile Lake owes its present existence to a manmade dam just west of the map area. Several other small lakes and numerous ponds are nestled among the hills of the Elmendorf Moraine.

Almost all of the map area is covered by surficial deposits of Quaternary age that are mapped mainly with respect to the landforms containing them. In a few places older Quaternary deposits are exposed as stratigraphic units which enhance interpretation of the geologic chronology beyond what can be gleaned from the surface units. Metamorphic bedrock of Upper Triassic to Cretaceous age may be exposed at one place and soft Tertiary bedrock at another place, both in the southeastern part of the map area.

SURFICIAL DEPOSITS

Surficial deposits that are widespread within the map area consist of glacial drift that includes much related glacioalluvium and that is almost entirely Pleistocene in age. Other deposits that are more restricted in areal extent, although some are widely distributed, include nonglacial alluvium and intertidal, colluvial, pond, and anthropogenic deposits most of which are Holocene in age. Glacial deposits cover large areas as drumlinoid or fluted ground moraine that includes some intervening kame fields in the northern two-thirds of the map area and as part of a classically arcuate end moraine, the Elmendorf Moraine, to the south; the northern (proximal, or toward-ice) part of the end moraine is bordered by a series of kames and kame terraces. Other glacioalluvial deposits occupy terraces within the Clunie Creek, Eagle River, and Fossil Creek valleys and dominate the southern part of the map area as the broad Mountain View fan. Nonglacial alluvium is restricted to the narrow floors of the valleys. Intertidal deposits occupy the Eagle River Flats in the center of the map area. Colluvial deposits of varying thickness, including a few landslide deposits, are present only on the extensive bluffs that border the major valleys and the shore of Knik Arm. Pond deposits occur mainly in the numerous glacial meltwater channels in the northern part of the map area and in the Otter-Sixmile channel where, adjacent to Otter Lake marl deposits are present (Moxham and Eckhardt, 1956); small areas of pond deposits occur within the Elmendorf Moraine. A ubiquitous mantle of organic material and windblown silt and fine sand, including minor amounts of tephra, covers all but the most recent deposits. This mantle has not been mapped separately but is included with the underlying deposits. Anthropogenic deposits are widespread but only major areas of engineered fill have been mapped.

GLACIAL DEPOSITS

Glacial deposits in the map area are mainly the products of several glacial advances from and retreats to distant mountainous regions to the north and east (Dobrovolny and Miller, 1950; Miller and Dobrovolny, 1959; Karlstrom, 1964; Cederstrom and others, 1964; Reger and Updike, 1983, 1989; Schmoll and Yehle, 1986). Each of these glaciers successively modified the terrain in the map area, but evidence for only the last two major advances and retreats is preserved at the surface. As in most glaciated regions, evidence for older glaciations is based largely on relict landforms and only those landforms resulting from the last glacier to occupy a given area commonly are preserved. Consequently, of the two glacial advances represented within the map area, the more extensive glacier advance for which there is evidence is the older, and the less extensive advance the younger. Surface evidence for any intervening advances of lesser extent than the last advance is thus lacking, and stratigraphic evidence suggests that no such ice advances of any significance occurred.

In addition to glaciers from distant sources, glaciers in nearby mountain valleys, notably Eagle River valley directly east of the map area, contributed deposits to the area. The interplay between glaciers from distant and nearby sources varied depending on the relative intensity of glaciation. Four successively less intensive stages of glaciation are outlined briefly as follows:

1. The most widespread glaciers to reach the map area from distant sources mostly overwhelmed nearby valley glaciers in the Chugach Mountains to fill the Cook Inlet-Susitna Lowland and cover parts of the adjacent mountains with ice.
2. When glaciers from the distant sources were less extensive, nearby glaciers such as those in the Eagle River valley were not overwhelmed and developed independently to greater extent. They still joined ice from distant sources in the lowland, however, and the resultant combined glacier flowed southwestward across the map area.
3. When glacier advances were even less extensive, nearby valley glaciers did not extend far enough downvalley to join with distant-source lowland ice. The lower parts of mountain valleys such as that of the Eagle River (Yehle and Schmoll, 1989) were free of glacier ice. Drainage in such mountain valleys was commonly blocked by a lowland glacier or its lateral moraines, and lakes at various levels formed between the lowland glacier and the upvalley glacier. Periodically these lakes drained, perhaps catastrophically, southwestward and westward across the map area, carving channels and (or) leaving deposits at various levels; the drainage was diverted laterally around and in part through the ice.
4. Although glacier ice is no longer present in the area, the Eagle River continues to follow a course influenced by the remaining channels and glacial deposits.

The glacial deposits that are found at the land surface are all contained within landforms of various kinds, and it is mainly the configuration and type of landform that serve as a guide to mapping the type of deposit and to understanding the relative ages of the glacial deposits. The two principal types of glacial deposits mapped are (1) morainal deposits, materials deposited directly by glacier ice and that occur in end and ground moraines, and (2) glacioalluvial deposits, materials deposited by running water within, around, and draining away from the ice and that occur in kames, kame terraces, outwash plains, meltwater-channels, and alluvial fans. 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 gravel and sand are present locally, as are lesser amounts of silt and clay. Glacioalluvial deposits consist mostly of gravel and sand, although some diamicton and finer-grained material are commonly present in kames.

For purposes of identifying the glacial deposits and to serve as a guide to their relative ages, glacial deposits are further subdivided according to, and named after, the named lateral and end moraines that they form and to which deposits in other moraines and related landforms can be correlated, as discussed by Schmoll and Yehle (1986). That paper also discusses difficulties in using the glaciation terminology developed by Karlstrom (1957; 1964) in classifying glacial deposits in the Anchorage area and used by Miller and Dobrovolny (1959) and most later workers. The localities from which Karlstrom's names are derived are located both in the vicinity of this map area and to the south on the Kenai Lowland (fig. 1). Because most of these typical deposits are not well dated and successive deposits are neither in stratigraphic or geomorphic contiguity, there are uncertainties in correlation between the two areas. Thus we do not use Karlstrom's terminology, but instead, use local terminology and relate our deposits directly to the standard chronology now in use for the Pleistocene (Bowen and others, 1986). We apply this chronology without using queries, but recognize that there are many remaining uncertainties with regard to the temporal placement of our deposits; some of these uncertainties are discussed below.

End-moraine deposits within the map area are entirely those of the Elmendorf Moraine. This prominent ridge deviates from the trend of the lateral moraines along the Chugach Mountain front just east of the map area to cross the Anchorage lowland in a broad arc that culminates about 6 km west of the map area at Cairn Point on the eastern shore of Knik Arm (fig. 1). The ridge was named as a geographic feature by R.D. Miller in 1955 (Orth, 1967) and shown by Miller and Dobrovolny (1959). It is here identified as the typical locality for the complex of moraine deposits of the Elmendorf Moraine. As defined geographically the Elmendorf Moraine extends north as far as Birchwood (near the mouth of Peters Creek) east of Knik Arm and to Big Lake west of the arm (fig. 1) and includes lateral-moraine and kame deposits as well. We prefer, however, to restrict the typical locality for the deposits to the 16-km stretch of well-defined end-moraine ridge that extends from Cairn Point eastward to the northeast end of map unit eme in the SE1/4 sec 18. T. 14 N., R. 2 W., in the map area to the east (Yehle and Schmoll, 1989). Within the western part of the map area the ridge has a double crest, and in the SE 1/4 sec. 25, T. 14 N., R. 3 W., a more northerly ridge crest that extends southwest from near the Otter-Sixmile channel and continues southwest to Cairn Point appears to truncate a more southerly ridge crest that extends northeast from this point as a topographically irregular single-crested ridge. The dual nature of the western part of the end moraine and the truncating relationship suggests that the more northerly ridge marks a minor readvance of the glacier. We regard, however, that both ridges constitute the typical locality for deposits of the Elmendorf Moraine.

Ground-moraine deposits correlated with those of the Elmendorf Moraine cover much of the northern and west-central parts of the map area. Here the land surface is marked by a prominent series of elongate hills that we map separately as drumlins although they commonly lack the longitudinal asymmetry (more blunt end facing the direction from which the ice approached) characteristic of many drumlins. The drumlins range widely in shape; some are relatively long and narrow and in places where these landforms are very narrow and close together they are grouped and mapped as fluted ground moraine (Prest, 1968). The drumlins and associated landforms in the northern part of the map area are aligned subparallel to the Chugach Mountain front and probably reflect the southwestward direction of ice-flow that was centered roughly along the present position of Knik Arm. Southward, however, the orientation curves to a more southerly alignment that is more nearly perpendicular to the Elmendorf end-moraine ridge.

The pattern of drumlinoid and fluted ground moraine that we map differs appreciably from the generalized pattern shown on the glacial geology map of the upper Cook Inlet area by Karlstrom (1965) which by inference includes approximately east-west trending end moraines at two positions, one just north of the Otter-Sixmile channel and the other just north of a small channel parallel to and about 600 m south of the shore of Knik Arm in the northernmost part of the map area. Like Miller and Dobrovolny (1959) we find no evidence for end moraines at either of these positions. The only linear features in those places are channels that are clearly post-morainal erosional features not indicative of any ice-margin position.

Ground-moraine deposits in the southeastern part of the map area are mapped as those of the Dishno Pond moraines (Schmoll and Yehle, 1986). They are better developed in map areas both to the east (Yehle and Schmoll, 1989) and to the south, where the typical area for deposits of the Dishno Pond moraines surrounds Dishno Pond (fig. 1).

Glacioalluvial deposits are scattered widely throughout the map area and, except near the southeast corner, all are related to deposits of the Elmendorf Moraine. Kames are locally prominent landforms that include irregular hills and areas of hummocky terrain and the deposits are subdivided in part on the basis of differences in amount of local relief within the landforms. They occur mainly within the area of predominantly ground moraine in the northern and western parts of the map area. Along the northern (proximal, or toward-ice) side of the end moraine, kames are aligned roughly parallel to the morainal ridge. Here they include both kames of high relief and a sequence of kames and kame terraces that are mapped separately. This latter sequence was formed by water that drained through the Fossil Creek channel and presumably back into the stagnating glacier, but behind the drainage barrier provided by the end-moraine ridge (Miller and Dobrovolny, 1959, p. 63-64, 86-87). We here identify these deposits as the Roosevelt Road kame-terrace deposits (about 1.5 km east of Otter Lake) and the Gwenn Lake kame deposits (about 3 km east of Otter Lake). Farther west another sequence is called the Tuomi Lake kame-terrace deposits, named for a small lake just west of the map area about 2 km southwest of Sixmile Lake. The alluvial sequences of which these deposits form a part are discussed more fully below.

Deposits of glacial outwash occur in plains in a few places bordering the south side of the Elmendorf Moraine. These deposits are mostly eroded remnants of what were probably more extensive plains that spread out in front of the moraine, deposited by meltwater streams that emerged from the ice. The outwash remnants occur at successively lower levels, the lowest of which is concordant with the level of the Mountain View alluvial fan deposits.

Glacioalluvium in channels and fans is extensive in the map area and includes deposits formed by meltwater from the downwasting glaciers as well as drainage from glacial lakes in Eagle River valley and from streams that bordered the ice east of the map area. Some of these deposits occur in a complex series of channels within areas of ground moraine, and include both deposits in slightly hummocky to irregularly floored channels that might have formed on melting ice, as well as deposits laid down in flat-floored channels that formed somewhat later.

Especially prominent are the deposits of the broad, low-gradient Mountain View fan (Bartsch-Winkler and Schmoll, 1984b, p. 16) that occupy much of the southern part of the map area and that extend to and form the major surface deposits at downtown Anchorage (Miller and Dobrovolny, 1959, map unit Qo; Schmoll and Dobrovolny, 1972a, map unit an). Although commonly so regarded, most of these deposits are not glacial outwash in a restrictive sense, but rather represent drainage mainly from the Eagle River valley, probably formed by the breakout of one or more lakes in the valley impounded by (and perhaps partly within) the Elmendorf glacier, as interpreted by Miller and Dobrovolny (1959, p. 86).

Subsequently drainage from the Eagle River valley flowed at various times through the channels of Fossil Creek, Eagle River, Otter-Sixmile, and Clunie Creek, each of which has a sequence of terraces that represent successively lower stages of drainage during the waning phases of the Elmendorf glacier. These deposits include the Fossil Creek and Clunie Creek alluvial deposits that have been separately named (Yehle and Schmoll, 1989) to facilitate tracing their courses across several map areas. In addition to the kame and kame-terrace deposits named previously, other deposits that are part of this glacioalluvial sequence are the Sixmile Lake and Bluff Road alluvial deposits, named here for the first time. The Sixmile Lake alluvial deposits occur at several levels within about 5 m or less of each other and extend from about 2 km northeast of Otter Lake through the Otter-Sixmile channel, continuing westward for about 1 km beyond the west edge of the map area. The typical locality for these deposits straddles Sixmile Lake in the western part of the map area. The Bluff Road deposits occupy a single channel that extends discontinuously possibly as far as downtown Anchorage and are named from a locality near the east end of Bluff Road about 1.5 km south of the southwest corner of the map area.

The glacioalluvial sequence described above, first presented by Miller and Dobrovolny (1959), has been further elaborated mainly by the matching of the present-day gradients of deposit remnants. This still somewhat tentative sequence may be summarized briefly as follows:

1. Drainage in the Eagle River and other, more northerly, valleys tributary to Knik Arm was blocked by the glacier that formed the Elmendorf Moraine. Some water, however, worked its way through the glacier and emanated from the ice to form a series of small outwash plains that may have coalesced into a larger plain in the area now occupied by the Mountain View fan. The highest level Tuomi Lake kame-terrace deposits may have formed comtemporaneously with these events.

2. Break-out of a lake in the Eagle River valley then eroded some of the outwash as well as the margins of the Elmendorf Moraine. The moraine was most notably eroded in the sector just south of Fossil Creek, where a single outlier of the moraine marks its former extent. The deposits of the Mountain View Fan then were laid down either in a single event or in a series of closely-timed breakout events that are analagous perhaps to the breakout of Lake George from behind Knik Glacier (fig. 1) that occurred almost annually earlier in this century (Stone, 1963; Bradley and others, 1972)
3. Cutting of the Fossil Creek channel then commenced, the position of the channel controlled by locally extensive erosion of the moraine, and the deposits of the highest-level terrace in the Fossil Creek channel were formed. The water flowed through this then-shallow channel and then entered the glacier, perhaps forming the massive high-relief kames just north of the end-moraine ridge and emerging from the glacier to flow across the surface of the Mountain View fan in a shallow channel that deepened to the southwest, depositing the Bluff Road alluvial deposits
4. As the glacier front retreated, water flowed at somewhat lower levels within the Fossil Creek channel, and formed deposits that now occupy the next lower terraces. The water continued southwestward marginal to the ice and formed the Roosevelt Road kame-terrace deposits and, farther west, the intermediate and lower Tuomi Lake kame-terrace deposits. By this time the snout of the Elmendorf Moraine had been breached, and for the first time Eagle River water was able to reach the ancestral Cook Inlet within the area that had been occupied by glacier ice.
5. As larger areas of glacier ice became stagnant, water was able to penetrate to lower levels, first to form the lower terrace deposits and finally to form the deposits on the floor of the Fossil Creek channel. This water then entered the glacier to form the Gwenn Lake kames before cutting through the deposits of the moraine in the Otter-Sixmile channel and laying down the higher-level Sixmile Lake alluvial deposits near the west edge of the map area.
6. With continued ice stagnation and retreat Eagle River water was able to follow a more northerly course, probably joining drainage from northerly sources. At this time, water apparently flowed through a higher-level channel in the position of the present Eagle River near the east edge of the map area, depositing the material that now occupies the higher terraces bordering the Eagle River. The water apparently continued southwestward, laying down the Sixmile Lake alluvial deposits northeast of Otter Lake and continuing westward through the Otter-Sixmile channel.
7. Somewhat later, but perhaps in part contemporaneously, water also flowed through the Clunie Creek valley at relatively high levels. Some water still flowing through the Eagle River-Sixmile Lake channel eventually made its way instead across the Elmendorf ground moraine to join water in Clunie Creek valley; thus, for the first time some Eagle River water followed approximately along its present course.
8. After a time, most of the water probably flowed through Clunie Creek valley, and deposits of the major terraces there were formed; they were graded to levels lower than those of the high terraces in the Eagle River valley but higher than the lowest terraces along the Eagle River.

9. Eventually, drainage from north of the Eagle River valley was able to follow more direct routes across the lowland to Knik Arm, and no longer joined Eagle River water. The Eagle River Flats, which may have started to form as an embayment during stages 4 through 8, became enlarged to approximately its present configuration. During this process, the Eagle River may have cut down to a sea level below that of the present, and the Eagle River cut the present deeper channel that it now occupies near the east edge of the map area.
10. Finally, sea level reached about its present level, the Eagle River Flats became filled in, and the present valley-floor alluvium was laid down.

INTERTIDAL DEPOSITS

Intertidal deposits occupy all of the Eagle River Flats and a few other areas bordering Knik Arm. The central and bayward parts of the Eagle River Flats lie within the modern tidal range of the Cook Inlet-Knik Arm estuary and are subject to the twice-daily flood and ebb of brackish water that circulates within the estuary. Mean tidal range at Anchorage (the closest tidal station) is 7.9 m, and the difference between mean higher high water and extreme low tide approximates 10.8 m (U.S. National Ocean Service, 1982). The modern intertidal deposits are divided into upper and lower zones, following the usage of Ovenshine and others (1976) and Bartsch-Winkler (1982). Older intertidal deposits constitute much or all of the fill beneath the Eagle River Flats and their surface now lies above the modern tidal range.

The intertidal deposits consist mostly of a mixture of silt and medium- to fine-grained sand; coarser sand occurs near the major channels, at a few beaches, and at the head of the flats where the deposits merge imperceptibly with alluvium. The finest-grained deposits occur on relatively higher intertidal surfaces away from the river channel. The fineness of such deposits may have resulted in part from seismically caused subsidence such as the 0.6 m reported by Plafker (1969, fig. 3) to have occurred in the map area during the 1964 Alaska earthquake.

The boundary between land and water is continually changing because of the great tidal range and is thus difficult to delineate. In effect, the lower intertidal deposits mark a broad area within which the land-water interface shifts continuously. Complicating the portrayal of the land-water interface on the topographic orthophoto base maps (U.S. Geological Survey, 1979a, b) is that they were prepared using several different series of airphotos taken at several different tide-level stages in 1972. These stages were not adjusted altitudinally to a uniform stage level. As a result, and for us to portray deposits as accurately as possible on the geologic map, other maps and charts were examined and interpreted (U.S. Geological Survey, 1952; U.S. National Ocean Service, 1982, 1986). The water-land contact that was selected is an approximation of a mean tide line, and it should be understood that the line does not represent a fixed position but rather one that occurs only at times of mid-tide in a tidal cycle.

COLLUVIAL DEPOSITS

Colluvial deposits (colluvium), as used here, include those deposits that occur on or at the base of a slope and that have accumulated primarily by 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 relatively long period of time and deposits that have moved en masse and formed in a relatively short time, perhaps a few days or even hours.

Colluvial deposits within the map area include mainly those deposited particle by particle on the steep walls of valleys and on the bluffs that border Knik Arm. These valley walls and sea bluffs are incised into surficial deposits and are particularly subject to instability and renewed erosion. They commonly are veneered by a downslope-thickening wedge of colluvium derived mainly from material into which the wall was cut during the last episode of erosion. Such erosion is likely to occur again at any place along the wall when the stream or the sea renews its lateral attack, removes at least part of the colluvium, and erodes anew the underlying material. Where the bluffs are actively eroding, spectacularly so where they constitute imposing cliffs along the east side of Eagle Bay, colluvial deposits are removed as fast as they accumulate at the base of the bluffs and the stratigraphy of the glacial deposits is well exposed. Waves and tidal currents here may be eroding the bluffs at rates approximating the 0.6 m/yr reported by Miller and Dobrovolny (1959, p. 89) at a similar bluff west of downtown Anchorage. In places valley-wall colluvium forms long, narrow belts along low terrace and channel escarpments that are too narrow to map separately; these occurrences are represented by a line symbol that marks minor differences in age of alluvial deposits within the same map unit. In the southeastern corner of the map area colluvium derived from moraines upslope mantles the base of the Chugach Mountain front.

The only colluvial deposits within the map area that have formed en masse include a few landslide deposits that occur on the bluffs within the belt of other colluvial deposits. None of the mapped landslide deposits is smaller than 0.3 km^2 in size; many others are too small to map separately. A few landslide deposits are queried because their identification on airphotos is uncertain, the morphology of these areas being merely suggestive that landslide activity has occurred. Upon further investigation, such areas may prove to be sites of more gradual accumulation of colluvium or other features caused by peculiarities of erosion; they thus would be relegated to the category of "pseudolandslides" (Shlemon and Davis, 1986). Especially when sea bluffs are eroding most actively, many small earthflows occur, but the deposits are commonly removed shortly after deposition.

Because of their rapid mode of emplacement, and their destruction of previously stable and perhaps inhabited or developed land, landslides have a high potential for impact on human activity. Within the map area landslides are most likely to occur within the belts of colluvial deposits that mark the valley and sea bluffs, areas that are also the most likely sites of stream or sea erosion as well. Thus the bluffs and the areas directly landward behind the tops of the bluffs, especially where the bluffs are eroding actively, are the areas of most likely instability; careful attention should be given such areas prior to undertaking developmental activities. As part of a general slope-stability analysis of the Anchorage area (Dobrovolny and Schmoll, 1974) the bluffs within part of this map area have been classified according to degree of stability including the likelihood of occurrence of major landsliding. Most of the bluffs are in category 4, generally low stability, or, where less steep, category 3, moderate stability. Only the actively eroding bluffs where stratigraphic units are exposed are in category 5, lowest stability. Even here, however, it is not regarded as likely that landslides of the magnitude of those that occurred in and near downtown Anchorage both during the 1964 earthquake (Hansen, 1965) and earlier as well (Miller and Dobrovolny, 1959) would occur on bluffs within the map area.

OTHER DEPOSITS

Other surficial deposits mapped include alluvial, peat and pond, and anthropogenic deposits. Alluvium that is not directly related to glacial activity has been mapped mainly in the Eagle River and Clunie Creek valleys. Alluvium also occurs within small valleys in areas that are too narrow to map separately. The alluvial deposits are subdivided into stream alluvium and fan alluvium, the latter deposited mainly along some valley walls and in the southeastern part of the map area at the base of the Chugach Mountain front. One large alluvial fan is present where the Eagle River enters the head of the Eagle River Flats.

In places, significantly younger and older alluvial deposits are mapped separately. The youngest alluvium occupies the narrow, active flood plain of the Eagle River, and is intermittently retransported as this area is continually subjected to inundation by the river. Older alluvial deposits occur in terraces that are as much as several meters above present stream levels, but below the higher terrace levels of glacioalluvial deposition.

Alluvial deposits consist mostly of sand and gravel. Locally, alluvium is finer grained, mainly silt and fine sand; some of these occurrences are mapped separately.

Peat and pond deposits are mapped in the many areas of boggy ground within glacial-meltwater channels and within the irregular terrain of the Elmendorf Moraine. Deposits consist of peat, varying amounts of silt and sand, and, locally, thin lenses of tephra. The deposits grade laterally into, but are thicker than, the unmapped mantle of organic and eolian deposits.

Anthropogenic deposits are those that have been emplaced or significantly disturbed by the activities of man. Engineered fill has been mapped mainly along the Glenn Highway and the Alaska Railroad. Areas in which naturally occurring materials have been extensively reworked are shown by overprint pattern. They include areas of both cut and fill and occur mainly in gravel pits and several areas of major construction. Minor reworking of deposits within the developed areas of the military bases is not indicated on the map.

QUATERNARY STRATIGRAPHY

In addition to the deposits mapped at the surface, other Quaternary deposits are exposed only in sea and river bluffs and are observed in a stratigraphic rather than in a geomorphic context. Such deposits include older glacial, glacioalluvial, glacioestuarine, and interglacial deposits that underlie deposits at the surface and do not have surface expression, as well as deposits that are also mapped at the surface, especially ground-moraine deposits of the Elmendorf Moraine. The stratigraphy is best and nearly continuously exposed in the bluffs on the east side of Eagle Bay. Intermittent exposures occur elsewhere in the bluffs both northeast and southwest of Eagle Bay, and at widely scattered places in bluffs along the Eagle River. Because the detail of these deposits cannot be adequately shown at the scale of the map, they are illustrated separately in figure 3. This

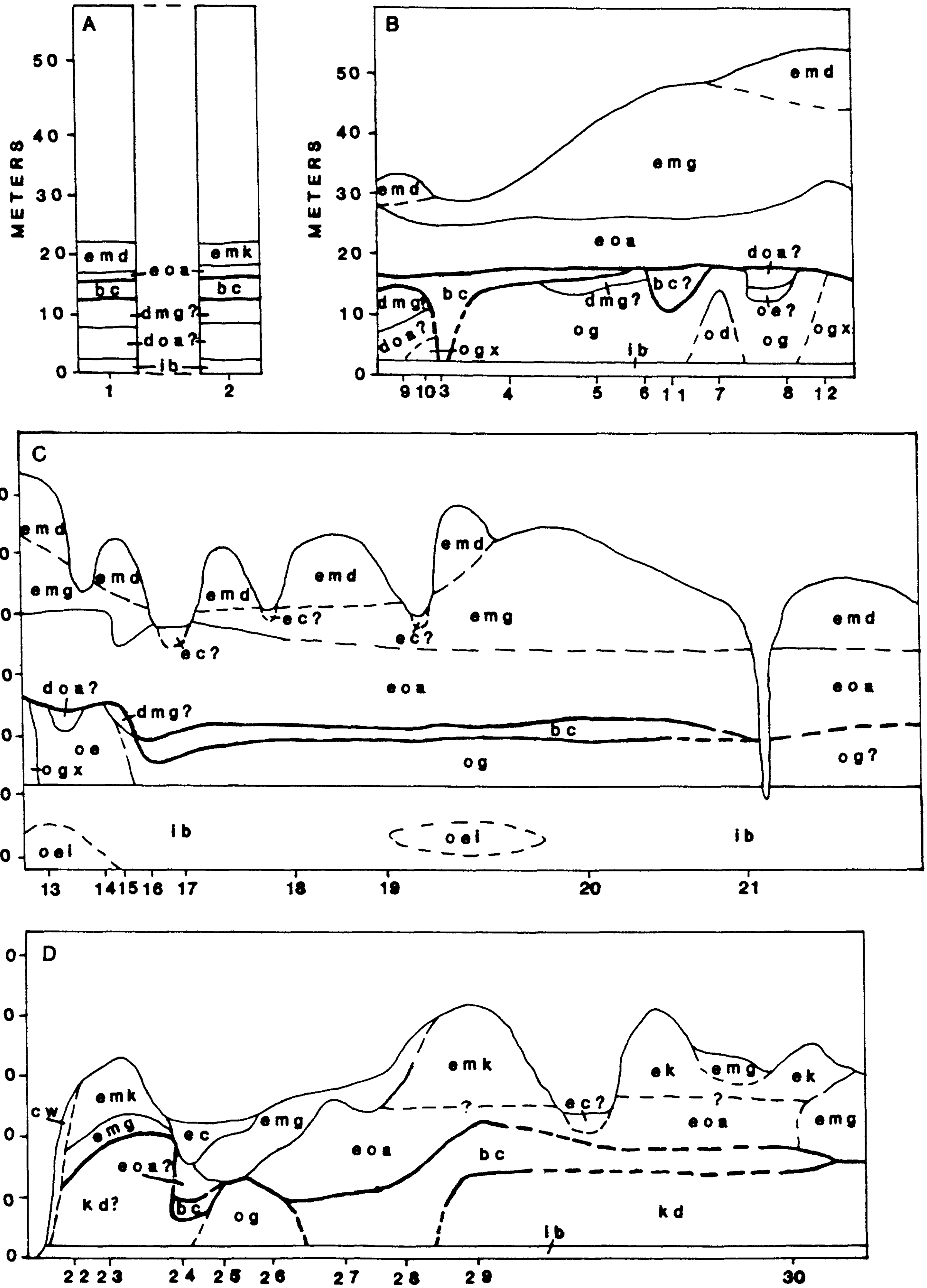


Figure 3.--Generalized stratigraphy exposed in bluffs along Knik Arm and Eagle Bay. Horizontal scale is same as that of the geologic map (pl. 1A). Location numbers, shown also on the map, indicate sites of measured sections or other detailed observations. Vertical scale corresponds approximately to altitudes represented on the map by contours, but field measurements were made with respect to the upper limit of the modern beach, unit ib. Symbols, some of which also appear on the map, are explained in description of map units. Dashed contacts are inferred.

stratigraphic diagram is divided into four sectors: (A), two isolated exposures near the northeast corner of the map area; (B), the bluffs northeast of Eagle Bay; (C), the bluffs along the east side of Eagle Bay; and (D), the bluffs that extend from the south side of Eagle Bay southwestward to the west edge of the map area. Locations of individual measured sections or other detailed observations are numbered 1 through 30 both on figure 3 and on the geologic map (plate 1A). Locations 1 through 8 were observed by Dobrovolny and Miller in 1949 and appear on plate 3 in Miller and Dobrovolny (1959). Some of those and all the remaining locations were observed by Dobrovolny and Schmoll in 1966 and (or) 1971, in the latter year with W.W. Barnwell. Preparation of figure 3 was aided by observations made from low-flying aircraft and oblique airphotos taken in 1988 by Schmoll and Yehle.

The deposits shown in figure 3 are divided into three main groups as indicated by heavy contacts on the figure: (1) Elmendorf ground-moraine deposits and related underlying gravel; (2) the Bootlegger Cove Formation; and (3) a complex of older deposits whose lateral relationships are somewhat ambiguous. Each of these groups is separated by a minor erosional disconformity; similar but less persistently recognizable disconformities may be present within group 3.

Till of the Elmendorf ground moraine is the highest unit recognized in the bluffs; in most places the steep upper parts of the bluffs were not examined closely, and uppermost stratigraphic details are not represented in figure 3. In sector C the till is consistently present as a unit consisting almost entirely of diamicton that is apparently massive and reasonably uniform in texture. It is, however, quite variable in thickness--as much as 12 m thick where the ground surface back from the bluff rim is highest (in a drumlin) and thinner elsewhere, especially where channels have been eroded into it. The till is lacking altogether only beneath the largest channel intersected by the bluffs (location 17). At this location, channel gravel apparently is in contact with the older gravel that underlies the till, although we have not observed such a contact between the two presumably different gravel deposits. In sector D there is substantially more gravel and poorly sorted silty gravel in the uppermost unit which, however, is still regarded as mainly ground moraine. The base of the till is relatively even, especially in sector C, implying that the glacier ice overrode a gravel plain without substantially, or at least differentially, eroding this surface.

The gravel that directly underlies the till is quite regular in configuration except in sector D and is about 5 m thick. This gravel probably represents outwash deposited by the glacier as it was advancing southwestward across the Anchorage lowland, indicating that an outwash plain extended from the glacier ice to an ancestral Knik Arm that probably existed somewhat farther down the axis of the lowland. The base of the gravel locally includes a lag concentrate of cobbles and some boulders, and probably marks a disconformity and indicates the erosion of both the Bootlegger Cove Formation and an underlying diamicton-gravel unit.

The Bootlegger Cove Formation ("blue clay" of Dobrovolny and Miller, 1950; "Bootlegger Cove Clay" of Miller and Dobrovolny, 1959; name revised to its present form in Updike and others, 1982) underlies much of the central part of the Anchorage lowland southwest of the map area (Miller and Dobrovolny, 1959; Trainer and Waller, 1965; Ulery and Updike, 1983; Updike and Carpenter, 1986; Updike and others, 1988) and is present in the bluffs within the map area and beyond to the northeast (Yehle and Schmoll, 1987b, map unit cwf). In sector D its presence is sporadic and its thickness is apparently quite variable, but thicknesses of as much as 16 m are observed and in places the base is not exposed, so that the formation may extend below sea level to an unknown depth; near downtown Anchorage, for example, at Lynn Ary Park (Updike and others, 1988) the base of the formation is at about 10 m below mean sea level. At most places in sectors A through C the formation is present more consistently but as a relatively thin unit in the lower middle part of the bluffs and rarely more than a few meters thick. One thick section in sector B (location 3) was observed in 1949 but apparently was not exposed in 1966. The formation is conspicuously absent near the prominent headland at the north end of Eagle Bay (locations 7 through 15), possibly because of nondeposition or thin deposition on top of a preexisting topographic (subestuarine) high area and subsequent erosion. The base of the formation apparently is irregular, a characteristic common throughout the Anchorage lowland where sufficient data permit such a determination. This irregular base has been interpreted to indicate a period of subaerial erosion preceding its deposition (Trainer and Waller, 1965) but could alternatively reflect an irregular surface, either subaerial or subestuarine, on which it was deposited.

In sector A, the Bootlegger Cove Formation is underlain by diamicton that is underlain, in turn, by gravel. These two units may represent the glacial interval prior to that of the Elmendorf Moraine that is associated with the Dishno Pond moraines, but such a correlation cannot be made with certainty. At most places in sectors B and C, the Bootlegger Cove Formation is underlain by gravel with some interbedded sand. The gravel and sand are generally well bedded and somewhat oxidized, and commonly 8 to 12 m thick. At location 18 a piece of wood incorporated in the gravel yielded a radiocarbon age of greater than 45,000 yr (table 1). At location 12 the gravel is strongly oxidized, and between there and location 13 the lower part of the bluffs contains mainly contorted interbeds of diamicton, sand, and silt. The strongly oxidized gravel is probably part of the same stratigraphic unit as the laterally adjacent gravel that is less oxidized. Rather than being an indication that the ozidized gravel is a separate, significantly older unit, the strong oxidation is more likely caused by the proximity of the more impervious diamicton-silt unit. The relationship of the gravel to the contorted complex is not clear, but probably the contorted beds are stratigraphically lower, the gravel beds lapping disconformably onto a pre-existing high area. At location 13, and exposed only at very low tides, the contorted beds are underlain by horizontally-bedded silt and clay containing some scattered stones; these beds are more indurated than the Bootlegger Cove Formation and between locations 19 and 20 the bedding appears gently warped as viewed from the air. The relationship between the two units may be gradational, but they are separated by a covered interval occupied by the modern beach; it is possible that the stratigraphically low silt-clay unit is substantially older than the other units. Only at location 7 is there a diamicton that was interpreted as till in 1949, but this deposit was not exposed at times of later observations to permit reevaluation.

In sector D wherever the Bootlegger Cove Formation does not extend to the base of the bluffs it is underlain by diamicton that exhibits a bedded character. This diamicton unit could be equivalent to the diamicton exposed in bluffs on the west side of Knik Arm that has served as the type deposit for the Knik glaciation of Karlstrom (1964, pl 6, section X) and that we informally refer to as the "Knik diamicton," and we show it as unit kd on figure 3. Alternatively, the bedded diamicton could represent a lateral change of facies within the Bootlegger Cove Formation and be equivalent to the pebble- and cobble-bearing facies V of that formation in the terminology of

Updike and Carpenter (1986). This interpretation is suggested by the lateral juxtaposition of this unit and the Bootlegger Cove Formation between locations 28 and 29. It is also possible that the "Knik diamicton" and Bootlegger Cove facies V are the same unit, but this is regarded as unlikely (R.G. Updike, oral commun., 1984). The well-exposed diamicton along the north side of the Eagle River, mainly in the N. 1/2 sec. 17, T. 14 N., R. 2 W., may also be "Knik diamicton" but its relationship to other stratigraphic units or to any named lateral moraines cannot be determined with certainty.

Although some diamicton beds, including the possible "Knik diamicton," could be correlative with the Dishno Pond moraines, we interpret that most of the units stratigraphically lower than the Bootlegger Cove Formation are related to glacier ice within the Anchorage lowland that probably remained farther north and east of the map area most of the time. Thus, these lower units cannot be associated with certainty with the glacial advances represented by lateral moraines along the Chugach Mountain front.

Interglacial deposits are not recognized in the bluffs shown on figure 3, but interglacial intervals may be represented by disconformities that are present between some of the units. Interglacial deposits have been found, albeit poorly exposed, along the Eagle River in the SW1/4 SE1/4 sec. 9, T. 14 N., R. 2 W. (Miller and Dobrovolny, 1959, p. 57), and are mapped separately there. The deposits include peat, silt, and clay; fresh-water gastropods are prominent in a few thin beds. The peat yielded an age beyond the range of the radiocarbon-dating method (table 1). We infer that these deposits are probably of Sangamon age, approximately 125,000 yr B.P. (Bowen and others, 1986). That they are at least this old is further suggested by the thermoluminescence age of 175,000 yr (Reger and Updike, 1989) determined for the 2-m thick Goose Bay peat bed (informal name; Reger and Updike, 1983; Karlstrom, 1964, p. 35, unit 7) exposed along the northwest shore of Knik Arm northeast of Goose Bay that is in a seemingly comparable stratigraphic position.

CHRONOLOGY

The deposits at the surface within this map area are better dated than those of many of the other map areas within the Anchorage lowland. Although no finite radiocarbon ages have been obtained within the map area, four sites in nearby areas provide good age data for many of the surficial deposits within the area (table 1). Both the deposits of the Elmendorf Moraine and the glacioalluvial sequence related to the waning stages of glacier ice in the area are bracketed by radiocarbon dates that seem to limit their ages fairly closely (table 1). An age of about or perhaps somewhat older than 14,000 yr is regarded as the most reasonable radiocarbon age for a macrofossil-bearing zone within the upper part of the Bootlegger Cove Formation (Schmoll and others, 1972). Radiocarbon locality 5 (fig. 1) is the closest to this map area of several sites from which similar dates have been obtained, and provides the youngest of the several dates. At this site the dated upper part of the Bootlegger Cove Formation has been observed clearly in place beneath the deposits of the Elmendorf Moraine, and it appears that deposition of the Elmendorf deposits began shortly after the time of the dated horizon.

Table 1.--List of radiocarbon dates in the Anchorage B-8 SE quadrangle, Alaska, and nearby areas

Locality number and name	Location[1]	Lab number[2]	Radiocarbon age[3]	Date of collection[4]	Reference
		Anchorage B-8 SE quadrangle			
1. Eagle River	SW1/4 SE1/4 sec.9, T. 14 N., R. 2 W.	W-535	>38,000	1949	Miller and Dobrovolny, 1959, p. 57
2. Eagle Bay	NW1/4 NW1/4 sec. 30, T. 15 N., R. 2 W.	W-2911	>45,000	September 3, 1971	(first publication here)
		Nearby areas			
3. Sixmile	SE1/4 NE1/4 sec. 20, T. 14 N., R. 3 W.	W-2936	9,760±350	June 13, 1969	(first publication here)
4. Cairn Point north	SE1/4 NE1/4 sec. 31, T. 14 N., R. 3 W.	W-2589	12,350±350	August 26, 1970	(first publication here)
5. Bridge point (informal name)	NW1/4 NW1/4 sec. 36 T. 14 N., R. 4 W.	W-2389	13,730±500	June 14, 1969	Schmoll and others, 1972
6. Goose Bay tidal bog	SE1/4 NW1/4 sec. 17 T. 15 N., R. 3 W.	I-11,717	3,270±90	July 11, 1980	Bartsch-Winkler and Schmoll, 1984a

[1]Shown on geologic map, plate 1A, or on figure 1.

[2]W-, Data from Meyer Rubin, U.S. Geological Survey radiocarbon laboratory, Washington, D.C. (now Reston, Virginia); I-, Data from Teledyne Isotopes.

[3]In years before present (1950).

[4]Collectors: 1, Ernest Dobrovolny and R.D. Miller; 2-5, Ernest Dobrovolny and H.R. Schmoll; 6, H.R. Schmoll and C.A. Gardner.

The age of the lowest unit at the base of a bog overlying the Elmendorf Moraine at locality 4 is about 12,000 yr. This age probably follows closely the deposition of the moraine, because there is only an interval of about 2,000 years within which glacier ice advanced from a point northeast of the map area, deposited the massive, perhaps multi-phased moraine, and then at least began its retreat. That so massive a deposit, one of the most prominent end moraines within the upper Cook Inlet region, should have formed in so short a time is perhaps somewhat surprising. It is, however, thought to be indicative that such end moraines can form in relatively short periods of time, perhaps even much less than the 2,000-year period permitted by the dates, especially when they form on dry land rather than in contact with estuarine water. Although the Elmendorf glacier initially advanced into such water (Cederstrom and others, 1964) the water probably soon receded, permitting the massive moraine to form. Other glacial advances within the upper Cook Inlet region, for which lateral moraines have been preserved on the flanks of the Chugach Mountains, but which lack recognizable end moraines, probably terminated in estuarine water of considerable depth (Schmoll and Yehle, 1986). These lateral moraines also may have been the product of relatively short-lived advances even though there were longer periods of time available within the Wisconsin glaciation during which they could form. We believe that this pattern of short-lived advances and retreats interspersed with relatively longer periods when upper Cook Inlet was dominated by estuarine water may have been dominant during much of the Wisconsin glaciation and perhaps during many of the older glaciations as well.

The glacioalluvial sequence, bracketed by the 12,000 yr-age of the base of the post-moraine bog at locality 4 and an age of about 10,000 yr for peat overlying alluvium of the sequence at locality 3, also appears to have been deposited within about 2,000 years. A possibility that the retreat of the glacier might have been even faster, and the alluvial sequence deposited within an even shorter period of time, perhaps only a few hundred years, is intriguingly suggested by dates at the base of a bog near the present-day Matanuska Glacier, about 120 km to the northeast (Williams, 1986). The ages for the base of this bog, as old as 13,100 yr, are seemingly incompatible with the dates given here for deposition of the Elmendorf Moraine, and the relationships between the two areas are not fully understood. Assuming, however, that dates from both areas are reasonably correct, stagnation of the glacier and its consequent withdrawal to areas far to the northeast of the map area must have been very rapid.

Although the age of the upper part of the Bootlegger Cove Formation is known, there are presently no dates for the lower part of the formation and thus the length of time it represents is not known. A few thousand years is perhaps a reasonable estimate, but a longer period of time might be more compatible with the concept of short-lived glacier advances espoused above. A major glacier retreat has been postulated for this period of time in Turnagain Arm to the south (fig. 1; Bartsch-Winkler and Schmoll, 1984b). A retreat of somewhat lesser magnitude appears to have occurred in Knik Arm, extending only into the part of the map area near Knik Arm, and perhaps not much farther northeast. This may be because of the much greater source area for glaciers in the combined Knik and Matanuska valleys at the head of Knik Arm in contrast to the much more limited source areas at the head of Turnagain Arm.

The glacial interval preceding deposition of the Bootlegger Cove Formation is probably represented by the Dishno Pond moraines and perhaps by poorly preserved stratigraphic units beneath the formation in the northern part of the bluff exposures (fig.3, sectors A and B). Such correlations are tentative, however, and can be made only on the basis of similarity of sequences of preserved deposits. The inability to correlate between stratigraphic units commonly exposed in the center of the Anchorage lowland and lateral moraines of the mountain flanks is a major limitation to establishing a satisfactory chronology. Also of import is the lack of finite ages for any of the older stratigraphic units. For example, attempts to determine radiometric ages for single stratigraphic units from each of two sites within the map area have yielded ages beyond the range of the radiocarbon method as then employed (table 1). These limitations are emphasized by Schmoll and Yehle (1986) and form the basis for their offering alternate chronologies for the older deposits. Consequently, we believe that the deposits of the Dishno Pond moraines form at least a part of the major glacial interval of the late Pleistocene, but whether almost all of that interval or only some later part of it is represented by the Dishno Pond and correlative deposits is not clear with present data. The latter interpretation is preferred at present and used in correlations in the map area to the east (Yehle and Schmoll, 1989).

The chronology described briefly above differs substantially from that proposed by Karlstrom (1957; 1964) whose terminology was also used, albeit with some substantial differences in correlation, by Miller and Dobrovolny (1959) and has generally been used, if with increasing departures from Karlstrom's interpretations, by subsequent workers (for example, Reger and Updike, 1983; 1989; Hamilton, 1986). Further changes in correlation have evolved from the determination by both radiocarbon and uranium-series methods that the age of a mollusk-bearing horizon in the upper part of the Bootlegger Cove Formation probably is about 14,000 yr (Schmoll and others, 1972) in contrast to the age of about 45,000 yr interpreted by Karlstrom (1964) from earlier uranium-series dates on mollusk shells from the same horizon.

Changes in correlation between the deposits of the Elmendorf Moraine at Anchorage and those of the moraine complex near Naptowne on the Kenai Lowland (fig. 1), the typical area for Naptowne moraines, are most pertinent to the present map area. The Naptowne moraines include four individually named and geomorphically separate moraine ridges, from oldest to youngest the Moosehorn, Killey, Skilak, and Tanya moraines. All of these moraines were correlated directly by Karlstrom to the Elmendorf Moraine, all but the Moosehorn moraine corresponding to end positions (Karlstrom, 1965, fig. 9-47) that we do not recognize as such within areas of ground-moraine deposits. The term Naptowne has been widely used in describing the Elmendorf and related deposits in the Anchorage area; in particular the deposits of the Mountain View alluvial fan have been commonly referred to as "Naptowne outwash."

As implied, at least, in Schmoll and Yehle (1986) we prefer correlation of the Elmendorf deposits with the deposits of only one of the inner Naptowne moraines, perhaps the Tanya, rather than with the Naptowne moraines as a whole, as did Karlstrom. Such a correlation has been suggested by Bartsch and Schmoll (1984b, p. 12) on the basis of radiocarbon-based work by Rymer and Sims (1982) indicating that deposits of the Skilak moraine are older than about 14,500 yr. In that case it is more reasonable to correlate Skilak deposits with those of the Dishno Pond moraines in the Anchorage area. The Dishno Pond moraines, however, are equivalent to Karlstrom's Knik moraines, which he correlated with subdued moraines beyond the limits of the type

Naptowne moraines. We prefer to correlate the subdued moraines with lateral moraines higher on the Chugach Mountain front near Anchorage. Because of these uncertainties of correlation, and the lack of radiometric ages to resolve them, we believe that the term Naptowne should be restricted to local use on the Kenai Lowland. Thus, we prefer to use local names in the Anchorage area rather than to continue to use the term Naptowne for deposits there.

Following, and perhaps in part coincident with at least the later stages of the glacioalluvial sequence, the most prominent geologic processes operating during Holocene time within the map area relate to retreat of the sea bluffs. The bluffs probably retreated by a process of differential erosion from an unknown position out beyond their present position; locally the retreat may have been accelerated by massive landsliding caused by great earthquakes, such as occurred near downtown Anchorage in 1964 (Hansen, 1965), even though no evidence for such landsliding is now present.

The embayment at the Eagle River Flats probably developed slowly throughout Holocene time, but may have reached its present configuration only after deposition of the Eagle River glacioalluvial sequence. It may have occurred concurrently with deposition represented by levels of lower terraces along the river. Neither the thickness nor the age of the base of the intertidal deposits that underlie the flats is known. However, at the Goose Bay tidal bog in a similar but larger filled embayment on the northwest side of Knik Arm (fig. 1; Karlstrom, 1964, pl. 6, line X, locality A-2; Reger, 1981b), intertidal deposits are exposed at lowest tides. These deposits are believed to be comparable to deposits in the Eagle River Flats, and have yielded radiocarbon ages as old as about 3,270 yr B.P. (table 1; Bartsch-Winkler and Schmoll, 1984a). Although the dated material probably was reworked in the estuarine environment, stratigraphic continuity and the occurrence of sequentially younger dates upward in the stratigraphy suggest that the dates provide a reasonably consistent age for the upper part of the deposits.

BEDROCK AND STRUCTURAL GEOLOGY

Bedrock is not known to crop out with certainty within the map area. However, rocks of both the Chugach and Peninsular tectonostratigraphic terranes (Coney and Jones, 1985; Jones and others, 1987) that have accreted to the North American plate probably underlie the area. One possible bedrock outcrop in the southeast corner of the map area may consist of structurally complex and variably metamorphosed sedimentary and igneous rocks of the McHugh Complex (Clark, 1973; Clark and Bartsch, 1971) that are Upper Triassic to Cretaceous in age of assemblage but include protoliths as old as Late Mississippian (Plafker and others, 1989; Winkler, 1990).

Rocks of the Peninsular terrane probably underlie the remainder of the map area at considerable depth. They are likely to include metamorphic rocks similar to those observed along the Chugach Mountain front (Clark and Bartsch, 1971; Clark, 1972) and may include igneous rocks and (or) Triassic to Jurassic sedimentary rocks as well (Plafker and others, 1982). These rocks are overlain by relatively soft, continental sandstone, siltstone, claystone, and minor coal of the post-accretionary Kenai Group of Tertiary age. Most of these rocks are probably Tyonek Formation (Calderwood and Fackler, 1972), as determined on paleobotanical evidence from outcrops along the Eagle River just east of the map area (Wolfe and others, 1966; Wolfe and Tanai, 1980; Wolfe, 1981) It is possible, however, that the upper part of the Kenai Group rocks, especially in the southwestern part of the map area, could instead be Sterling Formation. Rocks of this formation are thought to be present in a hole drilled in 1984 about 5.5 km south of the southwest corner of the map area, as interpreted from examination of plant microfossils (Stricker and others, 1988). The sedimentary rocks are not positively identified as cropping out within the map area, but may occur at one site, shown on the map as a queried occurrence, along the east side of the Glenn Highway; the coaly material observed there, however, may alternatively have been reworked by glacial activity rather than being indicative of in-place rock.

No known geologic structures have been mapped within the map area, probably because of the paucity of subsurface information. However, the Knik fault (Clark, 1972; Winkler, 1990), more commonly referred to as the Border Ranges fault (MacKevett and Plafker, 1974) is inferred to cross the southeastern part of the map area at a position about halfway between the Glenn Highway and the southeast corner (Clark, 1972; Magoon and others, 1976). This fault is defined as marking the accretionary boundary between rocks of the Peninsular and Chugach terranes. Although possible evidence for Holocene activity that might relate to this fault farther to the northeast has been discussed (Updike and Ulery, 1983; Updike and Schmoll, 1984), we have no evidence for any such activity either within this map area or directly to the northeast (Yehle and Schmoll, 1989).

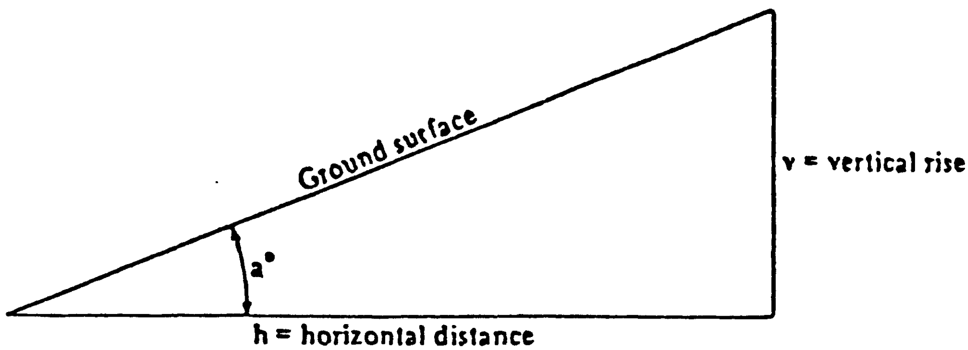
Several anticlines that trend in the same northeasterly direction as do the Border Ranges fault and the Chugach Mountain front have been mapped elsewhere in the Cook Inlet basin (Magoon and others, 1976) on the basis of subsurface information developed during exploration for oil and gas. None of these structures is shown transecting the map area, the nearest being on the northwest side of Knik Arm approximately coincident with the northwestern shore. In the northern Kenai Lowland, however, in a position with respect to the mountain front comparable to that of the map area, both anticlinal structures (Magoon and others, 1976) and minor faulting (Plafker and others, 1982) are known, and it is likely that similar features are present in the map area. In neither place are such features evident at the surface nor have they been studied in detail.

A feature expressed at the surface that might have structural antecedents is the northwest-southeast trending Goose-Eagle alignment although its origin is obscure. This feature consists of the Eagle River Flats within the map area and the similar but larger Goose Bay embayment on the northwest side of Knik Arm with which it is aligned (fig. 1). Both embayments appear to be filled with intertidal deposits, as are other embayments around the margins of upper Cook Inlet (Schmoll and others, 1984). The Goose-Eagle alignment is anomalous with respect to the distributional pattern of glacial deposits in that it does not appear to be a product of glacial deposition or erosion. It apparently is post-glacial in age, because it transects Elmendorf morainal deposits and is related more closely to the younger alluvial sequences in the Eagle River and Clunie Creek valleys rather than the older glacioalluvial sequences. Although transecting major geologic structures in the Cook Inlet basin, the trough is roughly parallel to, but not aligned with, other features that trend northwest-southeast, such as relatively broad valleys within the nearby Chugach Mountains (Yehle and Schmoll, 1989), and that also might be expressions of geologic structure.

Other evidence for possible structural genesis of the Goose-Eagle alignment is provided by the disparate ages of Quaternary deposits on either side of the it. Northeast of the alignment, stratigraphic units exposed in the lower part of the bluffs on both sides of Knik Arm are apparently older than stratigraphic units at comparable levels southwest of the alignment. Such older deposits include those within the map area near the north end of the bluff exposures along the east side of Eagle Bay (loc. 4-15, fig. 3) and the 175,000 yr old Goose Bay peat bed on the opposite side of Knik Arm. Stratigraphically beneath the peat bed and underlying gravel and sand deposits in the rarely-exposed Goose Bay beach site northeast of Goose Bay is a silt-clay complex that is sparsely organic and contains fragments of fragile shells (Karlstrom, 1964, pl. 6, line X, locality 1). Although thought by Karlstrom to be equivalent to the Bootlegger Cove Formation, we found these deposits to have the appearance of being much older, in part because of their greater induration and association with oxidized and partly indurated sand and gravel (Schmoll, Yehle, and Bartsch-Winkler, field observations, 1986), and now regard them as possibly middle or even early Pleistocene in age (Schmoll and Yehle, 1986, p. 204). Southwest of the Goose-Eagle alignment, on the other hand, the 14,000-yr-old upper part of the Bootlegger Cove Formation is exposed intermittently in the lower part of bluffs on both sides of the arm.

Elsewhere in Cook Inlet basin, notably at Chickaloon Bay (fig. 1), Kelly (1961) noted broad (but not paired) embayments and has postulated that such features might be a result of present-day anticline formation. One indication of this process is that the margins of Chickaloon Bay are characterized by raised beach and other shore features. The Chickaloon Bay feature lies on a known northeast-trending anticline (Magoon and others, 1976), although no measurements of any present anticline growth are known to have been made in that area. Geodetic relevelling farther east along Turnagain Arm (fig. 1) several years after the 1964 earthquake (Brown and others, 1977) has revealed a gentle arching upward of the land surface east of this alignment that has been ascribed to rebound following subsidence that occurred during that earthquake. Alternatively, however, such changes in surface level could be at least in part the result of present-day anticline growth, possibly on the southeast limb of the anticline that might pass through Chickaloon Bay. Two factors seemingly mitigate against the Goose-Eagle trough being the product of analogous conditions: (1) because of its orientation the Goose-Eagle trough cannot lie on a northeast-trending anticline, and (2) the Goose-Eagle trough lacks prominent raised beaches.

We conclude, nevertheless, that the Goose-Eagle trough could be related to possible structures that are developing parallel to the northwest-trending secondary structural grain of the region. Thus, although the origin of the trough remains obscure, we postulate that it might have structural significance.



Diagrammatic representation of slope-measuring terms

Slope in percent = v/h X 100

Slope angle in degrees = a°

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

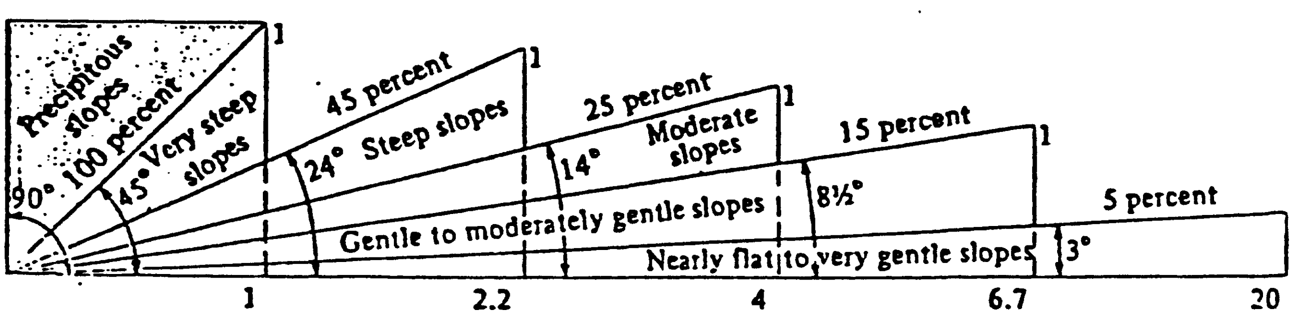


Figure 4.--Diagram illustrating slope categories used on this map (after Schmoll and Dobrovolny, 1972b).

DESCRIPTION OF MAP UNITS

Characteristics of the geologic materials delineated by the units of the geologic map (pl. 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, 1982). Slope data are generalized estimates derived mainly from Schmoll and Dobrovolny (1972b) whose slope categories are used (fig. 4). 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). Units that appear only on figure 3 are marked by an asterisk. The units described here may be overlain by as much as one meter of mainly organic and windblown materials as discussed above.

SURFICIAL DEPOSITS

Moraine Deposits

Subdivided according to type of moraine (end and several types of ground moraine) and according to correlations with named end and lateral moraines within and south of the map area. 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; locally mainly poorly sorted silty sandy gravel; includes scattered large boulders; generally moderately to well compacted.

End-moraine deposits (late Pleistocene)--Thickness probably about 20 m or more. Contacts sharply defined. Topography highly irregular; slopes gentle to moderate in small areas on some ridge tops and in bottoms of kettle holes, mainly steep elsewhere

eme Deposits of the Elmendorf Moraine--Occur in a wide arc across the southern part of the map area where they mark limit of glaciers during this advance of ice. Along with adjacent high-relief kame and other high-relief moraine deposits, form a massive and topographically bold complex of glacier-ice wastage landforms that constitute the Elmendorf Moraine, a formally-named geographic feature

emy Deposits of a younger phase of the Elmendorf Moraine--Occur south of Sixmile Lake and may mark a slight readvance of the glacier

Ground-moraine deposits (late Pleistocene)

emg Deposits of the Elmendorf Moraine, undivided--Thickness several to about 12 meters, commonly overlie gravel related to advance of the Elmendorf glacier or older glacial deposits. Contacts generally well defined except where gradational with other moraine deposits. Topography smooth to gently hummocky, slopes generally gentle to moderate. Occur in the northern and central parts of the map area

emh Deposits of the Elmendorf Moraine with high relief--Similar to other ground-moraine deposits but with more boldly hummocky to hilly topography. Occur in association with end-moraine deposits emd Deposits of the Elmendorf Moraine in well-developed drumlin forms--Thickness at least 5 to perhaps 15 meters. Occur in elongate hills with moderately steep slopes on their sides that merge laterally into low-relief terrain of other deposits, usually ground moraine. Extensively developed in northern and central parts of map area

emf Deposits of the Elmendorf Moraine in fluted terrain--Similar to other ground moraine but occur in elongated low ridges a few meters high that parallel direction of ice flow. Occur only in northern part of map area associated with drumlin deposits with which they are gradational in landform

emk Deposits of the Elmendorf Moraine that include some kame deposits--Similar to ground-moraine deposits, but may include gravel and sand either in large part or locally in areas too small to map separately. Only a few occurrences in northern and western parts part of map area

dmg Deposits of the Dishno Pond moraines--Thickness probably several to 10 meters. Contacts generally well defined. Topography smooth to somewhat irregular, slopes generally moderate, steep on sides of hills that comprise moraines. Present only in the southeastern part of map area

dmk Deposits of the Dishno Pond moraines that include some kame deposits--Similar to ground-moraine deposits, but may include gravel and sand in large part or locally in areas too small to map separately. Single occurrence near base of Chugach Mountain front in southeastern corner of map area

kd **Knik diamicton (late Pleistocene)**--Diamicton consisting of poorly sorted mixture of gravel, sand, silt, and clay; locally includes interbeds of silt, sand, and gravel and may have rudely bedded appearance. May be at least partly glacioestuarine in origin. Except for queried occurrence along the Eagle River in east-central part of map area shown only on figure 3

*od **Older diamicton deposits (Pleistocene)**--Diamicton consisting of poorly sorted mixture of gravel, sand, silt, and clay; material is somewhat oxidized and more compact than most deposits of ground moraine at the surface. Thickness at least 10 m. Shown only on figure 3 as occuring sporadically in lower part of bluffs along Knik Arm and Eagle Bay. Probably present as remnant deposits underlying deposits related to the Dishno Pond moraines, the Bootlegger Cove Formation, or, locally, interglacial deposits. Cannot be directly correlated with surface moraines

Glacioalluvial Deposits

Subdivided into (1) kame deposits, (2) kame-terrace deposits, and (3) meltwater-channel deposits that 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 in small eskers, some of which are shown by symbol. Moderately loose, but compact in cores of hills. Contacts generally well defined; locally merge with 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

ekg Kame deposits of the Elmendorf Moraine near Gwenn Lake--In landforms of fairly high relief. Thickness possibly a few tens of meters. Form part of a glacioalluvial train that extended from a former glacial lake east of the map area in the Eagle River valley, through Fossil Creek channel, and into the Otter-Sixmile channel

ekh Kame deposits of the Elmendorf Moraine that exhibit high relief--In landforms of generally higher relief and locally broader shape than most kames. Thickness probably several tens of meters. Located mainly along the proximal margin of the end-moraine ridge; may form part of the glacioalluvial train that extended from a former glacial lake east of the map area in the Eagle River valley, through Fossil Creek channel, and into the Bluff Road channel

ek Kame deposits of the Elmendorf Moraine, undivided--In landforms of moderate to low relief, includes some areas of pitted outwash. Thickness a few to several tens of meters. Extensive in northern part of map area

ekc Kame-channel deposits of the Elmendorf Moraine--In landforms of generally low relief that mainly lie at levels of the floors of major channels eroded into moraine surface. Thickness poorly known but probably only a few meters. Include pitted outwash-plain and pitted meltwater-channel deposits. Merge with meltwater-channel deposits and undivided kame deposits. Occur in moderately irregular topography having mostly gentle but some moderate slopes. Located mainly in northern part of map area

ektt Kame-terrace deposits of the Elmendorf Moraine near Tuomi Lake--In terraces, at 3 levels separated by scarp symbol, that were formed marginal to glacier ice. Located south of Sixmile Lake

ektr Kame-terrace deposits of the Elmendorf Moraine near Roosevelt Road--In terraces, at 3 levels separated by scarp symbol, that were formed mainly marginal to glacier ice. Part of the glacioalluvial train that extended from a former glacial lake east of the map area in the Eagle River valley, through Fossil Creek channel, and into the Otter-Sixmile channel. Located southeast of Otter Lake

dk Kame deposits of the Dishno Pond moraines, undivided--In landforms of of moderate to high relief. Thickness probably a few tens of meters. Occur only in southeastern part of map area dkb Kame deposits of the Dishno Pond moraines that may thinly mantle bedrock--Similar to kame deposits but thickness may be only one to a few meters overlying bedrock which may be exposed locally. Single occurrence in southeastern part of map area adjacent to a meltwater channel and the Chugach Mountain front

Meltwater-channel and meltwater-fan deposits of the Elmendorf Moraine (late Pleistocene)--Chiefly gravel and sand, well bedded and sorted; at the surface may include some finer-grained material with thin organic beds. Thickness poorly known, probably one to several meters. In places channel deposits may be very thin or absent and ground-moraine deposits may floor the channel or lie at shallow depth

ec Channel deposits--Occur mainly in the central part of the map area within areas of ground moraine. Merge locally with kame-channel deposits and some of the named glacioalluvial deposits

ecf Fossil Creek glacioalluvial deposits--Occur in a series of well-formed terrace levels within the prominent, single channel of Fossil Creek that is cut as much as 50 m lower than the surface of the Elmendorf Moraine and Mountain View fan. Graded to various levels of Roosevelt Road kame-terrace deposits and Gwenn Lake kame deposits that lie within area of the Elmendorf Moraine. This occurrence and its headward continuation eastward constitute the typical locality for the Fossil Creek deposits

mvf Mountain View glacioalluvial fan deposits--Occur in broad, large, low-gradient fan that heads from major meltwater channel east of the map area, widening here and extending southwestward toward and beyond the community of Mountain View (about 2.5 km south of the southwest corner of the map area) to downtown Anchorage. The area of the entire fan constitutes the typical locality

eo Outwash-fan deposits--Present mainly along the distal margin of the Elmendorf Moraine. Occur in three levels, the upper two of which are erosional remnants and the lower of which is graded to the level of the Mountain View fan

ecs Sixmile Lake alluvial deposits--Occur near and north of Sixmile Lake in western part of map area, subdivided into several different levels separated on the map by scarp symbols. Thickness probably a few meters.

ecb Bluff Road alluvial deposits--Occur in shallow channel in southwestern part of map area. Thickness probably a few meters

ecc Clunie Creek glacioalluvial deposits--Occur in major channels cut typically about 20 m lower than the general surface of the Elmendorf ground-moraine deposits and graded to levels below that of the ground moraine but well above modern sea level. Thickness may be a few tens of meters, commonly probably less than 10 m. Deposits in terraces along Clunie Creek in east-central part of map area, subdivided by scarp symbol into three levels, constitute typical locality

*eoa Advance outwash underlying ground-moraine deposits--Fairly well bedded and sorted pebble and cobble gravel with minor interbeds of sand. Thickness about 10 m. Exposed in bluffs along east side of Eagle Bay and shown only on figure 3.

Meltwater-channel and meltwater-fan deposits of the Dishno Pond moraines (late Pleistocene)--Chiefly gravel and sand, well bedded and sorted dc Channel deposits--Single occurrence near the base of the Chugach Mountain front in southeastern part of map area. Thickness probably a few meters

*doa Advance outwash deposits--Queried occurrence on figure 3 underlying diamicton possibly correlative with Dishno Pond moraine deposits. Thickness 2 to 6 m, base of unit not exposed

*og **Older glacioalluvial deposits (Pleistocene)**--Fairly well bedded and sorted gravel and interbedded sand. Moderately oxidized to yellowish gray in most places. Thickness about 8 to 15 m, base of unit not exposed. Occur mainly in bluffs along east side of Eagle Bay and shown on figure 3; single occurrence along the Eagle River

*ogx Older glacioalluvial deposits, oxidized--Similar to other older glacioalluvial deposits and may be stratigraphically equivalent to them, but more strongly oxidized to yellowish-orange color.

Alluvial Deposits

Alluvium deposited by present-day streams. Generally well bedded and sorted, clasts commonly well rounded. Thickness variable, probably a few to several meters; thickest in large valleys. Contacts well defined. Topography smooth, slopes nearly flat to very gentle

aa **Alluvium in active flood plain of the Eagle River (latest Holocene)**--Gravel and sand that is transported intermittently and deposited temporarily in bars which commonly change their position along braided and single channels. Vegetation cover generally absent or just beginning to develop in areas that have not been affected directly by the stream for a few years. Area subject to continuing erosion and flooding; in places stream may encroach upon areas adjacent to this map unit

al **Alluvial deposits along modern streams and in lowest terraces (Holocene)**--Chiefly sand and gravel. Generally at or no more than a few meters above stream level. Includes narrow active flood plains where too small to map separately. Located mainly along Eagle River and Clunie Creek

alf Fine-grained deposits along some minor streams--Chiefly silt and fine-grained sand; may include some peat deposits near surface. Occur mainly in the Otter-Sixmile channel southwest of Otter Lake

at **Alluvial deposits in terraces, undivided (Holocene)**--Somewhat older alluvium, chiefly gravel and sand, generally several meters above stream level. Developed along the Eagle River and Clunie Creek

ath Deposits in higher terraces--Occur at various levels at least 5 m above stream level mainly along the Eagle River (where they are highest) and its tributaries. Probably graded to sea levels relatively higher than those of the present and most recent past

Alluvial-fan deposits (Holocene)--Formed where there is a reduction of stream gradient as streams emerge onto a larger, flatter valley floor. Materials commonly less well sorted than other alluvium. Slopes low in larger fans, moderate to moderately gentle in smaller fans, but 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 in moderate-sized fans along the base of Chugach Mountain front in southeastern part of map area and along the Eagle River where it emerges onto the Eagle River Flats, and locally in small fans at the base of river bluffs.

aff Fine-grained deposits--Chiefly silt and fine sand. Occur mainly along the Otter-Sixmile channel

afo **Older alluvial-fan deposits (Holocene)**--Chiefly silt and fine sand. Occur near the mouth of Clunie Creek as remnant graded to a level above adjacent alluvial fan and probably correlative to deposits of one of the higher terraces

Estuarine Deposits

i **Modern intertidal deposits (latest Holocene)**--Chiefly silt and fine sand; somewhat coarser near major tidal channels. Well bedded and sorted. Loose, water saturated. Thickness less than one to a few meters, probably underlain by several meters or more of older intertidal deposits. Contacts variable in location with each tide as well as from season to season and year to year. Surface generally smooth, but incised one to a few meters by numerous channels that may have steep margins. Slopes otherwise nearly flat to gentle, commonly less than one percent. Commonly subdivided into lower and upper zones

il Deposits of the lower intertidal zone--In some places include driftwood and gravel at shoreward-most part of deposit in a discontinuous storm beach. Reworked several times daily by tides; covered by water at high tide; exposed at low tide. Lower boundary of map unit is considered to be a very generalized, arbitrary mean tide line; upper boundary may be as much as several meters above mean high water line

iu Deposits of the upper intertidal zone--Locally more sandy, gravelly, and driftwood laden than the deposits of the lower zone; covered by water only during exceptionally high tides coupled with extreme storms. Contain some organic and windblown material. Surface marked by some areas of standing water. Drainage very poor. Located chiefly in the Eagle River Flats; along most sea bluffs not differentiable from lower zone

io **Older intertidal deposits (Holocene)**--Chiefly silt and fine-grained sand, well bedded and sorted; locally may include thin beds of peat and other organic material including driftwood and some windblown material. More firm than the modern intertidal deposits. Not flooded by present-day high tides. Thickness several to a few tens of meters. Contacts well defined, except gradational in part to younger intertidal deposits. Located in Eagle River Flats and at one locality along coast in northern part of map area

ib **Deposits of the modern beach (latest Holocene)**--Chiefly sand with some gravel; locally driftwood laden near base of bluffs. Shown mainly on figure 3. Encompass the upper and lower intertidal zones containing similar material extending below the upper beach

ibo **Older beach deposits (Holocene)**--Chiefly sand with some gravel; occur mainly along the southwest margin of the Eagle River Flats *bc **Bootlegger Cove Formation (late Pleistocene)**--Silty clay and clayey silt with minor interbedded silt, fine sand, and fine to medium sand, and with scattered pebbles and cobbles in widely varying concentrations. Probably deposited in a glacioestuarine environment mainly following withdrawal of Dishno Pond ice and prior to and during advance of glacier to Elmendorf Moraine. Thickness ranges from about 1 to more than 10 m. Exposed in bluffs along Knik Arm and Eagle Bay and shown only on figure 3.

*oe **Older glacioestuarine deposits (Pleistocene)**--Interbedded diamicton, variably pebbly to cobbly silty clay and clayey silt, silt, and fine to medium sand. Bedding commonly contorted at locations 14 and 15, fairly even but less distinct elsewhere. Thickness about 10 to 14 m, base of unit not exposed. Occur in bluffs along east side of Eagle Bay and shown only on figure 3

*oei **Older glacioestuarine deposits, somewhat indurated (Pleistocene)**--Well bedded silt and clay that is more indurated than other estuarine deposits and that is intermittently exposed at levels below mean sea level where modern beach deposits have been eroded by tidal currents. Bedding gently warped in one place. About 6 m exposed. Occur in bluffs along east side of Eagle Bay and shown only on figure 3

Peat and Pond Deposits

p **Postglacial peat and pond deposits (Holocene and late Pleistocene)**--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; at deeper levels may be mostly sandy gravel. Form bogs, accumulated mainly at sites of small former lakes or former stream channels. 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. Distributed extensively within and north of the Elmendorf Moraine

pi **Interglacial pond deposits (Pleistocene)**--Chiefly silt and clay with some beds of fine sand; commonly include intermixed and interbedded organic material. As much as a few meters thick, overlain and underlain by glacial deposits. Exposed only along the Eagle River in the SW1/4 SE1/4 sec. 9, T. 14 N., R. 2 W. Radiocarbon analyses of organic material indicates an age for these deposits beyond the range of the radiocarbon method (loc. 1, table 1)

Colluvial Deposits (Holocene and late Pleistocene)

cm **Colluvial deposits derived mainly from moraines**--Diamicton similar to that of adjacent upslope moraines, but less compact; includes 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. Occur only in the southeast corner of the map area cw **Colluvial deposits on walls of stream and sea bluffs**--Loose accumulations derived from adjacent, upslope deposits that form a veneer on bluffs following erosion. Chiefly diamicton consisting of pebbly silt and sand with some clay, cobbles, boulders, and a variable amount of organic material. Non-bedded 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 vegetative cover, subject to instability because of renewed gully, stream, or coastal erosion and accompanying mass-wasting processes

cwf Fine-grained colluvial deposits on walls of sea bluffs--Chiefly silt, clay, and fine-grained sand; non-bedded to poorly bedded; poorly sorted. Occur northeast of Eagle Bay in northern part of map area; may obscure Pleistocene Bootlegger Cove Formation behind bluff face. Thickness probably as much as a few meters. Slopes irregularly moderate to steep, and particularly susceptible to instability

cl **Landslide deposits, undivided**--Include a wide variety of materials, chiefly diamicton, gravelly silt and sand with relatively minor amounts of clay, and some organic material. No individual slides larger than about 0.3 km^2. Include earthflow deposits too small to map separately. Nonbedded, and nonsorted to poorly sorted. Relatively loose. Thickness poorly known, probably several meters. Contacts moderately well to poorly defined. Topography irregular to slightly hummocky, slopes moderate to steep. Queried where identity uncertain. Occur locally on bluffs in association with other colluvial deposits

Anthropogenic Deposits (latest Holocene)

f **Engineered fill**--Chiefly compacted pebble gravel underlain by a more poorly sorted base course of sandy to silty gravel; in some areas fill may include a more heterogeneous assemblage of material. Mapped mainly along the Glenn Highway, the Alaska Railroad, at airfield runways, and in a few areas of other construction. Thickness one to several meters, thicker where roads and railroads cross deep valleys. Contacts well defined, width shown on map may be exaggerated to accommodate linear symbols for the highway and railroad

BEDROCK

by **Younger rocks (Tertiary)**--Uncertain occurrence of siltstone, claystone, and coal; probably Miocene and Oligocene Tyonek Formation. Exposed during reconstruction of the Glenn Highway during the 1970s in southeastern part of map area. Alternatively could represent incorporation of a glacially eroded and transported mass of Tertiary rock into the surficial deposits

bo **Older rocks (Cretaceous to Upper Triassic)**--Possible outcrop of rocks of the Cretaceous to Upper Triassic McHugh Complex, which includes variably metamorphosed graywacke, argillite, phyllite, and conglomeratic graywacke

REFERENCES CITED

American Geological Institute, 1982, Data sheets, second edition, Data sheet 17.1, Grain-size scales used by American geologists, modified Wentworth scale: Falls Church, Virginia, American Geological Institute.

Bartsch-Winkler, Susan, 1982, Physiography, texture, and bedforms in Knik Arm, upper Cook Inlet, Alaska, during June and July, 1980: U.S. Geological Survey Open-File Report 82-464, 6 p., 1 pl., map scale 1:63,360.

Bartsch-Winkler, Susan, and Schmoll, H.R., 1984a, Bedding types in Holocene tidal channel sequences, Knik Arm, upper Cook Inlet, Alaska: Journal of Sedimentary Petrology, v. 54, no. 4, p. 1239-1250.

______1984b, Guide to late Pleistocene and Holocene deposits of Turnagain Arm [guidebook prepared for the 80th annual meeting of the Cordilleran Section, Geological Society of America, May 30 and 31, and June 1, 1984]: Anchorage, Alaska Geological Society, 70 p.

Bowen, D.Q., Richmond, G.M., Fullerton, D.S., Sibrava, Vladimir, Fulton, R.J., and Velichko, A.A., 1986, Correlation of Quaternary glaciations in the Northern Hemisphere, in Sibrava, Vladimir, Bowen, D.Q., and Richmond, G.M., eds., Quaternary glaciations in the Northern Hemisphere: Quaternary Science Reviews, v. 5, p. 509-510.

Bradley, W.C., Fahnestock, R.K., and Rowekamp, E.T., 1972, Coarse sediment transport by flood flows on Knik River, Alaska: Geological Society of America Bulletin, v. 83, no. 5, p. 1261-1284.

Brown, L.D., Reilinger, R.L., Holdahl, S.R., and Balazs, E.I., 1977, Postseismic crustal uplift near Anchorage, Alaska: Journal of Geophysical Research, v. 82, no. 23, p. 3369-3378.

Calderwood, K.W. and Fackler, W.C., 1972, Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet basin, Alaska: American Association of Petroleum Geologists Bulletin, v. 56, no. 4, p. 739-754.

Cederstrom, D.J., Trainer, F.W., and Waller, R.M., 1964, Geology and ground-water resources of the Anchorage area, Alaska: U.S. Geological Survey Water Supply Paper 1773, 108 p.

Clark, S.H.B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-350, scale 1:250,000.

______1973, The McHugh Complex of south-central Alaska: U.S. Geological Survey Bulletin 1372-D, p. D1-D11.

Clark, S.H.B., and Bartsch, S.R., 1971, Reconnaissance geologic map and geochemical analyses of stream sediment and rock samples of the Anchorage B-7 quadrangle, Alaska: U.S. Geological Survey open-file report, 70 p., scale 1:63,360.

Coney, P.J., and Jones, D.L., 1985, Accretion tectonics and crustal structure in Alaska: Tectonophysics, v. 119, p. 265-283.

Daniels, C.L., 1981a, Geology and geologic materials maps of the Anchorage C-7 SE quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 67, 2 maps, scale 1:25,000.

______1981b, Geology and geologic materials maps of the Anchorage C-7 SW quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 71, 2 maps, scale 1:25,000.

Dobrovolny, Ernest and Miller, R.D., 1950, Descriptive geology of Anchorage and vicinity, Alaska: U.S. Geological Survey open-file report, 15 p., map scale 1:62,500.

Dobrovolny, Ernest, and Schmoll, H.R., 1974, Slope stability map of Anchorage and vicinity, Alaska, U.S. Geological Survey, Miscellaneous Investigations Map I-787E, scale 1:24,000.

Hamilton, T.D., 1986, Correlation of Quaternary glacial deposits in Alaska, in Sibrava, Vladimir, Bowen, D.Q., and Richmond, G.M., eds., Quaternary glaciations in the Northern Hemisphere: Quaternary Science Reviews, v. 5, p. 171-180.

Hansen, W.R., 1965, Effects of the earthquake of March 27, 1964 at Anchorage Alaska: U.S. Geological Survey Professional Paper 542-A, 68 p.

Jones, D.L., Silberling, N.J., Berg, H.C., and Plafker, George, 1987, Lithotectonic terrane map of Alaska (west of the 141st meridian): U.S. Geological Survey Miscellaneous Field Studies Map MF-1874-A, scale 1:2,500,000.

Karlstrom, T.N.V., 1957, Tentative correlation of Alaskan glacial sequences, 1956: Science, v. 125, no. 3237, p. 73-74.

______1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

______1965, Upper Cook Inlet area and Matanuska River valley, in Péwé, T.L., Ferrians, O.J., Jr., Nichols, D.R., and Karlstrom, T.N.V., Guidebook for Field Conference F, Central and South-Central Alaska-International Association of Quaternary Research, 7th Congress, USA 1965: Lincoln, Nebraska, Nebraska Academy of Science, p. 114-141.

Kelly, T.E., 1961, Photogeology, a quick, economical tool for oil hunters: Oil and Gas Journal, v. 59, no. 47, p. 265-274.

MacKevett, E.M, Jr., and Plafker, George, 1974, The Border Ranges fault in the western Chugach Mountains: Journal of Research, U.S. Geological Survey, v. 2, no. 3, p. 323-329.

Magoon, L.B., Adkison, W.L., and Egbert, R.M., 1976, Map showing geology, wildcat wells, Tertiary plant fossil localities, K-Ar age dates, and petroleum operations, Cook Inlet area, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1019, scale 1:250,000.

Miller, R.D., and Dobrovolny, Ernest, 1959, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p., map scale 1:63,360.

Moxham, R.M., and Eckhardt, R.A., 1956, Marl deposits in the Knik Arm area, Alaska: U.S. Geological Survey Bulletin 1039-A, 23 p.

Orth, D.J., 1967, Dictionary of Alaska place names: U.S. Geological Survey Professional Paper 567, 1084 p.

Ovenshine, A.T., Bartsch-Winkler, Susan, O'Brien, N.R., and Lawson, D.E., 1976, Sedimentation in the high tidal range environment of Turnagain Arm, Alaska, in Miller, T.P., ed., Recent and ancient sedimentary environments in Alaska: Anchorage, Alaska Geological Society Symposium Proceedings, p. M1-M26.

Plafker, George, 1969, Tectonics of the March 27, 1964, Alaska earthquake: U.S. Geological Survey Professional Paper 543-I, 74 p.

Plafker, George, Bruns, T.R., Winkler, G.R., and Tysdal, R.G., 1982, Cross section of the eastern Aleutian arc, from Mount Spurr to the Aleutian trench near Middleton Island, Alaska: Geological Society of America, Map and Chart Series MC-28P, scale 1:1,000,000.

Plafker, George, Nokleberg, W.J., and Lull, J.S., 1989, Bedrock geology and tectonic evolution of the Wrangellia, Peninsular, and Chugach terranes along the Trans-Alaska Crustal Transect in the Chugach Mountains and southern Copper River basin, Alaska: Journal of Geophysical Research v. 94, no. B4, p. 4255-4295.

Prest, V.K., 1968, Nomenclature of moraines and ice-flow features as applied to the glacial map of Canada: Geological Survey of Canada Paper 67-57, 32 p.

Reger, R.D., 1981a, Geology and geologic materials maps of the Anchorage B-8 NE quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 69, 2 maps, scale 1:25,000.

_______1981b, Geology and geologic materials maps of the Anchorage B-8 NW quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 70, 2 maps, scale 1:25,000.

_______1981c, Geology and geologic materials maps of the Anchorage C-8 SE quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 65, 2 maps, scale 1:25,000.

_______1981d, Geology and geologic materials maps of the Anchorage C-8 SW quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 68, 2 maps, scale 1:25,000.

Reger, R.D., and Updike, R.G., 1983, Upper Cook Inlet region and the Matanuska Valley, in Péwé, T.L., and Reger, R.D., eds., Guidebook to permafrost and Quaternary geology along the Richardson and Glenn Highways between Fairbanks and Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Guidebook 1, p. 185-263.

_______1989, Upper Cook Inlet region and Matanuska Valley, in Péwé, T.L., and Reger, R.D., eds., Quaternary geology and permafrost along the Richardson and Glenn Highways between Fairbanks and Anchorage, Alaska, 28th International Geological Congress Field Trip Guide T102: American Geophysical Union, p. T102:45-T102:54.

Rymer, M.J., and Sims, J.D., 1982, Lake-sediment evidence for the date of deglaciation of the Hidden Lake area, Kenai Peninsula, Alaska: Geology, v. 10, no. 6, p. 314-316.

Schmoll, H.R., and Dobrovolny, Ernest, 1972a, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-787-A, scale 1:24,000.

_______1972b, Generalized slope map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-787-B, scale 1:24,000.

Schmoll, H.R., Szabo, B.J., RRubin, Meyer, and Dobrovolny, Ernest, 1972, Radiometric dating of marine shells from the Bootlegger Cove Clay, Anchorage area, Alaska: Geological Society of America Bulletin, v. 83, no. 4, p. 1107-1114.

Schmoll, H.R., and Yehle, L.A., 1986, Pleistocene glaciation of the upper Cook Inlet basin, in Hamilton, T.D., Reed, K.M., and Thorson, R.M., eds., Glaciation in Alaska--the geologic record: Anchorage, Alaska Geological Society, p. 193-218.

Schmoll, H.R., Yehle, L.A., Gardner, C.A., and Odum, J.K., 1984, Guide to surficial geology and glacial stratigraphy in the upper Cook Inlet basin [guidebook prepared for the 80th annual meeting of the Cordilleran Section, Geological Society of America, May 30 and 31, and June 1, 1984]: Anchorage, Alaska Geological Society, 89 p.

Shlemon, R.J., and Davis, Paul, 1986, Engineering-geological implications of pseudo-landslides in an urbanizing area, San Juan Capistrano, California: Proceedings, Fifth International Congress, International Association of Engineering Geology, Buenos Aires, Argentina, 20-25 October, 1986, v. 6, p. 2011-2016.

Stone, K.H., 1963, The annual emptying of Lake George: Arctic, v. 16, no. 1, p. 26-39

Stricker, G.D., Brownfield, M.E., Yehle, L.A., and Wolfe, J.A., 1988, Mineralogy and stage assignment of some Tertiary coal from the Tikishla Park drill hole, Anchorage, Alaska, in Galloway, J.P., and Hamilton, T.D., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1987: U.S. Geological Survey Circular 1016, p. 121-123.

Trainer, F.W., and Waller, R.M., 1965, Subsurface stratigraphy of glacial drift at Anchorage, Alaska, in Geological Survey Research 1965: U.S. Geological Survey Professional Paper 525-D, p. D167-D174.

U.S. Geological Survey, 1952, Anchorage (B-8), Alaska, topographic map, scale 1:63,360.

______1979a, Anchorage (B-8) NE, Alaska, orthophotomap (topographic), scale 1:25,000.

______1979b, Anchorage (B-8) SE, Alaska, orthophotomap (topographic), scale 1:25,000.

U.S. National Ocean Service, 1982, Cook Inlet, Fire Island to Goose Bay, Alaska, Chart 16664, scale 1:40,000.

______1986, Cook Inlet approaches to Anchorage, Alaska, Chart 16665, scale 1:50,000.

Ulery, C.A., and Updike, R.G., 1983, Subsurface structure of the cohesive facies of the Bootlegger Cove Formation, southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 84, 5 p., map scale 1:15,840.

Updike, R.G., and Carpenter, B.A., 1986, Engineering geology of the Government Hill area, Anchorage, Alaska: U.S. Geological Survey Bulletin 1588, 21 p.

Updike, R.G., Cole, D.A., Jr., and Ulery, C.A., 1982, Shear moduli and damping ratios for the Bootlegger Cove Formation as determined by resonant-column testing, in Short notes in Alaskan geology, 1981: Alaska Division of Geological and Geophysical Surveys Geologic Report 73, p. 7-12.

Updike, R.G., Olsen, H.W., Schmoll, H.R., Kharaka, Y.K., and Stokoe, K.H., II, 1988, Geologic and geotechnical conditions adjacent to the Turnagain Heights Landslide, Anchorage, Alaska: U.S. Geological Survey Bulletin 1817, 40 p.

Updike, R.G. and Schmoll, H.R., 1984, A brief resume of the geology of Anchorage and vicinity: Geological Society of America Abstracts with Programs, v. 16, no. 5, p. 306.

Updike, R.G., and Ulery, C.A., 1983, Preliminary geologic map of the Anchorage B-6 NW (Eklutna Lake) quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-8, 1 map, scale 1:10,000.

_______1988, Bedrock geology of the Anchorage B-7 SE quadrangle: U.S. Geological Survey Open-File Report 88-418, map scale 1:25,000.

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

Williams, J.R., 1986, New radiocarbon dates from the Matamuska Glacier bog section, in Bartsch-Winkler, Susan, and Reed, K.M., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 85-88.

Winkler, G.R., 1990, Preliminary geologic map, cross sections, and summary geochronology of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 90-83, 2 sheets.

Wolfe, J.A., 1981, A chronologic framework for Cenozoic megafossil floras of northwestern North America and its relation to marine geochronology, in Armentrout, J.M., ed., Pacific Northwest Cenozoic biostratigraphy: Geological Society of America Special Paper 184, p. 39-47.

Wolfe, J.A., Hopkins, D.M., and Leopold, E.B., 1966, Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 398-A, 29 p.

Wolfe, J.A., and Tanai, Toshima, 1980, The Miocene Seldovia Point flora from the Kenai Group, Alaska: U.S. Geological Survey Professional Paper 1105, 52 p.

Yehle, L.A., and Schmoll, H.R., 1987a, Surficial geologic map of the Anchorage B-7 NE quadrangle, Alaska: U.S. Geological Survey Open-File Report 87-416, 20 p., scale 1:25,000.

________1987b, Surficial geologic map of the Anchorage B-7 NW quadrangle, Alaska: U.S. Geological Survey Open-File Report 87-168, 11 p., scale 1:25,000.

________1988, Surficial geologic map of the Anchorage B-7 SE quadrangle, Alaska: U.S. Geological Survey Open-File Report 88-381, 19 p., scale 1:25,000.

________1989, Surficial geologic map of the Anchorage B-7 SW quadrangle, Alaska: U.S. Geological Survey Open-File Report 89-318, 33 p, scale 1:25,000.