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East-West Geologic Cross Section Along the DeBarr Line, Anchorage, Alaska

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INTRODUCTION

This report consists of a single geologic cross section (plate 1) through the Anchorage lowland extending eastward from downtown Anchorage on the shore of Knik Arm to the lower slopes of the Chugach Mountain front. The cross section is drawn along the square mile-cadastral section lines on which DeBarr Avenue and DeBarr Road occur, extending westward along the alinement of 13th Avenue in downtown Anchorage where there are no square mile sections, and extending eastward into the Fort Richardson Military Reservation along unsurveyed section lines. The cross section encompasses the full widths of the Anchorage A-8 NW and A-8 NE topographic quadrangle maps and is drawn to the same 1:25,000 scale. It is accompanied by a planimetric sketch map at that scale showing relevant geographic features and the location of data points used in the cross section. A vertical scale of 1:1,000 is used resulting in a vertical exaggeration of 25 times.

The geologic cross section comprises a compilation of existing data relevant to a portrayal of the nature and distribution of subsurface geologic materials needed for predicting the response of those materials to earthquake ground motions. The compilation will also further elucidate the geologic history of upper Cook Inlet basin. This cross section is the first of several in the process of being constructed. These sections will ultimately lead to the production of a subsurface geologic map.

The cross section is derived almost entirely from lithologc logs of water wells drilled in the Anchorage area over a period of about 40 years; the logs are on file at the Anchorage subdistrict office, Water Resources Division (WRD), U.S. Geological Survey. The wells are identified herein by the older and simpler numbering system developed and used by WRD. In this scheme, the first number is the square mile section number within the system of legal land description, and the second number is a sequential accession number within that section. A unique identification for each well must therefore include township and range numbers as well as section number, and these can be determined from the accompanying map. We do not use the newer but more cumbersome scheme that further identifies the well according to the 1/256th section (about one hectare or one city block) in which it occurs, as the wells are located to that accuracy on the map.

The intent of this cross section is to portray conditions to as great a depth as possible, hence only those wells that penetrate more than about 50 m have been used. A larger volume of data from a wider variety of sources, including some data of substantially better quality, are limited to relatively shallow depths. The latter data set is the subject of a parallel study by the Alaska Division of Geological and Geophysical Surveys (R. G. Updike and C. A. Ulery, oral commun., 1984) that is far more detailed and that extends north and south of the DeBarr line. It is limited in depth, however, to about 60 m and in eastern extent to about the western half of this report, comprising roughly the area of this cross section that is occupied by the Bootlegger Cove Formation.

The geologic compilations used in this study were begun about 15 years ago by Barnwell, who carefully selected and interpreted the best well logs then available. At about the same time, Schmoll began further interpretations of the same data set in terms of geologic environments of deposition both in concert with and separately from Barnwell. Both of these preliminary compilations have remained unpublished. Very recently, the compilations were expanded to include data subsequently accumulated, including a preliminary account of a drill hole (USGS A-84-1) completed in August 1984 expressly for the purpose of sampling and identifying the subsurface materials in the Anchorage area.

It is necessary to comment briefly on some of the limitations of the data for making the desired interpretations. Most of the wells are represented by drillers' logs that are variable in quality. Only a few of the logs were prepared by geologists, and even those logs are based almost entirely on observations of cuttings and of drilling operations rather than on examination of cored material. Some of the lithologic logs are supplemented by a suite of geophysical logs, but these have not been utilized extensively in preparing the present report. While it is believed that in a gross manner the geologic units are correctly identified and interpreted, many fine details that would permit better identification and interpretation of the geologic units are lacking, and some parts of the logs may be incorrectly interpreted.

The cross section purports to represent the geology exactly along the DeBarr line, as does the topographic profile at the top of the section. The data points, however, are spread over a belt about 2-km wide centered on the DeBarr line. The well logs are projected to this line, and some wells that appear to coincide may be 1 km or more apart. In places the variability of the geologic material is such that closely positioned logs may be quite different in character. Consequently, the inferred geologic units represent only conditions generally present within the belt surrounding the DeBarr line. Another consequence of the spread of the data within this belt is that the tops of many of the wells, although actually at the ground surface, are shown either above or below the topographic profile. Further work will present an upgraded and more integrated, albeit more inferential, interpretation of the subsurface geology along this line.

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STRATIGRAPHIC UNITS

The Anchorage lowland lies at the eastern margin of upper Cook Inlet basin. It is underlain by thick wedges of (1) nonlithified glacial and estuarine deposits of Quaternary age and (2) weakly lithified terrestrial sedimentary rocks of Tertiary age. Both wedges thin rapidly to the east (Barnwell and others, 1973; Freethey and Scully, 1980). Here they abut, and may in part be fault separated from, the older McHugh Complex (metamorphic rocks of the Chugach terrane) which crops out in the adjacent Chugach Mountains (Clark, 1975). Most wells terminate within the Quaternary deposits, but a few penetrate the Tertiary rocks. None of the wells in the area of this report are known to reach the base of the Tertiary rocks. Therefore, the cross section has not been extended in depth to include older rocks that can be inferred from regional considerations (Plafker and others, 1982) but the identity and position of which are not as yet known along the DeBarr line. Among these are older sedimentary rocks, perhaps the Matanuska Formation, as reported in some oil and gas drill holes (Magoon and others, 1976) and the metamorphic and/or plutonic rocks that probably constitute the basement. Consequently, only the Quaternary deposits are described in detail. The Tertiary rocks are mentioned briefly, but the other rocks are excluded from this presentation.

Although no shear-wave velocities are known from within the area of this cross section, data from farther south in the Anchorage lowland on file at the WRD office indicate that a velocity of about 2,750 m/sec is appropriate for the top of the Tertiary rocks, as shown here, and that a velocity of about 5,400 m/sec might apply to the top of the metamorphic or other basement rocks. However, the position of the latter boundary beneath most of the cross section has not been established as yet.

Quaternary deposits

The geology of the Anchorage lowland is described in some detail by Miller and Dobrovolny (1959), and the regional Quaternary geology is presented by Karlstrom (1964). Trainer and Waller (1965) provided the first summary of subsurface deposits based on water-well data, a pioneering effort with respect to the work presented here. These data have also been used extensively in the preparation of an earlier analog (Barnwell and others, 1972) and more recent digital hydrologic model for the Anchorage lowland that is still undergoing development (L. D. Patrick, oral commun., 1984). Further work, mainly on the surface geology, has been in progress by Schmoll and Dobrovolny since 1965. More recently, Schmoll and Yehle (1983) and Schmoll and others (1984) have presented modified views of the geologic history of the upper Cook Inlet basin, emphasizing the glacioestuarine nature of much of the deposition. The following brief description of the surface geology and topography in the area of the DeBarr line is modified slightly from Bartsch-Winkler and Schmoll (1984).

Downtown Anchorage is built on a large alluvial fan, informally referred to as the Mountain View fan, whose apex lies adjacent to the Chugach Mountains about 19 km to the northeast; the fan thins to the southwest where it feathers out about 5 km from downtown. Beneath the fan lies the Bootlegger Cove Formation which is composed of estuarine clayey silt and silty clay with some interbedded sand and some variably stony silt and clay. Two prominent stream channels, those of Ship Creek to the north of downtown and Chester Creek to the south, interrupt the surface of the fan and are cut into the Bootlegger Cove Formation.

In many places where that formation is exposed in steep walls of the channels, as well as along Knik Arm, large landslides have occurred repeatedly, probably due to strong ground motion generated by large earthquakes, most recently that of 1964 (Hansen, 1965). The Fort Richardson moraines lie to the east on the lower flanks of the Chugach Mountains. Between the Mountain View fan and these older moraines lies an intermediate belt that includes slightly higher alluvial fan and channel deposits, marginal facies of the Bootlegger Cove Formation, and some partly modified ground moraine deposits.

Near-surface deposits

In order to relate the deposits encountered in the wells to those described above and shown on geologic maps, a series of deposits is shown on the cross section immediately beneath the topographic profile. These are identified by informal names currently in the process of development. They are mentioned briefly here, together with the corresponding map unit symbol that appears on the generalized geologic map of Schmoll and Dobrovolny (1972) which does not, however, use the names:

Mountain View alluvial deposits (an)-- gravel grading southwestward to sand.

East High alluvial deposits (al)-- gravel and sand in a channel slightly higher than the Mountain View fan.

Nunaka Valley alluvial deposits (al)-- gravel and sand in a channel graded to a level above that of the East High channel.

Russian Jack diamicton deposits (gm)-- ground moraine in modified drumlin form and, thus, of glacial origin; alternatively, a coarse facies of the Bootlegger Cove Formation, and estuarine in origin.

Muldoon Road interbedded deposits (mg)-- chiefly diamicton, stony silt, silt, and fine-grained sand, interpreted as morainal deposits partly reworked and modified by waters that deposited the Bootlegger Cove Formation.

Fort Ricardson kame deposits (ga)-- gravel, sand, and glacial diamicton.

Fort Richardson lateral moraines (m)-- glacial diamicton with some gravel and sand.

Other deposits, not named, include: (1) landslide deposits, resulting from both the 1964 and earlier earthquakes (ls); (2) other colluvial deposits on valley walls (c); and (3) thin sand, silt, and gravel deposits in channels younger than the Mountain View fan (al).

Subsurface deposits

The significance of the near-surface deposits, and also of the topographic form of the surface itself, is that they relate directly to the interpretation of deposits in the subsurface. Because the depositional model that has been developed for the upper Cook Inlet basin envisages a repeated series of glaciations, it appears applicable not only to the near-surface deposits but to subsurface deposits as well. During each glaciation, invading glaciers from the surrounding mountains encountered inlet waters on the floor of the basin and engaged in a series of "duels" between ice and water that dominated an environment called glacioestuarine (Schmoll and others, 1984). Consequently, many of the deposits present at depth can be interpreted in terms of those known at the surface either in Anchorage itself or elsewhere in the upper basin. In particular, the complexity and lack of continuity of the surface deposits, as well as the irregularity of the surface, are regarded as indicative of comparable complexities present at depth.

In consequence of the depositional model suggested above, the deposits described in well logs have been interpreted in terms of geologic units that generally have a counterpart in the near-surface deposits. These units are identified by single upper case letters and are described briefly below.

A *Alluvial gravel and (or) sand*-- These units define the key marker horizons within the Quaternary deposits. Comparable to the late glacial and interglacial gravel and sand that dominate the present surface, they can be identified as a series of correlatable units that roughly parallel those on the surface and are graded gently to the west or southwest. Ideally, these marker horizons divide the subsurface deposits into units that represent successive glaciations. That the A-units lack unequivocal correlatability, and in some cases cannot be clearly distinguished from one another, is not surprising in view of the complexities and irregularities of the surface deposits. The subsurface A-units are provisionally represented on the cross section as a series of numbered lines, beginning with 2 from top down (the number 1 being reserved for the near-surface alluvium). The lines, however, should be regarded as bodies of deposit rather than as contacts between deposits. The numbers on these A-unit lines are also used in conjunction with other lettered geologic units to denote the glacial and estuarine deposits beneath each successive A-unit. Ideally, in this provisional scheme, each increasingly higher number represents the deposits of each successively older glaciation, and the deposits of any one glaciation include an A-unit at the top and a laterally grading series of B-, D-, and other units, all designated by the same number. The A-units are of particular significance to the Anchorage area because they comprise the principal aquifers that furnish a major part of the city's water supply, both for individual domestic and commercial wells and for the municipal water supply system. Their existence and development for this use are totally responsible for the data presented here.

B *Bootlegger Cove Formation, and similar but older deposits*-- Originally named the Bootlegger Cove Clay (Miller and Dobrovolny, 1959) but changed to its present designation (Updike and others, 1982) because of its widespread inclusion of silt as well as interbeds of sand of various grain size, the Bootlegger Cove Formation has been studied extensively in recent years by Updike (1982, in press) and Ulery and Updike (1983). This work includes the establishment of a series of numbered facies, presently best described in Updike and others (1982). The Bootlegger Cove Formation is represented on the DeBarr cross section by unit B-1, but the base of the formation is defined here better in concept than by well data; it is anticipated that work in progress by Updike and Ulery will clarify that boundary. Below unit B-1 well logs show similar material that probably represents an older equivalent of the Bootlegger Cove Formation. Because the A-units are less well defined in the western part of the cross section where the B-units dominate, an alternative intepretation could place the lower boundary of the Bootlegger Cove Formation substantially lower, to encompass what are here termed the B-2 through perhaps the B-4 units. This interpretation is presently regarded as less likely, but should not be discarded pending analysis of additional data. Laterally the B- units grade to M- and perhaps S-units of the same numbered series.

M *Silty fine sand and fine sandy silt ("mo")*-- Present within the Bootlegger Cove Formation as facies VI and part of facies IV of Updike, beds of this material are thick enough to identify separately lateral to as well as above and below the B-units in many well logs. The term "mo" (pronounced "moo") is used here informally in the sense of Terzaghi (1925) for material of this commonly occuring size range that does not otherwise have a simple name.

S *Stony silt and clay*-- Equivalent to facies V of the Bootlegger Cove Formation as used by Updike, this material typically contains variably scattered stones in a matrix that is chiefly clayey silt and silty clay; the stones are presumably the result of random dropping from floating icebergs. Although this material could be considered a type of diamicton, it differs from the material called diamicton in this report (unit D) in that it contains fewer stones and has a finer-grained matrix than typical diamictons of this region. It is difficult, however, to make such a distinction in many well logs. The depositional model predicts the occurrence of stony silt and clay, however, and it is known to occur in some carefully described cores (Updike, in press; Updike, H. W. Olsen, and Schmoll, written commun., 1979). Thus, although it has been identified in some well logs, those identifications must be regarded as provisional.

D *Diamicton*-- Originally defined as a poorly sorted, terrigenous, noncalcareous deposit containing sand and/or larger particles in a muddy matrix (Flint and others, 1960a; 1960b), diamictons in the Cook Inlet basin typically include pebbles, cobbles, and scattered boulders in a matrix of sand, silt, and clay, the latter commonly in minor amounts. A nongenetic term, it can be applied to glacial till as well as to other deposits, both subaerial and subaqueous, that owe their origin at least in part to mixing of variously sized materials during the process of downslope movement. Many of the deposits classified from well logs as diamicton, especially in the eastern part of the area, are probably glacial till that occurs in lateral or ground moraines, whereas others may be more diverse in origin. At present it is not possible to distinguish between some of these origins, but the depositional model suggests that diamictons of various origins should be present.

G *Glacial gravel, sand, silt, and diamicton*-- Descriptions in well logs make it difficult to distinguish this unit from unit D, diamicton. This designation is used, however, where the logs suggest thin interbeds of these various materials, but it must be regarded as provisional. The depositional model suggests occurrences of such interbedded sequences, however, in kames, in modified moraines, and in sequences such as those described as glaciodeltaic from Fire Island (several kilometers west of the DeBarr cross section) by Schmoll and Gardner (1982) and by Schmoll and others (1984).

I *Interbedded gravel, sand, and silt*-- This designation is used for interbedded sequences that are interpreted as lacking diamicton, and possibly nonglacial in origin. Uncommon within the glacial-glacioestuarine-interglacial sequences, this unit is provisionally identified only beneath those sequences in the 1984 drill hole.

C *Colluvium*-- This designation is used for relatively thin occurrences of diamicton generally within or related to the A-units. These diamictons are interpreted as analagous to near-surface colluvial and landslide deposits. Although such identifications are speculative, they are to be expected in terms of the depositional model. Also included here is a thin unit of known man-made fill at the top of the 1984 drill hole.

Tertiary rocks

The Tertiary rocks reported from a few well logs and from the 1984 drill hole consist mainly of siltstone, claystone, and sandstone that are in part coal bearing. Readily identified as belonging to the Kenai Group which underlies all of upper Cook Inlet basin (Ehm, 1983), the rocks here are tentatively assigned to the Tyonek Formation, on the basis of identification of this formation about 15 km to the northeast in outcrops along the Eagle River (Wolfe and others, 1966; Magoon and others, 1976). Rocks generally similar to these have been described in more detail from drill holes on the west side of Cook Inlet (Chleborad and others, 1980, 1982; Odum and others, 1983; Odum and others, in press). They are here identified by two lower case letters and described very briefly as follows:

sc *Siltstone and claystone*-- Generally interbedded and commonly indistinguishable without mechanical analyses, these rock types are the dominant lithologies in the 1984 drill hole and may similarly dominate much of the subsurface beneath the Anchorage lowland. They are weakly lithified and fall within the strength range of very stiff soil to weak rock.

cs *Carbonaceous siltstone and claystone*-- These rocks include variable amounts of organic matter including thin beds of coal, and commonly occur in intervening sequences between beds of nonorganic rocks of similar size range. They tend to have slightly greater strength than the nonorganic rocks.

cl *Coal*-- Occurs in beds thick enough to identify separately only in one drill hole, but coal beds probably occur throughout the subsurface beneath Anchorage in thicknesses that are presently unknown.

ss *Sandstone*-- Occurs mainly in thin beds, only a few of which are thick enough to identify separately at the scale of this cross section. Where weakly cemented, sandstone may be friable and lacking in significant strength; some beds, however, are reported as cemented and constitute relatively hard rock.

ru *Rock, not otherwise identified*-- Occurs only at the base of a few holes in the eastern part of the cross section. Probably Tertiary sedimentary rocks of the Kenai Group, judging by occurrences of those rocks in nearby wells at similar depths.

SUMMARY AND RECOMMENDATIONS

Existing data, largely from water well logs, enable construction of several geologic cross sections through the Anchorage lowland. The cross section presented in this report, along the DeBarr line, shows that the upper part of the subsurface geology, in excess of 200 m on the west and thinning to a few meters on the east, consists of Quaternary glacial, estuarine, and alluvial deposits that are dominated in the west by silt and clay including that of the Bootlegger Cove Formation, and in the east by diamicton that is mainly glacial till. The transition between these dominant lithologies is irregular and variable but includes materials such as silty fine sand, sandy silt, stony silt and clay, and various interbedded combinations of these materials. Several silt and clay--diamicton sequences are separated in a general way by intervening beds of gravel and sand that are irregular in thickness and continuity but which nevertheless mark recognizable horizons that have been utilized as sources of ground water for urban use. Although this general picture of the Quaternary deposits is probably valid, data to elaborate on many details of the sequence, especially in its lower part, are lacking. In particular, it is not clear whether the Quaternay deposits can be considered as a single unit with repect to response to strong ground motion, or whether it should be divided into a lower part that could be established as substantially firmer and significantly higher in shear-wave velocity than one or more upper parts.

Underlying the Quaternary deposits is a thicker sequence of Tertiary sedimentary rocks of the Kenai Group, with shear-wave velocities of about 2,750 m/sec. These rocks also thin to the east. Because few wells penetrate them, the configuration of their upper boundary is known only in a general way, and details of the distribution of their principal lithologies, siltstone-claystone, sandstone, and coal, cannot be determined as yet, nor has the position of the base of the Kenai Group been established. The identity, nature, and thickness of older sedimentary rocks that underlie the Kenai Group can only be surmised from regional considerations.

The easternmost part of the area in the Chugach Mountains is composed of metamorphic rocks of the Chugach terrane with a probable shear-wave velocity of about 5,400 m/sec. The extension of these or similar but older metamorphic and (or) plutonic rocks to comprise the basement beneath upper Cook Inlet basin can also be inferred from regional considerations, but the configuration and position of the important boundary at the top of these rocks is not presently known.

To fill the gaps in the present knowledge base indicated above, additional data, especially from depths of perhaps 200 to 1,500 m, are needed. Seismic reflection supplemented by drilling, sampling, and geophysical logging at carefully selected sites would provide a minimum framework within which the details of the geology presented here could be amplified, and would facilitate extension of the cross section downward to the basement. Modelling of the response of the total thickness of rocks underlying the Anchorage lowland to earthquake-generated strong ground motion could then be more adequately undertaken.

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