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URANIUM FAVORABILITY OF THE COOK INLET BASIN, ALASKA

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URANIUM FAVORABILITY OF THE COOK INLET BASIN, ALASKA

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"Uranium Favorability of the Cook Inlet Basin, Alaska" has been open filed (in three volumes) as GJBX-41(78). Volume 1 consists of the original text; volume 2 consists of appendices A, B, C, D, E, and F; and volume 3 consists of maps.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF PLATES (Cont.)

LIST OF PLATES (Cont.)

LIST OF PLATES (Cont.)

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1. SUMMARY

The study was undertaken by WGM Inc. under subcontract for Bendix Field Engineering Corporation, a prime contractor for the Department of Energy. The intent of the study is to review available literature, and in so doing, evaluate the uranium favorability of Tertiary and Mesozoic strata of the Cook Inlet Basin, Alaska. Nonmarine sedimentary rocks are emphasized, but crystalline rocks are included in the evaluation in the sense that they are the sources of sediment. A sandstone-type uranium environment appears to be the most reasonable type to expect in the basin. Other sedimentary uranium deposits could occur but no evidence was found in the literature to support such a hypothesis. The sedimentary section in the Cook Inlet Basin contains abundant sandstone units which have been evaluated for their favorability as hosts for uranium mineralization. Further investigations for uranium should be carried out using direct methods of exploration, such as airborne and ground radiometric surveys, geochemical surveys, and radon emanometry with particular attention to the Susitna Lowlands portion of the Cook Inlet Basin.

The following formations (see fig. 13) are listed in order of decreasing uranium favorability:

Tyonek Formation
Sterling Formation
Tsadaka Formation
Chickaloon Formation
Wishbone Formation
West Foreland Formation
Beluga Formation
Hemlock Formation
Arkose Ridge Formation
Matanuska Formation
Naknek Formation
Chinitna Formation
Tuxedni Group
Talkeetna Formation

Work accomplished includes preparation, collection, and study of bibliographic material, well logs, Landsat imagery, and ground and surface water data. Subsurface correlations made by government agencies and professional organizations were studied. Water samples from water wells were not collected because none penetrate beneath the thick deposits of gravel that cover much of the Cook Inlet Basin. Field checks of sedimentary units and petrographic studies of crystalline rocks were made. Analysis of existing and

project-generated radiometric data has proven to be inconclusive. Available data on coal studies do not include analyses for elements commonly associated with uranium deposits and are considered to be of limited applicability. Most data collected by private companies are confidential. The information acquired from the private sector has been included.

References containing information pertinent to the study were acquired and are on file at the Bendix Field Engineering Corporation office in Anchorage, Alaska. Selected references are listed at the end of the report. Many more reports dealing with various geology-related aspects of the Cook Inlet Basin are available from State and Federal agencies and professional organizations. The information contained in the articles varies from very general to specific.

Overlays have been compiled for the eight quadrangles that cover the study area. The overlays show the following: radioactive occurrences, regional geology, petroleum wells, location of measured sections referred to in text, K-Ar age dates, metallic mineral occurrences, mining claims, and geochemical, water and placer concentrate samples. Other overlays show airborne radiometric and airborne magnetic surveys for some of the quadrangles. Lineaments interpreted from Landsat imagery are shown on overlays for all the quadrangles, and are accompanied by Landsat imagery mosaics. Relative soil moisture content is shown on overlays for four of the quadrangles.

Two regional-scale environments in Cook Inlet are recognized as permissive to occurrence of uranium deposits; deposits associated with granitic intrusives in the surrounding highlands, and sandstone-type deposits in the continental sediments. Regional environmental factors deemed favorable for sandstone-type uranium deposits have been used as criteria to evaluate the sedimentary rocks in the Cook Inlet Basin. The Shirley Lake area contains the only known uranium occurrence in sedimentary rocks in the basin. Base and precious metal associated granitic intrusives in the Alaska-Aleutian Range and Talkeetna Mountains are recognized as being more favorable source rocks than older unmineralized intrusives. There appears to be no direct relationship between the Chulitna-Yentna Mineral Belt and radioactive placer concentrates found in the Yentna District.

The Cook Inlet Basin is part of the northernmost segment of the Western Cordillera of North America. Both the Mesozoic Matanuska geosyncline and the Tertiary Cook Inlet Basin received sediment from surrounding crystalline, sedimentary and metamorphic highlands. Crystalline rocks form the cores of the Aleutian Range, the Alaska Range, and the Talkeetna Mountains. In general, Jurassic plutons are more mafic than Cretaceous or Tertiary plutons, and are not considered to be prospective sources or hosts for uranium deposits. The younger intrusives are considered to be favorable or permissive.

The Cook Inlet region was warped into positive and negative belts of erosion and deposition, respectively, during middle Mesozoic time, probably in response to interaction between oceanic and continental lithospheric plates. A second period of deformation commenced near the end of Cretaceous time and continued into the Paleocene. Cretaceous units consist of a eugeosynclinal assemblage locally metamorphosed to greenschist facies, and a marine sequence of sedimentary clastic rocks, volcanic flows, and pyroclastic deposits. The thickness is in excess of 25,000 feet. Nonmarine units constitute a very small part of the Cretaceous section. Tertiary sedimentation was predominantly nonmarine. The Tertiary Cook Inlet Basin formed as a graben superimposed over the Mesozoic Matanuska geosyncline. The southcentral Alaska province consists of a complex of arcuate mountain ranges, linear lowlands, and a narrow continental shelf whose structural trends reflect the influence of the Alaska orocline and subduction zone along the Cenozoic Aleutian arc. The Cook Inlet Basin is more strongly deformed than other basins known to contain deposits of sandstone-type uranium.

The genetic models developed for the western United States uranium deposits are the best accepted and most commonly applied, but comparisons can be drawn between Cenozoic sedimentary rocks of the Cook Inlet Basin and the host rocks of sedimentary uranium deposits of other countries. Permian and Tertiary uranium-bearing units of Europe and Japan are similar to the Cook Inlet Basin in geologic setting and depositional history. The possibility that erosion channel "Japanese-type" deposits might be present in the Cook Inlet region exists.

2. SUMMARY OF CONCLUSIONS

The overall uranium favorability in the Cook Inlet Basin is low on the basis of current information. Certain formations are considered to contain favorable environments for sandstone-type uranium deposits. This conclusion is based on comparisons between environmental factors characteristic of the Cook Inlet formations studied (table 3) and environmental factors characteristic of sandstone-type uranium deposits in other parts of the world (table 2). The deposits listed in table 2 represent a variety of geographical locations. Since a relatively large amount of information is available for uranium deposits of the western United States, criteria considered to be favorable for uranium are biased and emphasize characteristics of these deposits. Based on the study presented in the following report, the areas shaded in figure 7 are considered favorable for uranium mineralization.

The following named Jurassic through Tertiary stratigraphic units are listed in order of decreasing favorability, based on comparison with known uranium districts and deposits (tables 2 and 3):

Tyonek Fm. Areally widespread; dominantly nonmarine; favorable lithologies limited to lower part of section.
Sterling Fm. - Areally widespread; dominantly nonmarine; favorable lithologies throughout (?).
Tsadaka Fm. - Limited to the Matanuska Valley area; dominantly nonmarine; favorable lithologies throughout (?); equivalent to Hemlock Conglomerate.
Chickaloon Fm. - Limited to the Matanuska Valley area and northeast part of Cook Inlet; nonmarine in part; favorable features scattered throughout (?).
Wishbone Fm. - Limited to the Matanuska Valley area; dominantly nonmarine; favorable features throughout (?); equivalent to the West Foreland Formation.
West Foreland Fm. - Areally widespread; nonmarine in part; favorable lithologies throughout (?); equivalent to the Wishbone Formation.
Beluga Fm. - Areally widespread; dominantly nonmarine; favorable lithologies occur less frequently than in above formations.
Hemlock Conglomerate - Areally widespread; dominantly marine; less favorable lithologies; equivalent to the Tsadaka Formation.
Arkose Ridge Fm. - Areally limited to Matanuska Valley.
Matanuska Fm. - Areally widespread (?); dominantly marine; favorable lithologies occur less frequently than in above formations.
Naknek Fm. - Areally widespread (?); dominantly marine; less favorable lithologies.
Chinitna Fm. - Areally widespread (?); dominantly marine; less favorable lithologies.
Tuxedni Fm. - Areally widespread (?); dominantly marine; less favorable lithologies.
Talkeetna Fm. - Areally widespread (?); dominantly marine; less favorable lithologies.

Certain facies are more favorable than others within any particular formation. A portion of the lower ranked formation may be more favorable than the entirety of a higher ranked formation. Moreover, it is likely that further work will indicate that priority lists for favorability criteria developed in areas elsewhere will require modification for use in northern environments, such as the Cook Inlet Basin.

The above statement of uranium favorability is tempered by the fact that much of the detailed information presented in this study is based on data acquired from a limited number of rock exposures. It is estimated that the combined exposures of sedimentary rocks in the Cook Inlet Basin that have been given even moderate attention, cover an area of 900 square miles. This is 7% of the estimated 13,000 square mile basin. It is prudent to conclude that the basin is far from being proven a poor environment for sandstone-type uranium deposits in consideration of the dearth of hard data pertinent to uranium mineralization.

The Tertiary sedimentary sequence is dominantly nonmarine, and much less disturbed than the underlying Mesozoic sequence. Mesozoic sedimentary rocks are dominantly marine and have undergone as many as three orogenic episodes, each one further deforming and metamorphosing the sedimentary section. Tertiary sedimentary rocks are more favorable than Mesozoic sedimentary rocks on the basis of lithology, tectonics and structure.

The provenance for much of the Tertiary section is granitic highlands that border the basin on all but the southeast side. Although radioelemental data is sparse or unavailable for the various acidic intrusive phases that comprise much of the highlands, it is reasonable to assume that the intrusives contain at least the average 4 ppm uranium content of granitic rocks (Robertson, 1970). The highlands also contain felsic volcanic centers which have contributed lava, tuff, and tuffaceous material to the basin sediments. Felsic volcanic rocks contain an average of 5.6 ppm uranium (Adams, 1954). The abundance of granitic and volcanic source rocks supports the conclusion that certain Tertiary sedimentary rocks are favorable environments for sandstone-type uranium deposits.

Paleoclimates during the Tertiary ranged from tropical (Paleocene) to cool temperate (Pliocene). The Wyoming Basins and Colorado Plateau are known to have developed while climatic conditions were tropical and subtropical (Rackley, 1976). The importance of climatic conditions to the formation of sandstone-type uranium deposits is not well defined, but it may be important to note that the prevailing climate during Tertiary deposition of clastic sediments in the Cook Inlet Basin was similar to that of the western

United States basins during deposition of uranium host rocks.

It is proposed that the Tertiary Tyonek, Tsadaka, and Sterling Formations are the most favorable units for sandstone-type uranium mineralization. The Tyonek and Sterling Formations are considered the more favorable of the three based on the greatest numbers of features in common with known uranium hosts, such as, fluvial depositional environment, granitic provenance, association with adjacent unconformities, and presence of arkosic and tuffaceous units within the sequence. The Tyonek Formation may be ranked as the most favorable since the paleoclimate and age of deposition are more closely similar to those of known host rocks in the western United States than are features of the Sterling Formation. The Tsadaka Formation is ranked third because it is apparently limited in areal extent and does not contain tuffs or tuffaceous material.

Little is known of the stratigraphy or structure within the northern extension of the basin. The Susitna Lowlands cover much of this area. The three formations discussed above could be represented by equivalent units in that part of the basin; but even if they are, there is no evidence that features affecting favorability are coextensive.

Uranium deposits other than the classic sandstone-type may occur in the study area, including sedimentary uranium deposits similar to the Tono Mine (Japan) that have formed in continental sedimentary rocks overlying older granitic bodies (Katayama and others, 1974). Several occurrences of Mesozoic and Tertiary sedimentary rocks resting on granitic rocks are known in the study area. The occurrences are discussed in the uranium favorability sections for the Talkeetna Formation, Tuxedni Group, West Foreland Formation, and Arkose Ridge Formation.

Oil industry well logs have been of limited use. Few of the approximately 500 exploration and development wells in the basin are shown on available correlation charts of subsurface stratigraphy. Since the vast majority of the wells are not correlated, the investigator is left to determine which stratigraphic unit he or she may be studying when viewing logs. Lithologic descriptions provided on the logs are not detailed, and all too often are too general to provide an accurate description of any one interval of the stratigraphic section. Gamma ray logs and their usefulness to this type of investigation are described in section 6.2.

It is suggested that early reports on the geology of the study area be referred to after the most recent and more detailed reports have been studied.

3. RECOMMENDATIONS

Recommendations for further work are tempered by the following considerations:

The first-phase study was confined primarily to compiling, synthesizing, and interpreting available data with spot field checks to verify previous findings.

The study has been a useful first step in providing the base for studies designed to determine the uranium favorability of specific areas, facies, and positions in the stratigraphic sections. Most of the existing data available for the Cook Inlet Basin was originally collected for purposes other than uranium studies; accordingly, information pertinent to uranium is missing in many cases.

Petroleum-related data is useful for discerning uranium potential on a broad scale, but detailed data such as would be acquired during typical mineral appraisal studies, is not available.

1. It is recommended that the favorability of the Tyonek, Sterling, and Tsadaka Formations be investigated by direct methods.

   A. Surface water, ground water, stream sediments, and representative rocks should be sampled and analyzed for uranium.

   B. Spectrometer or scintillometer surveys should be conducted across representative exposed stratigraphic sections to determine which, if any, facies contain direct evidence of uranium mineralization. The formations should be tested in the following areas: the Tyonek Formation in the Capps Glacier area, the Sterling Formation on the Kenai Peninsula, and the Tsadaka Formation in the lower Matanuska Valley.

   C. Track-etch cup and other radon emanometry methods should be planned for some of the areas mapped as the Tyonek, Sterling and Tsadaka Formations, and for the Susitna Lowlands in areas mapped as undivided Mesozoic and Tertiary rocks.

2. It is recommended that detailed geologic mapping be initiated in the following areas:

A. Capps Glacier Area: Specific attention directed to exposures of the Tyonek and West Foreland Formations.

B. Tyonek Village Area: Specific attention directed to exposures of the Beluga Formation to determine if the granitic highlands to the west and north were major contributors of detritus to the various facies in the formation. Such evidence would greatly increase the favorability of the formation on the west side of the basin.

C. Northern Susitna Lowlands: Specific attention directed to exposures of upper Tertiary continental sedimentary rocks.

D. Lower Matanuska Valley: Specific attention directed to exposures of the Tsadaka Formation.

E. Mount Susitna-Capps Glacier Area: Specific attention directed to exposures of the West Foreland and Tyonek Formations where they overlie granitic intrusives.

Any or all of the mapping projects should be designed to seek data pertinent to exploration for sandstone-type and other sedimentary uranium mineralization. Such data should include, but are not limited to: the lithologies of favorable facies - arkosic, tuffaceous, feldspathic, or quartzose; the presence of reductants - coalified plant remains, hydrogen sulfide, humate substances, and pyrite; and the presence of elements commonly associated with uranium mineralization, e.g. vanadium, molybdenum, copper, iron, sulfur, and selenium. Random sampling of rock, sediment, and water combined with spot checks for radioactivity using a scintillometer or spectrometer are also recommended during mapping.

3. It is recommended that the Castle Mountain fault zone be investigated along its surface trace from the Chackachatna River (Capps Glacier area) to the Little Susitna River (lower Matanuska Valley) by the following methods:

Track-etch Cup Measurements
Other Radon Gas Emanometry Methods
Ground Radiometric Traverses
Geochemical Sampling

The fault is a major structural break that could serve as a channelway for the migration of hydrogen sulfide-bearing gases originating from the petroleum rich strata to the south and introduced into permeable facies along the fault. Subsequent migration of uranium-bearing ground water through such hydrocarbon-enriched facies would facilitate the reduction and precipitation of uranium.

4. Further recommendation is given to drilling for the purpose of stratigraphic control in the following areas.

   A. Lower Matanuska Valley: If the Tsadaka Formation continues to appear favorable after the investigation recommended in item 1A and B, then subsurface information should be acquired. Three to four drill holes varying from 500 to at least 5,000 feet in depth would be required to penetrate the Tsadaka Formation beneath the lowland in the Palmer-Wasilla area.

   B. Northern Susitna Lowlands: Exploratory holes should be drilled in the lowlands adjacent to exposures of upper Tertiary sedimentary rocks. The location and depth of the drill holes will be dependent upon the structure and favorability of the units observed while completing recommendations given in item 2B. The number of drill holes needed will depend in part on the results of the earlier study; but one drill hole in each township from the Tokositna River south to the Skwenta River (requiring ten drill holes) will provide a basis for a relatively comprehensive interpretation of the basin in a north-south direction (see plates 75A and 84A). A similar drill pattern east-west across the basin will require at least ten drill holes. The depth of the drill holes required is not known, but it seems probable that many of the holes would reach below 1,000 feet to penetrate Tertiary sedimentary rocks.

The holes should be drilled by a rotary rig for faster drilling rates and lower drilling costs. The drill holes should be analyzed by a gamma ray probe, and any ground water encountered should be sampled and analyzed for uranium. Drill cuttings should be studied and logged according to lithology and mineralogy.

5. The following recommendation for additional study of petroleum well logs is given with the understanding that such a study is limited by the general nature of the data. Additional studies of oil industry logs for the following are needed:

   A. Gross determinations of sand/shale ratios.

   B. Generalized lithologic descriptions.

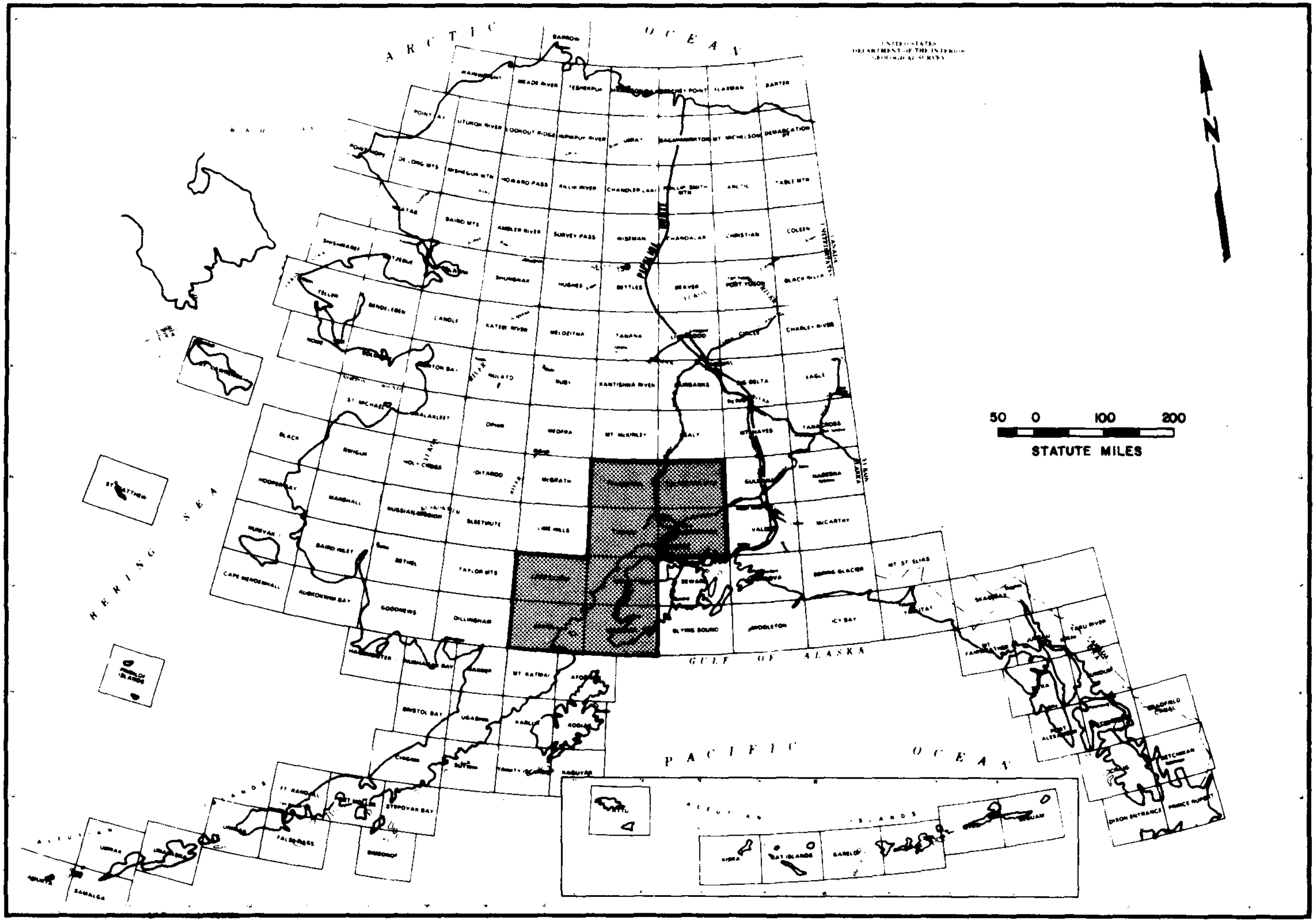
   C. Indications of anomalous gamma ray activities. Schulte (personal communication, 1976), has found that in the Powder River Basin in Wyoming a gamma ray reading of seven times background (on oil industry logs) is anomalous.

Figure 3 shows the wells for which logs were not studied (as well as those that were) and to which the above recommendations apply. Petroleum well logs are available through Petroleum Information Company in Anchorage and the Alaska State Division of Oil and Gas in Anchorage. It is of interest to point out that a comprehensive study titled "Subsurface Geology of the Cook Inlet Basin, Alaska" is now available for purchase from the American Stratigraphic Company. The report contains many cross sections of the basin as well as lithofacies maps. The data have not been included in this report because of the late availability.

4. INTRODUCTION

The evaluation of the uranium favorability of Tertiary and Mesozoic strata of the Cook Inlet region (fig. 1) was undertaken by WGM Inc. under subcontract number 76-017-S for the Bendix Field Engineering Corporation. Bendix Field Engineering Corporation is a prime contractor for the Department of Energy (DOE).

The study is primarily a review and synthesis of published and unpublished investigations of the subsurface and surface stratigraphic, structural, and radiometric features of clastic rocks of the Cook Inlet Basin. The Sterling Formation of Pliocene age, the Beluga Formation and Tyonek Formations of Miocene age, the lower Tyonek Formation, Hemlock Conglomerate, and Tsadaka Formation of early Eocene age, and the Arkose Ridge and Chickaloon Formations of Paleocene age have been emphasized. The small amount of



WGM INC. MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA

Scale: AS SHOWN	STUDY AREA	BX126 FIG. 1
Data By: WGM INC. Date: 4/77		

data available on surrounding crystalline terranes also were reviewed.

Mesozoic units included in the study are the Matanuska Formation of Late Cretaceous age, the Naknek and Chinitna Formations of Late Jurassic age, the Tuxedni Group of Middle Jurassic age, and the Talkeetna Formation of Early Jurassic age.

4.1 SCOPE

The scope of the study is the evaluation of available information pertinent to the geology of the Cook Inlet Basin and the recommendation of any needed follow-up to determine the uranium favorability of the formations listed below.

	Cook Inlet Section	Matanuska Valley Section
Tertiary	Sterling Formation Beluga Formation Tyonek Formation Hemlock Conglomerate West Foreland Formation	Tsadaka Formation Wishbone Formation Chickaloon and Arkose Ridge Formation
Cretaceous	Matanuska Formation	
Jurassic	Naknek Formation Chinitna Formation Tuxedni Group Talkeetna Formation	

The study is basically a compilation of available geophysical, geological, and hydrological information that identifies areas and rock units where follow-up studies are warranted. The study emphasizes clastic continental rocks of the basin, but also includes crystalline source rocks. The only field work within the scope of this study was to confirm questionable data. The intent of the program was not to explore for uranium deposits.

Work planned for the study includes:

1. Extracting and highlighting information from public and available private data pertinent to uranium mineralization.

2. Comparisons with known uranium occurrences elsewhere in the world in similar geological and climatological environments.

3. Acquisition of available field data from on-going and previous uranium exploration programs, and from petroleum companies.

4. Evaluation of known uranium occurrences in the Cook Inlet Basin (Shirley Lake area).

5. Organization of research materials to be available for multiple use while on file in the Bendix Field Engineering Corporation Anchorage office.

6. Preparation of maps with geological, geophysical, and hydrological data; mining claim locations; point locations (mineral occurrences and oil wells) and other pertinent data at 1:250,000 scale.

7. Study of pertinent well logs from selected oil and gas wells.

8. Study of any available analytical data on coal deposits, including radioactivity and metal content, particularly of those metals associated with uranium deposits.

9. Petrographic review of available thin sections of igneous rocks deemed favorable as source rocks.

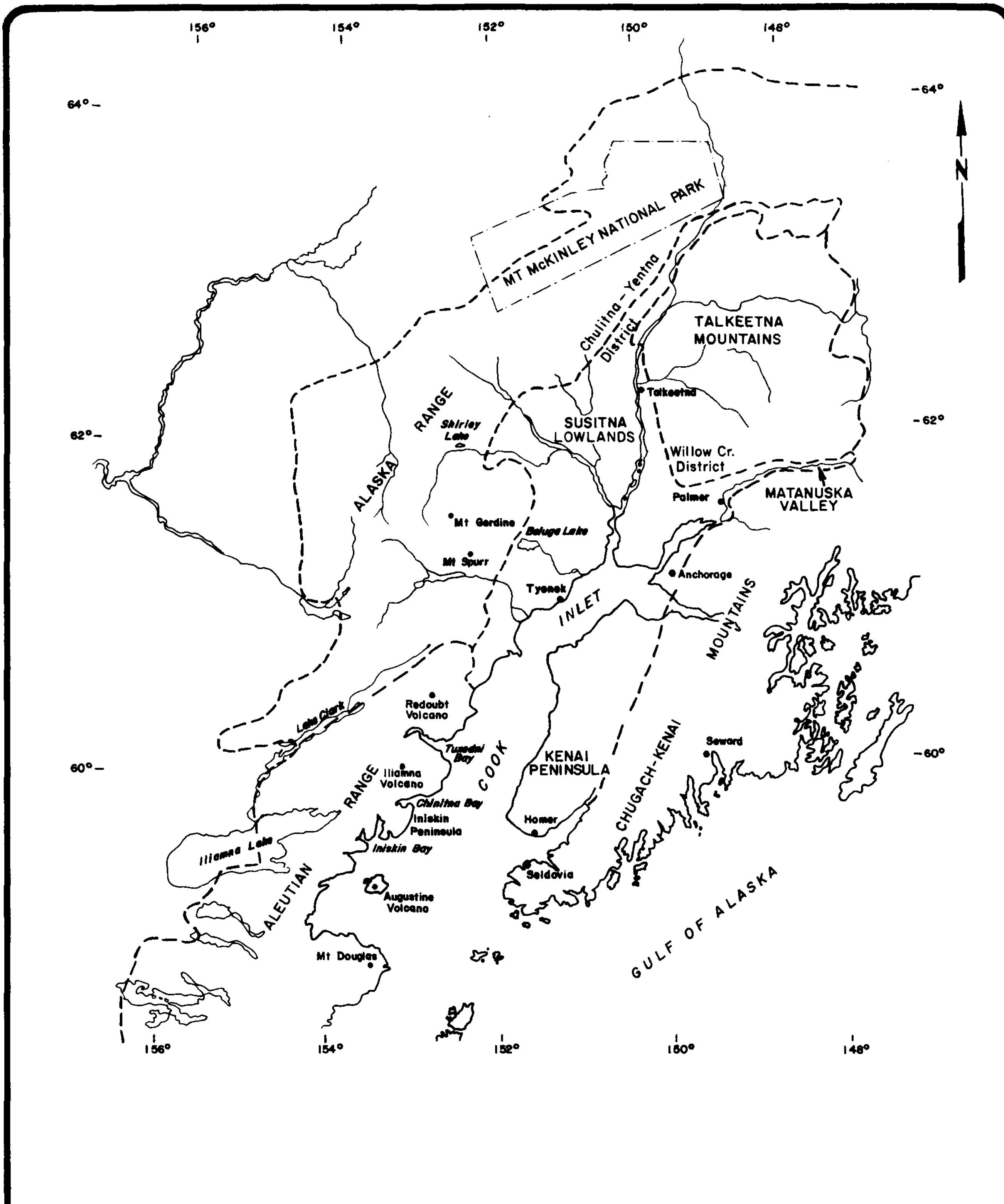
10. Analysis of water samples when it appears the water is derived from units with favorable uranium host rock characteristics.

11. Field checking of questionable data only.

4.2 LOCATION AND ACCESS

The Cook Inlet region is located in southcentral Alaska. Anchorage, Alaska's largest city, is near the north end of Cook Inlet between Knik Arm and Turnagain Arm (fig. 2).

The study area includes the major parts of eight 1:250,000-scale quadrangles: Anchorage, Kenai, Talkeetna, Talkeetna Mountains, Lake Clark, Tyonek, Iliamna, and Seldovia (fig. 1). The Alaska Railroad crosses the region in a south to north direction from the southern coastal ports at Seward and Whittier, through the port of Anchorage, then northward across the lower Matanuska Valley and along the Susitna Valley toward the northern terminus at Fairbanks. The railroad is paralleled for much of its length by the Seward-Glenn-Parks Highways. The Glenn Highway continues from the Palmer area eastward toward the Richardson and Alaska



Modified from Grantz, Zietz, and Andreason (1963b)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H. / DATA BY: C.C. / DATE: 4/77	REVISED	MAJOR PHYSIOGRAPHIC PROVINCES OF THE COOK INLET AREA
SCALE: 50 0 50 miles			FIGURE 2 BX132

Highways. The Sterling Highway branches from the Seward Highway southwestward to serve the Kenai and Homer communities area.

Several major domestic and international airlines serve the Anchorage area. Scheduled barge, ship and ferry services are provided at Seward, Whittier, Homer, Kenai and Anchorage.

4.3 PHYSICAL FEATURES

Five major physiographic provinces are within the study area, namely: (1) Cook Inlet-Susitna Lowland, (2) Aleutian Range, (3) west and west-central Alaska Range, (4) Talkeetna Mountains, and (5) Chugach-Kenai Mountains (fig. 2).

The Cook Inlet province comprises approximately 13,000 square miles, including the broad topographic lowland, adjacent foothills slopes and Cook Inlet. Over half of the area is below sea level.

The topography of the lowland area is dominated by features resulting from five major Pleistocene glacial episodes and recent fluvial glacial stream action. Local relief ranges from 50 to 250 feet. Characteristic features and deposits include eskers, ground moraine, drumlins, outwash plains, kettles, a large number of lakes and ponds, meandering streams, and a few rivers which cross the lowland to enter Cook Inlet. There is a general paucity of bedrock exposures in the lowlands with outcrops restricted to edges of the surrounding uplands and local incised drainages. Cook Inlet is characterized by a tidal range of 30 feet. Broad mud flats are common in many areas.

The surrounding uplands are characterized by rugged mountains and hills, with local relief generally in excess of 2,000 feet, and commonly much more. Glacier derived streams have sharply incised the uplands. Bedrock, rubble, ice, and thin immature soils characterize the higher areas. Rubble, stream and glacial float, soil and extensive bedrock along the canyon walls characterize the lower slopes.

4.4 CLIMATE AND VEGETATION

Temperate weather conditions prevail at the lower elevations in the region and Alpine conditions above timber line. Average summer temperatures are 50°F to 60°F, and drop to as low as -20°F to -40°F during cold spells in the winter months. More extreme variations are common to the higher elevations and in areas farthest from the ocean.

Vegetation below elevations of 1,000 to 1,500 feet consists of tundra, muskeg and spruce in poorly drained areas, and various types of deciduous trees and bushes in well drained areas. Vegetation at higher elevations consists of arctic and/or alpine flora with local areas virtually devoid of vegetation.

4.5 PREVIOUS INVESTIGATIONS

Numerous United States Geological Survey reports, and a lesser number of other reports have been written about the geology of the study area. Only those with information pertinent to this study are discussed below.

The most comprehensive report of the geology and resources of the Kenai Peninsula was written by Martin, Johnson, and Grant (1915). Martin worked the western part of the Kenai Peninsula, Johnson the central and northern portions, and Grant the southeastern side. Martin's area included Tertiary sedimentary rocks, subsequently named the Sterling Formation, which are of particular interest to the present study. Capps (1917) reported on the mineral resources of the upper Chulitna region, Willow Creek District, and of the western Talkeetna Mountains (fig. 2). Chapin (1918) surveyed the headwaters of the Matanuska and Susitna Rivers in an effort to connect or extend former surveys of the region. The geology of the Alaska Railroad region prepared by Capps (1940) served for many years as the guide to the regional geology of a 140-mile wide strip extending from the coastal terminus at Seward to the inland terminus at Fairbanks.

Recent surveys of Jurassic sections in the Cook Inlet Basin are described by Detterman and Hartsock (1966), and Lyle and Morehouse (1977). Tertiary sedimentary rocks are covered in less detail in the above studies. More detailed descriptions of Tertiary sections in the Homer-Capps Glacier areas are given by Adkison, Kelley, and Newman (1975b). Clardy (1974) reported on middle Tertiary rocks exposed in the Matanuska Valley. Calderwood and Fackler (1972) subdivided the subsurface Kenai Group into five distinct formations based on lithology and electric-log characteristics.

Miscellaneous Investigations Map I-1019 (Magoon and others, 1976) is the most up-to-date published compilation of geology covering the Anchorage, Kenai, and Seldovia quadrangles, and portions of the Iliamna, Lake Clark, and Tyonek quadrangles.

Reports soon to be released are the United States Geological Survey PAMRAP and AMRAP studies of the Talkeetna and the Talkeetna Mountains quadrangles.

Radioactivity investigations were conducted by the United States Geological Survey throughout Alaska during the late 1940's and early 1950's. The resulting Trace Element Investigations reports are either unpublished or no longer available. Many of the results are included in one or more of the following publications:

Moxham and Nelson (1947)
White and others (1951)
Bates and Wedow (1953)
Moxham and Nelson (1949)
Robinson, Wedow and Lyons (1955)
Freeman (1956)

Eakins (1969) tabulated much of the published data on radioactivity studies in Alaska. A mineral investigations resource map was compiled by Cobb (1970) showing uranium, thorium, and rare earth occurrences in Alaska. Klein (1975, unpublished report) speculated on the presence of sandstone-type uranium deposits in Alaska. An extensive examination of Alaska's uranium potential was prepared by Eakins (1975). Sainsbury and Thomas (1976) tabulated and plotted locations of placer concentrates containing anomalous concentrations of various elements, including uranium and thorium. Dickinson (1977), during a preliminary investigation, determined the average uranium content of various Tertiary continental sedimentary rocks in the Cook Inlet Basin to be 2.4 ppm.

Earliest investigations carried out specifically for uranium by the United States Geological Survey in the 1940's-1950's consisted of spot checks and analyses of stream gravel concentrates in an effort to locate potential source areas of uranium mineralization. Although uranium and thorium minerals were found in some of the gravels, their concentrations do not appear to be significant. The average value for the unconcentrated material approximates 14 ppm eU.

Two unsubstantiated reports of uranium mineralization appear in the literature. The following quote is taken from Eakins (1975).

> "Samples of metatyuyamite-bearing limestone submitted by H. N. Fowler, a prospector from Anchorage, contained as much as 0.92 percent uranium (Matzko and Bates, 1955, p. 7-10; Wedow, 1956 p. 86-87). According to reports, an Indian named Chickalusian from Tyonek found the samples in 1949 on the north side of the valley of a left-limit tributary of Nikolai Creek, 16 miles northwest of Tyonek. Chickalusian's description of the outcrop from which the samples were reportedly taken indicate it to be approximately 50 feet long and 10 feet thick with lenses of "yellow rock" up to 3 inches thick between thin beds of limestone."

Subsequent efforts to find that particular outcrop or any of a similar description have failed.

Another example taken from Eakins (1975) reads:

> "During 1918, a sample of carnotite was submitted to the Fairbanks Assay office by an Alaska Railroad construction worker named Grotto. If Grotto's find was authentic, the ore was probably found somewhere along the railroad belt, possibly in the Kobe-Susitna River portion which was under construction in the summer of 1918 (Moxham and West, 1953; Wedow, 1956, p. 85-86)."

Results of the assay were not included in the brief summary given by Eakins.

The Shirley Lake area (fig. 2), has been prospected since the early 1950's when radioactive occurrences were first reported in that area. The following is quoted from Freeman (1963) after his brief visit to the prospect:

> "Anomalous radioactivity was found in 1954 in a unit of tuff and tuff-breccia that underlies a ridge along the north side of Shirley Lake. The tuff and tuff-breccia are indurated but, except for a little epidote, do not appear to be metamorphosed. The unit is broken by many joints and by a few faults. The radioactive areas are very small, at the most a few feet in length, and occur in and adjacent to joint surfaces.
>
> "Exploration work at the prospect consists of a few shallow pits in the tuff unit. The pits have not disclosed any extension of radioactive rocks below the surface or away from the joints and, therefore, show the dependence of the radioactivity on joints.
>
> "The maximum amount of uranium detected in samples from Shirley Lake by the U.S. Geological Survey is 0.21 per cent (J. J. Matzko, written communication). A prospector reported that a sample from the area assayed 0.29, which is possible considering the spotty nature of the radioactivity."

A prospector currently exploring the Shirley Lake area reported other radioactive occurrences in the area but did not have any specimens of radioactive rock when he talked to WGM, Inc. geologists, and could not provide any significant details on the occurrences.

5. WORK ACCOMPLISHED

A comprehensive bibliography was prepared and literature was collected and studied. Petroleum well logs including gamma ray probe results were examined. Field work was accomplished, and a limited petrographic study was undertaken.

A variety of data specific to the study area and radioactive occurrences within the study area were researched and compiled. These data include: mineral occurrences, lode and placer claim locations, geochemical sample sites and analyses, petroleum well locations, geochronology of crystalline rocks, geology, airborne radiometric data and aeromagnetic data. The data are plotted at a scale of 1:250,000 on overlays keyed to the following quadrangles: Talkeetna Mountains, Talkeetna, Anchorage, Tyonek, Kenai, Lake Clark, Seldovia and Iliamna.

The overlays, referred to as plates, are listed at the beginning of this report. Each quadrangle is covered by three to five plates depending on available information. Each plate is given an alphabetical designation A, B, C, D, E, or F that is prefixed by the Alaska kardex number for the quadrangle. For example, the kardex number for the Anchorage quadrangle is 85 and the plates are numbered 85A through F. Locations of metallic mineral occurrences from compilations by Cobb (1972) and Cobb and Richter (1972) are plotted on plates B. Radioactive occurrences are shown on plate C of each of the eight quadrangles. Tables listing data collected by previous investigators of radioactive occurrences are given in appendix F.

The locations of mining claims are shown on plates B as taken from the United States Bureau of Mines Open File Report 20-73. A list of commodities and the number of claims staked at each location is coordinated with the State of Alaska's kardex system and are given in appendix B.

Geochemical sample sites of stream sediments and rock samples collected by geologists working for the United States Geological Survey and Alaska State Division of Geological and Geophysical Surveys are shown on plates C. Analytical results for these samples have been reproduced from various reports and included in this study as appendix F. There are no uranium analyses for any of the geochemical samples. No attempt was made during the course of this study to evaluate the results of the geochemical data exclusive of uranium. It is the intention of this report to make the reader aware that these data exist for whatever comparisons or conclusions the reader may want to draw.

The geology of the region is compiled at a scale of 1:250,000 on overlays of the United States Geological Survey quadrangle series (plates A). Many sources were used in order to compile this information and they are credited on plate 1 (Legend Sheet). The geological detail varies from quadrangle to quadrangle, depending upon the source and information available.

Exploration and wildcat petroleum well locations are plotted on plates B for those quadrangles where such wells have been drilled. The deepest rock units encountered and total depth are shown for 60 of the wells. Well names and other information are included in Appendix C. Many of the wells have gamma ray logs available for them and 27 wells are represented on published cross sections and stratigraphic correlation charts of the Cook Inlet Basin. Results of the investigation of gamma ray logs of certain wells in the basin are discussed in section 6.2 of this report and listed in appendix C.

Landsat imagery mosaics were prepared for each quadrangle at 1:250,000 scale. Lineaments are plotted on overlays for each of the mosaics and are given in the list of plates at the front of the report.

An investigation of groundwater and surface water data was made. Water data was acquired from the Water Resources Division of the United States Geological Survey and evaluated for usefulness in determining the uranium favorability of the Cook Inlet Basin. Considerable data were collected from streams, rivers, and private and public water wells. Most of these sites are located on the east side of Cook Inlet, in the lower Matanuska Valley and east of the Susitna River. All of the data are water quality analyses and only a few samples were analyzed for radioactive elements. Some of the constituents commonly analyzed include Ca, Na, Fe, As, F, SO_4, CO_3, Mg, Mn, and SiO_2. The few water sites that have been sampled and analyzed for uranium are listed as follows:

Kenai River at Soldotna	0.01 - 0.13μg U/L (four samples)
Ship Creek at Anchorage	0.16μg U/L (one sample)
Talkeetna River at Talkeetna	0.01 - 21μg U/L (six samples)

Planned water well sampling was not carried out. The samples would have no significance since the wells do not penetrate below the gravel that covers the basin.

Airborne radiometric data acquired by earlier investigators is presented on plates D at a scale of 1:250,00 for portions of the Anchorage, Tyonek, and Talkeetna quadrangles. Some anomalies were reported by that investigation and are described in Section 6.7.

Information concerning element concentrations in Cook Inlet coal is lacking, so a study is not included in this report. Reports presenting analyses and tests of coal have been written by Warfield (1967), and Geer and Fennessy (1962). The reports provide information on the suitability of coal but not the mineral content of the coal. Many reports are available on the coal fields in the study area. They are too numerous to list but can be found in bibliographies of geological literature compiled by Maher and Trollman (1969) and McGee and others (1977).

6. RESULTS

6.1 LITERATURE COMPILATION AND STUDY

Bibliographies of published geological literature concerning the Cook Inlet Basin and surrounding highlands were compiled at the start of the study.

The main sources of information are United States Geological Survey bulletins, circulars, maps, open-file reports, professional papers, and water resource papers; State of Alaska annual reports, geochemical reports, geological reports, open-file reports and special reports; United States Bureau of Mines compilations and publications; and American Association of Petroleum Geologists bulletins and memoirs. Some unpublished data were obtained from private companies. Considerable effort was made to obtain preprints and unpublished data from both public and private agencies. In almost all cases the efforts proved unsuccessful, although much of the data are soon to be released. The literature and data compilation and investigations have continued throughout the project as reports became available or were deemed applicable to the study.

Articles, reports, and collected data are filed by United States Geological Survey quadrangles and stored at the Bendix Field Engineering Corporation office in Anchorage, Alaska. Within each quadrangle file, the information is subdivided according to subject and/or specific location. This filing system will allow for multiple use, especially in concert with the overlays developed for each quadrangle.

Reports and articles concerning sandstone-type uranium deposits elsewhere in the world, particularly in the western

United States and in northern latitudes, were reviewed to establish the uranium favorability criteria to be used in the evaluation of the clastic continental sedimentary rocks in the Cook Inlet Basin. Particular results of this research are given in later sections.

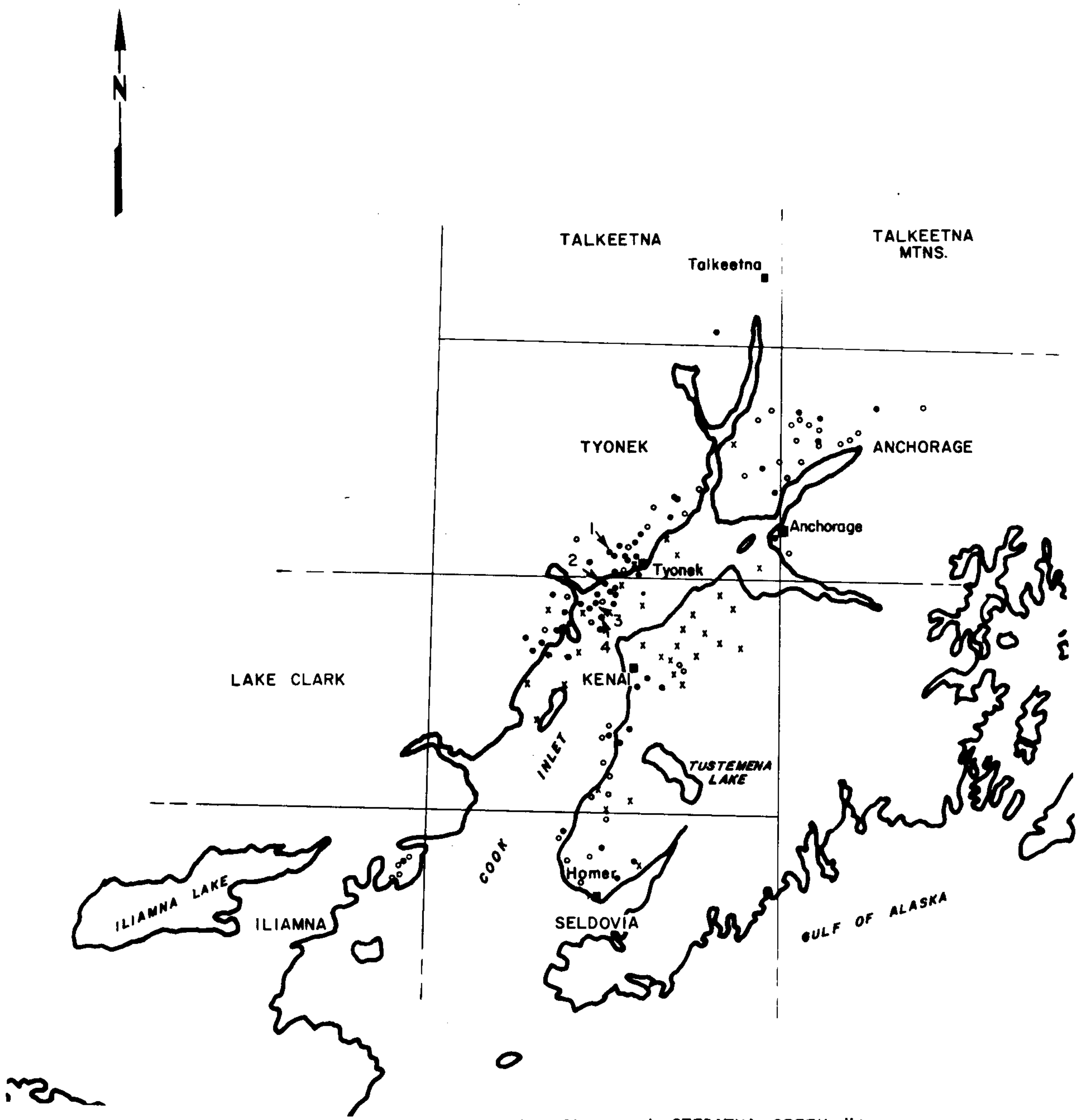
6.2 PETROLEUM WELL LOG INVESTIGATIONS

Approximately 500 petroleum wells have been drilled in the Cook Inlet Basin. A complete index of all the logs for any particular well is not available, but it is estimated that as many as 120 wells may have gamma ray logs. The library of the State of Alaska Oil and Gas Division has on file a complete inventory of well logs that are available to the public upon request. However, an index to this inventory is not available. Petroleum Publications Incorporated maintains a list of well logs available for purchase from their office in Anchorage.

In the course of this study 71 exploratory wells were selected on the basis of location of the well in the basin and gamma ray log availability. The gamma ray logs were studied to determine if the wells had penetrated stratigraphic intervals displaying anomalous radioactivity. The majority of the data are from exploratory wells, but some logs of development wells were also studied. The distribution of the 71 wells that were selected for study are shown in figure 3. As many as 29 are represented on cross-sections prepared by the Alaska Geological Society (1969); Hartman, Pessel, and McGee (1971); McGee (1971); and Carter and Adkison (1972).

Discussion of the Gamma Ray Log

The gamma ray log is a record of the natural radioactivity of rock sensed by a gamma ray probe as it travels up or down the well. The probe is very sensitive to low concentrations of radioactivity and can be used to help differentiate between shale and sandstone, since shale generally contains more radioactive minerals than sandstone. The radioactivity is measured in API units. API units are defined by the American Petroleum Institute and are based on an artificial source of radioactivity designed to represent a sedimentary unit equivalent to a mid-continent shale. The artificial source contains 3 percent K, 8 ppm Th, and 8 ppm U_3O_8. The difference between this synthetic mixture and a barren shale is approximately 200 API units. Average radioactivity values to be expected for sandstones and shales are 10-30 API units and 80-140 API units, respectively (Schlumberger, 1972). API units, however, are of limited use to uranium exploration because it is difficult to equate API units with eU_3O_8. Factors inherent in the design of the oil industry



x PETROLEUM WELLS THAT ARE REPRESENTED ON AVAILABLE STRATIGRAPHIC CORRELATION CHARTS

• PETROLEUM WELLS THAT WERE INVESTIGATED DURING THIS STUDY

° OTHER PETROLEUM WELLS

1. STEDATNA CREEK #1
2. NICOLAI CREEK #4
3. TRADING BAY STATE #1
4. MIDDLE GROUND SHOAL ST. A.#43-11

SEE APPENDIX C FOR DETAILS OF THIS STUDY

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	DISTRIBUTION OF EXPLORATORY PETROLEUM WELLS IN THE COOK INLET BASIN	FIGURE 3 BX134
SCALE: 20 0 40 miles	DATA BY: C.C.			
	DATE: 4/77			

gamma ray probe, such as sensitivity, will not allow the instrument to register the true value of radioactivity when concentrations exceed 0.005% eU_3O_8 (Schulte, written communication, 1976). This is referred to as "dead time" and is recorded on the gamma ray log as less radioactivitiy than is actually present. From experience Schulte has determined that levels of radioactivity seven times background on oil industry gamma ray logs are anomalous. Schulte listed a few rule of thumb formulas that have been used to equate API units to eU_3O_8; 2 X 10^{-5} X API units = % U_3O_8; 2 X 100 API units = 0.004% eU_3O_8; 100 API units = 0.002% eU_3O_8.

Results of Gamma Ray Log Investigations

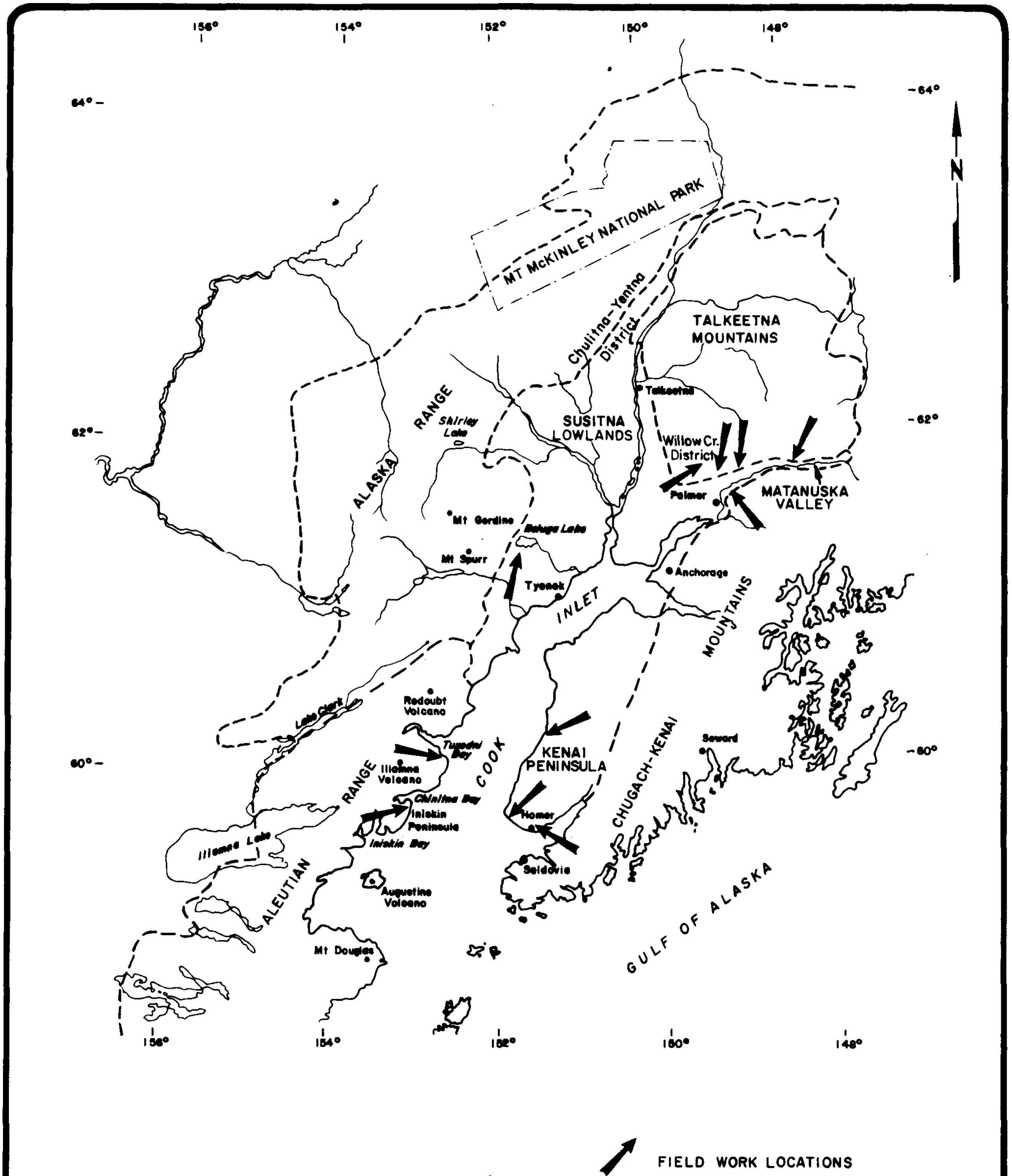
The use of oil industry gamma ray logs by the mineral exploration industry in an effort to reveal possible uranium deposits is an inexact science. It is an effort of trial and error that varies with each area. Without the aid of previous studies of this kind in the Cook Inlet region background levels of radioactivity were estimated through visual inspection of gamma ray logs. Anomalous levels were empirically chosen to be roughly three times the background level. Few of the well logs studied meet that requirement, yet numerous logs indicate radioactivity levels in excess of two times the established background value.

Radioactivity levels exceeding the upper limit of three times background were found on gamma ray logs of only four petroleum wells. Samples of the rock from these anomalous intervals were acquired from the State of Alaska Oil and Gas Division and analyzed using a spectrometer. The results are inconclusive. The details of the study are given in appendix C. Background levels of radioactivity established for all of the 71 wells are included in appendix C.

6.3 FIELD WORK

Field work was conducted in the Matanuska Valley, Homer-Anchor Point area, Beluga-Capps Glacier area, and the Iniskin-Tuxedni region on August 19-22, August 26-27, September 27 and 29, and October 1-3, 1976 (fig. 4). The purpose of the field work was to clarify questionable data and to visit outcrops of each of the Mesozoic and Cenozoic clastic sedimentary units in the study area.

A total of 66 radiometric measurements were made at outcrops utilizing a Geometrics GR 410 spectrometer and 3 X 3 inch NaI detector. The value of the outcrop measurements is diminished because calibration constants and stripping ratios were not available for the instrument. As a result, an accurate determination cannot be made of equivalent uranium and thorium at each outcrop. While strong anomalies would have been detected, more subtle anomalies may have



WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY M.H.	REVISED	FIELD WORK LOCATIONS IN THE COOK INLET AREA	FIGURE 4
SCALE 50 0 50 miles	DATA BY C.C.			
	DATE 4/77			BX132

been missed. None of the measurements are considered significantly anomalous. No obvious indications of uranium mineralization were observed.

Geologic observations made during the course of the field work are incorporated in the descriptive sections of the report.

6.4 PETROGRAPHIC STUDY OF CRYSTALLINE ROCKS

Thin sections of crystalline rocks were studied in an effort to gain a first hand knowledge of the nature of the igneous instrusives that have contributed detritus to the Cook Inlet Basin. Section 7.10 of this report describes the details of this study.

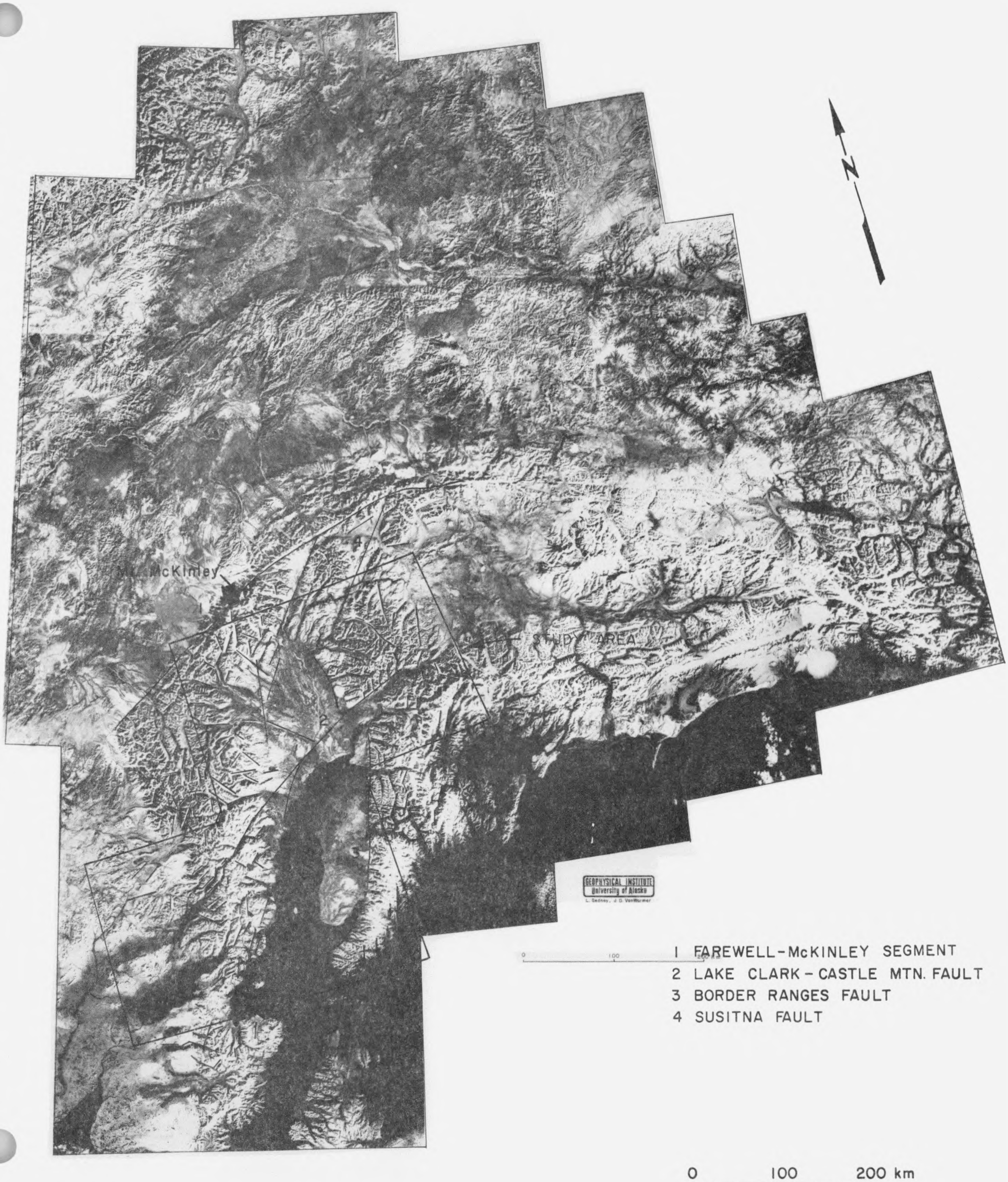
Thirty-four thin sections of granitic rocks from the Talkeetna Mountain batholithic complex were made available by M.W. Henning of the Alaska State Geological and Geophysical Surveys. The rocks studied fall into two compositional groups: a mafic suite of tonalite and granodiorite, and a felsic suite of granitic rocks. The ages of the crystalline rocks studied in thin section are considered to be Late Cretaceous to early Tertiary, but no radiometric age dates are available to support that interpretation.

Thin sections of 24 rocks from the Alaska-Aleutian Range batholith were also examined. These thin sections were made available by B.L. Reed of the United States Geological Survey. Granitic rocks of Early to Middle Jurassic and Late Cretaceous to early Tertiary age were examined. The Jurassic rocks studied are predominantly granodiorite whereas the younger suite is generally more potassic. Radioelemental data on samples collected by United States Geological Survey geologists from the Alaska-Aleutian Range batholith have not been published and were not made available for publication.

6.5 LINEAMENTS IN SOUTHCENTRAL ALASKA

Because faults could control the loci of potential uranium mineralization, Landsat imagery at a scale of 1:250,000 was studied to identify the lineaments and linear patterns in the study area. An analysis of the structure responsible for the northern extension (Susitna Lowlands) of the Cook Inlet Basin was also made during that study.

Figure 5 is a tracing of all prominent lineaments visible on a 1:1,000,000 scale landsat mosaic of the study area. Two major northeast-trending fault systems transect the region. The northernmost fault is the Denali fault and is made up of



W G M INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	MAJOR LINEAMENTS IN THE STUDY AREA	FIGURE 5
	DATA BY: C.C.			
SCALE: AS SHOWN	DATE 4/77			BX127

the Farewell and McKinley segments in the map area (fig. 5). Paralleling the Denali fault to the south is the Castle Mountain fault, referred to as the Lake Clark fault along its southwestern extension in the map area. Both faults display right lateral and dip-slip offset. Lineaments other than those representing major fault systems display distinct northwest and northeast trends. South of the Castle Mountain fault, the margins of the Cook Inlet Basin are known fault zones. Movement along the faults has produced the graben in which that part of the basin rests.

Interpretation of lineaments north of the Castle Mountain fault suggests that the Susitna Lowlands is also a graben-like structure. The graben structure is complicated by faulting and granitic intrusives near its southwestern corner. The eastern margin is bordered by the Talkeetna Mountain uplift which forms a sharp north-northwest trending scarp. The western margin appears to be more complex, and probably formed as a result of movement along a set of strong northeast trending faults. The Susitna fault to the east parallels the trend of the western margin of that part of the basin. The sense of motion along these faults is not known.

It is probable that at least some of these faults influence groundwater movement. If the groundwater is uranium-bearing, the faults could provide channelways for uranium mineralization. The Castle Mountain fault would most likely affect the migration of groundwater since it passes across the basin, separating the northern portion from the southern portion. It is likely that groundwater migrating toward Cook Inlet would be interrupted at this fault zone. The fault would also be an effective channelway for the migration of hydrocarbons (oil or gas). Uranium-bearing groundwater encountering the reducing environment provided by the presence of hydrocarbons along the fault or contained in favorable facies along the fault, would cause deposition of the uranium. Other faults, such as the Susitna fault, trend into the northern portion of the basin and could very well restrict or control groundwater movement and influence uranium mineralization processes.

In summary, it seems probable that at least some of the faults, especially the Castle Mountain fault, that trend toward the basin could act as channelways and/or loci for uranium mineralization.

6.6 INVESTIGATION OF GROUNDWATER AND SURFACE WATER DATA

Published data of uranium content of groundwater and surface water in the study area are sparse. Recent surface water quality work (Water Resources Division of the United States

Geological Survey) was made available by D.R. Scully and the preliminary data are plotted in parts per billion (ppb) uranium on plates 84C and 75C. (See also appendix F.) None of the samples exceed 0.04 μg/L = ppb of uranium. The uranium content is much lower than the average content of 0.1 to 10 ppb uranium in most natural surface water (Hem, 1970). The streams sampled in the Tyonek quadrangle drain sedimentary rocks of the West Foreland and Tyonek Formations. The two streams sampled in the Talkeetna quadrangle drain undivided Mesozoic and upper Tertiary sedimentary rocks.

A brief review of water quality records kept by the United States Geological Survey Water Resources Division provides some insight as to the nature of the groundwater and surface water found in the study area. In general, both surface and ground water is of the calcium bicarbonate type. The pH of both systems averages about 7.4. No peculiarities were noted in the concentrations of the common elements (Ca, Mg, Na, K, F, Cl, Fe, Mn) found in groundwater or surface water with the exception of the water in the public water well at Palmer containing higher than average boron.

Groundwater and surface water data were acquired from the Water Resources Division of the United States Geological Survey. The granting of approval to analyze certain stream silt samples for uranium, collected during past United States Geological Survey field programs, was delayed and eventually the request was withdrawn.

6.7 OTHER RADIOMETRIC INFORMATION

Airborne radiometric and Track-etch cup data from a privately financed exploration program were made available to WGM Inc., and are incorporated in this report.

The airborne radiometric data cover parts of the Anchorage, Tyonek and Talkeetna quadrangles (plates 85D, 84D, 75D). Airborne anomalies are divided into three classes according to strength (relative to background) and sharpness of expression. The anomaly classification was established for airborne radiometric studies throughout Alaska, which WGM Inc. has completed, including data which were released for inclusion in this report. Class I anomalies are sharp and strong (5 X background or greater). Class II anomalies are broader and of moderate strength (3 to 5 X background). Class III anomalies are very broad and relatively weak (2 to 3 X background). Anomalies were further classified as to which of the four channels (total count, potassium, uranium and thorium) was considered anomalous. In most cases two or more channels were anomalous for a given anomaly.

The airborne radiometric survey was conducted from a helicopter equipped with two 6 X 4 inch NaI detectors and a Scintrex GAM-25 spectrometer. The radar altimeter was not functioning properly but flight elevation was maintained at 200 to 400 feet above ground level for most of the survey. All of the anomalies detected by the survey fall into Class III. Many correspond to roads and areas of gravel exposure and may indicate the contrast between rock and tundra. Several of the anomalies in the Capps-Beluga Lake area in the Tyonek quadrangle (plate 84D) may be significant as they occur in areas underlain by Tertiary Kenai Group sedimentary rocks. Some of the anomalies in the Talkeetna quadrangle (plate 75D) may also be underlain by Tertiary sedimentary rocks.

Track-etch cups were used to measure radon in soil gas. Cups were laid out approximately perpendicular to regional strike in an area along the Wasilla-Fishhook Road where gravel deposits overlie Tertiary sedimentary rocks (fig. 6). Results are listed in table 1 and are not considered anomalous. The data has value in that it can be used as background for future studies.

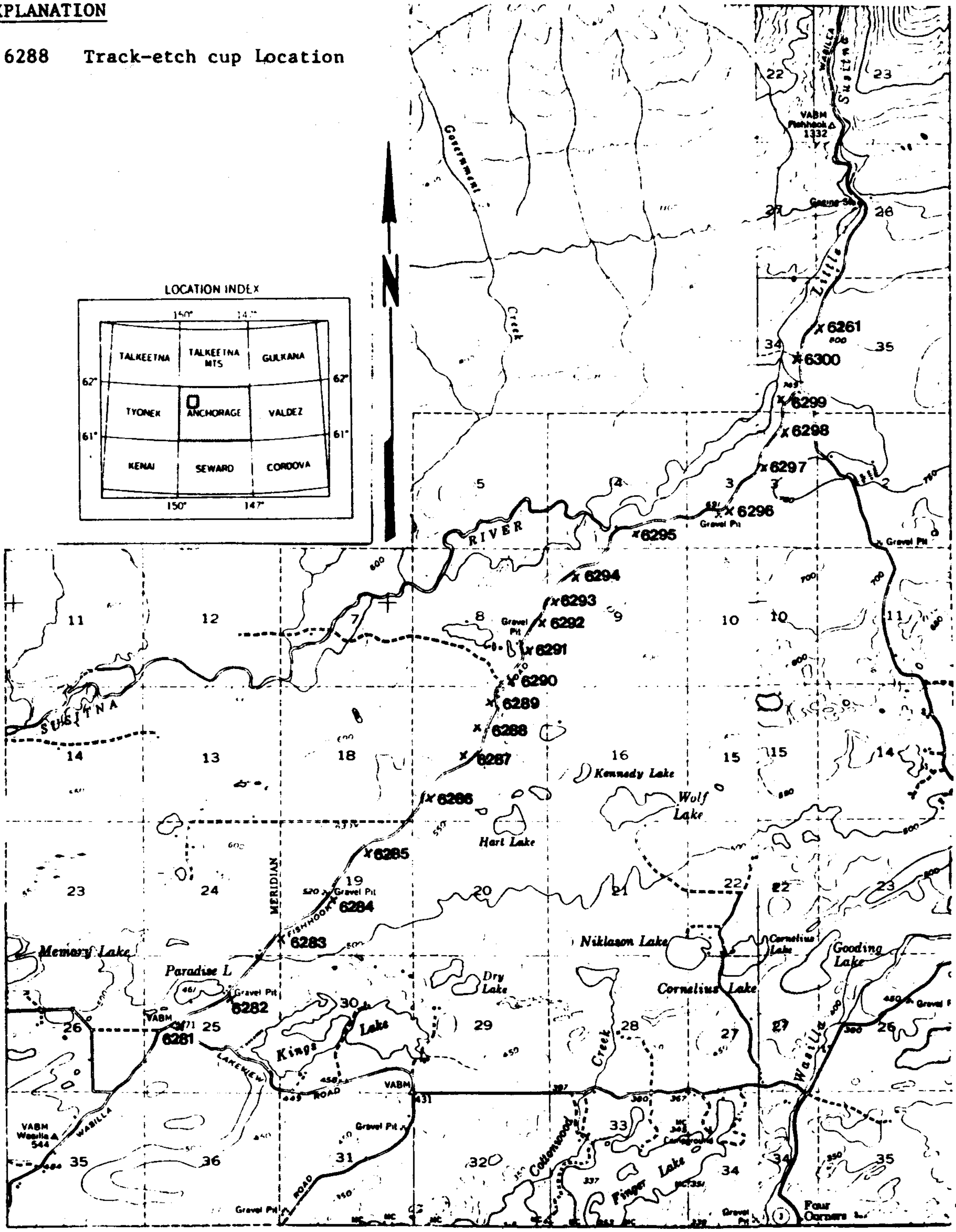
Companies are known to be exploring the Cook Inlet Basin for uranium. Their activities include outcrop examination, geochemical surveys and radiometric logging of holes drilled in the course of coal exploration. Data from these programs were not available for this study.

TABLE 1

Cup Number	Tracks/mm^2
6261	8.151
6281	21.144
6282	9.238
6283	22.824
6284	13.042
6285	14.672
6286	Cup lost
6287	9.238
6288	12.499
6289	3.804
6290	7.608
6291	20.650
6292	8.695
6293	14.129
6294	3.260
6295	10.325
6296	3.260
6297	14.129
6298	24.454
6299	16.846

EXPLANATION

X 6288 Track-etch cup Location



WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY: S.B.	REVISED	Track-etch Cup Location Map Matanuska Valley	FIGURE 6
SCALE: 1:63360 — 1/2 0 1 mile	DATA BY: J.L.			
	DATE: 4-77			

7.0 REGIONAL GEOLOGY

7.1 GENERAL STATEMENT

The Cook Inlet Basin and adjacent mountain provinces comprise the northernmost segment of the Western North America Cordillera. Paleozoic to Mesozoic volcanic and sedimentary rocks with very local areas of Precambrian(?) to Tertiary rocks form the backbone of the Aleutian Range, Alaska Range, Talkeetna Mountains and Kenai-Chugach Mountains provinces. The layered rocks have been intruded by granitic plutons in a number of localities. Mafic to ultramafic bodies are exposed locally in and near the boundaries of the study area. Tertiary sedimentary rocks and local volcanic rocks fill the Cook Inlet Basin and are exposed along the foothills of adjacent mountain provinces.

A Paleozoic eugeosyncline covered much, if not all, of the study area and surrounding regions. Deposition in the eugeosyncline continued into the Triassic in parts of the basin. The Mesozoic Matanuska geosyncline formed over a portion of the Paleozoic eugeosyncline, and the Tertiary Cook Inlet Basin in turn overlies a portion of the Matanuska geosyncline. Refer to Section 9.0 for more detail.

The scope of the current study is restricted to Jurassic and younger rocks, but a variety of older rocks from Precambrian(?) to Triassic are exposed in various places within the study area.

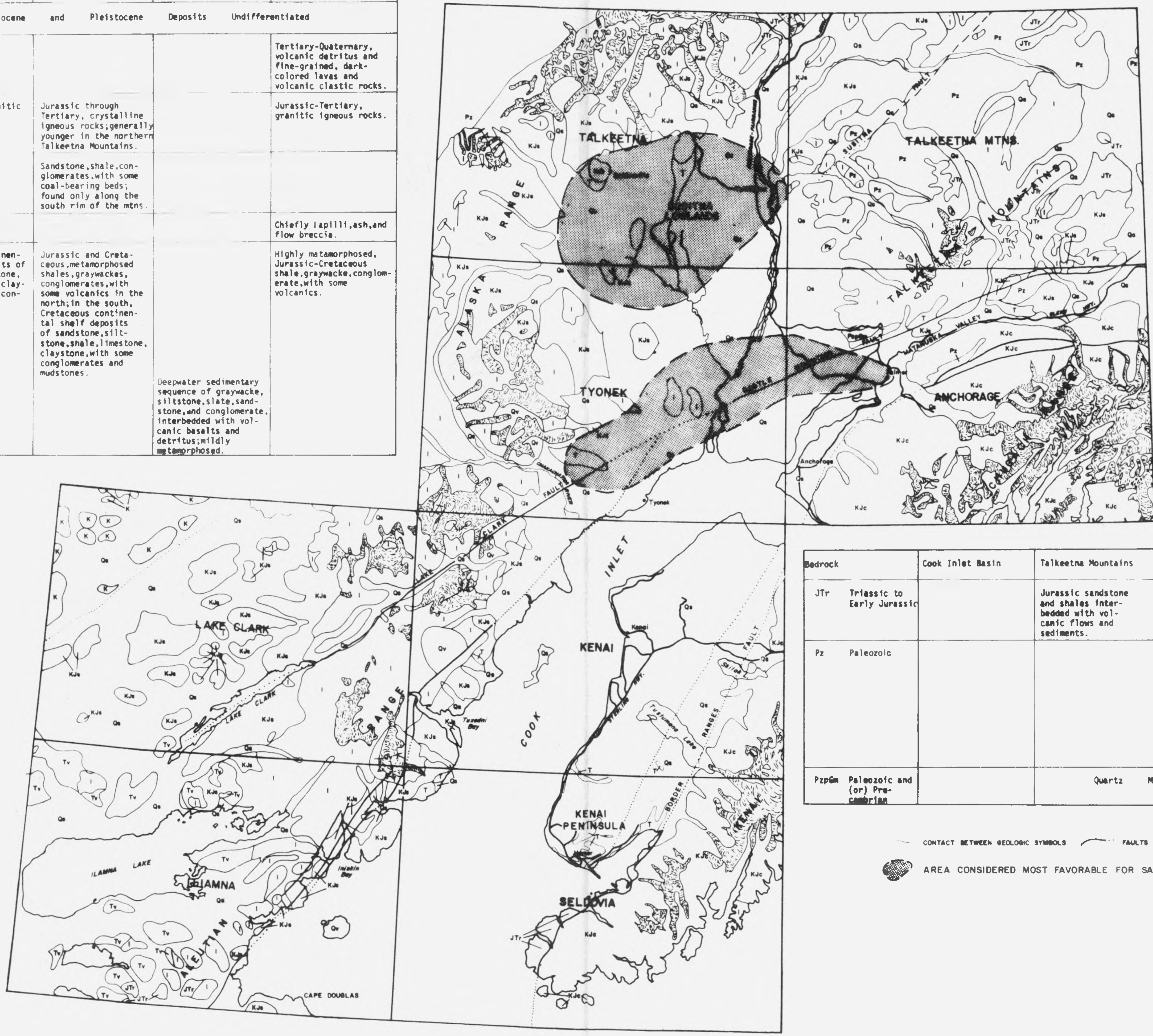
7.2 PRECAMBRIAN ROCKS (pzpCm)

The oldest known rocks in the region are Palezoic and/or Precambrian quartz-mica schist, formerly included in the Birch Creek schist, which underlies a 20 square mile area on the north side of the lower Matanuska Valley (fig. 7).

7.3 PALEOZOIC ROCKS (Pz)

An eugeosynclinal basin extended over much of south-central Alaska during Paleozoic time. The southern margin of the hinterland may have been as much as several hundred miles to the north of the Cook Inlet study area.

A northeast-trending belt of Paleozoic rocks crops out in the Talkeetna Mountains (fig. 7). Equivalents of these rocks probably occur beneath the Tertiary Cook Inlet Basin. The Paleozoic rocks (Pz) consist mainly of Pennsylvanian and Permian volcanics and local interbedded shallow water



Bedrock		Cook Inlet Basin	Talkeetna Mountains	Kenai-Chugach Mountains	Alaska-Aleutian Range
Qs	Surficial Deposits	Holocene and Pleistocene Deposits Undifferentiated			
Qv	Quaternary Volcanics				Tertiary-Quaternary, volcanic detritus and fine-grained, dark-colored lavas and volcanic clastic rocks.
I	Intrusives	Cretaceous, granitic igneous rocks.	Jurassic through Tertiary, crystalline igneous rocks; generally younger in the northern Talkeetna Mountains.		Jurassic-Tertiary, granitic igneous rocks.
T	Tertiary		Sandstone, shale, conglomerates, with some coal-bearing beds; found only along the south rim of the mtns.		
Tv	Tertiary Volcanics				Chiefly lapilli, ash, and flow breccia.
KJs	Mid-Jurassic to Late Cretaceous	Cretaceous continental shelf deposits of sandstone, siltstone, shale, limestone, claystone, with some conglomerates and mudstones.	Jurassic and Cretaceous, metamorphosed shales, graywackes, conglomerates, with some volcanics in the north; in the south, Cretaceous continental shelf deposits of sandstone, siltstone, shale, limestone, claystone, with some conglomerates and mudstones.		Highly metamorphosed, Jurassic-Cretaceous shale, graywacke, conglomerate, with some volcanics.
KJc	Late Jurassic to Cretaceous			Deepwater sedimentary sequence of graywacke, siltstone, slate, sandstone, and conglomerate, interbedded with volcanic basalts and detritus; mildly metamorphosed.	
JTr	Triassic to Early Jurassic		Jurassic sandstone and shales interbedded with volcanic flows and sediments.		
Pz	Paleozoic			Metamorphosed, dark-colored volcanic lavas and associated volcanic sedimentary rocks, with local shallow water sedimentary rocks. South of the Matanuska River these are largely covered by Tertiary sedimentary rocks. All are Pennsylvanian to Permian age.	Pennsylvanian-Permian, metamorphosed basalts and associated volcanics, sedimentary rocks, with some shallow water sedimentary rocks found locally.
PzpCm	Paleozoic and (or) Precambrian		Quartz Mica Schist		

CONTACT BETWEEN GEOLOGIC SYMBOLS — FAULTS (DOTTED WHERE INFERRED) — GLACIER

AREA CONSIDERED MOST FAVORABLE FOR SANDSTONE-TYPE URANIUM MINERALIZATION

AFTER ALASKA REGIONAL PROFILES, STATE OF ALASKA (1974)

WGM INC. MINING & GEOLOGICAL CONSULTANTS
ANCHORAGE, ALASKA

REGIONAL GEOLOGY
COOK INLET BASIN

Scale: 0 10 20 miles

Data By: WGM INC.

Date: APRIL, 1977

FIG. 7

sedimentary rocks. The Paleozoic belt and included Triassic(?) rocks are believed to be remnants of a volcanic island arc system. The predominant rock type is andesite, with interbedded phyllite and local marble lenses. The presence of very pure limestone lenses indicates deposition on local platforms during periods of volcanic quiescence.

In the northeast corner of the study area (plate 75A) early Paleozoic rocks are exposed. They consist of argillite, graywacke, phyllite, quartzite, slate, limestone and chert, ranging in age from Cambrian through Devonian. Highly metamorphosed clastic rocks of early Paleozoic or Precambrian age crop out near the east-central part of the study area (plate 85A).

Older (Devonian) Paleozoic rocks (Pz) are exposed on the west side of the Chulitna River along the foothills of the Alaska Range province near McKinley National Park and as far east as the extreme northwest corner of the Talkeetna Mountains quadrangle (fig. 7). Similar rocks are exposed along the foothills north of the Alaska Range in the northwest part of the Talkeetna quadrangle. The older rocks are characterized by a notable absence of volcanic lavas. Lithologies consist of limestone, conglomerate, slate, argillite and graywacke. Metamorphism is generally low grade.

Ultramafic rocks consisting of peridotite, dunite, and pyroxenite of Paleozoic and/or Mesozoic age crop out along the northern flank of the Chugach Mountains (fig. 7).

It is probable that the Paleozoic rocks contributed detritus to at least the Mesozoic section and in part to the Tertiary sedimentary rocks of the Cook Inlet Basin.

7.4 JURASSIC-TRIASSIC ROCKS (JTr)

Lower Mesozoic rocks are defined either as Triassic rocks or undifferentiated Lower Jurassic and Upper Triassic rocks.

It is difficult to assign ages to the older units. The rocks of different reported ages commonly are similar in appearance. Regional and local structural elements are poorly understood and large areas have not been mapped. It is likely that many so-called Precambrian, Paleozoic and lower Mesozoic rocks are improperly correlated and/or dated.

Jurassic-Triassic (JTr) layered rocks are reported at the southwest edge of the Kenai Peninsula (fig. 7) and at two areas in the Talkeetna Mountains quadrangle. Lithologies include shallow to deep water marine limestone, dolomite, chert, tuff, tuffaceous conglomerate and breccia, and shale.

Triassic rocks, because of their limited exposure and the scale of figure 7, are included with the Jurassic-Triassic rocks (JTr). Triassic volcanic rocks, chiefly basaltic lava, crop out along the northern margin of the Permian-Pennsylvanian belt described above (plate 76A). The lava is commonly amygdaloidal and locally contains interbedded volcaniclastic rock and conglomerate. Triassic rocks crop out along the southern tip of the Kenai Peninsula and Kamishak Bay area in the southern portion of the study area (plates 103A and 104A). Upper Triassic limestone, tuff, chert, tuffaceous conglomerate and breccia form the section in the Kenai Peninsula exposures. Late Triassic to Early Jurassic, shallow to deep water limestone, dolomite, shale and chert are exposed in the Kamishak Bay area on the west side of Cook Inlet.

7.5 CRETACEOUS AND JURASSIC ROCKS (KJc)

An undifferentiated sequence of rocks described as Cretaceous and Jurassic (KJc) underlies most of the Kenai-Chugach province along the east side of the Cook Inlet Basin. The rock units consist of a eugeosynclinal assemblage of siltstone, graywacke, slate, and argillite with lesser conglomerate, volcanic rock and associated ultramafic rock. The units are moderately metamorphosed locally to greenschist facies. The sequence is bounded on the west and north by major reverse faults, including the Border Range fault. Tertiary rocks crop out or underlie Quaternary sediments to the west and north of the western edge of the Cretaceous and Jurassic sequence with limited exceptions. Jurassic-Triassic rocks are in contact with Cretaceous and Jurassic rocks to the soutwest of Homer. A wedge of Paleozoic rocks is in fault contact with Cretaceous and Jurassic rocks to the east of Palmer.

7.6 CRETACEOUS AND JURASSIC ROCKS (KJs)

Cretaceous and Jurassic rocks (KJs) occur in the Matanuska Valley, the eastern Talkeetna Mountains, and along the foothills of the Alaska-Aleutian Range in the Talkeetna, Tyonek, and Iliamna quadranges. A narrow belt of Cretaceous and Jurassic rocks (KJs), considered to be early Jurassic through late Cretaceous, crops out along the western side of Cook Inlet from Cape Douglas to the Chakachatna River (fig. 7). The sequence from youngest to oldest includes:

Matanuska Formation
Naknek Formation
Chinitna Formation
Tuxedni Group
Talkeetna Formation

Detailed descriptions of the formations are presented in section 11. The assemblage is a predominantly marine sequence of sandstone, siltstone, shale, and volcanic flows and pyroclastic rocks as much as 25,000 feet thick. Most of the volcanic rocks occur in the oldest unit, the Talkeetna Formation. Rocks containing detritus derived from granitic sources occur in increasing abundance in the younger units. The Naknek Formation contains considerable granitic detritus in conglomerate and sandstone units. The arkosic units serve to record the first period of widespread unroofing of the Mesozoic granitic complex located in the Aleutian Range to the northwest (fig. 7).

Cretaceous and Jurassic (KJs) units of the eastern Talkeetna Mountains province are poorly studied. The Talkeetna Formation and the Naknek Formation are exposed in the lower Matanuska Valley. All five of the formations mentioned above are present in the upper Matanuska Valley and in the eastern Talkeetna Mountains.

Cretaceous and Jurassic rocks are undivided along the Alaska Range foothills. The lithologies described in the northern half of the map area (fig. 7), consist of argillite, shale, graywacke, conglomerate, lava, tuff, and agglomerate. Metamorphism ranges from moderate to intense (amphibolite facies).

The Cretaceous Matanuska Formation is included with the Cretaceous and Jurassic rocks. The unit is limited to exposures in the Matanuska Valley and the eastern part of the Talkeetna Mountains. The formation consists of moderately to severely folded marine shale and sandstone, and minor nonmarine units.

7.7 CRETACEOUS ROCKS (K)

Other Cretaceous rocks (K) are not of interest in the current study because they are found outside of the Cook Inlet Basin. They are restricted areally to the northwest corner of the Lake Clark quadrangle. Lithologies consist of sandstone, siltstone, shale, limestone, claystone, conglomerate, and mudstone. They are marine shelf deposits that range in age from Early to Late Cretaceous.

7.8 CENOZOIC ROCKS

Tertiary sedimentary rocks (T), predominantly nonmarine, have been distinguished from Tertiary volcanics (Tv) on the geologic map (fig. 7).

The sedimentary rocks, described in detail in section 11, were deposited in the Cook Inlet Basin. They have been studied in considerable detail by government agencies and private sector geologists, primarily for oil exploration, development and production.

The Tertiary section consists of the Kenai Group and four other formations that are, in part, equivalent to formations of the Kenai Group. The Tertiary Kenai Group is divided into five formations, from youngest to oldest as follows:

Sterling Formation
Beluga Formation
Tyonek Formation
Hemlock Conglomerate
West Foreland Formation

The lithologies consist mainly of nonmarine sandstone, siltstone, conglomerate, coal, and shale. Tuff and tufface-ous units are locally abundant in some formations. Detritus shed from the rising Aleutian and Alaskan Ranges occurs throughout the section. Tertiary rocks are the least meta-morphosed of the rocks in the study area.

The other four Tertiary formations occur mainly in the lower Matanuska Valley (fig. 7). They are named from youngest to oldest as follows:

Tsadaka Formation
Wishbone Formation
Arkose Ridge Formation and Chickaloon Formation

Lithologies are similar to those described for the Kenai Group. The Tsadaka and Wishbone Formations are considered lateral equivalents of Hemlock Conglomerate and West Fore-land Formation, respectively.

Tertiary rocks (T) in the northern Susitna Lowlands have not been given the extensive attention directed to the remainder of the basin. It is likely that the Tertiary rocks in the northern Susitna Lowlands are completely nonmarine because of slower subsidence of that area relative to the part of the basin located beneath Cook Inlet.

Tertiary volcanic rocks (Tv) occur mainly in the southwest-ern part of the study area (fig. 7). The volcanic rocks consist of rhyolite, trachyte, minor andesitic lava flows, tuffs, flow breccias, lapilli tuff, and ash. Tertiary basalt flows and associated pyroclastic flows exposed in the southern Talkeetna Mountains are not shown on the map.

7.9 PLEISTOCENE, QUATERNARY, AND HOLOCENE DEPOSITS (Q)

Unconsolidated Pleistocene, Quaternary, and Holocene deposits are abundant in the Cook Inlet Basin and along slopes of the highlands (fig. 7). Quaternary volcanics occur mainly in the southern Alaska Range and Aleutian Range provinces. They consist of andesitic flows and associated pyroclastic rocks deposited on the flanks of volcanoes.

7.10 CRYSTALLINE ROCKS

Crystalline rocks form the cores of the Aleutian Range, Alaska Range, and the Talkeetna Mountains. Few rocks of this nature occur in the Kenai and Chugach Mountains within the study area, and those that do, occur as relatively small isolated masses along the coastline in the Seldovia quadrangle (fig. 7).

The crystalline rocks of the Aleutian and Alaska Range provinces are considered together.

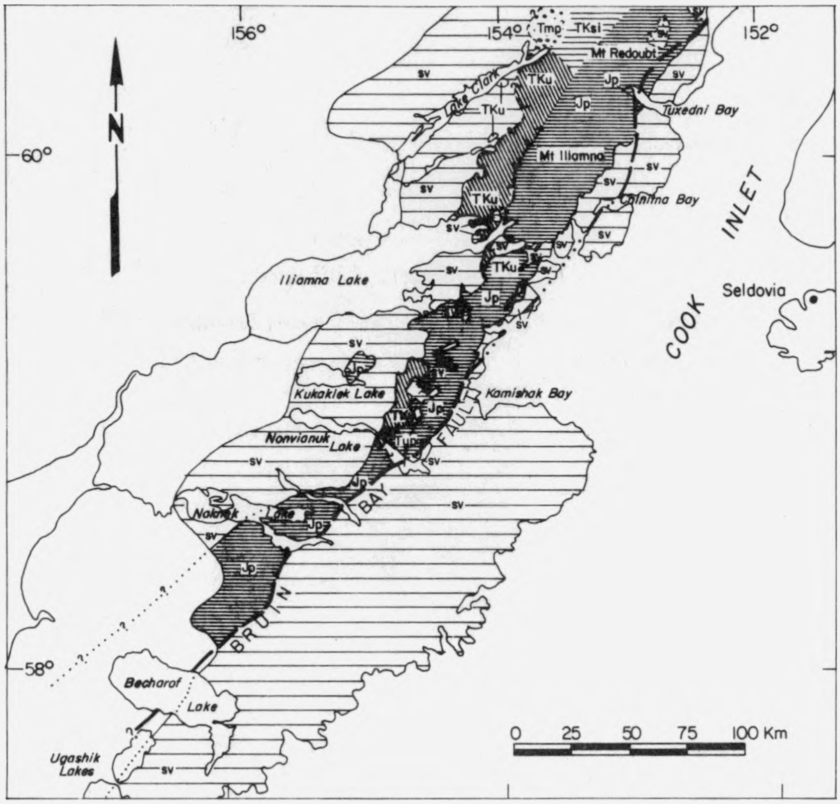
Alaska-Aleutian Range Batholith

The Alaska-Aleutian Range crystalline rocks are exposed along the west and northwest margin of the Cook Inlet Basin. Features discussed in the text are shown on figures 8 and 9.

Jurassic plutonic rocks are exposed to the south of Iliamna Lake, and in two belts located on the southeast side of the Chigmit Mountains. Cretaceous and Tertiary plutons are found primarily in the western and northwestern parts of the Alaska Range and between the two northern Jurassic belts in the Chigmit Mountains.

The Alaska-Aleutian Range crystalline complex consists of a variety of igneous rocks of Mesozoic and Tertiary age (figs. 8 and 9). The rocks were emplaced during three main episodes: Early and Middle Jurassic, 176-154 m.y.; Late Cretaceous-early Tertiary, 83-58 m.y.; and middle Tertiary, 38-26 m.y.; (Reed and Lanphere, 1973a). Compositions are mainly granitic with local grabbroic phases.

The Jurassic crystalline rocks are generally more mafic than the younger intrusives. Rocks rich in potassium feldspar are predominant in plutons of Cretaceous and Teriary age. Subordinate amounts of potassium feldspar-rich rocks of Jurassic age also occur. Quartz-plagioclase-potassium feldspar modal and normative trends are toward more quartz in Jurassic suites but toward more potassium feldspar and only slightly increasing quartz in the younger suites (Reed and Lanphere, 1969).



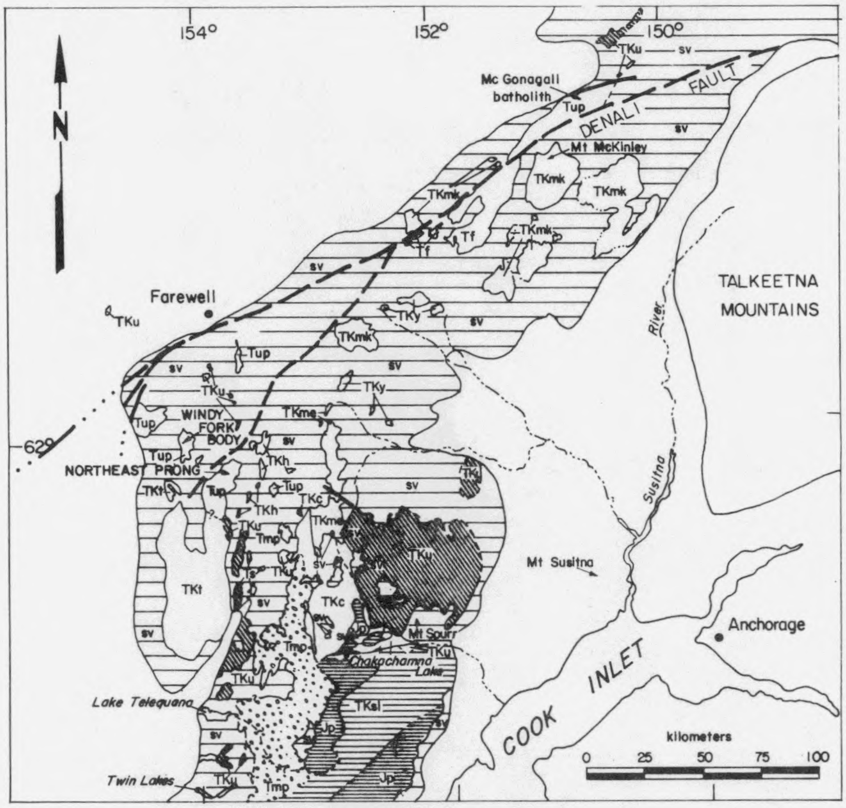
DESCRIPTION OF MAP UNITS

Tup	Unassigned plutonic rocks
Tmp	Merrill Pass sequence
Tf	Granodiorite of Mt. Foraker
Ts	Snowcap sequence
TKmk	McKinley sequence
TKt	Quartz monzonite of Tired Pup
TKc	Crystal Creek sequence
TKh	Hartman sequence
TKme	Granodiorite of Mt. Estelle
TKy	Yentna sequence
TKsl	Summit Lake rocks
TKu	Undivided plutonic rocks
Jp	Quartz diorite & granodiorite northwest of Cook Inlet
sv	Sedimentary & volcanic rocks of Paleozoic to Tertiary age

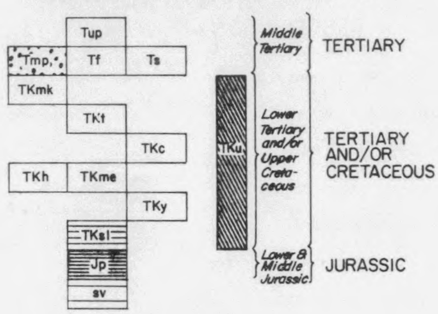
See fig. 9 for correlation of map units

Modified from Reed and Lanphere (1972)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H. / DATA BY: / DATE: 9/77	REVISED	GEOLOGIC MAP OF THE ALEUTIAN RANGE PLUTONIC ROCKS
SCALE: AS INDICATED			FIGURE 8 BX150



CORRELATION OF MAP UNITS



See fig.8 for description of map units

Modified from Reed and Lanphere (1972)

WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	GEOLOGIC MAP OF THE ALASKA RANGE PLUTONIC ROCKS	FIGURE 9
SCALE: AS INDICATED	DATA BY:			BX151
	DATE: 9/77			

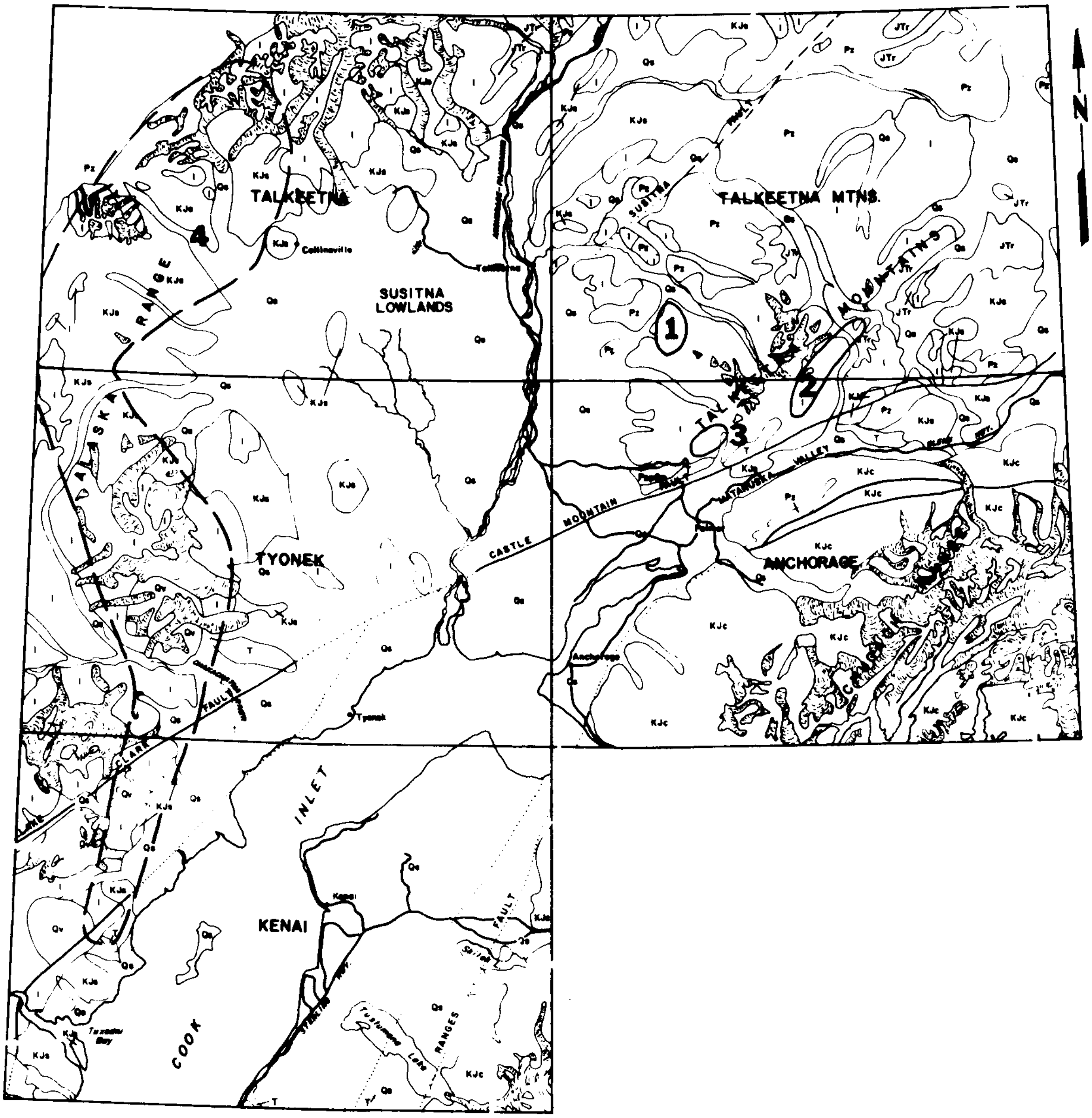
Twenty-four Alaska-Aleutian Range batholithic rocks were examined in thin section. The rock samples were collected by United States Geological Survey geologists during field seasons from 1966 to 1976 (fig 10, area 4). Unfortunately, many thin sections cut from samples of Cretaceous and Tertiary plutonic rocks were not available for study.

Jurassic Intrusives: The Jurassic plutons of the Alaska-Aleutian Range batholith are similar in age and composition to those of the batholithic complex in the Talkeetna Mountains. The Jurassic rocks range in composition from gabbro to adamellite, with quartz diorite and granodiorite most common. Granodiorite compositions are predominant in the southern Jurassic exposures. No thin sections of the southern Jurassic rocks were examined during the study.

Specimens from three Jurassic intrusives located to the north of Tuxedni Bay were examined in thin sections (figs. 8 and 9). One section consists of very fresh hornblende tonalite with accessory magnetite and apatite. The rock appears to be representative of the more mafic intrusives in the area (Detterman, Reed and Lanphere, 1965). A second thin section is of a biotite adamellite from a body intruding the Talkeetna Formation south of Chakachamna Lake. The adamellite is composed of quartz, orthoclase, and plagioclase with minor biotite and some interstitial perthite. Accessory minerals include zircon, sphene, apatite, opaques, and two grains of allanite. Zircons produce only moderately developed metamict haloes. Alteration is minor, with slight chloritization of biotite and patchy sericitization of feldspars. The third thin section of Jurassic rock studied is a hornblende pyroxene syenite collected northeast of Chakachamna Lake from what is thought to be a Jurassic roof pendant in a Tertiary pluton. Only small amounts of apatite, zircon, and opaques occur as accessories; however, considerable amounts of sphene are present, probably the result of metamorphism.

The overall Jurassic pluton lithologies are too mafic to be considered good sources of uranium for derivative sediments. However, the more felsic differentiates may contain sources of intergranular uranium or uranium in accessory minerals such as the allanite, zircon, and sphene observed in the few thin sections studied.

Cretaceous and Tertiary Intrusives: B. L. Reed (1972) and co-workers in the Alaska-Aleutian Range batholith have recognized and dated a number of distinct Cretaceous and Tertiary plutons (figs. 8 and 9). Some of the plutons probably were emplaced at shallow depths, and a few may have vented to produce some of the pyroclastic rocks observed in younger Cook Inlet Basin sedimentary rocks. The shallower



AFTER ALASKA REGIONAL PROFILES, STATE OF ALASKA, (1974)

1,2,3,4 INDICATE AREAS REFERRED TO IN TEXT

SEE FIG. 7 FOR EXPLANATION OF SYMBOLS

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY M.H. / DATA BY C.C. / DATE 4/77	REVISED	AREAS REPRESENTED IN PETROGRAPHIC STUDY
SCALE 0 10 20 30 40 miles			FIGURE **10** BX140

intrusives studied in thin sections are the Crystal Creek sequence and the McKinley sequence near Cathedral Spire. Thin sections of other McKinley sequence rocks, the Mt. Estelle granodiorite, and undivided plutonic rocks were also studied. Some of the latter may be related to the Crystal Creek sequence.

Plutons dated as Late Cretaceous to Early Tertiary include the Summit Lake rocks, the Mt. Estelle granodiorite, the Hartman sequence, the Yentna sequence, the Tired Pup pluton, the Crystal Creek sequence, and the McKinley sequence (Reed and Lanphere, 1973a).

The Summit Lake rocks to the south of Chakachamna Lake are quartz diorites to adamellites. According to Reed and Lanphere (1973a), the rocks are mineralogically similar to some of the Jurassic rocks of the Alaska-Aleutian Range.

The Mt. Estelle plutons and the Hartman and Yentna sequences are quartz diorites to adamellites. Accessory tourmaline and gold-bearing quartz-sulfide veins have been reported from the Mt. Estelle bodies. A thin section of the Mt. Estelle granodiorite contains abundant blue and brown tourmaline and accessory opaques, zircon, and sphene. An abundance of late muscovite and the corroded nature of the feldspar are indicative of alteration probably related to hydrothermal processes.

The Tired Pup pluton and the Crystal Creek and McKinley sequences consist of leucocratic early Tertiary adamellites and granites, with biotite rarely exceeding 10%. Accessory hornblende occurs in the place of biotite in some Crystal Creek rocks. Thin sections of the McKinley sequence studied are biotite adamellites, two-mica adamellites, and tonalite.

The McKinley sequence pluton exposed in the Cathedral Spires area, is a biotite adamellite that contains quartz, zoned plagioclase, and coarse perthitic orthoclase. Accessory minerals include fluorite, allanite, zircon, and apatite. Zircon and allanite grains produce well-developed metamict haloes in biotite. Biotite grains have lost all of their original structure in some cases. Alteration is minor to moderate with sericitization of feldspars, chloritization of biotite and secondary carbonate. Similar biotite adamellites occur in other McKinley sequence plutons, but the thin sections do not contain as many accessory minerals as do the examples sited above.

The McKinley sequence two-mica adamellites are similar to the biotite adamellites, but contain minor muscovite as well as biotite. Plagioclase is often myrmekitic. Alteration is very minor with only small amounts of secondary mica. Zircon, apatite, and traces of opaques are the only accessories observed.

The McKinley sequence tonalite studied in thin section is composed of quartz, plagioclase, biotite, hornblende, and interstitial microcline. Accessory minerals include apatite, sphene, zircon, allanite, and traces of garnet. Metamict haloes in biotite are faint and other alteration appears limited to minor amounts of deuteric epidote.

Middle Tertiary Crystalline Rocks: Quartz diorite to granite intrusive rocks include the Merrill Pass sequence, the Windy Fork pluton, and the northern part of the Tired Pup pluton (figs. 8 and 9). The Merrill Pass sequence is predominatly granite to adamellite with some fine-grained phases that display granophyric and perthitic intergrowths. It is likely that at least the northern portion of the sequence vented (Reed and Lanphere, 1973a). The Windy Fork body is a granite anomalously high in beryllium, tin and niobium. Eudialyte is abundant in late-stage quartz-amphibole-potassium feldspar pegmatite veins. The Tired Pup pluton is dominantly adamellite in composition, although the northern portion has some biotite granite as well. Rocks in the northeast prong of the Tired Pup body are slightly enriched in silica.

Undivided Cretaceous and Tertiary Intrusives: Several intrusives, located in an area north of Chakachamna Lake mapped by Reed and Lanphere (1973a) as undivided Cretaceous and Teritary plutonic rocks, were studied in thin sections (figs. 8 and 9). The rocks range in composition from alkali granite to tonalite. It is likely that some of the intrusives around the Tordrillo Mountains vented (Reed and Lanphere, 1973).

The most felsic rocks examined in thin section include a coarse-grained arfvedsonite alkali granite and a biotite granite. Both rocks have accessory opaques and zircon. The alkali granite also contains allanite. The rocks are almost unaltered although the biotite granite has some secondary muscovite and chlorite.

Most of the undivided Cretaceous and Tertiary cystalline rocks studied in thin section fall into the adamellite compositional range. One thin section of adamellite shows minor to moderate alteration of the feldspars, chloritized mafics and patchy secondary carbonate. The rock contains accessory allanite, zircon, apatite and opaques. There is essentially no development of metamict haloes. A second thin section of adamellite contains accessory zircon, opaques, and traces of apatite and garnet. Except for a few metamict halos around zircons in biotite, the rock is unaltered.

Other thin sections of biotite adamellite and biotite-hornblende tonalite were studied. The tonalite contains accessory zircon, apatite and opaques. A thin section of adamellite has one very large grain of allanite. Metamict haloes around zircons in biotite are small. The tonalite is unaltered, but the adamellites have minor alteration of feldspar and patchy chlorite and chloritization of biotite.

Some of the Cretaceous and Tertiary intrusives may have contributed significant amounts of uranium in granitic detritus to the Cook Inlet Basin sediments. Felsic compositions are more common in the younger age suites. Allanite and zircon also appear to be more common in the younger rocks and uranium could occur in these accessory minerals. Several of the younger intrusives are thought to have vented and shed pyroclastic material into the basin. Any uranium associated with the pyroclastic material would have been deposited directly in the basin providing a second mechanism for addition of uranium to sedimentary formations.

Talkeetna Mountains Batholith

Less information is published regarding the nature of the intrusives in the Talkeetna Mountains batholithic complex than for the Alaska-Aleutian batholithic complex. The United States Geological Survey is currently involved in a study of the Talkeetna Mountains and some of the results of that study should be released during 1977. The Talkeetna complex is considered separately, although there is reason to believe that this batholith and the Alaska-Aleutian batholith are connected beneath the northern margin of Cook Inlet (Grantz, 1963b).

The Talkeetna Mountains batholithic complex formed during two intrusive episodes. Radiometric dates range from 160 m.y. to 165 m.y. for the age of the batholith as determined from rock samples of eastern exposures (Grantz, 1963a). The western and southern portions of the complex are considered to be of Late Cretaceous to early Tertiary age.

The batholith is composite although the number and nature of the plutons is not known. Predominant rock types known to occur are tonalite, quartz diorite, granodiorite, granite, and subordinate diorite and gabbro.

Petrographic studies by Csejtey (1974) of crystalline rocks from the western portion (fig. 10, area 1) of the complex indicate that typical tonalite is a coarse- to medium-grained granitic textured rock with fairly well-developed flow foliation. Mineralogically, the rocks are composed of andesine (An_{38}), quartz, hornblende and biotite (in clusters), and subordinate interstitial orthoclase. Accessory minerals include sphene, magnetite, apatite, and zircon. Alteration is restricted to minute amounts of epidote, chlorite, and sericite.

Late stage alaskite dikes are associated with the tonalites and quartz diorites of Csejtey's study area. These rocks are medium- to fine-grained with irregular and aplitic textures in the dikes and granitic texture in the cores of larger bodies. The alaskites are composed of oligoclase, microcline, quartz, biotite, subordinate hornblende, and accessory apatite, magnetite, and sphene. Myrmekitic intergrowths of oligoclase and potassium feldspar are common. Alteration in some rocks consists of moderate sericitization of feldspars and chloritization of mafics.

Thin sections were studied of rocks from the Talkeetna Mountains batholithic complex acquired from the Alaska State Division of Geological and Geophysical Surveys. The rocks were collected during the 1973 and 1974 field seasons from the northern Anchorage quadrangle and southern Talkeetna Mountains quadrangle. The rocks studied fall generally into two compositional groups: a mafic suite of tonalites and granodiorites and a felsic suite of granitic rocks (fig. 10, area 2).

The tonalites and granodiorites are medium- to coarse-grained, granitic textured rocks with moderate flow foliation present in some specimens. The rocks examined consist of andesine, quartz, hornblende, minor biotite and muscovite and subordinate orthoclase or microcline. The plagioclase, usually An_{35-40}, is twinned and normal zoning is common. Occasionally interstitial plagioclase has a myrmekitic texture. Quartz has undulatory extinction in virtually all grains. Hornblende is pleochroic in bluish-green or dark green to light brown, locally poikilitic with feldspar and black opaques. Biotite and muscovite occur separately or intergrown with each other. Orthoclase and microcline are normally interstitial. Accessory minerals include sphene, apatite, magnetite, pyrite, and trace amounts of tourmaline. Alteration in the mafic suite varies from very minor deuteric sausseritization and sericitization to very low grade metamorphism. Chlorite, calcite, white mica, albite, epidote, and less frequently pumpellyite, are the most common metamorphic products.

The felsic suite includes microcline granite, alaskitic granite, two-mica granite and adamellite. Compositions are apparently gradational into the more leucocratic of the granodiorites discussed in the preceding paragraphs.

The felsic suite is comprised of fine- to coarse-grained, granitic to slightly porphyritic textured rocks, with some aplitic and pegmatitic dikes. The rocks are composed of quartz, plagioclase, orthoclase or microcline, and muscovite and/or biotite. Quartz is a major phase in all but one of the rocks studied, a quartz-bearing monzonite. The calcic plagioclase may be andesine (An_{30-35}) or oligoclase (An_{25-30}). Most grains are twinned. Larger grains are normally zoned and have poikiltic and myrmekitic textures. Albite is an important constituent in the alkali granites, and also occurs as the rim composition in some andesine and oligoclase grains in other rock types. Orthoclase and microcline occur interstitially and as anhedral to subhedral grains. Microcline is commonly perthitic and occurs in graphic intergrowth with quartz in microcline granite pegmatite. Orthoclase and microcline occur together in two fairly alkaline granites. Muscovite and biotite occur separately or intergrown with each other. Most granitic rocks are either muscovite-, or muscovite- and biotite-bearing. Garnet, zircon, sphene, tourmaline, apatite, pyrite, magnetite and ilmenite constitute the accessories. Metamict varieties of sphene and a mineral tentatively identified as allanite have been recognized in two rocks in trace amounts. Minor deuteric alteration of feldspars is present in most samples. Minor silicification was recognized in two samples. Epidote, chlorite, calcite and rarely zeolites are products of low-grade metamorphism common in many of the thin sections studied.

A quartz diorite intrusive is cut by pegmatites near the southwestern portion of the batholithic complex (fig. 10, area 3). Lamprophyre and diabase dikes are common in this area; aplite dikes occur less commonly. The pegmatite dikes are typically irregular and discontinuous, ranging from less than 1 inch to 2 feet in width. More than 20 pegmatites were tested for radioactivity and found to average 0.004 percent eU_3O_8 (Moxham and Nelson, 1952). Mineralogic study of the pegmatites indicates that the radioactivity is attributed to the presence of one or more of the following minerals:

Uraninite	$(U^{+4}{}_{1-x}, U^{+6}{}_{x})O_{2+x}$
Thorite	$ThSiO_4$
Cyrtolite	$ZrSiO_4$
Allanite	$(Ca,Ce,Th)_2(Al,Fe,Mg)_3\ Si_3O_{12}(OH)$

The lamprophyre, diabase, and aplite dikes were also examined, but no radioactivity anomalies were noted.

Moxham and Nelson (1952) concluded that the radioactive pegmatite minerals do not occur in sufficient quantity to be a commercial source of uranium mineralization. It is possible, however, that uranium leached from the Cretaceous-Tertiary intrusive could have provided significant amounts of uranium to the nearby Tertiary sediments.

Any uranium in sediments derived from the batholithic complex may come from several other sources as well. Uranium may be easily released from biotite and hornblende or carried in the more refractory accessory minerals such as zircon, apatite, or sphene. It appears that a higher background source for uranium would be the alaskitic rocks because uranium and thorium have been correlated with higher Si and K contents and lower Ca and Mn contents in the magmatic series (Malan and Sterling, 1969). It is known that leachable uranium occurs in granites:

1. As primary uranium minerals.
2. Isomorphically admixed in metamict phases of primary minerals.
3. Absorbed on crystal surfaces.
4. In liquid inclusions and interstitial waters.

The metamict sphene and allanite occurrences in rocks from area 2 (fig. 10) may be of importance. Feldspars and quartz in the thin sections studied contain abundant bubbles that may have provided a source of uranium, probably as dissolved U^{+6} in liquid inclusions.

Kenai - Chugach Mountains

The Tertiary intrusives in the southernmost portion of the Kenai-Chugach Range are local features that are not of importance to the study. They are chiefly granodiorite intrusives and any detritus derived from them would be transported away from the Cook Inlet Basin into the present Gulf of Alaska.

8. STRUCTURE

Major faults in the Cook Inlet region include the Denali fault, Castle Mountain fault, and Lake Clark fault (fig. 5). Offset along the Denali fault east of Mt. McKinley indicates 400 km of right lateral movement since post Cretaceous time (Gedney, 1975). In contrast Grantz (1966) determined that offset along the Denali Fault, west of Mt. McKinley, is only 110-115 km. It is probable that the large component of strike slip movement determined for the eastern portion of the Denali fault, is relieved along related faults to the west such as the Susitna fault.

Cenozoic displacement along the west end of the Denali fault (Farewell segment) is chiefly dip slip. Locally the displacement is up on the north (in excess of 2.5 km) while recent fault scarps indicate uplift (2.5 meters) on the south side of the fault in the same area (Grantz, 1966). The McKinley segment shows evidence of right lateral displacement (30 km) during this same recent period.

Several kilometers to several tens of kilometers of right lateral displacement since Late Cretaceous is indicated along the eastern portion of the Castle Mountain fault system. Similar but less movement is indicated along the Lake Clark portion of the fault system. In the Matanuska Valley the Castle Mountain fault shows evidence of dip slip movement. The north side of the fault has been uplifted as much as 10,000 feet locally since late Tertiary (Detterman and others, 1976).

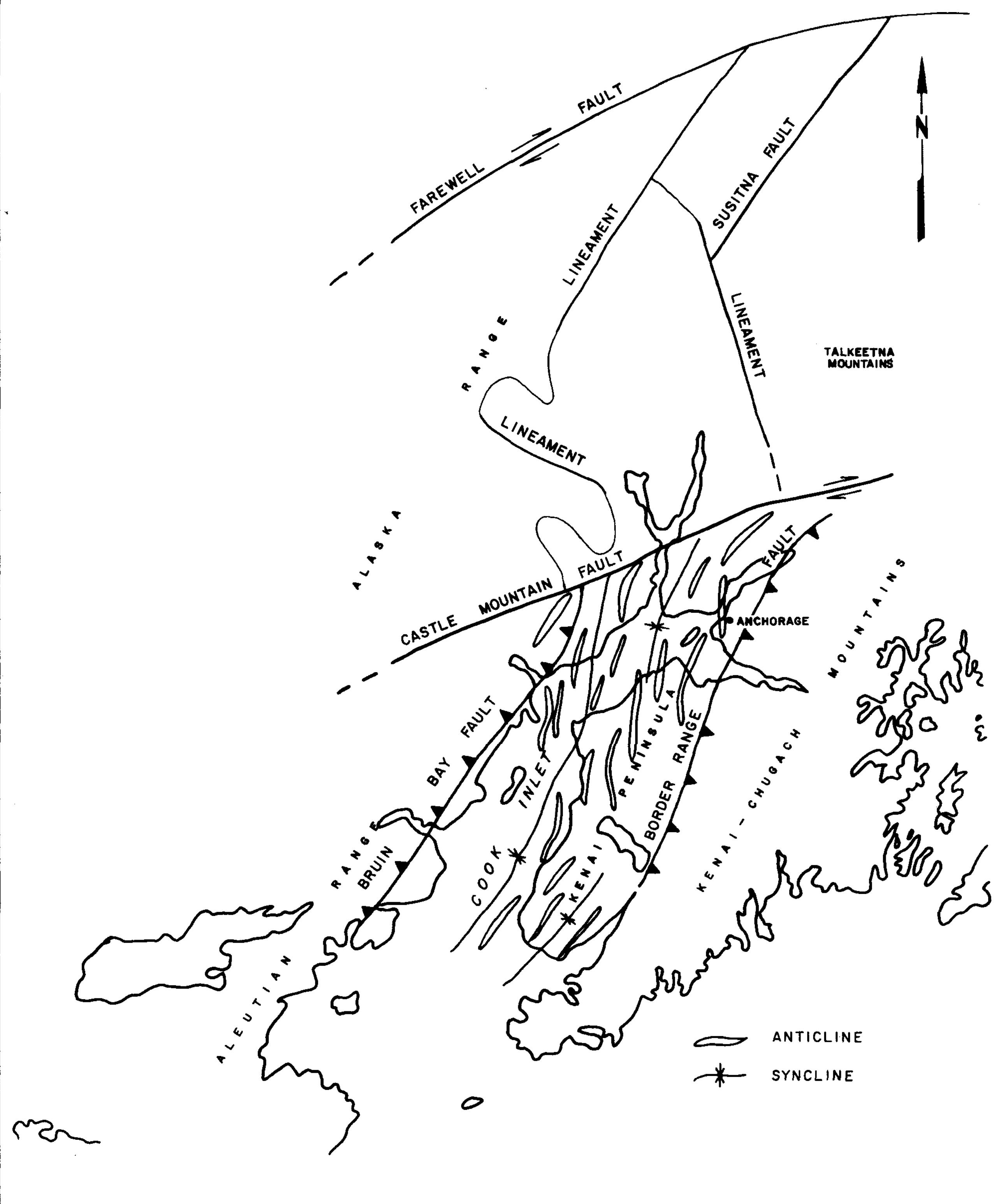
The Cook Inlet Basin consists of two grabens separated by the Castle Mountain fault (fig. 11). The graben north of the fault trends north-south. The larger graben south of the fault trends N 30° E.

South of the Castle Mountain fault the Tertiary sedimentary rocks have been folded into an en echelon series of anticlines. According to Kirschner and Lyon (1973), the Tertiary sedimentary beds within the basin have been shortened about 5 miles from a total of 72 miles by orogenesis during late Tertiary to Holocene time. The folds trend subparallel to the basin. They are asymmetrical with steep west flanks that are commonly faulted (Kirschner and Lyon, 1973). Anticlines underlying the Kenai Peninsula generally follow the trend of the basin while those near the Castle Mountain fault appear to have been influenced by the right lateral movement along the fault. Kirschner and Lyon suggest that continental underthrusting along the Aleutian Trench could account for the structural deformation of Tertiary sediments in the Cook Inlet Basin.

The nature of deformation of the Tertiary rocks north of the Castle Mountain fault is not known because of limited exposures and lack of geologic study.

Mesozoic rocks underlying the Tertiary sedimentary rocks are similarly deformed. Less is known about the details of deformation in these rocks because they have not been of primary interest as petroleum resevoirs. In general, it appears that the degree of deformation of the sedimentary rocks in the Cook Inlet Basin increases with age of the rocks.

Known uranium districts such as the Shirley Basin and Gas Hills of Wyoming, South Texas, and the San Juan Basin of New Mexico, are characterized by gentle dips and minor folding and faulting of the host sandstones. This structural characteristic is considered important in the development and preservation of geochemical roll fronts responsible for



Modified from Kirschner & Lyon, (1973)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	GENERALIZED STRUCTURE OF COOK INLET BASIN	FIGURE 11
SCALE: 20 0 40 miles	DATA BY: C.C.			
	DATE: 4/77			8X137

uranium mineralization. Structurally, the Cook Inlet Basin is more complex than other basins known to contain districts of sandstone-type uranium mineralization. Whether this alone is enough to preclude the formation of uranium deposits is yet to be determined.

9. TECTONIC OVERVIEW

9.1 GENERAL

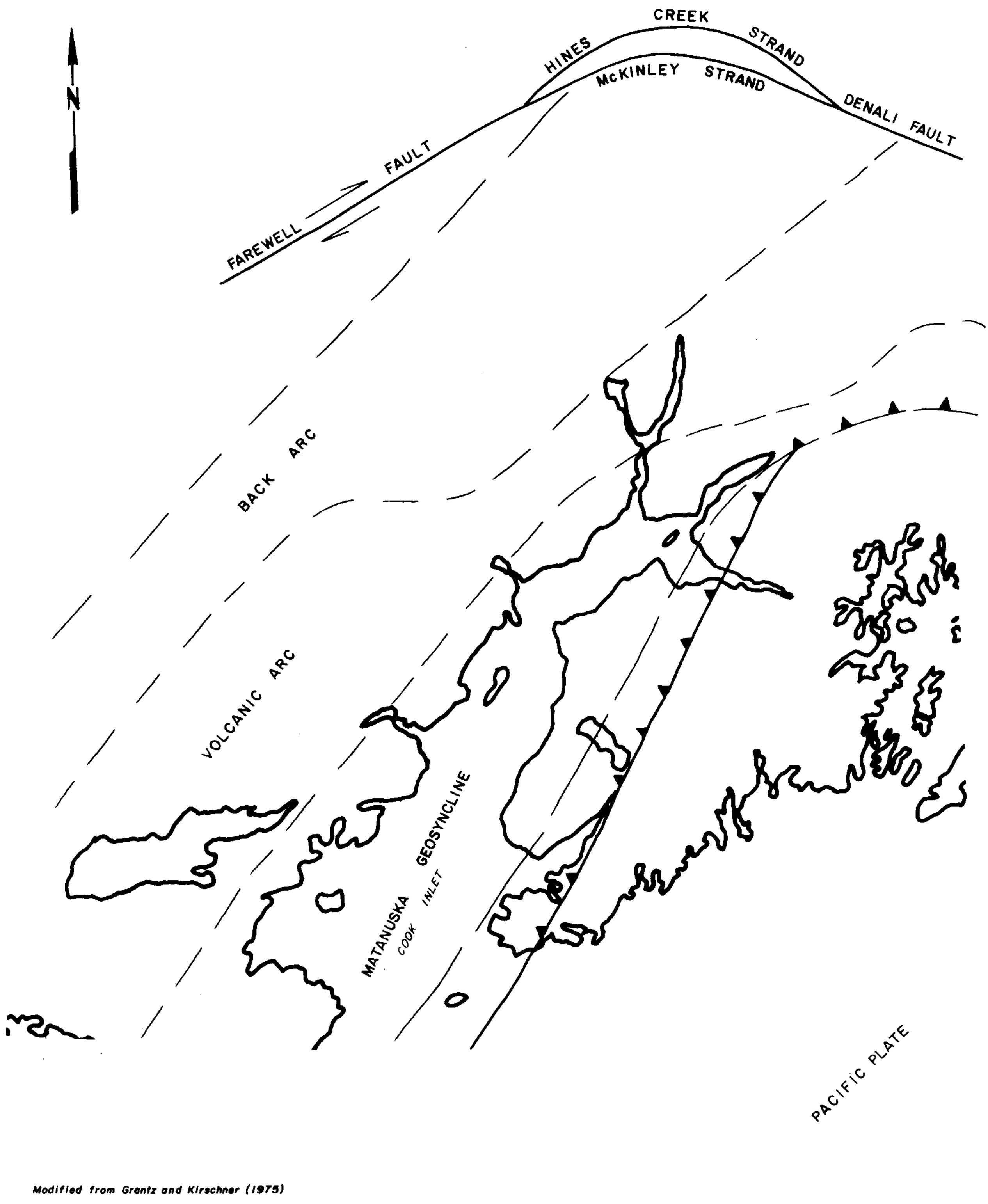
The southern Alaska province consists of a complex of arcuate mountain ranges, linear lowlands, and a narrow continental shelf whose structural trends reflect the influence of the Alaska orocline and subduction along the Cenozoic Aleutian arc. Payne (1955), Kelley (1963), Gates and Gryc (1963), and Grantz and Kirschner (1975), have described the tectonic framework of the region. The following paragraphs summarize the major tectonic elements active from Mesozoic through Tertiary time.

From the Late Triassic and Early Jurassic through the Early Cretaceous, southcentral Alaska experienced the first of a series of orogenic events that marked a major change in geologic conditions. Broad geosynclinal basins filled with clean limestone and associated sediments were deformed into relatively narrow elongate troughs and uplifts. The Precambrian(?) and Paleozoic rocks were severely deformed and metamorphosed to varying degrees, including local granitization. The arcuate trends of the Mesozoic basins and uplifts suggest a strong influence by underlying Precambrian and Paleozoic structures (Churkin, 1973). The Matanuska geosyncline and bordering features developed in the Cook Inlet-Susitna Lowland region at the culmination of the orogeny.

The second major orogeny characterized by uplift and erosion commenced in Late Cretaceous time and continued into the Paleocene. The Cook Inlet Basin, which in large part is superimposed on a portion of the earlier Matanuska geosyncline, developed in the course of the later orogeny. Vigorous mountain building in fringing areas accompanied basin subsidence. The Late Cretaceous to Paleocene orogeny was followed by a third period of uplift and erosion in the Oligocene.

9.2 JURASSIC-EARLY CRETACEOUS OROGENIES

A series of arc-trench systems had developed by Late Jurassic time in the region (fig. 12). A Middle to Late Jurassic eugeosyncline represented by the rock sequence in the Kenai-Chugach Mountains province was succeeded to the north by back-arc and arc-trench gap basins, which in turn were



Modified from Grantz and Kirschner (1975)

WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY: MH	REVISED	TECTONIC FRAMEWORK OF SOUTHERN ALASKA MESOZOIC
SCALE: 20 0 40 miles	DATA BY: C.C.		FIGURE 12
	DATE: 4/77		BX125

succeeded further to the north by the continental terranes of northern Alaska. The Mesozoic Matanuska geosyncline arc-trench gap basin and the Aleutian volcanic arc developed along the north side of the Jurassic eugeosyncline, and are genetically related to it.

Cretaceous and Jurassic rocks (KJs) that extend across the study area from Cape Douglas to the Matanuska Valley (fig. 7) accumulated along the northern margin of the Matanuska geosyncline (fig. 12). The Jurassic and Cretaceous units, which include the Talkeetna Formation, Tuxedni Group, Chinitna Formation, Naknek Formation and Matanuska Formation, are described in sections 11.1 and 11.2.

The total thickness of Jurassic and late Cretaceous rocks in the deepest portion of the geosyncline is thought to exceed 4.5 kilometers (Reed, 1973). Later underflow of the Pacific Plate beneath the Matanuska geosyncline and bordering eugeosyncline resulted in moderate to locally intense deformation and significant foreshortening of the sediment deposits.

The Aleutian volcanic arc was undergoing uplift and plutonic activity during the initial stages of the Early mo Middle Jurassic orogenic disturbance. Volcanic activity, characterized by explosive eruptions and lava flow, was most prevalent during early Jurassic time. Much of the volcanic episode is recorded by the presence of lava and tuff units at various stratigraphic intervals throughout the Talkeetna Formation. The age of the granitic intrusives in the Aleutian volcanic arc province is placed at 176 to 154 m.y., which coincides with the early depositional period of the Talkeetna Formation sedimentary and volcanic rocks.

Granitic clasts from unroofed plutonic rocks in the Gaikema Sandstone Formation of the Tuxedni Group mark the first known occurrence of granitic debris in Middle Jurassic sedimentary rocks. Granitic clasts in conglomerate facies of the Naknek Formation mark the earliest evidence of unroofing to the north in the Talkeetna Mountains province (Grantz, 1963).

Sedimentation was dominantly marine from the Middle Jurassic through the Cretaceous. The Mesozoic section is almost complete. Rocks of Aptian (middle Early Cretaceous) age are absent (fig. 13). The hiatus during this stage is probably due to regional uplift and erosion.

9.3 LATE CRETACEOUS-EARLY TERTIARY OROGENY

Subduction of the Pacific Plate along the Aleutian Trench commencing in Late Cretaceous or early Tertiary time (fig. 14) caused uplift of the Cook Inlet region and the formation

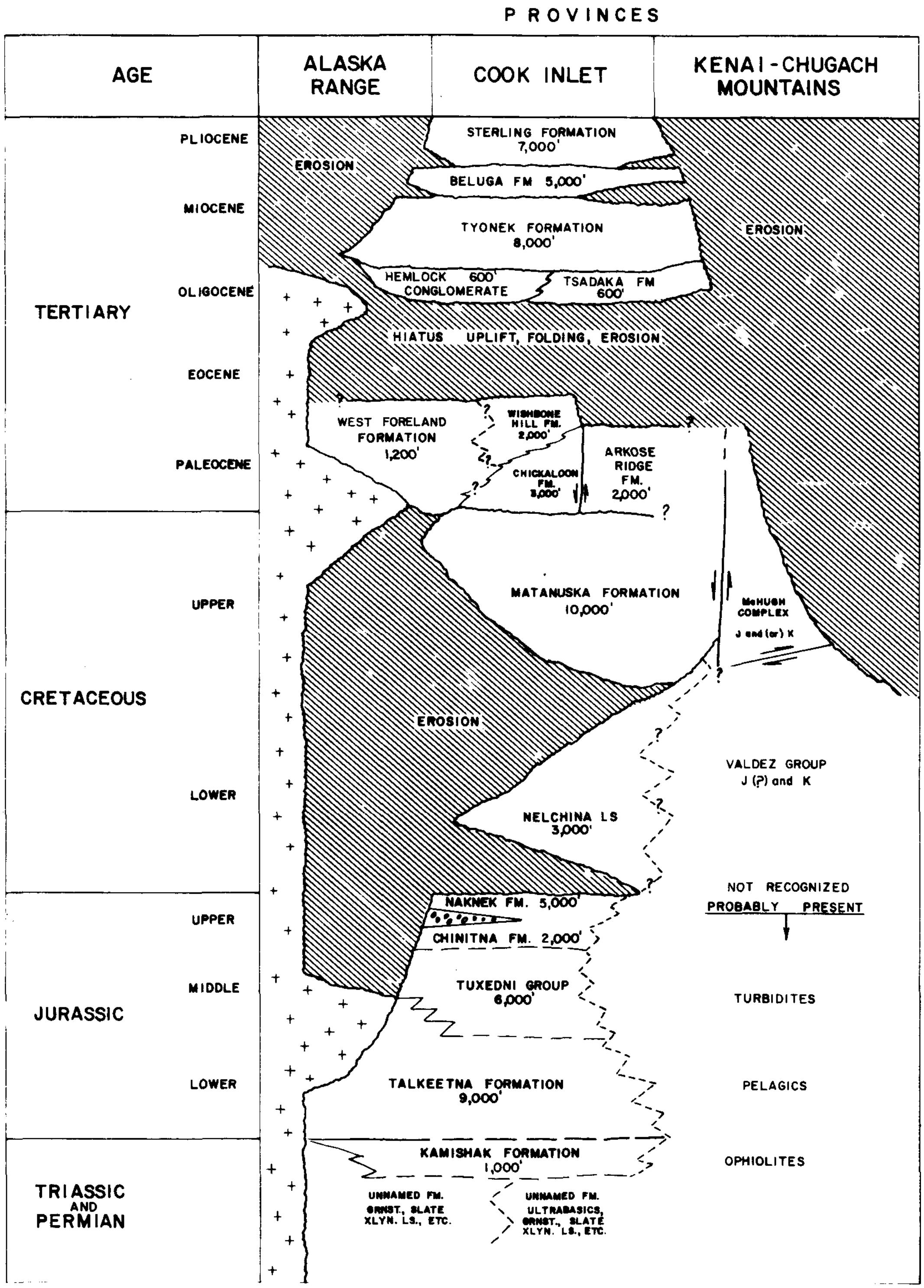
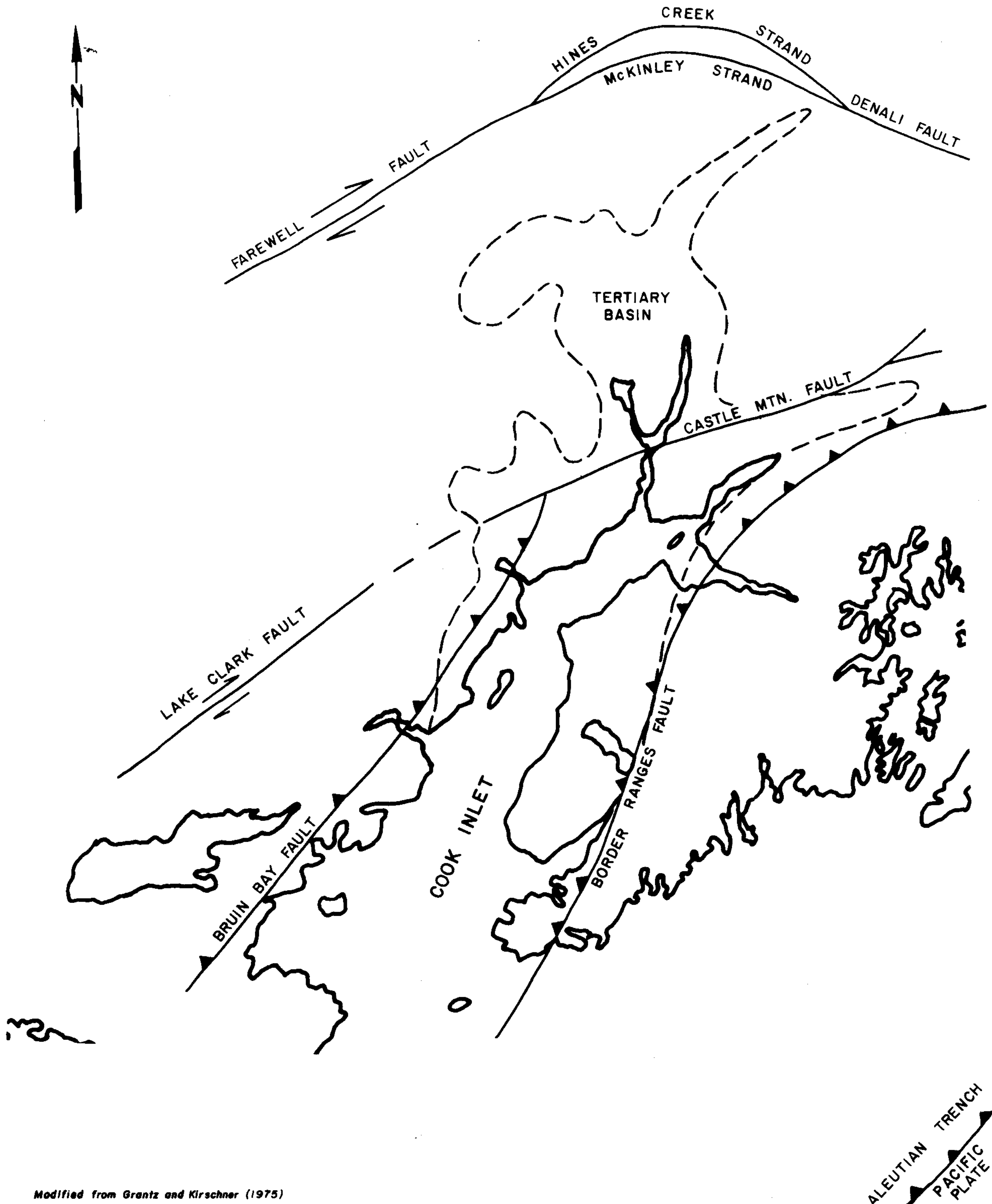


Chart does not represent any particular cross-section through the basin. The Arkose Ridge Formation is not known to occur between the Chickaloon Formation and the Kenai-Chugach Mountains. It is shown on this chart in this fashion only to point out the stratigraphic relationship between the Arkose Ridge Formation and the Chickaloon Formation.

WGM INC	MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	CORRELATION CHART OF MESOZOIC THROUGH TERTIARY SEDIMENTARY ROCKS IN THE COOK INLET BASIN	FIGURE 13
MODIFIED FROM KIRSCHNER & LYON (1973)		DATA BY: C.C.			8X130
		DATE: 4/77			



Modified from Grantz and Kirschner (1975)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA

SCALE: 20 0 40 miles

DWN BY: M.H. | REVISED
DATA BY: C.C.
DATE: 4/77

TECTONIC FRAMEWORK OF SOUTHERN ALASKA
TERTIARY

FIGURE 14
BX129

of a Tertiary continental basin. Strong to moderate deformation of Mesozoic sediments in the inactive Matanuska geosyncline accompanied the orogeny.

The Tertiary Cook Inlet Basin formed as a graben superimposed over the Matanuska geosyncline. The Tertiary basin crosses older tectonic trends in the Susitna Lowland area. Subsequent uplift has produced the present day intermontane basin bordered to the west by the Aleutian volcanic arc province, to the north by the Alaska Range province, to the east by the Talkeetna Mountains province, and to the southeast by the Kenai-Chugach Mountains province.

Granitic intrusives, generally less mafic than Middle Jurassic plutons, were emplaced during the Late Cretaceous to early Tertiary orogeny. Reed and Lanphere (1973) have determined that the Tertiary intrusives range in age from 83 to 58 m.y. The time of earliest unroofing is unknown; however, the presence of Paleocene Arkose Ridge sedimentary rocks resting on the erosional surface of a Tertiary-Cretaceous pluton, located a few miles to the north of Palmer, (plate 85A) allows for some speculation. The composition of Arkose Ridge sedimentary rocks indicate that the sediments may have been derived from the erosion of the intrusive upon which the Arkose Ridge formation rests. The association suggests rapid unroofing of the intrusive in that part of the Cook Inlet region. Furthermore, because of the close association between tuffs and sedimentary uranium deposits, it is significant to note that volcanism was again active in Paleocene and Eocene time. Sediments of the West Foreland Formation are commonly tuffaceous, and lava flows occur locally within the unit. The frequency of tuffs and tuffaceous units in the formation indicate that volcanism was limited chiefly to explosive eruptions from volcanoes that were probably located in the Alaska-Aleutian Range region.

9.4 MIDDLE TERTIARY OROGENY

Early Tertiary and older rocks were uplifted and eroded during early Oligocene time. Nonmarine sedimentary rocks including the Hemlock Conglomerate, Tsadaka, Tyonek, Beluga and Sterling Formations were deposited after the orogeny and vary in gross composition in response to the differential uplift of the surrounding highlands. The Beluga Formation differs from the other formations because much of its sediment was derived from metasedimentary rocks that comprise the Kenai-Chugach Mountains. The other formations contain significantly more granitic detritus.

Middle and upper Tertiary volcanic episodes are well recorded in sedimentary rocks of the Tyonek and Sterling Formations. Volcanism is represented by pyroclastic rocks indicating a period, or periods of explosive eruptions.

9.5 SUMMARY

The tectonics of southern Alaska are complex. The region was warped into belts of erosion and deposition during Mesozoic time, probably as a consequence of interaction between oceanic and continental lithospheric plates. A second period of tectonic activity during Early Cretaceous time is characterized by uplift and erosion. A third period of deformation commenced near the end of the Cretaceous and continued into the Paleocene. The nonmarine Cook Inlet basin of primary interest for sandstone-type uranium favorability began to develop at this time. The last major orogenic event occurred in middle Oligocene time in reaction to the continued underthrusting of the contintental plate. The subduction zone between the continental and oceanic plates migrated further south in succeeding orogenic periods to its present location (fig. 14).

10. OVERVIEW OF URANIUM FAVORABILITY

10.1 GENERAL STATEMENT

Two regional-scale environments are recognized as permissive to the occurrence of uranium deposits in the Cook Inlet Basin and the bordering crystalline belts. Uranium may occur in the plutonic environment as a normal rock constituent or as hydrothermal concentrations. Too little information about most of the crystalline highland terranes is available to speculate on the possible presence or absence of features favorable for uranium occurrences.

The more obvious permissive environments are in continental sedimentary rocks, at least in part derived from erosion of the unroofed plutons. Several features generally recognized as favorable for occurrence of uranium deposits are displayed in a number of Cook Inlet Basin continental sedimentary units.

Most of the Cook Inlet regional geologic data have been collected during petroleum investigations and not for the purpose of assisting in uranium appraisals. A relatively large amount of useful information on the stratigraphy of units important in the development and production of petroleum resources is available. Sufficient information is available to provide a basis for determining if additional studies directed specifically toward uranium appraisal of the continental sections in the Cook Inlet Basin are warranted.

Lithologic studies have provided the most extensive and most useful data for the Cook Inlet-Susitna Lowlands uranium appraisal. The data have been collected by others at selected areas of outcrop and from well logs. The areas most extensively studied are closest to the oil-producing environments in the southern part of the Cook Inlet Basin. The northern area (Susitna Lowlands) has been investigated in far less detail.

Oil industry gamma ray logs, representing sections that are buried to several thousand feet, provide information of limited value for the purposes of the current study. Radioactivity data available from surface appraisals are limited to the ones discussed under section 4.5. The usefulness of this data is limited because of the general nature of some of the reports on radioactivity, the types of samples collected, the low values of radioactivity and the fact that most of the values are given as equivalent uranium. Preliminary studies of mineral districts or deposits near the margins of the Cook Inlet Basin provide a moderate source for additional information.

It is with the limitations outlined above that the overview of uranium favorability is presented.

10.2 CRITERIA UTILIZED TO DETERMINE URANIUM FAVORABILITY

The Cook Inlet Basin includes marine to nonmarine sedimentary rocks contaminated with volcanic debris and in some places interbedded with volcanic rocks. Prospective host rocks for uranium consist of Jurassic to Tertiary nonmarine and marginal marine sections. The continental sedimentary rocks exhibit features similar to those present at productive sandstone-type uranium districts and deposits. In table 2, which is a summary of regional factors influencing possible uranium deposits, characteristics considered to be most significant are indicated by an "X" and subordinate factors are indicated by "O". The table presented by Grutt (1972) has been expanded to include additional occurrences.

Table 3 shows favorable regional environmental factors of the various formations appraised in the current study. The table is patterned after table 2 for comparison purposes. Local or detailed characteristics are not included in table 3 because of lack of sufficient information for many of the sedimentary units.

Local factors considered in the study, for lithologies where adequate information is available, include the following:

1. Grain size and sorting
2. Sand/shale ratio
3. Presence of iron sulfide (pyrite or marcasite)

URANIUM DISTRICTS

REGIONAL GEOLOGIC CRITERIA

REGARDED AS FAVORABLE

TABLE 2*

ENVIRONMENTAL FACTORS		Uranium Areas, Lisbon Valley, Utah	Monument Valley-White Canyon Arizona-Utah	Uravan Mineral Belt, Colorado	Ambrosia Lake, New Mexico	Black Hills, Wyoming-South Dakota	Gas Hills, Wyoming	Powder River Basin, Wyoming	Texas Gulf Coast	Maybell-Baggs, Colorado-Wyoming	Tono Mine Area, Japan	Obermoschel Area, West Germany	Lodeve Basin, France	Mecsek Mountains, Hungary	Healy Basin, Alaska
Age of Host Rock	Permian	o										x	x	x	
	Triassic	x	x												
	Jurassic			x	x										
	Cretaceous					x									
	Tertiary						x	x	x	x	x				x
Depositional Environment of Host Rock	Terrestrial-aeolian									o					
	Fluvial-coalesced alluvial fan			x	x		x	o						x	
	Fluvial-stream channel and flood plain	x	x	x	o	x	o	x	x	x		x	x	x	x
	Marginal marine: deltaic lagoonal barrier bar					o			x						
Provenance of Host Rock	Granite and metamorphic rocks	x	x	o	x		x	x	o	o	x		x	x	x
	Sandstones and shales			x	x	x	o	o	x	x					
	Limestones	o				o			o						
	Acid Volcanic Centers-tuffs	o	o	o			o		x	o	o	x	x		o
Special Strati-graphic Factors	Unconformity superjacent		x			x	x	x	x						o
	Unconformity subjacent	x	x			x	x	x	x	x			x		x
	Tuffaceous sediments in section above host	x	x	x	x	x	x	x	x	x	x	x			x
	Host sandstone unconformably overlies granite or acid volcanic										x				
Type of Host Rock	Feldspathic or arkosic sandstone	x	x	o	x		x	x	o		x		x	x	
	Quartzose sandstone			x		x			x	x					x
	Tuffaceous or bentonitic sediments present within host	x	o				o	o	x	x	x	x	x		
Tectonic Element	Intracratonic basins	x	x	x	x	x	x	x		x					x
	Geosynclinal								x						

X--Dominant or of Primary Importance
O--Subordinate or of Secondary Importance
OPEN SPACE - Factor Is of Doubtful Significance, Absent, or Does Not Apply.

Modified After Grutt, 1972

*Information in available literature is not sufficiently detailed to allow a more comprehensive breakdown.

FORMATIONS AND MEMBERS OF COOK INLET BASIN

REGIONAL GEOLOGIC CRITERIA REGARDED AS FAVORABLE

TABLE 3

ENVIRONMENTAL FACTORS		Talkeetna Formation	Marsh Creek Breccia	Portage Cr. Agglomerate	Horn Mountain Tuff	Tuxedni Group	Red Glacier Formation	Gaikema Sandstone	Fitz Cr. Siltstone	Cynthia Falls Sandstone	Twist Cr. Siltstone	Bowser Formation	Chinitna Formation	Tonnie Siltstone	Paveloff Siltstone	Naknek Formation	Chisik Conglomerate	Snug Harbor Siltstone	Pomeroy Arkose	Matanuska Formation	Arkose Ridge Formation	Chickaloon Formation	West Foreland Formation	Wishbone Formation	Hemlock Congl.	Tsadaka Formation	Tyonek Formation	Beluga Formation	Sterling Formation
Age of Formation or Member	Permian																												
	Triassic																												
	Jurassic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X										
	Cretaceous																			X									
	Tertiary																				X	X	X	X	X	X	X	X	X
Depositional Environment of Formation or Member	Terrestrial-aeolian																												
	Fluvial-coalesced alluvial fan																				X	X	X	X		X	X	X	X
	Fluvial-stream channel and flood plain																				X	X	O	O	O	O	X	X	X
	Marginal marine;deltaic-lagoonal barrier bar						O										O	O	O				O		X				
Provenance of Formation or Member	Granite and metamorphic rocks					O	O	X	O	O	O	O	O	O	O	X	X	O	X	X	X	X	X	X	X	X	X	O	X
	Sandstones and shales																											O	
	Limestones																												
	Acid volcanic centers-tuffs	X	X	X	X	X	X	O	X	X	X	X	X	X	X	O	X	X		O			O				O		O
Special Strati-graphic Factors	Unconformity superjacent to Fm-Mem.	X			X					O	X		X			X			X	X		X	X	X			X	X	
	Unconformity subjacent to Formation-Member					X	X					O				X				X	X	X	X	X		X	X	X	X
	Tuffaceous sediments in section above Fm-Mem.																								X			X	
	Host sandstone unconformably overlies granite on acid volcanic																				X		O						
Common Type of Facies	Feldspathic or arkosic sandstone				X		O	X	O	O		O					O		X		X		O	X		X	O		X
	Quartzose sandstone											O							X							X	O		O
	Tuffaceous or bentonitic sediments present within facies			X	X														O				O				X		X
Tectonic Element	Intermontane basin																				X	X	X	X	X	X	X	X	X
	Geosynclinal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									

X--Dominant or of Primary Importance
O--Subordinate or of Secondary Importance
OPEN SPACE* - Not Reported, Does Not Apply, or of Questionable Importance.

*Information in available literature is not sufficiently detailed to allow a more comprehensive breakdown.

4. Local structure
5. Presence of organic material
6. Presence of alteration and bleaching

Uniform evaluation of lithologies, facies, areas, and units is not possible considering the substantial disparities in the available data. Also, evaluations of any one formation are based on combined exposures that make up only 1% of the total land mass (14,700 square miles) in the basin and less than 0.6% of the total area of the basin (26,000 square miles). Setting priorities of favorability criteria in comparing the various lithologies is subject to reordering as more information becomes available. Following completion of additional study it is likely that presently undifferentiated and poorly studied exposures in certain areas will be demonstrated to contain features considered favorable for uranium deposition.

10.3 RELATIONSHIP OF ADJACENT BASE AND PRECIOUS METALS MINERALIZED AREAS TO URANIUM FAVORABILITY OF THE COOK INLET BASIN

Base and precious metal deposits adjacent to the Cook Inlet Basin occur in the Alaska and Aleutian Ranges, Talkeetna Mountains, and the Kenai-Chugach Mountains. Intrusive rocks in the above-named provinces, except the Kenai-Chugach Mountains, were sources of sediment for Cretaceous and Tertiary clastic formations of the Cook Inlet Basin. Some of the Jurassic plutons that were unroofed apparently contributed detritus to Middle and Upper Jurassic sedimentary rocks. Although no uranium or thorium mineralization has been reported in the preliminary studies of the source areas, the presence of base and precious metals indicates that late-stage magmatic differentiation and hydrothermal activity were operative. The presence of these mineralized source areas enhances the favorability of the resulting sedimentary rock, particularly the clastic rocks located near the mineralized areas.

The Jurassic plutons in parts of the Aleutian Range that served as sources of sediment to the Cook Inlet Basin appear to be unmineralized and chemically unfavorable for uranium mineralization. The younger crystalline rocks of the Alaska Range and the Talkeetna Mountains, on the other hand, are mineralized and are more favorable as prospective sources for uranium. Gold, silver, copper, and molybdenum are associated with the younger intrusives at a number of localities. The better known mineralized intrusives are in the Chulitna-Yenta Mineral Belt in the foothills of the Alaska Range and in the Willow Creek District in the Talkeetna Mountains. The Willow Creek gold mineralization is associated with a Late Cretaceous quartz diorite (Reed and Lanphere, 1969). Uranium mineralization is reported in pegmatite dikes that intrude the quartz diorite, but the low uranium content (0.005% eU) and sporadic nature of the dikes probably precludes the occurrence of a significant deposit in the area (appendix F and plate 85C).

The Chulitna-Yentna Mineral Belt extends from Collinsville in the Talkeetna quadrangle northeastward to near Cantwell, located just south of Mt. McKinley National Park (fig. 7). The area is in foothills of the Alaska Range province. Hawley and Clark (1973) have summarized the geology and mineral deposits of the belt. Sedimentary and volcanic rocks are intruded by numerous igneous bodies ranging in composition from ultramafic to granitic. The mineral deposits are epigenetic and appear to be related to intrusive rocks. Arsenic and gold are common throughout the belt with local concentrations of copper, tin, antimony, bismuth, and silver. Other metals include zinc, lead, tungsten, chromium, nickel, and molybdenum. No uranium or thorium mineralization is reported in the lode deposits. The best-known mineralization consists of base metal sulfides and gold at the Golden Zone mine, which has been interpreted to be a breccia pipe and/or a structural intersection-controlled deposit.

Uranium and thorium have been reported in heavy mineral concentrates from placer operations in the Yentna District (plate 75C). Equivalent uranium values ranging from 0.001% to 0.237% are reported in concentrates (Robinson and others, 1955). However, the higher values could not be duplicated by later studies (Robinson and others, 1955). Robinson and co-workers conclude that the uranium and thorium are present in resistate minerals such as monazite, zircon, and uranothorianite. The original source of the radioactive minerals is unknown, but the composition of the gravels indicates the Alaska Range granites and the nearby Peters Hills and Dutch Hills slates and graywackes are significant contributors to the gravel deposits.

There appears to be no direct correlation between the lode mineral deposits of the Chulitna-Yentna Mineral Belt and the radioactive placer concentrations. Concentration of heavy resistates from erosion of large areas of radioactive granites would provide a source of uranium. Prospective sources include unroofed crystalline rocks exposed in the Alaska Range as well as granitic bodies along the Chulitna-Yentna Mineral Belt. The presence of uranium-bearing minerals in sediments available for leaching enhances the possibility for the occurrence of sandstone-type deposits in the Tertiary sedimentary rocks of the Susitna Lowlands.

The Shirley Lake radioactive occurrence(s) is in tuff and tuff breccia of unknown age. Regional geologic maps show that the area is underlain by Middle Jurassic to Late Cretaceous sedimentary rocks. If the tuffs are of Cretaceous or Tertiary age it is probable that they contain significant amounts of uranium available for leaching.

11. STRATIGRAPHY AND URANIUM FAVORABILITY

11.1 JURASSIC

Rocks of Jurassic age occur throughout the study area. In the northwestern portion of the region (plates 84A, 75A, and 76A) the Mesozoic section is not well studied and is not subdivided. Jurassic rocks probably comprise a significant portion of the undivided Mesozoic rocks shown on the plates. In general the rocks range in age from Early Jurassic to Late Cretaceous and consist of argillite, shale, graywacke, conglomerate, tuff and agglomerate. Lower Jurassic rocks are moderately to highly metamorphosed, either as a result of mid-Jurassic and later plutonic episodes, or oceanic-continental plate interaction. Jurassic rocks have been studied in greater detail in the southwestern portion of the region along the west side of Cook Inlet (plates 93A, 94A and 103A) and in the east-central part of the region in the eastern Talkeetna Mountains (plates 76A and 85A). In these areas the Jurassic section has been divided into four formations, from youngest to oldest as follows:

Naknek Formation
Chinitna Formation
Tuxedni Group
Talkeetna Formation

Much of the information used in the following section is taken from Detterman and Hartsock's (1966) work because it is a relatively complete summary of all the detailed studies on the Jurassic section in the Cook Inlet Basin.

11.1.1 TALKEETNA FORMATION

The Talkeetna Formation is the oldest sequence of layered rocks that are described in detail in this report. The formation is Early Jurassic in age and is subdivided locally into three members (table 4) as follows:

Horn Mountain Tuff (upper)
Portage Creek Agglomerate
Marsh Creek Breccia (basal)

TABLE 4

STRATIGRAPHIC UNITS IN THE INISKIN-TUXEDNI REGION, ALASKA
(Modified from Detterman and Hartsock, 1966)

Period	Epoch		Unit	Thickness (feet)
Quaternary	Recent		Alluvial deposits	0-100+
			Littoral deposits	0-50+
	Recent and Pleistocene		Colluvial deposits	0-400+
			Glacial deposits	0-100+
	Pleistocene		Iliamna flows	80-400+
			Residual deposits[1]	0-20+
Tertiary	Middle(?) to late(?)		Flows	0-300+
	Oliogocene(?) and Miocene		Kenai Formation	0-1,085
Jurassic	Late	Naknek Formation	Pomeroy Arkose Member	850-3,300+
			Snug Harbor Siltstone Member	720-860
			Lower Sandstone Member	0-840
			Chisik Conglomerate Member	0-560
		Chinitna Formation	Paveloff Siltstone Member	900-1,370
			Tonnie Siltstone Member	820-1,310
	Middle(?) and Late	Tuxedni Group	Bowser Formation	1,250-1,830
	Middle		Twist Creek Siltstone	0-420
			Cynthia Falls Sandstone	600-765
			Fitz Creek Siltstone	640-1,280
			Gaikema Sandstone	500-880
			Red Glacier Formation	1,980-4,540
	Early(?) and Middle		Aleutian Range Batholith	
	Early	Talkeetna Formation	Horn Mountain Tuff Member	1,800-2,850
			Portage Creek Agglomerate Member	2,250-2,850
			Marsh Creek Breccia Member	1,850-3,350
Triassic	Late(?)		Metamorphic Rocks Undivided	160-1,300±

[1]Range in age from Tertiary through Recent.

The above units have been studied for many years in the Iniskin-Tuxedni region because the Jurassic section is well exposed and oil seeps in these rocks attracted the earliest petroleum exploration efforts (fig. 7, plates 93A, 103A, and 104A). Previous investigators are Martin (1905), Martin and Katz (1912), Martin (1926), Moffit (1927), Detterman and Hartsock (1966), and Lyle and Morehouse (1977). Undivided equivalents of the members have been studied in the eastern Talkeetna Mountains (Capps, 1927; and Grantz, 1960), and the lower Matanuska Valley (Barnes and Payne, 1956; and Barnes 1962).

The Talkeetna Formation is present at the base of several wells along the west side of Cook Inlet in the West Foreland and Tyonek areas (plates 84B and 94B). The depth of the wells is generally in excess of 8,000 feet. The formation is present on the east side of the inlet in the bottom of the Atlantic Richfield Co. Swan Lake Unit No. 2 (plate 84B). Few other wells have penetrated Jurassic rocks on the east side of the inlet and the rocks have not been identified according to formation status. The Talkeetna Formation is exposed in the lower Matanuska Valley, the eastern Talkeetna Mountains the south side of Kachemak Bay, and the Iniskin-Tuxedni region (fig. 7).

The formation is generally bedded and is mainly of volcanic origin, particularly in the lower Matanuska Valley. Lithologies include tuff, lava, and greenstone. Grantz (1960) described the formation in the eastern Talkeetna Mountains as a marine sequence of sandstone, argillite, and lava and pyroclastic rock of intermediate composition. The sedimentary rocks are found to be dominant in the upper part of the sequence in the Talkeetna Mountains. The rocks are folded and faulted and bedding dips are commonly greater than 15°.

The formation is bounded by unconformities. In the Iniskin-Tuxedni region the Talkeetna Formation rests unconformably on Triassic metamorphic and granitic rocks and is overlain by the Middle Jurassic Tuxedni Group. The lower Matanuska Valley section of the Talkeetna Formation is overlain unconformably by Cretaceous and Tertiary sedimentary rocks. The formation is unconformably overlain by the Tuxedni Group in the eastern Talkeetna Mountains.

The thickness of the formation varies from 7,000 feet in the Iniskin-Tuxedni region to an unknown thickness in the eastern Talkeetna Mountains. Grantz (1960) estimated the eastern Talkeetna Mountain exposures of the formation to be several thousand feet. The thickness of the formation on the east side of the inlet is not known.

The Talkeetna Formation is well exposed in the Iniskin-Tuxedni region and much is written on the stratigraphy of the area. The section consists of marine layered rocks that are commonly folded and faulted and dip to the southeast at 15° to 20° beneath Cook Inlet (fig. 15). The Iniskin-Tuxedni region is the only area where the Talkeetna Formation is subdivided into three members. The history and stratigraphy of the members is summarized by Detterman and Hartsock (1966).

Marsh Creek Breccia Member

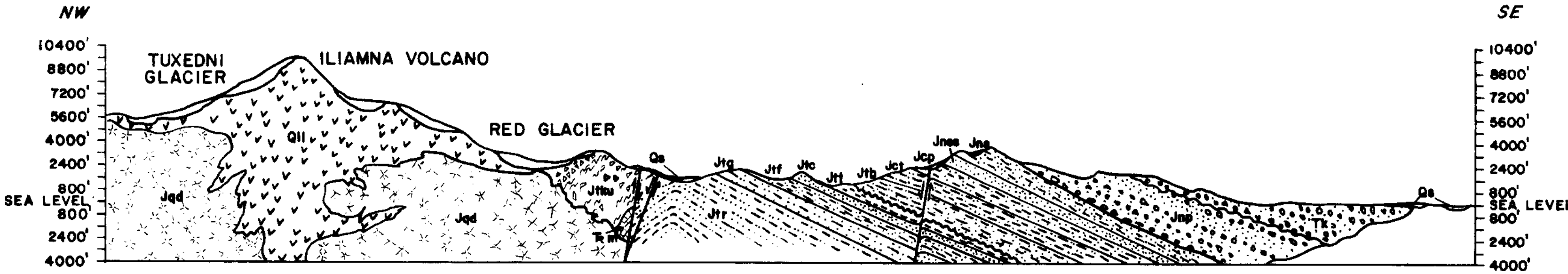
The mapped portions of the Marsh Creek Breccia Member cover approximately 25 square miles of the basin. No attempt was made to show the individual members of the Talkeetna Formation on the plates because of the scale of these figures.

The stratigraphic contact between the Marsh Creek Breccia Member and the Triassic metamorphic rocks is not understood clearly because of obscure contact relationships. Detterman and Hartsock (1966) suggest the contact is an unconformity. The upper contact with the Portage Creek Agglomerate Member is faulted in many exposures and conformable in a few.

The Marsh Creek Breccia Member consists of lava, volcanic breccia, tuff, and greenstone. The thickness varies from 1,850 to 3,350 feet. The type section of the Marsh Creek Breccia was studied by Arthur Grantz and J. K. Hartsock in 1951, and by R. W. Juhle in 1951 and 1952. The following type section (plate 94A, measured section 1) description is taken from Detterman and Hartsock (1966):

Type section of Marsh Creek Breccia Member along south shore of Tuxedni Bay

	Thickness (feet)
Fault.	
Marsh Creek Breccia Member:	
Volcanic breccia, massive, coarse, green, tuff matrix; green aphanitic lava flow in upper part.	400
Lava flow, bedded, aphanitic, green; porphy ritic sill near middle; unit cut by minor fault.	250
Volcanic breccia, massive, medium to coarse, green, several dikes and a green aphanitic lava near base.	850
Lava flow, aphanitic, green.	150
Greenstone.	250
Lava flow, aphanitic, green.	150
Covered.	350
Lava flow, aphanitic, green.	50



EXPLANATION

SURFICIAL DEPOSITS

Qs — Alluvial deposits

BEDDED ROCKS

PLEISTOCENE — Qll — Iliamna Lava flows

OLIGOCENE(?) & MIOCENE — Tk — Kenai Formation

UPPER JURASSIC
- NAKNEK FORMATION
  - Jnp — Pomeroy Arkose Member
  - Jns — Snug Harbor Siltstone Member
  - Jnss — Lower Sandstone Member
- CHINITNA FORMATION
  - Jcp — Paveloff Siltstone Member
  - Jct — Tonnie Siltstone Member

MIDDLE(?) & UPPER JURASSIC — Jtb — Bowser Formation

MIDDLE JURASSIC — TUXEDNI GROUP
- Jtt — Twist Creek Siltstone
- Jtc — Cynthia Falls Sandstone
- Jtf — Fritz Creek Siltstone
- Jtg — Gaikema Sandstone
- Jtr — Red Glacier Formation

LOWER JURASSIC — TALKEETNA FORMATION — Jtku — Talkeetna Formation Undivided

UPPER(?) TRIASSIC — Ћm — Metamorphic Rocks Undivided

INTRUSIVE IGNEOUS ROCKS

Jqd — Quartz diorite

HORIZONTAL SCALE

2 1 0 1 2 miles

Modified slightly from Detterman and Hartsock (1966)

WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	SECTION OF JURASSIC SEDIMENTS INISKIN PENINSULA	FIGURE 15
SCALE: AS INDICATED	DATA BY: C.C.			BX144
	DATE: 4/77			

Tuff, coarse, greenish.	250
Volcanic breccia, massive, coarse, green to dark-green.	400
Tuff, light-green.	100
Volcanic breccia, massive, green; increasing metamorphism near contact with pluton.	150
Total	3,350

The lava flows, which are mainly microcrystalline andesite and dacite, are commonly of submarine origin. Tuff fragments and the tuff matrix of the volcanic breccias consist partly of andesine plagioclase. Local beds of dark green argillite near the top of the member are the only sedimentary rocks described in measured sections of the Marsh Creek Breccia Member.

Portage Creek Agglomerate Member

Rocks mapped as the Portage Creek Agglomerate Member are exposed in a northeastward-trending belt that covers approximately 30 square miles.

The nature of the contact between the Portage Creek Agglomerate Member and the overlying Horn Mountain Tuff Member is unclear. Where observed, the contact is usually a fault, but in some exposures the contact appears to be conformable.

The Portage Creek Agglomerate Member consists of massive agglomerate, lava flows, volcanic breccia, and minor argillite. The thickness ranges from 2,250 feet at the type locality (plate 94A, measured section 2) to over 2,800 feet elsewhere. The type section was studied by Arthur Grantz and J. K. Hartsock in 1951 and by R. W. Juhle in 1951 and 1952. The petrologic type section description from Detterman and Hartsock (1966), which generally applies to all known exposures, is as follows:

Type section of Portage Creek Agglomerate Member from south shore of Tuxedni Bay

Fault. Portage Creek Agglomerate Member:	Thickness (feet)
Agglomerate, massive, coarse, red to pink, tuff matrix; green volcanic breccia near base; small fault cuts section.	400
Lava flow, bedded, biotite andesite porphyry; diorite dike and sill cuts lava.	400
Agglomerate and breccia, coarse, red tuff matrix.	150

Volcanic breccia, massive, coarse, red; several thick units of hard crystalline tuff; andesite porphyry flow near base.	550
Lava flow, massive, aphanitic, green.	150
Sandstone, massive, coarse-grained, tuff aceous.	450
Fault, probably small.	
Agglomerate and breccia, coarse, red to pink; cut by diorite dike.	150
Total	2,250

Fault.
Marsh Creek Breccia Member.

The Portage Creek Agglomerate Member is dominantly marine andesite but also contains sedimentary units. The sedimentary rocks are probably of marine origin, as suggested by the presence of limestone, and consist of massive coarse-grained tuffaceous feldspathic sandstone and finer-grained tuffaceous graywacke and argillite.

Locally the member contains several tuffaceous sandstone units ranging in thickness from 60 to 100 feet and bounded by argillite, volcanic breccia, or bedded tuffs. One exposure contains several beds of dark arkosic sandstone and fine-grained tuffaceous sandstone interbedded with a thick argillite sequence.

Horn Mountain Tuff Member

Rocks mapped as the Horn Mountain Tuff Member cover approximately 11 square miles of area. The Horn Mountain Tuff is unconformably overlain by sediments of the Middle Jurassic Tuxedni Group. The top of the Talkeetna Formation is locally marked by a fault.

The Horn Mountain Tuff Member consists of sandstone, tuff, and lava flows. The member ranges in thickness from 1,800 to 2,800 feet. The type section was studied by Arthur Grantz in 1951 and R. W. Juhle in 1952. Detterman and Hartsock (1966) summarized the lithology of the type section (plate 103A, measured section 1) as follows:

Type section of Horn Mountain Tuff Member at Horn Mountain

Horn Mountain Tuff Member:	Thickness (feet)
Top of exposed section.	
Porphyritic andesite lava flow.	100
Sandstone, arkosic to feldspathic, thin-bedded, fine- to coarse-grained, tuffaceous; few interbeds of brown to gray siltstone and a few pebble layers; plant and belemnite fragments.	550
Tuff, bedded, coarse, red and mottled; a few interbeds of tuffaceous sandstone.	300
Tuff, thin-bedded, fine- to coarse-grained, red, green, purple, and mottled; volcanic breccia near top and a thin unit of green argillite in lower part; few plant fragments.	550
Sandstone, massive, fine- to coarse-grained, feldspathic, tuffaceous; few interbeds of red and mottled tuff.	300
Total	1,800

Portage Creek Agglomerate Member.

The dominant lithologies present in the Horn Mountain Tuff Member are bedded tuff and tuffaceous feldspathic sandstone. Porphyritic andesite lava flows, volcanic breccia, agglomerate, and argillte are minor constituents.

The bedded tuffs are well indurated, fine- to coarse-grained and occur as thin-bedded to massive units. The sequence is dominantly marine, but nonmarine units are indicated by tree stumps that are found preserved in an upright position in some of the bedded tuff units. The sandstone units commonly contain volcanic as well as other rock fragments up to a few inches in diameter. Many of the so-called arkosic sandstone units are probably more accurately described as felspathic graywacke (Detterman and Hartsock, 1966). They are well indurated, and generally have low porosity.

Model of Sedimentation for the Talkeetna Formation

Insufficient detailed information is available for the Talkeetna Formation on which to base an accurate account of the depositional history. It is generally agreed that the formation is a marine sequence which comprises a minor portion of the many thousands of feet of first cycle volcaniclastic material that accumulated in the Matanuska geosyncline during the Jurassic period.

The Aleutian volcanic arc, bordering the geosyncline on the north, provided the lava and tuff that make up much of the Talkeetna Formation in the Iniskin-Tuxedni region. Sedimentary units become dominant higher in the section. Tuffs appear to be more prominent higher in the section which indicates that volcanism was more explosive during the later stages of deposition. The arkosic sandstones (felspathic graywackes) in the Horn Mountain Tuff Member probably were derived from partial unroofing of granitic plutons or smaller granitic bodies, that may have been emplaced along the volcanic arc before deposition of the Horn Mountain Tuff Member.

Locally, nonmarine conditions of deposition must have existed because certain units such as the bedded tuffs which contain tree stumps, indicate a nonmarine environment.

Uranium Favorability

Neither the unsubdivided formation, nor any of its individual members appear to contain environments favorable for the formation of sandstone-type uranium deposits. Although some of the features described in the Horn Mountain Tuff Member (arkosic sandstones, tuffs and plant remains) may seem to be favorable criteria when comparing with table 3, most factors indicate otherwise. The degree of induration and low porosity common to all Jurassic rocks of the Cook Inlet Basin are unfavorable unless the induration and loss of porosity occurred later than the introduction of potential uranium-bearing solutions. Relatively steep bedding plane dips, locally 50° and commonly 15° to 20° (plate 103A), are not typical of the gently dipping sedimentary rocks that are known to host many of the sandstone-type uranium deposits.

Uranium mineralization could occur in association with the contact between the Talkeetna Formation and the granitic complex of the Aleutian Range batholith (plate 94A). The nature of the contact is not known. Uranium mineralization similar to that found in the "Japanese type" sandstone deposits may occur. The location of these contacts in the study area will be discussed briefly in the following paragraph.

The Talkeetna Formation overlies Late Cretaceous-Early Tertiary granitic rocks in the southern Talkeetna Mountains (plates 76A and 85A). Lower Jurassic rocks, some of which undoubtedly include equivalents of the Talkeetna Formation, are in contact with granitic rocks in the eastern half of the Lake Clark quadrangle (plate 93A) and in the central Talkeetna Mountains along the Talkeetna, Oshetna and Black Rivers (plate 76A). Many such contacts occur between undivided Mesozoic rocks and the Jurassic, late Cretaceous-early Tertiary, and middle Tertiary granitics in the northwest portion of the study area (plates 75A and 84A). A general description of undivided Mesozoic rocks is given in section 7.6 and the crystalline rocks are described in section 7.10 of this report.

11.1.2 TUXEDNI GROUP

The Tuxedni Group is middle Jurassic in age and is divided into six formations in the Iniskin-Tuxedni region. They are as follows:

Bowser Formation (upper)
Twist Creek Siltstone
Fitz Creek Siltstone
Gaikema Sandstone
Red Glacier Formation (basal)

The group is not subdivided elsewhere in the study area. The Tuxedni Group is recognized in one petroleum well in the basin, the Iniskin Bay Association IBA No. 1 (plate 104B). A few wells have bottomed in undivided Jurassic rocks along the west side of Cook Inlet near Kalgin Island (plate 94B) and Tyonek (plate 84B). It is possible that part of the Tuxedni Group is present in these wells. Fewer wells penetrate Jurassic rocks on the east side of the inlet (plates 94B and 104B) than on the west side. It is not known if the group extends to the east side of the inlet because it has not been recognized there in the subsurface or in outcrop.

The group is mapped in the eastern Talkeetna Mountains (Grantz, 1960), upper Matanuska Valley (Detterman and others, 1976) and the Iniskin-Tuxedni region (Detterman and Hartsock, 1966). The combined area of mapped Tuxedni Group is approximately 140 square miles.

The Tuxedni Group is commonly folded and faulted in the eastern Talkeetna Mountains - upper Matanuska Valley area and consists dominantly of arkosic sandstone with some siltstone and shale beds. The section is marine except for some nonmarine sandstone beds in the lower part.

The group rests unconformably on the Talkeetna Formation and the unconformity represents a hiatus of considerable but unknown time. The top of the section is marked by a local unconformity between the Tuxedni Group and the overlying Chinitna Formation.

The thickness of the Tuxedni Group ranges from 4,970 to 9,715 feet in the Iniskin-Tuxedni region and is more than 2,000 feet thick in the upper Matanuska Valley. The thickness of the group in the eastern Talkeetna Mountains is not known.

Red Glacier Formation

The Red Glacier Formation, as mapped, covers approximately 16 square miles in the Iniskin-Tuxedni region. Detterman and Hartsock's 1966 map is the only available compilation of the region that shows the various members and formations of the Jurassic section in the region. The contact between the Red Glacier Formation and the overlying Gaikema Sandstone appears to be gradational over a distance of 50 to 100 feet.

The sedimentary rocks of the Red Glacier Formation consist of siltstone, arkosic sandstone and shale. The formation varies in thickness from 1,980 to 4,540 feet along a northeastward-trending belt. Detterman and Hartsock (1966) summarized the lithology of the type section measured by Arthur Grantz and Richard Hoare in 1951 (plate 94A, measured section 3) as follows:

Type section of Red Glacier Formation

Gradational contact. Red Glacier Formation:	Thickness (feet)
Siltstone, thin-bedded, coarse-grained, brownish-gray; thin interbeds of very fine-grained sandstone; large limestone concretions in upper part; porphyritic andesite sill near middle of unit; many thin coquina beds containing *Witchellia*, *Parabigotites*, *Holcophylloceras*, and the pelecypods *Meleagrinella*, *Trigonia*, and *Inoceramus*.	750
Siltstone, massive coarse-grained gray; weathers grayish brown.	410
Sandstone and siltstone; the sandstone is thin- to medium-bedded, fine- to medium-grained, light brown; the siltstone is thin-bedded, coarse grained, brownish gray; plant fragments and a few pelecypods and belemnites.	1,060

Sandstone, arkosic, massive, fine- to medium-grained, buff; 35-40 percent feldspar in kaolinitic matrix; few plant fragments.	720
Shale, massive, silty to arenaceous, black, very soft and easily weathered, carbonaceous; large concretions and lenticular beds of limestone in upper part; siltstone interbeds in lower parts; many plant fragments; few invertebrate fossils, *Tmetoceras*; fault near middle, section below fault measured on ridge north of Red Glacier.	1,000
Sandstone, arkosic, massive.	200
Shale, thin-bedded, silty, banded, black and gray; altered to slate in upper part; few thin sandstone interbeds.	210
Sandstone, arkosic, massive, tan.	190
Total section exposed	4,540

Angular unconformity.

The siltstones are coarse-grained, thin-bedded to massive, contain numerous rock fragments, and are arenaceous, with a composition similar to that of the interbedded fine-grained subgraywacke sandstone. Siltstone forms 40 percent of the exposed formation, occurring mainly in the upper part. A few thin carbonaceous seams occur in the siltstone.

Arkosic sandstone forms about 25 percent of the Red Glacier Formation. The sandstone is massive, fine- to medium-grained, and well indurated. Much of the sandstone consists of angular to subangular grains of feldspar.

The shale is silty to arenaceous, black, soft, and in part, highly carbonaceous.

Gaikema Sandstone

Sedimentary rocks mapped as Gaikema Sandstone comprise an area of nine square miles. The unit is conformably overlain by the Fitz Creek Siltstone.

The Gaikema Sandstone is characterized by cliff-forming sandstone and varying amounts of siltstone, shale, and conglomerate. It ranges in thickness from 500 to 880 feet. The type section (plate 103A, measured section 2) was measured by L. B. Kellum and Helmuth Wedow in 1944 and reported by Detterman and Hartsock (1966) as follows:

Type section of Gaikema Sandstone

Contact. Gaikema Sandstone:	Thickness (feet)
Sandstone, medium-bedded, medium-grained, dark-olive-green; weathers dark brown; cobble conglomerate near middle of unit, mainly well-rounded volcanic rock.	120
Sandstone, thin- to medium-bedded, medium-grained, olive-green to gray; mottled by many light-gray angular feldspar fragments; few silty shale interbeds containing fossils; _Witchellia_.	220
Sandstone, medium-bedded, medium- to coarse-grained, arkosic; numerous thick beds of cobble-boulder conglomerate, mainly green and red felsitic rocks; numerous thin coquina beds, mainly _Meleagrinella_ and _Trigonia_.	110
Covered interval.	50
Sandstone, medium-bedded, medium- to coarse-grained, arkosic, greenish-gray; well-rounded felsic and aphanitic igneous cobble conglomerate; thin coquina beds, mainly pelecypods as above.	130
Covered interval.	40
Sandstone, medium-bedded to massive, medium- to coarse-grained, olive-gray to dusky-yellow-green; weathers dark brown; lenticular beds of pebble-cobble conglomerate; silty shale and siltstone in lower part of unit; one thin bed of chocolate-brown friable sandstone near base of unit; many coquina beds, _Witchellia_, _Trigonia_, and _Inoceramus_.	180
Total section measured	850

The formation is a bedded sequence of graywacke and arkosic sandstone, conglomerate, and siltstone. Pebble- to boulder-size clasts in conglomeratic facies consist of aphanitic igneous and metasedimentary material similar in composition to rocks of the Talkeetna Formation. Some granitic clasts are present, possibly derived from the Aleutian Range plutonic complex. Pelecypod fossils occur throughout the section. The sandstone is massive to thin-bedded and grain size varies from very fine to coarse. The siltstone is massive to thin-bedded and sandy. Minor carbonaceous debris is localized in lenticular pockets along irregular surfaces of the beds.

Fitz Creek Siltstone

The Fitz Creek Siltstone covers an area of eight square miles. The formation is conformably overlain by the Cynthia Falls Sandstone with the exception of one exposure where the contact is an unconformity.

The Fitz Creek Siltstone consists of massive bluish-gray arenaceous siltstone ranging in thickness from 640 to 1,280 feet. L. B. Kellum and Helmuth Wedow measured the type section in 1944 (plate 103A, measured section 3) and Detterman and Hartsock (1966) published the following description of that section:

Type section of Fitz Creek Siltstone

Contact. Fitz Creek Siltstone:	Thickness (feet)
Siltstone, arenaceous, massive, gray; weathers rusty yellow brown and nodular; numerous small limestone concretions and a few beds of nodular limestone and silty sandstone; contains *Normannites* and *Chondroceras*.	530
Sandstone, medium-bedded, very fine-grained, silty, gray; weathers brown.	70
Siltstone, platy, blue-gray; thin beds of silty greenish-gray sandstone; few small limestone concretions; contains abundant *Chondroceras*, *Holcophylloceras*, and *Zemistephanus*.	340
Covered interval; approximate thickness.	70
Siltstone; platy, blue-gray; few limestone concretions; *Sonninia*.	80
Total section measured	1,090

The siltstone is typically bluish-gray, fine- to coarse-grained, and is abundantly fossiliferous. Siltstone grades upward into silty shale near the top of the section. Very fine specks of disseminated limonitic material give weathered outcrops a rusty-red-brown appearance. Sandstone and conglomerate occur interbedded with the siltstone. Detterman and Hartsock (1966) suggest that the presence of volcanic, chloritic, and feldspar detritus in the sandstone indicates that part of the formation was derived from Lower Jurassic Talkeetna Formation.

Cynthia Falls Sandstone

The Cynthia Falls Sandstone covers an area eight square miles in size. The formation is conformably overlain by the Twist Creek Siltstone. However, in at least one exposure Detterman and Hartsock (1966) report that the contact is an unconformity.

Massive sandstone and conglomerate are the main lithologies of the Cynthia Falls Sandstone. The formation ranges in thickness from 500 to 765 feet. L. B. Kellum and Helmuth Wedow measured the type section (plate 103A, measured section 4) and Detterman and Hartsock (1966) published the description in their report as follows:

Type section of Cynthia Falls Sandstone

	Thickness (feet)
Local unconformity.	
Cynthia Falls Sandstone:	
Sandstone, massive, coarse-grained, gray-green; weathers light gray; mottled by light green; splotches of minerals rich in zeolite; few lenticular beds of small pebbles, mainly volcanic rocks.	280
Siltstone, thin-bedded, coarse-grained, arenaceous, brownish-gray.	50
Sandstone, similar to top unit except fewer pebbles.	270
Total section measured	600
Contact.	

The sandstone is thick-bedded, and commonly composed of angular fragments of feldspar and volcanic rocks. Graded bedding features are present and zeolites occur in the sandstone matrix. Conglomerate units consist of well sorted pebble- to cobble-size clasts of aphanitic igneous rocks and metasedimentary rocks. Arenaceous siltstone constitutes about 15 percent of the total section and is commonly interbedded with the sandstone.

Twist Creek Siltstone

Twist Creek Siltstone covers an area of four square miles as mapped by Detterman and Hartsock (1966). The contact between the Twist Creek Siltstone and the overlying Bowser Formation is an unconformity.

The Twist Creek Siltstone consists mainly of massive arenaceous siltstone and ranges in thickness from 0 to 420 feet. The type section (plate 103A, measured section 5) was measured by L. B. Kellum and Helmuth Wedow in 1944. The following description of the type section is taken from Detterman and Hartsock (1966).

Type section of Twist Creek Siltstone

	Thickness (feet)
Unconformity.	
Twist Creek Siltstone:	
Siltstone, thin-bedded to massive, arenaceous, brownish-gray; weathers dark-rusty brown; numerous volcanic ash layers 1/4 to 1/2 inch thick; many small, yellow-weathering discoidal limestone concretions containing *Liroxyites*, *Megasphaeroceras*, and *Leptosphinctes*.	240
Total section exposed	240

The section is dominantly marine sediments and consists of soft, poorly consolidated siltstone and silty shale. A few thin beds of graywacke are interbedded with the siltstone. Ash layers interbedded with the sediments commonly weather to a bright orange color. The Twist Creek Siltstone is abundantly fossiliferous.

Bowser Formation

The Bowser Formation is Middle to Late Jurassic and is the upper formation of the Tuxedni Group. The formation, as mapped by Detterman and Hartsock (1966), covers 20 square miles in a northeastward-trending belt in the Iniskin-Tuxedni region. The formation underlies the Late Jurassic Chinitna Formation and the contact is conformable. Massive sandstone and conglomerate are the dominant lithic types in the Bowser Formation. The unit ranges in thickness from 1,250 to 1,830 feet. The type section (plate 103A, measured section 6) was measured by L. B. Kellum and Helmuth

Wedow in 1944 and reported by Detterman and Hartsock (1966) as follows:

Type section of Bowser Formation

Contact. Bowser Formation:	Thickness (feet)
Sandstone, massive, medium- to coarse-grained, dark-gray; interbeds of calcareous light-gray sandstone containing numerous coquina layers; thin to thick irregularly bedded layers of small pebble- to cobble-conglomerate, mainly felsitic rocks.	180
Siltstone, massive, arenaceous, olive-gray; weathers light brown; thin interbeds of fine-grained graywacke sandstone; contains the ammonites *Kepplerites* and *Kheraiceras*.	250
Conglomerate, massive, irregularly bedded, cobble to small boulder, mainly felsite and porphyry but some basalt and granitic rock types; matrix is coarse-grained feldspathic sandstone.	170
Sandstone, thin- to shaly-bedded, fine- to medium-grained, light-gray; few interbeds of medium-grained dark-gray mottled sandstone and lenticular beds of pebble conglomerate; abundant pelecypods.	170
Siltstone, thin-bedded to massive, arenaceous, dark-gray; contains pelecypods.	130
Sandstone, medium-bedded to massive, medium- to fine-grained, light olive-gray; contains numerous interbeds of coarse-grained sandstone and pebble conglomerate.	250
Siltstone, massive, sandy, gray.	260
Conglomerate, massive; cobbles mostly volcanic rock types and some intraformational sandstone; lenticular interbeds of coarse-grained sandstone.	70
Siltstone, massive, coarse-grained, arenaceous; few small pebbles.	50
Siltstone, massive, coarse-grained, arenaceous, dark-gray; contains *Cranocephalites* sp.	230
Sandstone, thin- to shaly-bedded, fine- to medium-grained, dark-gray; few pebbles.	70
Total section exposed	1,830

Unconformity.

The sandstone units are massive, coarse-grained, and consist of angular fragments of feldspar and quartz. The units are commonly calcareous, resembling the Cynthia Falls Sandstone. The conglomerates consist of felsite, basalt, and granite pebbles, cobbles and boulders in a matrix similar in composition to the sandstone beds. Massive to thin-bedded siltstone units ranging up to 260 feet in thickness are interbedded with the coarser clastic rocks. Much of the siltstone is well indurated. The Bowser Formation is the most fossiliferous unit in the Tuxedni Group.

Model of Sedimentation for the Tuxedni Group

Details of sedimentary processes responsible for the deposition of the Tuxedni Group are lacking. Continued uplift in the Alaska-Aleutian Range area provided the gradient necessary for transportation of the detritus to the active Matanuska geosyncline and its landward margins. Based on the presence of granitic clasts occurring in the conglomerate units of the Gaikema Sandstone and Bowser Formation, it is probable that small portions of Early to Middle Jurassic intrusives were unroofed. Detterman and Hartsock (1966) suggest a source area to the north for at least the Cynthia Falls Sandstone based on the nature of the facies change. They also suggest that sedimentation was rapid without any major breaks during deposition of the Red Glacier Formation and for all of the Gaikema Sandstone, Fitz Creek Siltstone, and Cynthia Falls Sandstone.

The lithologies of the different formations and exposures of Tuxedni Group rocks indicate a decrease in volcanic activity during Middle Jurassic as compared to Early Jurassic.

On the basis of the variety and abundance of fossils, the Middle Jurassic Tuxedni Group is considered to be a dominantly marine sequence, nearshore in part.

Uranium Favorability

The Tuxedni Group is not considered to be a favorable host for sandstone-type uranium deposits on the basis of currently recognized criteria (table 2). The marine character, steep bedding dips, and the numerous faults and folds within the group indicate that these sedimentary rocks are not typical of known sedimentary uranium host rocks (tables 2 and 3). It is likely that the overall favorability of the group could be higher in the Susitna Lowlands where exposures of undivided Mesozoic rocks occur.

The reader is referred to the discussion on the uranium favorability of the Talkeenta Formation. Mention is made of the potential of uranium mineralization in sedimentary rocks of the Talkeetna Formation that are in contact with granitic rocks. Similar potential exists for the Tuxedni Group and for equivalents most likely present in the undivided Mesozoic that overlie granitics in the northwestern portion of the study area (plates 84A, 75A, 76A).

11.1.3 CHINITNA FORMATION

The Chinitna Formation is Late Jurassic in age and is subdivided locally into an upper and lower unit named from youngest to oldest as follows:

Paveloff Siltstone Member
Tonnie Siltstone Member

The members are recognized only in the Iniskin-Tuxedni region.

The Chinitna Formation was studied by Kirschner and Minard (1949), and initally subdivided by Imlay (1953). Detterman and Hartsock redefined the subdivisions and named them the Paveloff Siltstone and Tonnie Siltstone Members (table 4). Sedimentary rocks of the Chinitna Formation are probably present in the petroleum wells discussed in the sections on the Talkeetna Formation and Tuxedni Group since the formation overlies the latter two. The character of Chinitna Formation in the subsurface is not known.

The Chinitna Formation is mapped in the Iniskin-Tuxedni region by Detterman and Hartsock (1966) and Magoon and others (1976). The formation occurs in the upper Matanuska Valley and eastern Talkeetna Mountains where it is mapped by Grantz (1960). It is probable that the Chinitna Formation is represented by equivalents in the unsubdivided Mesozoic rocks that occur throughout the northern portion of the basin (plates 75A, 76A, 84A, and 85A). The Chinitna Formation as presently mapped covers an area of approximately 70 square miles.

The formation is dominantly siltstone with some shale and sandstone. The rocks are folded and faulted much the same as the underlying Tuxedni Group.

The Chinitna Formation overlies the Tuxedni Group and is overlain by the Naknek Formation. Both the upper and lower contacts are conformable except for local unconformities that occur in the Iniskin-Tuxedni region.

Grantz (1960) measured sections of the Chinitna Formation in the eastern Talkeetna Mountains and found that they range from 1,200 to 1,500 feet, but may be as much as 2,700 feet thick. The formation ranges in thickness from 1,700 to 2,700 feet in the Iniskin-Tuxedni region.

Tonnie Siltstone Member

The Tonnie Siltstone Member is exposed along a northeastward-trending belt. The combined exposures cover 18 square miles of area along the west side of Cook Inlet.

The lower contact with the Bowser Formation of the Tuxedni Group is conformable. The upper contact with the Paveloff Siltstone Member is gradational through 50-75 feet of section. The Tonnie Siltstone Member is in fault contact with older rocks at several localities.

The rocks are dominantly massive arenaceous siltstone with some sandstone. The member ranges in thickness from 820 to 1,310 feet. The type section (plate 103A, measured section 7) was measured by L. B. Kellum and Helmuth in 1944. Detterman and Hartsock (1966) describe the type section as follows:

Type section of Tonnie Siltstone Member

Gradational Contact. Tonnie Siltstone Member:	Thickness (feet)
Siltstone, massive; becomes more massive and arenaceous toward the top; brown on fresh and weathered surfaces; fewer concretions than underlying units.	340
Siltstone, massive, dark-gray; weathers brown to dark brown; small light-yellowish-brown limestone concretions scattered at random and in parallel bands; Lilloettia buckmani, L. milleri.	240
Sandstone, thin-bedded, fine-grained, silty, greenish-gray; Paracadoceras tonniense.	25
Siltstone, massive, fine-grained, gray; weathers brown; small brown-weathering concretions and a few large lenticular limestone beds; contains Xenocephalites vicarius.	135
Sandstone, medium-bedded, fine-grained, greenish-gray; siltstone interbeds.	40
Siltstone, similar to above unit; thin sandstone interbeds near base.	140
Siltstone, massive, arenaceous, dark-gray, weathers brownish-gray; many small buff- to brown-weathering limestone concretions in parallel bands; fossiliferous, Kepplerites abruptus, Paracadoceras tonniense.	80

Sandstone, massive, fine- to medium-grained, greenish-gray; few pebbles, mostly volcanic rock types.	20
Total sections measured	1,020

Contact.

Sandstone is present as thin beds in the siltstone and limestone concretions occur randomly in parallel bands throughout the section. Thin beds of volcanic ash occur locally. The arenaceous siltstone contains almost enough feldspar grains to be classified as a feldspathic siltstone. The siltstone is well indurated and commonly forms cliffs. Pyrite is an accessory mineral. Graywacke occurs as thin beds throughout the section, and is similar in composition to the siltstone. A cobble-boulder channel conglomerate occurs locally in the region. Detterman and Hartsock (1966) consider this and other channel-like features to be submerged stream channels. The member is abundantly fossiliferous.

Paveloff Siltstone Member

Sedimentary rocks of the Paveloff Siltstone Member cover 15 square miles of the basin. The upper contact with the Naknek Formation is conformable over most of the Iniskin-Tuxedni region but is locally an unconformity.

The Paveloff Siltstone Member consists of massive arenaceous siltstone much like that of the Tonnie Siltstone Member. The thickness ranges from 900 to 1,370 feet. The type section (plate 103A, measured section 8) was measured by Kirschner and Minard in 1946 and reported by Detterman and Hartsock (1966) as follows:

Type section of the Paveloff Siltstone Member
(Measured with tape and Brunton by Kirschner and Minard in 1946)

	Thickness (feet)
Contact.	
Paveloff Siltstone Member:	
Siltstone, massive, fine-grained, gray to greenish-gray; weathers dark gray; thin irregularly spaced fine-grained dark greenish-gray calcareous sandstone inter beds; few concretions.	700

Siltstone, massive, gray; weathers gray in upper part and brownish gray in lower part; regularly spaced fine-grained gray to buff sandstone interbeds; many lenticular beds and ellipsoidal concretions of dark dense limestone; pelecypods and belemnites.	640
Sandstone, thin- to medium-bedded, fine- to medium-grained, gray.	30
Total section measured	1,370

Gradational contact.

The Paveloff Siltstone Member is grossly similar to the Tonnie Siltstone with the exception that the former contains much less pyrite. The siltstone of the Paveloff member is well indurated and commonly fractured. Graywacke sandstone is feldspathic and locally contains well-rounded pebbles of volcanic rock types. The member contains pelecypods, belemnites, brachiopods, and gastropods.

Model of Sedimentation for the Chinitna Formation

Insufficient detailed information is available for the Chinitna Formation on which to base an accurate account of the depositional history. The formation is dominantly marine and possibly marginal marine as suggested by Detterman and Hartsock (1966). They also suggest a nearby source area for the formation.

Uranium Favorability

The Chinitna Formation is considered to be unfavorable for sandstone-type uranium deposits based on the criteria given in table 2. Tuff and tuffaceous material is absent in the section. The rock is well indurated which is an unfavorable factor if the loss in porosity occurred during or shortly after deposition. Folding and faulting are common in the areas where the formation is exposed. The relatively complex structure is not favorable for sandstone-type uranium mineralization.

It should be added that little is known of the formation in other parts of the basin. It is possible that a higher favorability could be given the formation after correlative units have been identified and studied.

11.1.4 NAKNEK FORMATION

The Naknek Formation is Late Jurassic in age and is subdivided into the following members, from youngest to oldest:

Pomeroy Arkose Member
Snug Harbor Siltstone Member
Chisik Conglomerate and Lower Sandstone Members

The formation is subdivided only in the Iniskin-Tuxedni region.

The Naknek Formation has been studied by Spurr (1900), Martin (1905), Moffit (1927), Kirschner and Minard (1949), Detterman and Hartsock (1966), and Lyle and Morehouse (1977). Detterman and Hartsock (1966) summarized the work of the previous investigators and in their report subdivided the Naknek Formation as shown earlier.

The Naknek Formation is mapped in the Iniskin-Tuxedni region by Detterman and Hartsock (1966) and Magoon and others (1976). It has not been recognized in the petroleum wells in the basin but likely is present in many that have penetrated Jurassic rocks along the west side of Cook Inlet. The formation is exposed in the eastern Talkeetna Mountains and is mapped by Grantz (1960). Sedimentary rocks equivalent to the Naknek Formation are likely present in the Jurassic and Mesozoic rocks that occur throughout the northern portion of the basin (plates 75A, 76A, and 85A). Areas mapped as Naknek Formation cover approximately 220 square miles of the Cook Inlet Basin.

The formation is predominantly siltstone and sandstone with some conglomerate. Folding and faulting is common in the formation, but not to the extent that is present in the underlying rocks.

The Naknek Formation overlies the Chinitna Formation and the contact between the two is unconformable. The contact between the Naknek Formation and the overlying sedimentary rocks is a regional angular unconformity. The angular discordance between the Naknek Formation and the overlying Tertiary sedimentary rocks is 5°-8°. In the Iniskin-Tuxedni region the Naknek Formation is the youngest Mesozoic unit present.

The formation ranges in thickness from 1,600 to 4,600 feet in the Iniskin-Tuxedni region and is at least 2,300 feet thick in the eastern Talkeetna Mountains exposures.

Chisik Conglomerate and Lower Sandstone Members

The lower sandstone member is an informal name given to a lateral equivalent of the Chisik Conglomerate (Detterman and Hartsock, 1966) and the two will be discussed together. The Chisik Conglomerate Member covers 25 square miles of the basin along a northeastward-trending belt in the Iniskin-Tuxedni region.

The lower contact with the Chinitna Formation is unconformable. The upper contact with the Snug Harbor Siltstone Member is conformable.

The Chisik Conglomerate Member is predominantly massive conglomerate. The member ranges in thickness from 0 to 840 feet. The type section (plate 94A, measured section 4) measured by Arthur Grantz and J. K. Hartsock in 1951, and reported by Detterman and Hartsock (1966) is as follows:

Type section of the Chisik Conglomerate Member

	Thickness (feet)
Gradational Contact.	
Chisik Conglomerate Member:	
Conglomerate, massive, pebble to boulder; cobbles and boulders near base; becomes less coarse toward top; lenticular and irregular beds of coarse-grained sandstone and grit scattered throughout; conglomeratic constituents 40 percent intrusive rock, 40 percent volcanic and metamorphic rock, 20 percent intraformational rock.	560
Total section measured	560
Unconformity.	

The conglomeratic constituents include diorite and other granitic rocks, red and green volcanic rocks, gray quartzite, and cobbles of arkosic sandstone. Lenticular beds of arkosic sandstone occur throughout the massive conglomerate. The lower sandstone member consists of thin-bedded to massive, fine- to coarse-grained arkosic sandstone. Thin beds of arenaceous siltstone are not uncommon between thick sandstone units in the lower sandstone member. Rapid facies changes are common and all clastic elements show a high degree of sphericity. Pelecypod and ammonite fossils occur in the member but are not as numerous as in the underlying Chinitna Formation.

Snug Harbor Siltstone Member

The mapped sedimentary rocks of the Snug Harbor Siltstone Member cover 20 square miles of the Cook Inlet Basin. The upper contact between the Snug Harbor Siltstone Member and the overlying Pomeroy Arkose Member is sharp and conformable.

The Snug Harbor Siltstone Member is dominantly massive to thin-bedded siltstone. The member ranges in thickness from 720 to 860 feet. Arthur Grantz and J. K. Hartsock measured the type section (plate 94A, measured section 5) in 1951. Detterman and Hartsock (1966) report the description of the type section as follows:

Type section of Snug Harbor Siltstone Member

Local unconformity. Snug Harbor Siltstone Member:	Thickness (feet)
Siltstone and shale, thin- to medium-bedded gray, calcareous; interbeds of fine-grained calcareous sandstone; beds become thinner and more lenticular toward the top.	280
Siltstone, massive, gray, hard; few limestone concretions scattered throughout; rare interbeds of sandstone.	260
Siltstone and claystone, massive to medium-bedded, gray; few thin interbeds of shale; large limestone and small marcasite concretions.	230
Siltstone, laminated with dark- and light-gray bands; interbeds of fine-grained sandstone.	90
Total section exposed	860

Gradational contact.

The siltstone is hard and fractures into concentric patterns or angular fragments, depending on the grain size of the unit. Thin layers of sandstone and volcanic ash occur locally. Ammonite fossils are locally abundant in the section. Detterman and Hartsock suggest the source area for the sediments was to the northwest.

Pomeroy Arkose Member

The combined mapped areas of Pomeroy Arkose Member cover 45 square miles of the Cook Inlet Basin. The upper contact between the Pomeroy Arkose Member and overlying Tertiary sedimentary rocks is a regional angular unconformity, discussed earlier in this section.

Sedimentary rocks of the member are mainly massive arkosic sandstone and conglomerate. The member ranges in thickness from 850 to more than 3,300 feet. G. C. Martin and T. W. Stanton first measured the type section (plate 103A, measured section 9) in 1904. The section has been rechecked several times. The description reported in Detterman and Hartsock (1966) follows:

Type section of the Pomeroy Arkose Member from Chinitna Bay

Unconformity. Pomeroy Arkose Member:	Thickness (feet)
Arkose, thin- to medium-bedded, coarse-grained, light-gray; pebbles and cobbles mainly granite and volcanic rocks; thin interbeds of siltstone; belemnites near base.	110
Siltstone, arenaceous, dark-gray; <u>Buchia</u> near top.	20
Arkose, medium-bedded, coarse-grained, con glomeratic; large-scale cut-and-fill channels.	80
Siltstone, arenaceous; thin interbeds of arkose.	80
Covered interval.	400
Arkose, massive, coarse-grained, light-gray, cross-bedded; few lenticular beds of pebbles; thin interbeds of dark-gray siltstone.	360
Siltstone, thin-bedded, dark-gray; thin sandstone interbeds.	50
Sandstone, thin-bedded to massive.	160
Arkose, thick-bedded to massive, medium- to coarse-grained; conglomeratic; siltstone interbeds.	470
Siltstone, medium-bedded, dark-gray,; weathers brown; hard; thin interbeds of fine-grained sandstone.	280
Arkose, massive, coarse-grained, gray-brown; few pebbles.	200
Siltstone, massive, gray, hard.	80
Arkose, massive, coarse-grained, gray-brown; conglomeratic zones.	110
Total section exposed	2,400

Contact.

The arkosic sandstones contain 40 to 45 percent quartz, 30 to 35 percent feldspar, and 15 to 20 percent dark minerals, mainly hornblende and tourmaline. Most of the sandstones have a clay matrix, but locally the matrix is tuffaceous or chloritic. The conglomerates consist mainly of well-rounded pebbles and cobbles of granitic and volcanic rocks. The siltstone more closely resemble the graywacke of the older formations.

Model of Sedimentation for the Naknek Formation

Sedimentary rocks of the Naknek Formation are dominantly marine. Marine fossils are found throughout the section. Lyle and Morehouse (1977) report that the formation contains sedimentary units that represent lower shoreface to marginal marine mudflat deposits. The source area for some of the sediments is to the northwest. The high percentage of granite and diorite in the conglomerate units indicates that the Aleutian Range and Talkeetna Mountains Kosina batholiths were being actively eroded by this time.

Uranium Favorability

Sedimentary rocks of the Naknek Formation do not appear to be favorable as hosts for sandstone-type uranium deposits. Although some of the criteria of uranium favorability listed in table 2 are applicable to units within the formation, the majority of them are not (table 3).

All of the rocks are well indurated. In the Iniskin-Tuxedni region samples show the sediments to be tightly packed, with many grains broken during compaction (Lyle and Morehouse, 1977). This is an unfavorable factor if the present degree of induration developed shortly after deposition. Steep bedding attitudes, and faulting and folding are common in exposures in the eastern Talkeetna Mountains. The strata of the formation commonly dip 19° to 20° in the Iniskin-Tuxedni region.

It is likely that the formation is more favorable in the northern portion of the basin where Naknek Formation equivalents are probably present in the Jurassic and undivided Mesozoic sedimentary rocks (plates 75A, 76A, 84A and 85A).

11.2 CRETACEOUS

Nonplutonic rocks of Cretaceous age are exposed primarily in the Kenai-Chugach Mountains and in the Matanuska Valley.

The Kenai-Chugach Mountains rocks have not been studied in detail but are thought to be dominantly marine sedimentary and volcanic rocks of the Valdez Group and the McHugh Complex.

North of Cook Inlet the Cretaceous section is subdivided into the Matanuska Formation and the Nelchina Limestone. The Nelchina Limestone is Lower Cretaceous and consists of massive sandy limestone composed of comminuted mollusk shells. The Nelchina Limestone is mapped only in the eastern Talkeetna Mountains (Grantz, 1960).

11.2.1 MATANUSKA FORMATION

The Matanuska Formation is Upper Cretaceous in age. It has been studied by Mendenhall (1900); Martin (1926); Capps (1927); Eckhart (1959); Grantz (1953, 1964); and Barnes (1962). It is mapped in the Matanuska Valley where it covers an area of 90 square miles of the Cook Inlet Basin.

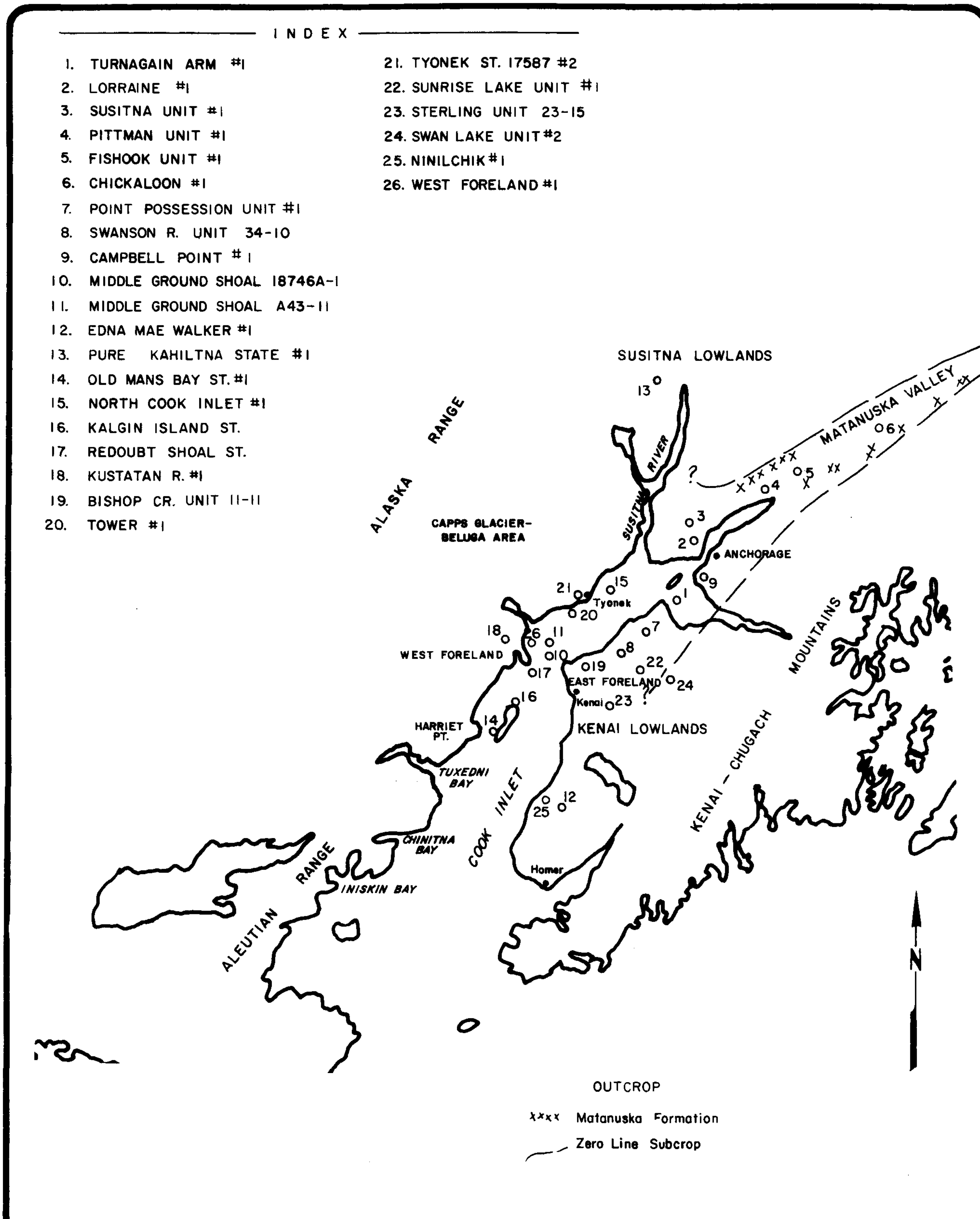
The formation is present in many wells in the basin. It occurs at the bottom of several wells (plate 94B) in the southern Kenai Peninsula at depths generally in excess of 12,000 feet (plate 94B). The formation is present as far west as Shell Oil Co. SRS State No. 1 (plate 94B) where it is encountered at a depth of 16,381 feet. The southern limit of deposition has not been determined (fig. 16).

The formation rests unconformably on lower Jurassic rocks in the Matanuska Valley and on upper Jurassic rocks and the Nelchina Limestone in the eastern Talkeetna Mountains. The lower contact represents a major hiatus during which time major faulting, some folding, uplift, and deep erosion occurred. Other relationships are unclear because the contacts are faults.

The thickness of the Matanuska Formation ranges from 0 to more than 8,000 feet. The thicker sections are in the eastern Talkeetna Mountains. Martin (1926) measured the formation and the following description is of a representative section (plate 85A, measured section 1) in the Matanuska Valley:

Representative section of the Matanuska Formation

	Thickness (feet)
Black shale at base, overlain by thin-bedded gray sandstone, some of which is very fine and has contorted laminae, and gray or drab-gray shales (beds are interleaved lenses rarely more than 6 inches thick).	12



WGM INC	MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	EXTENT OF MATANUSKA FORMATION	FIGURE 16
SCALE: 20 0 40 miles		DATA BY: C.C.			8X128
		DATE: 4/77			

Black sandy shale.	4-6
Thin-bedded gray sandstone and shale.	15
Black nodular shale.	8
Sandstone, mainly thick beds about 5 feet thick, with thin interbedded shales.	30
Interbedded black shale and thin gray sandstone and shale.	50
Massive sandstone, feldspathic and micaceous.	20
Interbedded gray shale, gray sandstone, and black shale.	40
Sandstone.	12
Alternating beds, 1 to 8 feet thick, of gray sandy shale and black shale.	250
Similar beds increasingly to dominantly sandy and light gray.	80
Dark-colored sandstone and sandy shale.	75
Light-gray sandstone including several thick, massive beds and some very thin shales (in east bank; estimated thickness).	200
Dark shale in beds alternating with thin sandstones and light-colored shale.	450
Sandstone, heavy bedded at the top but dominantly thin bedded (beds 1 to 2 feet and less than 1 foot), with many beds of very thin shaly sandstone having contorted laminae; also a few thin shale beds and an increasing number of dark shales in the lower part.	840
Exposures interrupted and inaccessible for 1,500 feet along the creek, equivalent to an estimated stratigraphic interval of	500
Dark bluish-black sandy shales outcropping for 200 feet in a direction about N 17° E; strike, N 40° E; dip, 60° SE; computed thickness	80±
Exposure interrupted and inaccessible for 800 feet along the creek, equivalent to an estimated stratigraphic interval of	300±
Hard dark blue-black shale, outcropping for about 200 feet in a direction N 17° E; strike, N 28° E; dip, 60° to 65° SE; computed thickness	90±
Exposure interrupted and inaccessible for about 200 feet along the creek, equivalent to an estimated stratigraphic interval of	90±
Hard dark blue-black shale, outcropping for 400 feet along the creek in a direction N 17° E; strike, N 47° E; dip, 50° SE; computed thickness	170±
Exposure interrupted and inaccessible for 100 feet along the creek, equivalent to an estimated stratigraphic interval of	45±

Hard dark blue-black shale, outcropping for about 1,000 feet along the creek; estimated thickness	400±
	3,760±
No exposure for 7,500 feet.	
Several small outcrops through 1,200 feet along the east bank of the creek in a northerly direction; strike, N 23° E; dip, 49° SE; computed thickness	350±

From descriptions in well logs the subsurface sections consist of sandstone, siltstone, claystone, shale, and volcanic rocks. Exposures in the lower Matanuska Valley consist of dark colored claystone, shale, siltstone, and greenish-gray sandstone. The shale and siltstone contain limestone concretions, iron sulfide nodules, and pelecypod shells. Plant fragments are found in some of the sandstone and siltstone beds. Thin layers of volcanic ash have been tentatively identified in the formation by earlier investigators (Grantz, 1964).

The Matanuska Formation in the eastern Talkeetna Mountains consists of an upper sequence of sandstone, siltstone and shale; a middle sequence of shale and siltstone; and a basal unit of sandstone. The basal unit is a fine-grained arkosic sandstone. Carbonaceous debris occurs locally throughout the section.

Model of Sedimentation for the Matanuska Formation

Much of the Matanuska Formation is considered to have been deposited as upper shoreface and deeper water deposits (Grantz, 1964). Barnes (1962) also considers these sediments to be of marine origin, but suggests that plant fossils from the upper part of the formation indicate that some of the sediments are continental in origin. Subsurface exploration for oil indicates that the Matanuska Formation is absent from the crests of some anticlinal structures beneath Cook Inlet. This condition suggests erosion or nondeposition of the formation as a result of folding and uplift of the anticlines. This hiatus is referred to as the Jurassic-Early Cretaceous orogeny (section 9). Later orogenies produced extensive moderate to severe folding in sedimentary rocks of the Matanuska Formation.

Uranium Favorability

The Matanuska Formation is not considered to be favorable for the occurrence of sandstone-type uranium deposits. Few of the criteria given in table 2 are found in the Matanuska Formation table 3. Much of the areal extent of the formation is within the Matanuska Valley, an area that has undergone considerable compression and faulting. This tectonic activity has deformed the sedimentary rocks well beyond the relatively undeformed condition that typifies sandstone-type uranium hosts elsewhere. The nonmarine facies may be favorable if they occur in less deformed areas of the basin, perhaps beneath Cook Inlet where the formation has been encountered in drill holes.

11.3 CENOZOIC

11.3.1 TERTIARY

The sedimentary rocks that fill Cook Inlet are more than 20,000 feet thick in the deepest parts of the basin. The Tertiary stratigraphic section in the Cook Inlet area consists of the Kenai Group which has been well studied for petroleum potential. Calderwood and Fackler (1972) divided the Kenai Group into five formations, named from youngest to oldest as follows:

Sterling Formation
Beluga Formation
Tyonek Formation
Hemlock Conglomerate
West Foreland Formation

The Matanuska Valley Tertiary section consists of four formations that are less extensive than the above Kenai Group. From youngest to oldest, they are:

Tsadaka Formation
Wishbone Formation
Chickaloon Formation and Arkose Ridge Formation

The Tertiary sedimentary rocks exposed in the Susitna Lowlands are mapped as undivided upper Tertiary continental deposits. Recent, but yet unpublished studies of these rocks are sure to report them as equivalents of some of the formations in the Cook Inlet and probably the Matanuska Valley sections. The Susitna Lowlands section has been studied only partially in the subsurface from one exploratory well.

11.3.1.1 ARKOSE RIDGE FORMATION

Sedimentary rocks of the Arkose Ridge Formation are some of the oldest known Tertiary rocks deposited in the narrow easterly-trending trough of the lower Matanuska Valley. Kirschner and Lyon (1973) report that the Arkose Ridge and Chickaloon Formations are coeval, representing Paleocene and Eocene deposition. Recent evidence indicates that the two formations are no younger than Paleocene (Magoon and others, 1976). Early investigators of the Arkose Ridge Formation, which was named by Barnes (1956), include Paige and Knopf (1907), Martin and Katz (1912) and Capps (1915).

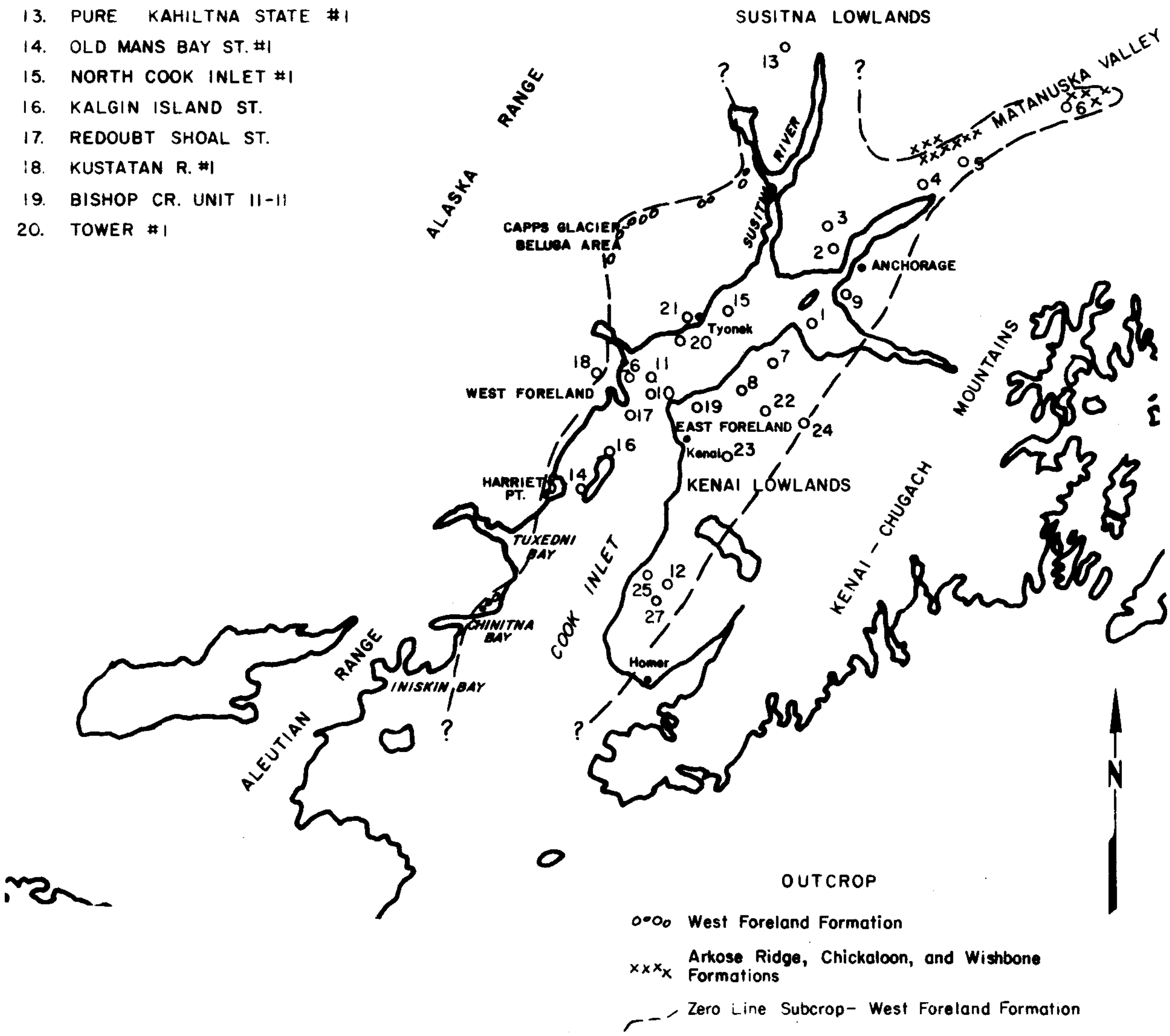
The Arkose Ridge Formation is limited areally and appears to be limited in the subsurface as well (fig. 17, plate 85A and B). The formation is reported as far west as Anchorage Gas and Oil Development Co. Rosetta No. 4 (plate 85B, well 7) but is not reported in other wells. Exposures of Arkose Ridge Formation are known only north of the Castle Mountain fault in the lower Matanuska Valley. The combined exposures cover approximately 50 square miles along a narrow trend that follows the north slope of the lower Matanuska Valley.

The stratigraphic relationship of the Arkose Ridge Formation to other formations is unclear (fig. 13). It is likely that the Arkose Ridge Formation represents a local variant during the time the Chickaloon Formation was deposited. The unit was locally deposited on a granitic basement (fig. 18). Other contacts are faults, with the exception of the area east of Kings River, where Arkose Ridge Formation rests on Talkeetna Formation (plate 85A). The exact nature of the latter contact is not known. Faulting within the formation has made it difficult to measure the true thickness of the section, but it is reported to be at least 2,000 feet thick. A measured section of Arkose Ridge Formation has not been published. The following description is a summary of work by the above mentioned investigators.

The unit consists of well indurated arkose, shale, sandstone and conglomerate. The clastic material is dominantly granitic, and appears to represent detritus derived from the Late Cretaceous to early Tertiary Talkeetna batholith located to the north. Conglomerates, which commonly form the basal member of the formation, consist of pebble- to boulder-size clasts of granitic composition in an arkosic matrix. The conglomerate is locally absent and in places metamorphosed near its contact with the pluton. Beds of arkose comprise the greater part of the formation. Quartz and feldspar are the most abundant constituents, but some beds are micaceous. Carbonaceous plant remains occur in some of the sandstone beds. Irregular lenses of shale interbedded with micaceous sandstone, arkose, and conglomerate occur in the upper portion of the sequence. Thin carbonaceous layers occur locally.

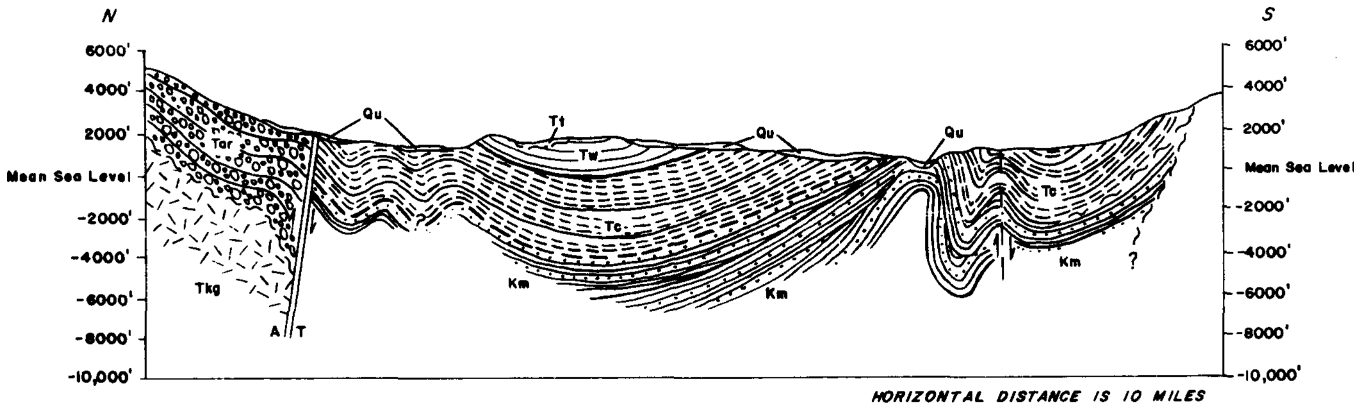
INDEX

1. TURNAGAIN ARM #1
2. LORRAINE #1
3. SUSITNA UNIT #1
4. PITTMAN UNIT #1
5. FISHOOK UNIT #1
6. CHICKALOON #1
7. POINT POSSESSION UNIT #1
8. SWANSON R. UNIT 34-10
9. CAMPBELL POINT #1
10. MIDDLE GROUND SHOAL 18746A-1
11. MIDDLE GROUND SHOAL A43-11
12. EDNA MAE WALKER #1
13. PURE KAHILTNA STATE #1
14. OLD MANS BAY ST. #1
15. NORTH COOK INLET #1
16. KALGIN ISLAND ST.
17. REDOUBT SHOAL ST.
18. KUSTATAN R. #1
19. BISHOP CR. UNIT 11-11
20. TOWER #1
21. TYONEK ST. 17587 #2
22. SUNRISE LAKE UNIT #1
23. STERLING UNIT 23-15
24. SWAN LAKE UNIT #2
25. NINILCHIK #1
26. WEST FORELAND #1
27. DEEP CREEK UNIT #1



Modified from Kirschner and Lyon, (1973)

WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY M.H.	REVISED	EXTENT OF LOWER TERTIARY SEDIMENTS	FIGURE 17
SCALE: 20 0 40 miles	DATA BY C.C.			BX128
	DATE 4/77			



LEGEND

SURFICIAL DEPOSITS

Qu	Alluvium

BEDDED ROCKS

Tt	Tsadaka Formation
Tw	Wishbone Formation
Tc	Chickaloon Formation
Tar	Arkose Ridge Formation
Km	Matanuska Formation

INTRUSIVE IGNEOUS ROCKS

Tkg	Tertiary–Cretaceous Intrusive
A/T	Strike Slip fault showing relative movement (A - away from and T - toward the reader)

Modified from Clardy (1974)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H.	REVISED	SECTION OF UPPER CRETACEOUS AND TERTIARY SEDIMENTS MATANUSKA VALLEY
SCALE: AS INDICATED	DATA BY: C.C.		FIGURE 18 BX136
	DATE: 4/77		

Model of Sedimentation for the Arkose Ridge Formation

The amount of information available on the Arkose Ridge Formation is insufficient to ascertain the processes of the sedimentation in detail. The predominant granitic composition indicates that the sediment was not transported far enough from the granitic source area to mix with detritus from other source rocks. Since the granitic composition of the sandstones and conglomerates appears to reflect that of the pluton on which the formation rests, it is likely that the source of the Arkose Ridge Formation is the Talkeetna batholith.

Interbedded coal layers indicate local swampy conditions. Wolfe (1966) has determined through paleobotany studies that climatic conditions during Paleocene time were frost-free, allowing lush vegetal growths to develop. Scattered plant remains occurring throughout the formation support Wolfe's conclusions. Deposition was rapid and swampy areas did not prevail for long periods of time. Considering the coarse nature of the sediments in the formation, it is most likely that they were transported by steep gradient-high energy streams. Uplift of the Talkeetna batholith apparently provided the steep gradient necessary for transportation of much of the sediment that formed the Arkose Ridge Formation.

Uranium Favorability

Certain environmental factors present in the Arkose Ridge Formation suggest moderate uranium favorability (table 3). They are: deposition by fluvial processes, a granitic provenance, unconformity with underlying rocks, arkosic composition, and presence of carbonaceous material. The present degree of induration of the sediments, however, would probably impede or prevent circulation of ground water necessary for the formation of sandstone uranium deposits. Primary porosity and permiability may have been more favorable. A uranium deposit similar to the sedimentary uranium deposits in Japan (table 2) described briefly in section 12 of this report, would be more likely to form in the Arkose Ridge Formation.

The Arkose Ridge Formation is not well studied where it is known to occur in the subsurface. The character of the formation may be very different farther away from the batholith.

11.3.1.2 CHICKALOON FORMATION

The Chickaloon Formation has been described by Martin and Katz (1912) as a nonmarine formation within a Tertiary sequence in the lower Matanuska Valley. The remaining formations of the Tertiary section in the Matanuska Valley were subsequently defined as the Arkose Ridge, Wishbone, and Tsadaka Formations (Barnes and Payne, 1956). Barnes and Payne describe several exposures of Chickaloon sedimentary rocks in the vicinity of Wishbone Hill and other parts of the lower Matanuska Valley. The Chickaloon Formation has been described in detail by Waring (1936) and Barnes (1967).

Chickaloon strata are more extensive in the Matanuska Valley than the Arkose Ridge sedimentary rocks. The Chickaloon Formation crops out at a number of localities throughout the lower Matanuska Valley and combined exposures cover an area of approximately 80 square miles (plate 85A). The formation is thought to underlie the younger Tertiary rocks and most of the area beneath the Quaternary deposits (Barnes, 1962). Based on exploratory well intercepts it is estimated that the formation is present beneath more than 2,000 square miles of the eastern part of the basin of the lower Matanuska Valley. The Chickaloon Formation has been encountered in petroleum wells (fig. 17) as far southwest as Pan American Oil Company Turnagain Arm No. 1 which cuts 350 feet of the unit. The unit occurs as far west as Pan American Petroleum Corp. Chuitna River State No. 1 (near Tyonek St. 17587 #2) which bottomed in the Chickaloon Formation. The formation thickens to the north where the Humble Oil Company Susitna Unit No. 1 well bottomed in 4,500 feet of Chickaloon strata (fig. 17). Other exploratory wells, in which the Chickaloon Formation is the deepest rock unit, are shown on plates 84B and 85B.

The Chickaloon Formation rests unconformably on the Matanuska Formation in the central and southern parts of the Matanuska Valley. Stratigraphic relationships with the Arkose Ridge Formation are undetermined. The two formations are separated by the Castle Mountain Fault system (fig. 13). The Wishbone Formation unconformably overlies the Chickaloon Formation (fig. 18).

The Chickaloon Formation consists of an irregular succession of shale, sandy shale, sandstone, conglomerate, claystone, and coal. A representative section (plate 85A, measured section 2) from Martin (1926) is presented below.

Section in the Chickaloon Formation beginning at east end of the outcrop in the bluff at Chickaloon coal camp.

	Thickness (feet)	(inches)
Coal bed.	15+	
Gray shales with ironstone bands and nodules; lower 6 feet thickly packed with large nodules.	21	
Carbonaceous shale.	1	6
Coal bed.	8	3
Shales and sandy shales with many sandstone lenses and ironstone nodules.	27	3
Gray shale.	7	8
Carbonaceous shale with thin coal streaks.		9
Sandy shale and sandstone with ironstone.	8	6
Fissile carbonaceous shale.	1	2
Coal bed.	4	6
Shales with many ironstone bands.	21	6
Coal, clean, bright.	1	8
Shaly sandstone.	1	5
Coal with shaly bands.	1	2
Largely concealed, chiefly shale.	10	10
Hard sandstone; weathers rusty.		9
Gray shaly sandstone.	1	6
Bluish nodular shale with sandy lenses and ironstone nodules.	12	9
Coal beds.	7	6
Coal and shale.	4	4
Black waxy shales with thin coaly streaks, sandy at top.	2	9
Gray sandy shales (one eighth inch coal streak near top).	10	
(Continuity doubtful).		
Dirty coal and carbonaceous shale with thin coal lenses.	2	4
Gray sandy shales with many bands of ironstone nodules, grading laterally into massive gray sandstone.	30	
Coal, varying greatly in character along strike and containing large silicified sticks.	1	3
Gray shale and ironstone nodules.	9	7
Concealed.	25	
Gray shale with thin carbonaceous shales, ironstone nodules and sandstone lenses.	10	6
Coal and carbonaceous shale.		9
"Waxy" carbonaceous shale.		6

	Thickness (feet)	(inches)
Gray shale with ironstone nodules.	7	6
Coal bed.	7	11
Nodular gray shale, ironstone concretions in band at base.	7	
Gray shale as above poorly exposed.	19	6
Concealed but probably gray shale with ironstone and a little carbonaceous shale containing coal streaks.	28	
Coaly shale and coal, in places bony.		5-8
Gray shale with ironstone nodules and sandy lenses.	9	6
Carbonaceous and sandy shales and sandstone, partly concealed.	11	6
Shale.	7	
Sandstone.	2	9
Thin beds of sandstone with 6 inches of ironstone.	4	4
Carbonaceous, fissile shale with small coal lenses, 2 inches or less thick, much crumpled.	8	
Sandy nodular shales with large sandstone lenses and large ironstone concretions.	29	
Gray nodular shales and carbonaceous shales with short lenses of coal up to 2 inches thick.	0-2	6
Gray nodular and sandy shales, fissile and carbonaceous at the top, grading laterally into and interleaved with shaly sandstone containing numerous ironstone nodules.	19	6
Dark-bluish nodular shale chiefly, with carbonaceous shale and thin coal lenses, sandstone lenses, and ironstone nodules.	8	
Bluish dark leaf-bearing shale with very thin coal streaks and several ironstone bands laterally overlapping sandstone lens.	7	9
"Waxy" fissile carbonaceous shale.		4
Shaly sandstone and shales with ironstone nodules, varying rapidly in character laterally.	9	9
Fissile carbonaceous shales, with coaly streaks, gray sandy shales, and ironstone.	9	3
Nodular sandy shales with several bands of ironstone concretions.	11	6
Gray sandstone, grading laterally into sandy shales, and large ironstone nodules.	9	10
Sandy shales and ironstone nodules.	7	3
Sandy shales with small coal streaks and lenses and a few small ironstone nodules; carbonaceous shale at top.	4	9
Sandy shales and thin sandstone lenses.	9	

	Thickness (feet)	(inches)
Gray speckled sandstone with carbonized plant remains and bits of coal.	3	4
Dark leaf-bearing and gray shales containing thin bands of ironstone and a lens of coked shaly coal at base.	8	
Diabase sill.		
Gray shale.	1	10
Sill (probably not extensive). Below this sill the exposure is continued in the cliff along Chickaloon River, but is more or less concealed by slide or is inaccessible.		
Gray sandy shales and dark carbonaceous shales and thin sandstones containing a 15-foot sandstone bed and several diabase sills; estimated thickness.	200	
Heavy diabase sill.		
Shales, dominantly gray and concretionary, with intercalated sandstone beds and lenses and ironstone concretions; computed thickness.	30	
Diabase sill.		
Gray sandy and concretionary shales with five or more thin ironstone bands and thin lenses of sandstone in lower part; computed thickness.	104	
Gray sandstone.	4	3
Sandy shales and thin sandstone.	28	
Diabase sill.		
Thin-bedded and slightly cross-bedded sandstone.	13	6
Shale.	1	
Concealed.		
Shale (including 5 1/2-foot sill); estimated thickness.	90	
Concealed.	40	
Dark-gray and brownish shales with ironstone nodules and in part sandy; computed thickness.	176	
Concealed.		
Gray thin cross-bedded sandstone and sandy concretionary shale.	20	
Sill.		
Dark-gray shale with ironstone band.	4	
	1,218	

Concealed.
Sill.

Rapid facies and thickness variations within the unit complicate correlation attempts. The shaly layers are dark gray, poorly bedded, carbonaceous, and locally fossiliferous. The sandy shales are fairly well consolidated, feldspathic, contain little quartz, and are gray to yellowish in color. Waring (1936) describes a thick-bedded, greenish-gray sandstone in the basal part of the formation in the Anthracite Ridge area. The green color is attributed to the presence of chlorite. Ubiquitous conglomerate contains well rounded quartz and chert pebbles generally less than one inch in diameter. A unit in the Anthracite Ridge (plate 85) area is interpreted as a basal conglomerate (Waring, 1936). The conglomerate grades into sandstone along the central part of Anthracite Ridge. A concordant whitened band 30 to 50 feet thick occurs in both facies, and an underlying shale unit is similarly whitened. Waring attributed the "bleaching" to hydrothermal alteration. Field investigation of this unit indicates that calcite cementation and replacement(?) cause the "whitening" of the otherwise gray-brown sandstone.

Coal beds are numerous in the upper 1,400 feet of the formation. Coal beds are 1 to 23 feet thick in the Wishbone Hill district (plate 85) (Barnes, 1967). The coal increases in rank from subbituminous in the lower Matanuska Valley to semianthracite in the upper valley to the east of Chickaloon (plate 85). Abundant plant fragments are found in the shale and sandy shale facies. Pertified wood occurs locally.

Subsurface penetrations of the Chickaloon Formation by various petroleum wells provide additional lithologic information. The lithology in the ARCO Lorraine No. 1 well, (fig. 17) which penetrates 3,800 feet of Chickaloon, is best described as interbedded gray to brown carbonaceous shale; fine- to medium-grained sandstone, claystone, siltstone, and stringers of lignite; and conglomerate near the top of the section. The Humble Oil Susitna State Unit No. 1 well located six miles to the north bottoms in Chickaloon Formation which consists of fine- to medium-grained sandstone and siltstone commonly containing carbonaceous debris and coal.

Model of Sedimentation for the Chickaloon Formation

The Chickaloon Formation was deposited under subtropic to warm-temperate climatic conditions (Wolfe, 1966). Wolfe suggests that the abundance of coarse-grained conglomerate and its proximity to the front of the Chugach Mountains indicates that the Chugach may have been an important source of sediment. A remote source for most of the unit is proposed by Kirschner and Lyons (1973). Drainages may have reached hinterland areas as distant as western Canada supplying the basin with large volumes of garnetiferous, quartzitic graywacke sandstone and micaceous siltstone. It is likely that both sources provided sediment as well as the highlands adjacent to the trough on the north. A model is hereby proposed in which sediments of the Arkose Ridge and Chickaloon Formations were deposited in a narrow linear trough confined between the Talkeetna Mountains on the north and Chugach Mountains on the south during the Paleocene. The margins of the trough accumulated coarse alluvial detritus that overlapped into the axial area where it was reworked by a river larger than the present Matanuska River occupying a broadening valley. The extensive shale and sandy shale sequences probably represent deposition during an extended period of marine transgression that produced estuarine conditions. The coal deposits suggest that swampy conditions prevailed locally throughout the deposition of the Chickaloon Formation.

Uranium Favorability

Based on the criteria given in table 2 it is seen that the general character of the Chickaloon Formation includes some of the features considered important to known uranium host rocks, e.g. rapid facies changes, granitic and metamorphic provenance, fluvial to marginal marine deposition, feldspathic sandstone units, and carbonaceous material scattered throughout the section (table 3). The presence of iron is indicated by a few thin ironstone beds and nodules of iron carbonate in shales.

However, several other characteristics of the formation make it unfavorable for uranium deposition. Bedding angles are steep and folding is common. Tuffaceous sediment is lacking. Only one thin unit of bentonite is described (Waring, 1936).

Published radioelemental content in the bordering intrusive masses is restricted to a few pegmatites in the Willow Creek Mining district located 15 miles northwest of Palmer (plate 85C). As noted in appendix F and section 7.10 of this report, the pegmatites contain relatively low concentrations of uranium.

In summary the Chickaloon Formation is not considered to be highly favorable as a host for sandstone-type uranium deposits.

11.3.1.3 WISHBONE FORMATION

The Wishbone Formation is considered to be an eastern equivalent of the West Foreland Formation (fig. 13) (Kirschner and Lyon, 1973; and Clardy, 1974). Barnes and

Payne (1956) designated Wishbone Hill as the type area for the Wishbone Formation. Originally, the lower portion of this formation was mapped as the Eska Conglomerate (Martin and Katz, 1912).

The Wishbone Formation is areally restricted to the north side of the Matanuska Valley where several exposures cover an area of approximately 50 square miles (fig. 17). The extent of the subsurface Wishbone Formation is not known because it is not recognized in petroleum wells.

The Chickaloon Formation normally grades into the overlying Wishbone Formation, but Clardy (1974) reports that locally an angular unconformity is present between the two (fig. 18). The Tsadaka Formation rests unconformably on the Wishbone Formation and in places truncates Wishbone strata. Tertiary basaltic and andesitic flow rocks unconformably overlie the Wishbone Formation in the Puddingstone Hill and Castle Mountain area (plate 85A).

The Wishbone Formation consists of 2,000 feet of massive conglomerates and sandstones where it is exposed at Wishbone Hill (plate 85A). On Castle Mountain and Puddingstone Hill the formation forms steep cliffs and slopes consisting of 3,000 feet of massive conglomerate and thin interbedded sandstones.

The following lithologic description of a representative section (plate 85A, measured section 2) of Wishbone Formation is taken from Clardy (1974):

Section of Wishbone Formation

	Thickness (feet)
Unconformity (covered)	
Covered interval, probably underlain by sandstone with interbedded conglomerate, as below.	500
Sandstone, tan coarse-grained to granular, angular, poorly sorted, quartz and lithic fragments with occasional chert and felsic volcanic fragments, interbedded with pebble conglomerate; well rounded, poorly sorted with predominantly volcanic clasts.	157

Conglomerate, pebbles with occasional cobbles, well rounded, poorly sorted with lithic sandstone matrix, massive, with occasional feldspatholithic sandstone-gritstone lenses.	230
Sandstone, tan, medium-grained, fair sorting, subangular to sub-rounded, contains quartz, lithic fragments, some feldspar, chert, carbonaceous matter; interbedded with pebble conglomerate, well rounded, thick-bedded, poor imbrication.	56
Conglomerate, pebble, massive as below.	95
Conglomerate, pebble to boulder, well rounded, poorly sorted, felsic volcanic, quartzite and greenstone clasts, silty sandstone matrix, contains occasional brown, medium- to coarse-grained, poorly sorted, well rounded, sandstone lenses with occasional quartz pebbles and lithic fragments; contains prominent sandstone lense (as above) at top, lense appears conformable, contains rare planar cross beds.	177
Covered interval.	?

Unconformity (covered).

Total Thickness 1,266

In general, the Wishbone Formation consists of thick, cross-bedded sandstones and poorly sorted conglomerates. The sandstones are brown, coarse-grained, subangular, poorly sorted, and moderately indurated. Pore spaces in most cases are filled with clay, and the matrix is commonly recrystallized to chlorite.

In the Castle Mountain exposures, lenticular sandstone bodies contain abundant carbonized wood and plant fragments. Through petrographic examination Clardy determined that the sandstone units of the Wishbone Formation are lithic wacke or volcaniclastic sandstones. The matrix of the conglomerate consists of lithic sandstone surrounding well-rounded clasts ranging in size from pebble to boulder. The conglomerates consist predominantly of volcanic clasts (60%), chert and quartz (15%), and plutonic clasts (15%).

The formation is cut by transverse faults in many places, and is moderately to strongly folded, especially at Wishbone Hill.

Model of Sedimentation for the Wishbone Formation

Clardy proposed a provenance of mafic to intermediate volcanic terrane with minor contribution from a metamorphic source (suggested by the presence of garnet, hornblende, and epidote). He considers the Wishbone Formation similar in composition to the Chickaloon Formation and suggests that either the source area or reworking of Chickaloon strata is responsible for the similarity.

Clardy suggests that the Wishbone Formation was deposited in early Eocene time in a humid, lush environment. Sedimentation was characterized by deposition of alluvial fans and later braided streams. Movement along the Castle Mountain fault controlled the relief of the source area and the gradient of streams draining the source area. The Talkeetna Formation was the predominant source of volcanic detritus found in the sandstone and conglomerate units in the Wishbone Formation.

Uranium Favorability

The Wishbone Formation has several features that would make it a favorable host for uranium deposition (table 4). It contains thick alluvial sandstone and conglomerate units. It also contains detritus derived from tuffaceous units of the Talkeetna Formation, assuming the sedimentary model is correct. An unconformity is present at the top of the Wishbone Formation and locally at its base. The bounding unconformities take on additional significance for uranium favorability when it is considered that the Wishbone Formation is predominantly sandstone.

However, the overall uranium favorability is considered to be only moderate because the Wishbone Formation is restricted to the narrow Matanuska Valley. In addition relatively steep dips (up to 30°) are frequent and folding is locally strong.

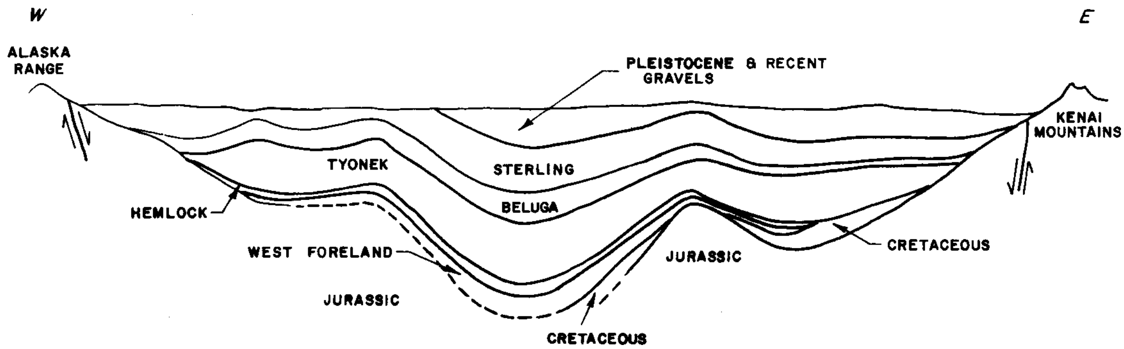
11.3.1.4 WEST FORELAND FORMATION

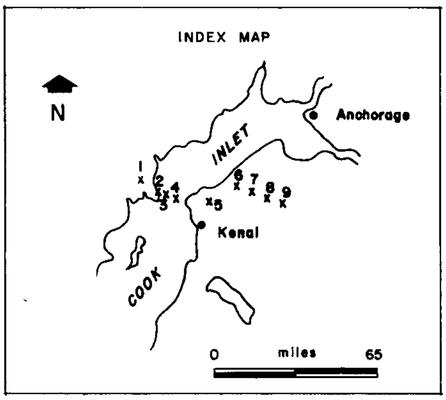
Calderwood and Fackler (1972) have subdivided the Kenai Group into five formations. The West Foreland Formation is the oldest of these units. Originally considered to be Oligocene in age, it is now placed in the early Eocene. Kirschner and Lyon (1973) conclude that the West Foreland Formation was deposited immediately after the Oligocene orogenic episode. They consider the deposition to mark the beginning of a transgressive phase of their proposed late Tertiary cycle of events. It now appears that it is the Tsadaka Formation-Hemlock Conglomerate, and not the West Foreland Formation, that marks the start of the late Tertiary cycle. Magoon and others (1976) consider West Foreland deposition to be pre-Oligocene orogeny and have separated it from the Kenai Group.

The West Foreland Formation underlies more than 5,000 square miles of the Cook Inlet Basin (fig. 17). Wells that have intersected the West Foreland Formation are shown on plates 84B, 94B and 104B. Intervals of West Foreland Formation are listed in appendix C for wells in which the stratigraphy is correlated. The formation is absent in some areas, and in general, thins toward the margins of the basin (fig. 19). Approximately 100 square miles of West Foreland Formation are exposed in the study area. It crops out at various localities along an eastward trending belt from the Capps Glacier area to the Susitna River on the northwest side of the basin (plate 84A), and is also exposed 60 miles to the south near Harriet Point (plate 94A). The unit is present in the subsurface to at least as far east as Susitna Unit No. 1 (fig. 11, item 3) where the thickness is 1,200 feet, but it is absent further to the east in Pittman Unit No. 1 (fig. 11, item 4), and to the south in Turnagain Arm No. 1 (fig. 11, item 1). No outcrops of West Foreland strata have been reported in the Chugach-Kenai area on the east and southeast side of the basin, and it is likely that the area is beyond the eastern limit of deposition. The unit is exposed south of the study area at Cape Douglas, however, the southern limit of deposition, toward the lower Cook Inlet area, has not been determined.

The West Foreland Formation rests unconformably on Jurassic and Cretaceous rocks. At one exposure near Chinitna Bay the unit is separated by an angular unconformity from the older Naknek Formation. The West Foreland dips at 17° SE, and the Naknek at 24° SE at this locality (Lyle and Morehouse, 1977). The Tyonek Formation unconformably overlies the West Foreland Formation where exposed in the Capps Glacier area (plate 84A). Beneath Cook Inlet, the lower contact of the West Foreland Formation is unconformable with Jurassic rocks and sedimentary rocks of the Matanuska Formation. As shown in figure 13, the normal stratigraphic sequence is represented by sediments of the Hemlock Conglomerate resting unconformably on the West Foreland Formation.

The thickness of the West Foreland Formation varies to a maximum of at least 1,600 feet. Calderwood and Fackler (1972) have designated the 890 foot interval from 10,620 to





1. KUSTATAN R. #1
2. WEST FORELAND #1
3. FORELANDS CH. No. 1
4. MGS 18746
5. BISHOP CR. UNIT 11-11
6. SWANSON R. #1
7. SUNRISE L. #1
8. SWAN L.U. #34-27
9. SWAN L.U. #2

Modified from Carter and Adkison (1972)

1 inch = 6 miles HORIZONTAL SCALE
1 inch = 10,000 feet VERTICAL SCALE

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H. / DATA BY: C.C. / DATE: 4/77	REVISED	SECTION OF TERTIARY SEDIMENTS COOK INLET	FIGURE **19** BX135
SCALE: AS NOTED				

11,510 feet in the Pan American Oil West Foreland Unit No. 1 well (fig. 17, item 26) as the type section. The following stratigraphic description is taken from their work:

Type Section of the West Foreland Formation

Hemlock Conglomerate
Unconformity(?)
West Foreland Formation:

Depth	
10,620-10,888	Predominantly claystone, light-gray, silty, micaceous, carbonaceous in part; interbedded brown to brown-gray claystone with siltstone laminae. Thin coal beds in middle and at base of unit.
10,888-10,925	Sandstone, gray to white, fine-grained argillaceous to slightly calcareous, some red or green grains; interbeds of light-green and green-gray silty claystone.
10,925-10,956	Claystone ranging in color from light gray to green-gray, green, red, and brown.
10,956-10,980	Conglomeratic sandstone, white, glassy to ashy, tripolitic pore filling; grain size ranges from fine to coarse, with green pebbles of probable volcanic origin in finer sand matrix.
10,980-11,041	Claystone, green-gray, green, brown, soft bentonitic, tuffaceous; thin white ashy sandstone interbed. Carbonaceous claystone and black bituminous coal laminae in upper part of unit.
11,041-11,221	Primarily white sandstone, medium-to coarse-grained with a few pebbles scattered throughout. Many pebbles are composed of volcanic material, and pore space has been partly filled with clay and volcanic ash. Sandstone beds are separated by thin claystone interbeds, green to gray to brown, silty, tuffaceous.
11,221-11,260	Claystone, gray to dark-gray, carbonaceous; coal laminae and thin beds; green waxy claystone interbed.
11,260-11,285	Volcanic ash, white, argillaceous, silty; some welded tuff.

11,285-11,376	Shale, dark-gray, silty, micaceous, carbonaceous; thin dark-gray siltstone and gray calcareous sandstone interbeds; several thin beds of green, waxy claystone.
11,376-11,510	Primarily claystone, white, green, and brown; abundant volcanic ash and tuffaceous material; several coal streaks. Green, tuffaceous, slightly sandy siltstone and brown claystone form base of sequence.

Base of West Foreland Formation.

The common lithologies described in well logs consist of sandstone, conglomerate, graywacke, siltstone, and coal. The sandstones are described as varicolored, fine- to coarse-grained, and tuffaceous. The siltstones are commonly brown, carbonaceous and tuffaceous.

Exposures of the West Foreland Formation near Chinitna Bay area (Lyle and Morehouse, 1977), are described as nonmarine arkosic sandstone, siltstone, and conglomerate of variable thickness from 125 feet to 797 feet (plate 104A). The sandstone facies occur as narrow lenses up to beds with a maximum thickness of 190 feet. A coal exposure contains a fossil tree in the upright position. Cross bedding and cut and fill features are present. The conglomerate consists of pebble- to boulder-size clasts of plutonic and metamorphic rocks bound in a silty sandstone matrix. Some of the sandstones contain pods and concretions of tuff. The sandstones have low porosity (average of 6%) as a result of compaction of mineral grains and the presence of interstitial zeolite.

In the Capps Glacier area (plate 84A) in the foothills of the Alaska Range, the West Foreland Formation consists of about 1,200 feet of conglomerate with a few interbeds of sandstone (Adkison and others, 1975b). The conglomerates range from 5 to 210 feet in thickness, consisting of pebble- to cobble-size clasts of granitic, metamorphic, and volcanic rocks in a clayey to silty sand matrix. Zeolite cement is common. The sandstone is brownish gray in the lower part of the formation where it is well indurated and iron-stained in places. The upper 285 feet of the unit contains several medium gray to greenish gray sandstone beds ranging from less than 1 foot to 14 feet thick. The thickest bed includes a thin lens of carbonaceous siltstone.

The conglomerates and lavas are most conspicuous near the west margin of the basin. Tuffaceous material appears to be widespread in the central and eastern areas. Arkose is reported near the west margin where the formation is typically conglomeratic.

Model of Sedimentation for the West Foreland Formation

The proposed model is one in which deposition was active in the entire midbasin area, except along the eastern and locally along the western margins. Uplift of Jurassic and Cretaceous strata accompanied emplacement of Late Cretaceous-early Tertiary intrusive masses to the northwest of the basin in the Alaska Range. Subsequent erosion of granitic, volcanic and metamorphic rocks of uplifted Mesozoic formations provided detritus for the sediments of West Foreland Formation.

Size and heavy mineral studies were conducted on samples from surface and subsurface sections of the West Foreland Formation (Hite, 1975). The heavy mineral study shows that the formation is characterized by very low garnet content and high hornblende content. Highly variable amounts of epidote, sphene, and hornblende in the basal section tend to reflect the mineralogy and lithology of the underlying Mesozoic strata. It is likely that some material was supplied from a remote source in interior Alaska as suggested by Kirschner and Lyon (1973).

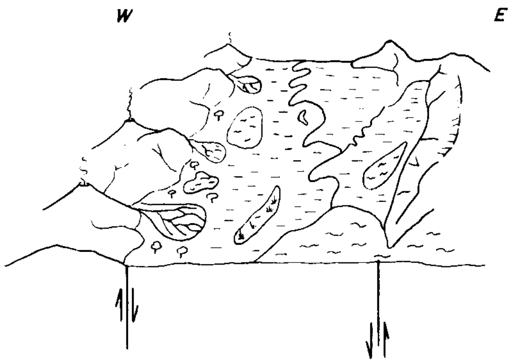
Sedimentation was dominantly fluvial with alluvial fans stretching southward from the foothills and coalescing with deposits of flood plain and locally swampy environments (fig. 20).

In the Chinitna Bay area (plate 104A), the units are described by Lyle(1977) as channel and fluvial flood plain deposits oriented normal to the Cook Inlet Basin. If that interpretation is correct, the suggestion is that the source along the northwestern part of the basin is to the north and northwest. The size analysis study by Hite (1975) noted above, indicates a west or northwest source and predominantly fluvial environment of deposition for the West Foreland sediments.

Tidal conditions are indicated by Hite (1975) near the distal end of the nonmarine fluvial deposits and, where marine processes were active, deposition occurred from turbulent suspension.

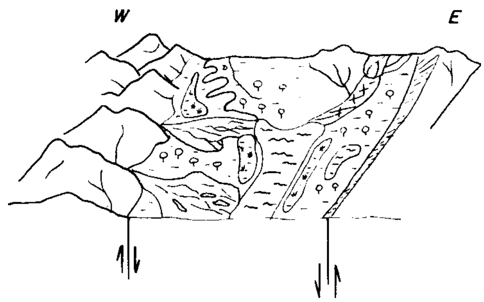
Uranium Favorability

The West Foreland Formation contains many features considered to be favorable for uranium deposits as listed in tables 2 and 3.



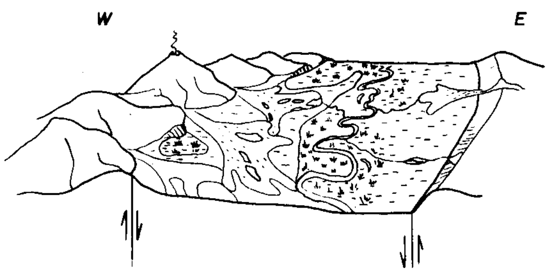
WEST FORELAND - PALEOCENE

EXPLOSIVE VOLCANISM - DOMINANT CONTRIBUTION OF SEDIMENT FROM THE WEST



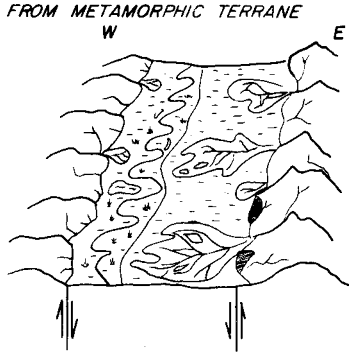
HEMLOCK - LATE OLIGOCENE

INLAND SEA — DOMINANT CONTRIBUTION FROM METAMORPHIC TERRANE



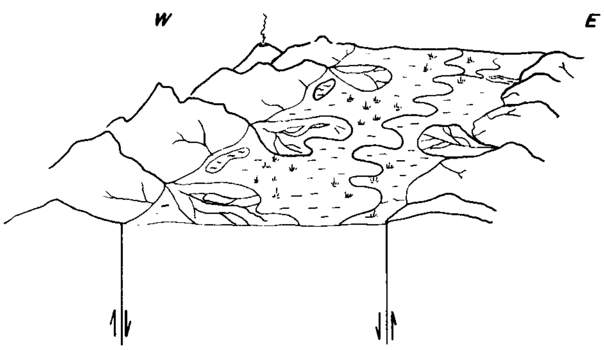
TYONEK - MIOCENE

SWAMPY CONDITIONS - DOMINANT CONTRIBUTION FROM PLUTONIC COMPLEX TO THE WEST



BELUGA - LATE MIOCENE

SWAMPY CONDITIONS - DOMINANT CONTRIBUTION FROM METAMORPHIC COMPLEX TO THE EAST



STERLING - PLIOCENE

EXPLOSIVE VOLCANISM - SIGNIFICANT CONTRIBUTION FROM PLUTONIC COMPLEX TO THE WEST

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY: M.H. DATA BY: C.C. DATE: 4/77	REVISED	PALEOGEOGRAPHIC INTERPRETATIONS OF COOK INLET BASIN
SCALE: DIAGRAMS REPRESENT THOUSANDS OF SQUARE MILES			FIGURE **20** BX131

Nonmarine facies are present in the Capps Glacier and Chinitna Bay areas along the west edge of the Cook Inlet Basin. Nonmarine fluvial environments are attested to by stream channel and flood plain deposits. Arkosic sands were deposited from south flowing streams that headed in the Aleutian Range and Alaska Range. Sources of granitic debris in the unit are believed to be Jurassic quartz diorite and granodiorite plutons, and possibly newly unroofed Late Cretaceous to early Tertiary adamellite and granodiorite bodies. The younger intrusives are considered a more favorable provenance and source of leachable uranium than the Jurassic intrusives because of their lithologies (sections 7.10 and 10.2).

The West Foreland Formation is both overlain and underlain by unconformities. Dips are gentle, and the sandstone units are porous.

Tuffaceous and carbonaceous materials are reported in the arkosic beds. Tuff, interbedded with arkose, is reported in wells logs to the east.

Data on West Foreland lithologies are lacking for the north end of the Cook Inlet Basin. It is not known if the Susitna Lowlands extension of the basin developed prior to deposition of the West Foreland Formation. It is probable that the Cook Inlet graben structure was developed in the northern extension area during the Tertiary if proposed conjugate faults (fig. 5) bordering the Susitna Lowland are related to the Denali Fault. (See Tectonic Overview, page 53). Nonmarine sediment would be expected in the basin north of the Castle Mountain fault if the area subsided more slowly than that portion of the nonmarine Cook Inlet Basin located to the south of the fault. Arkosic sediments would be expected if uplift of the bordering Alaska Range and Talkeetna Mountains Provinces was sufficiently rapid to provide adequate relief and to unroof the granitic bodies. The West Foreland strata would be thinner in the northern area than in the more rapidly subsiding basin to the south of the Castle Mountain fault.

There is good reason to suspect that favorable features for uranium deposition described for the Capps Glacier and Chinitna Bay areas, are present in the Susitna Lowlands part of the basin. This conclusion is based on consideration of the apparent similar paleogeographic setting described above.

West Foreland strata project to depths well in excess of 5 to 10 thousand feet under large parts of the northern and western areas of the basin. A majority of the petroleum drill holes bottom above the West Foreland Formation. The unit is known to be present at a depth of 8,000 feet at the extreme west limit of Cook Inlet.

West Foreland lithologies pass from nonmarine to marine facies southward and westward toward the early Tertiary sea. Due to a paucity of data, it is not possible to plot the strand line. Features recognized as favorable for uranium occurrences decrease as the marine environment is approached. In the central part of the basin, the continental depositional environment probably extends to depths below which deposits would be exploited by conventional means.

Nonmarine conditions may have prevailed throughout West Foreland time in the northern or Susitna Lowlands area. The various facies in the formation become increasingly continental upward in the section.

Gamma logs from 10 drill holes indicate that normal radioactivity averages 50 API units (appendix C). The radioactivity values range from 32 to 64 API units. No stratigraphic intervals are considered anomalous. It should be noted that the areas considered to be most attractive for uranium occurrences are located primarily to the west and north of most of the West Foreland Formation subsurface drill intercepts.

Summarily, West Foreland lithologies near the west side, and the northern margins of the Cook Inlet Basin contain a sufficient number of favorable features to indicate a reasonable possibility for occurrence of uranium deposits.

11.3.1.5 TSADAKA FORMATION

The Tsadaka Formation was originally mapped as the upper portion of the Eska Conglomerate (Martin and Katz, 1912). Barnes and Payne (1956) later separated the Eska Conglomerate on Wishbone Hill into the Wishbone Formation and Tsadaka Formation on the basis of contrasting conglomerates. The Tsadaka Formation is middle to late Oligocene in age and considered equivalent to the Hemlock Conglomerate of the Kenai Group (Magoon and others, 1976). Kirschner and Lyon (1973) consider the Tsadaka Formation equivalent to the Tyonek Formation (fig. 13).

The areal extent of the formation is limited to approximately 30 square miles of exposure along the north side of the Matanuska Valley (plate 85A); however, Clardy interprets the Tsadaka Formation to be present in the Union Oil Pittman Unit No. 1 and the Hill Production Fish Hook No. 1 wells (fig. 21, items 4 and 5). If this is the case, a conservative estimate of the extent of the subsurface Tsadaka Formation, limited to the lower Matanuska Valley, would be 3,000 square miles.

In Tsadaka Canyon (plate 85A) the Tsadaka Formation rests unconformably on deformed strata of the Chickaloon Formation. On Wishbone Hill the basal contact is in angular unconformity with the Wishbone Formation (fig. 15). The top of the Tsadaka Formation has not been identified in outcrop. The Tsadaka Formation is overlain by undivided upper Tertiary Kenai Group sedimentary rocks beneath the lower Matanuska Valley.

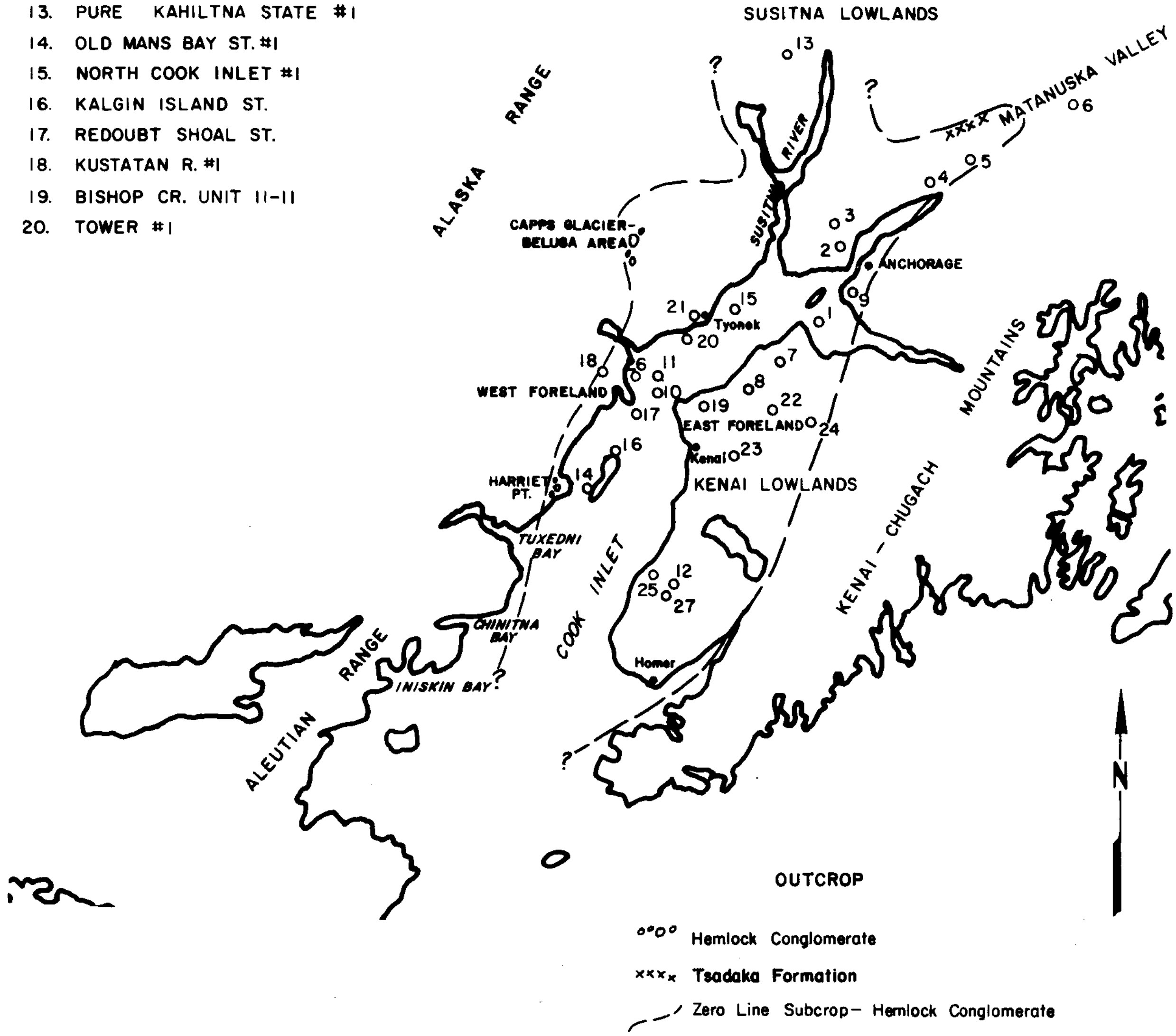
Along Tsadaka Canyon, Clardy (1974) measured 515 feet of Tsadaka Formation, including a 45 foot thickness of massive basal conglomerate. The Wishbone Hill exposure is at least 200 feet thick. The following representative section (plate 84A, measured section 4) of Tsadaka Formation is taken from Clardy (1974):

Section of Tsadaka Formation

	Thickness (Feet)
Unconformity	
Sandstone, dark gray, medium- to coarse-grained subangular, massive with very hard calcite-cemented beds up to 3 feet thick near middle, grades upward to silty cross-bedded sandstone.	46
Conglomerate, well rounded pebbles up to 1 inch in diameter, well sorted, well bedded, some large cross beds.	14
Conglomerate, well rounded pebbles and cobbles up to 6 inches in diameter, poorly sorted, massive, poorly consolidated.	16
Sandstone, gray, medium- to very coarse-grained poorly sorted, well rounded, massive, feldspathic, contains pebbly lense with granitic clasts.	16
Sandstone, brown, fine-grained to silty, well rounded, well sorted, laminated with abundant cross-beds near top and bottom, some carbonaceous material in lower 1/3, concretions in middle 1/3, discontinuous pebble beds near middle.	49

INDEX

1. TURNAGAIN ARM #1
2. LORRAINE #1
3. SUSITNA UNIT #1
4. PITTMAN UNIT #1
5. FISHOOK UNIT #1
6. CHICKALOON #1
7. POINT POSSESSION UNIT #1
8. SWANSON R. UNIT 34-10
9. CAMPBELL POINT #1
10. MIDDLE GROUND SHOAL 18746A-1
11. MIDDLE GROUND SHOAL A43-11
12. EDNA MAE WALKER #1
13. PURE KAHILTNA STATE #1
14. OLD MANS BAY ST. #1
15. NORTH COOK INLET #1
16. KALGIN ISLAND ST.
17. REDOUBT SHOAL ST.
18. KUSTATAN R. #1
19. BISHOP CR. UNIT 11-11
20. TOWER #1
21. TYONEK ST. 17587 #2
22. SUNRISE LAKE UNIT #1
23. STERLING UNIT 23-15
24. SWAN LAKE UNIT #2
25. NINILCHIK #1
26. WEST FORELAND #1
27. DEEP CREEK UNIT #1



Modified from Kirschner and Lyon, (1973)

WGM INC — MINING & GEOLOGICAL CONSULTANTS, ANCHORAGE, ALASKA	DWN BY M.H.	REVISED	EXTENT OF HEMLOCK CONGLOMERATE	FIGURE 21
SCALE: 20 0 40miles	DATA BY C.C.			8X128
	DATE 4/77			

Siltstone, dark brown, poorly bedded, contains abundant carbonaceous material.	3
Sandstone, gray, iron-stained, medium- to coarse-grained, well sorted, sub-rounded, feldspathic, poorly bedded, locally well cemented with calcite, interfingers with underlying conglomerate unit.	16
Conglomerate, pebbles and cobbles up to 5 inches in diameter, well rounded, well sorted, abundant fractured pebbles, abundant volcanic clasts and red chert.	33
Sandstone, gray, iron-stained, medium- to coarse-grained, sub-rounded, feldspathic, poorly planar bedded, locally well cemented with calcite, interbedded with gray laminated siltstone which grades upwards to brown carbonaceous shale; cyclical.	49
Covered interval, probably silty sandstone as above.	16
Conglomerate, pebbles and boulders up to 10 inches in diameter, iron-stained, poorly sorted, massive, contains sandstone interbeds, gray, coarse to very coarse, sub-rounded, fair sorting, micaceous, well cemented; scour at base of unit.	46
Siltstone, sandy, grades upward to silty, laminated shale.	16
Sandstone, fine-grained, micaceous, iron-stained, well rounded, pebble lense near middle.	13
Siltstone, greenish-gray, sandy (fine-grained), micaceous, finely laminated, friable, grades upward to carbonaceous shale.	16
Sandstone, tan, medium- to coarse-grained, contains sparse pebbles, well sorted, sub-rounded, feldspathic, poorly bedded, contains interbeds of gray siltstone.	27
Conglomerate, pebbles and cobbles up to 8 inches in diameter, fair sorting, common chert clasts, contains sandstone lenses, buff gray, medium- to coarse-grained, well sorted.	64
Sandstone, buff to gray colored, medium- to coarse-grained, well sorted, partly indurated, quartzose, interfingers with overlying conglomerate.	10

Conglomerate, cobbles and boulders up to 15 inches in diameter, poorly sorted, well rounded, firmly cemented, abundant granitic clasts, coarse gritstone matrix, feldspathic. 46

Unconformity.

Total Thickness 496

The Tsadaka Formation is characterized by a massive, poorly sorted basal conglomerate. Well rounded clasts, pebble- to boulder-size, of acidic plutonic composition are set in a matrix of arkosic sandstone. In contrast to the Wishbone conglomerates, the Tsadaka conglomerates contain few volcanic and chert clasts. The overlying siltstones, sandstones, and pebble conglomerates are typically lenticular and discontinuous. The sandstones are medium- to coarse-grained, well sorted, and in places well indurated. Features such as trough cross-stratification, ripple marks, and scour and fill marks are common. Carbonized wood and plant fragments are abundant in siltstone lenses. The less friable sandstones commonly are cemented with calcite. Interstitial clay is not as abundant as in the sandstones of the Wishbone Formation. Clardy (1974) determined by visual inspection that the porosity of the sandstones ranges from fair to good. The chloritic matrix common to Wishbone sandstones was not observed in the Tsadaka sandstones.

Model of Sedimentation for the Tsadaka Formation

Clardy (1974) has proposed a sedimentary model for the Tsadaka Formation similar to that of the Wishbone Formation. The formation was deposited along a mountain front as alluvial fans and braided stream deposits during a time when the environment was humid. Bed configurations present in the formation indicate that some of the units were deposited as dunes, bars, transverse bars, and cut-off channels. Clardy's interpretation that these deposits represent a braided stream environment in a distal facies away from the apex of an alluvial fan is probably correct.

A felsic igneous source is indicated by the composition of the conglomerate clasts and the high quartz and feldspar content of the sandstones. Heavy mineral associations are dominated by epidote (average 40%) in the Tsadaka Canyon exposures (Clardy 1974). The lower part of the section contains anomalously high garnet (in excess of 30%) and low hornblende (10%). The middle section is characterized by low garnet (less than 3%) and low hornblende (less than 10%) content. Hornblende increases (up to 70%) and epidote decreases (to 20%) in the upper section of the Tsadaka Formation. The heavy mineral content suggests that low-grade metamorphic terrane was also contributing sediments. The igneous source was probably the Talkeetna Mountain plutonic complex to the north. Vertical movement along the Castle Mountain fault caused the uplift of the igneous source area and provided the gradient necessary for the transportation of the coarser conglomerate material to the trough. The predominance of sandstone and siltstone in the upper portion of the formation suggests reduced uplift toward the end of Tsadaka deposition.

Uranium Favorability

The regional geologic setting of the Tsadaka Formation appears similar to that of known uranium hosts. The provenance of the formation is granitic and metamorphic rocks. The depositional environment fits the fluvial model, and composition of the sandstone is comparable to uranium host types. An unconformity is subjacent to the basal conglomerate. Carbon is present in siltstones higher in the formation.

The general favorability of the Tsadaka Formation as a host to economic sandstone-type uranium deposits will necessarily be limited by the areal extent of the favorable rocks. If the few observed outcrops reflect the overall distribution of the formation, it would be a poor target. If, on the other hand, Clardy's (1974) interpretation that the Tsadaka Formation is present in the subsurface as far west as Pittman Unit No. 1 is correct, then the general favorability is greatly enhanced. The area from the Pittman Unit No. 1 well east to the Wishbone Hill area may well be worth investigating for evidence of Tsadaka Formation. That area is mapped as Quaternary surficial material of unknown thickness. Farther to the west the Tsadaka Formation grades laterally into the dominantly marine Hemlock Conglomerate, discussed in the following section.

Gamma ray logs could not be obtained for the Pittman Unit No. 1 and Fish Hook No. 1 exploratory wells that penetrated the Tsadaka Formation. However. it is probable that gamma ray logs are available for some of the other wells that undoubtedly penetrated the Tsadaka Formation in the vicinity of the lower Matanuska Valley but for which no correlations have been made (plate 85B). Gamma ray logs can be obtained upon request for specific wells through the Oil and Gas Division of the Alaska State Geological and Geophysical Surveys.

11.3.1.6 HEMLOCK CONGLOMERATE

The Hemlock Conglomerate is Late Oligocene in age and is one of five lithologic divisions proposed by Calderwood and Fackler (1972) for the Kenai Group. Clardy (1974) and Magoon and others (1976) interpret the Hemlock Conglomerate to be equivalent to the Tsadaka Formation of the Matanuska Valley (fig. 13).

Few surface exposures of Hemlock Conglomerate are known. Magoon and others (1976) report that rocks equivalent to the Hemlock Conglomerate crop out near Harriet Point (fig. 21). They have mapped them as undivided Hemlock Conglomerate-Tyonek Formation covering approximately 30 square miles of area. Hemlock equivalents are reportedly exposed in the Capps Glacier area (Kirschner and Lyon, 1973). No surface descriptions of the formation accompany these reports. The subsurface Hemlock Conglomerate is well studied since the formation contains most of the known petroleum reservoirs in the basin.

Like the West Foreland Formation, the Hemlock Conglomerate thins towards both the eastern and the western margins of the basin. Based on exploratory well intercepts it is estimated that the Hemlock Conglomerate underlies more than 7,000 square miles of the Cook Inlet Basin (fig. 21). Wells in which the Hemlock Conglomerate is the deepest rock unit encountered are shown on plates 94B and 104B. Intervals of Hemlock Conglomerate are listed in appendix C for wells for which the stratigraphy is correlated. The Hemlock Conglomerate is known to crop out in only a few locations on the west side of the basin and to be absent along the eastern margins of the basin (fig. 11). Lack of exposures definitely identified as Hemlock Conglomerate makes it difficult to evaluate the limits of the formation.

The Hemlock Conglomerate unconformably overlies the West Foreland Formation. The upper contact with the overlying Tyonek Formation was originally interpreted to be conformable, and interrupted by only minor local unconformities (Calderwood and Fackler, 1972). A more recent comparison of the palynology, heavy mineral suites, and electric log characteristics of the two formations indicates that the contact is an unconformity of basinwide extent (Hite, 1975).

The Hemlock Conglomerate reaches a maximum thickness of 1,030 feet in the Pan American Middle Ground Shoal No. 1 well (fig. 21, item 10). The type section for the Hemlock

Conglomerate was established as the interval from 11,130 feet to 11,700 feet in the Richfield Swanson River No. 1 well (fig. 21, item 8). (Calderwood and Fackler, 1972).

Type section of the Hemlock Conglomerate

Tyonek Formation.
Hemlock Conglomerate:

Depth	
11,130-11,145	Sandstone, gray to brown, fine- to medium-grained, firm to friable; silty laminae.
11,145-11,150	Siltstone, gray to dark-gray; thin gray fine-grained sandstone interbeds; carbonaceous laminae.
11,150-11,233	Sandstone, brown fine- to medium-grained at top becoming more conglomeratic in basal part. Pebbles are 1/4-2 inches in size, round to subround, composed of quartz, chert, and rock fragments; color ranges from white to black, green and red. Unit varies from firm to friable with fair to good porosity and permeability. Some carbonaceous laminae and thin streaks.
11,233-11,300	Alternating siltstone and sandstone beds. Siltstone is dark gray, hard, micaceous, sandy, with scattered carbonaceous laminae. Sandstone beds are approximately 10 ft. thick, gray to brown, fine- to medium-grained, friable in part; some carbonaceous laminae.
11,300-11,380	Sandstone, gray to brown, conglomeratic, medium- to coarse-grained matrix, friable to firm, crossbedded in part, carbonaceous laminae, silty streaks, micaceous, calcareous-cemented hard streaks; thin black bituminous coal bed. Gray siltstone bed with coal streaks near base of unit.
11,380-11,406	Siltstone, gray, hard, micaceous; plant remains; thin coal beds up to 2 ft. thick.
11,406-11,435	Sandstone, gray, firm to hard, calcareous cement in part, fine- to medium-grained, silty, micaceous; some thin, black, carbonaceous laminae.

11,435-11,512	Siltstone, gray, hard, micaceous, plant remains, carbonaceous laminae; interbeds of gray, fine- to medium-grained, silty, hard sandstone; carbonaceous laminae.
11,512-11,586	Conglomerate with sandy matrix grading to conglomeratic sandstone. Pebbles are up to 2 in. and consist of chert, quartzite, quartz, igneous rocks, and metasediments. Pebbles are in medium- to coarse-grained sandstone matrix, friable to cemented. Some pore space is filled with gray-white clay, possibly kaolinite. Thin gray siltstone interbeds and some coal beds are present.
11,586-11,610	Siltstone, gray to dark-gray, scattered sandy streaks, gray shale interbeds; carbonaceous laminae; coaly streaks.
11,610-11,700	Sandstone, brown, with gray to white blebs of clay material, hard to friable; conglomeratic sandstone interbeds and lenses, pebbles up to 2 in. diameter are of quartz, chert, quartzite, metasediments, and volcanic rocks; calcareous cemented lenses and interbeds. Several gray to green-gray siltstone interbeds; brownish black crossbedded carbonaceous laminae; coaly streaks.

Base of Hemlock Conglomerate.
Unconformity(?).
West Foreland Formation.

A similar description was given for the Hemlock Conglomerate by Adkison and Newman (1973) in part of a reference section for Tertiary sedimentary rocks in the Standard Oil of California Deep Creek Unit No. 1 well (fig. 21, item 27). In this well the Hemlock Conglomerate consists of 536 feet of sandstone, conglomerate, siltstone, shale, and coal. The sandstone is typically light gray, fine- to coarse-grained, micaceous and commonly in a matrix of white clay. Rounded to sub-rounded pebbles in the sandstone consist of quartz, chert, basalt, and in some cases, plutonic rocks. Conglomerate occurs in the upper part of the sequence and ranges up to 3 feet in thickness. Clasts are generally less than one inch in size and consist of quartz, basalt, chert, and intrusive igneous rocks. Medium to coarse sand and white clay form the matrix of the conglomerate. Some carbonaceous material is present in both the sandstone and conglomerate.

In general, lithologies consist of a thick sequence of coarse conglomerates and conglomeratic sandstones. The sandstones are generally fine- to medium-grained, consisting of quartz, chert, and rock fragments. Some carbonaceous material is present in the sandstones and the siltstones are commonly carbonaceous. Bituminous coal occurs only as thin beds and is generally scarce in the unit.

Model of Sedimentation for the Hemlock Conglomerate

The Hemlock Conglomerate marks the end of a widespread hiatus that began in early Oligocene time. Warm temperate conditions prevailed during deposition. Hite (1975) has proposed a model of deposition much like the present tidal estuary environment of the Cook Inlet. Sediment was transported to the inlet mostly by major streams where tidal action swept the material along the tidal channels and deposited it offshore. The coarsest material was deposited in the deepest portions of the basin and finer material toward the margins. The low flat regions adjacent to the inlet provided swampy environments for coal development. Further landward, alluvial channel and fan deposits developed (fig. 20). Clasts and sand grains are commonly angular indicating a nearby source for some of the Hemlock Conglomerate. Sedimentary units appear to fine toward the south suggesting a north or northwest source.

Heavy mineral studies (Hite, 1975) of surface and subsurface samples of Hemlock Conglomerate from the west side of the basin indicate that it is characterized by a high epidote (52%) content. This contrasts with both the overlying Tyonek Formation and underlying West Foreland Formation. Moderate amounts of garnet (25%) are present while hornblende content is generally low (7%). The high epidote and moderate garnet content suggests that a metamorphic source similar to the Kenai-Chugach Mountains provided the sediments for the Hemlock Conglomerate. A similar study by Kelley (1973) determined that the heavy mineral content of Hemlock Conglomerate averages 50% garnet. Samples from the Standard Oil Company Deep Creek Unit No. 1 well were used for Kelley's study.

Based on the lithologic description of the type section given by Calderwood and Fackler (1972) it seems that both a metamorphic terrane and a volcanic plutonic complex provided sediment to the Hemlock Conglomerate. The heavy mineral content of the Hemlock as well as the micaceous character of the sandstone suggests that the metamorphic terrane was the dominant source area.

Additional analyses (Hite, 1975) show that when compared to the other formations of the Kenai Group, a greater proportion of the sediments of the Hemlock Conglomerate represents deposition by turbidity processes. The distribution of the turbidity deposits corresponds to the deepest portion of the basin where the Hemlock Conglomerate is thickest. Other sedimentary rocks of the formation were deposited by fluvial and tidal processes.

Sandstone deposits within the Hemlock Conglomerate are thickest in the mid-basin area. Coal occurs as two bands parallel to the basin margins but apparently is absent in mid-basin. This distribution of lithologies suggests that marine conditions probably existed basinward of the coal throughout most of Hemlock deposition.

Uranium Favorability

Overall, the Hemlock Conglomerate is considered to be unfavorable for sandstone uranium deposits. The formation is bounded by unconformities, but other criteria characteristic of sandstone-type uranium deposits are lacking (table 2). The sediments are neither arkosic nor tuffaceous (table 3).

A relatively high percentage (42%) of the grain sizes common to Hemlock Conglomerate sandstone and siltstone suggest marine deposition. The dominant provenance appears to be the metamorphic complex of the Chugach-Kenai Mountains with some contribution from the plutonic complex of the Alaska-Aleutian Range. Gamma ray logs of 11 exploratory wells indicate that the normal radioactivity of the Hemlock Conglomerate averages 40 API units (appendix C). The radioactivity values range from 35 to 55 API units and are not considered anomalous.

11.3.1.7 TYONEK FORMATION

The Tyonek Formation is the middle formation of the Tertiary Kenai Group and is late Oligocene to mid-Miocene in age.

The contact with the underlying Hemlock Conglomerate is considered to be unconformable as deduced from the character of electric logs, palynology studies, and heavy mineral suites (Hite, 1975). Calderwood and Fackler (1972), on the other hand, suggest that the contact is conformable with the exception of local unconformities in the Capps Glacier area.

The Tyonek Formation is extensive throughout the Cook Inlet Basin and, like the underlying Hemlock Conglomerate and West Foreland Formation, it thins toward the basin margins (fig. 16). The subsurface Tyonek Formation is known from drill hole intercepts to underlie 7,000 square miles of Cook Inlet

Basin (fig. 22). Plates 94B, 84B, and 85B show exploratory wells in which the deepest rock encountered is Tyonek Formation. Maximum deposition occurred in the west-central part of Cook Inlet as it did in the underlying Hemlock Conglomerate. Several outcrops of Tyonek Formation are known in the Capps Glacier-Beluga Lake area on the west side of the Cook Inlet (fig. 22). In the Capps Glacier area 2,005 feet of exposed Tyonek Formation has been described by Adkison and others (1975b). Magoon and others (1976) map undivided Tyonek Formation and Hemlock Conglomerate in the Harriet Point area. Hite (1975) reports that possibly as much as 400 feet of the Tyonek Formation crop out at Harriet Point. Magoon and others (1976) map three small exposures of Tyonek Formation along Eagle River north of Anchorage (plate 85A). The total area of exposed Tyonek Formation is approximately 90 square miles.

The upper contact of the Tyonek Formation is an unconformity with the Beluga Formation. Kirschner and Lyon (1973) had considered the Tsadaka and Tyonek Formations to be equivalents, but based on flora studies and similar lithology, the Tsadaka Formation is now recognized as equivalent to the Hemlock Conglomerate.

The stratigraphic thickness is variable to a maximum of 9,000 feet. Calderwood and Fackler (1972) have designated 7,650 feet of Tertiary sedimentary rocks in Pan American Tyonek State 17587 No. 2 well as the type section (fig. 22, item 21). The following stratigraphic section is taken from their work:

Type section of the Tyonek Formation

Beluga Formation.
Unconformity.
Tyonek Formation:

Depth	
4,300-5,420	Sandstone, light-gray, fine- to medium-grained with some coarse grains and scattered pebbles; loosely cemented with silty, bentonitic clay matrix. Interbedded with light-gray, silty, bentonitic claystone; gray to dark-gray, argillaceous, calcareous, siltstone; numerous lignitic to subbituminous coal beds up to 20 ft. thick.

INDEX

1. TURNAGAIN ARM #1
2. LORRAINE #1
3. SUSITNA UNIT #1
4. PITTMAN UNIT #1
5. FISHOOK UNIT #1
6. CHICKALOON #1
7. POINT POSSESSION UNIT #1
8. SWANSON R. UNIT 34-10
9. CAMPBELL POINT #1
10. MIDDLE GROUND SHOAL 18746A-1
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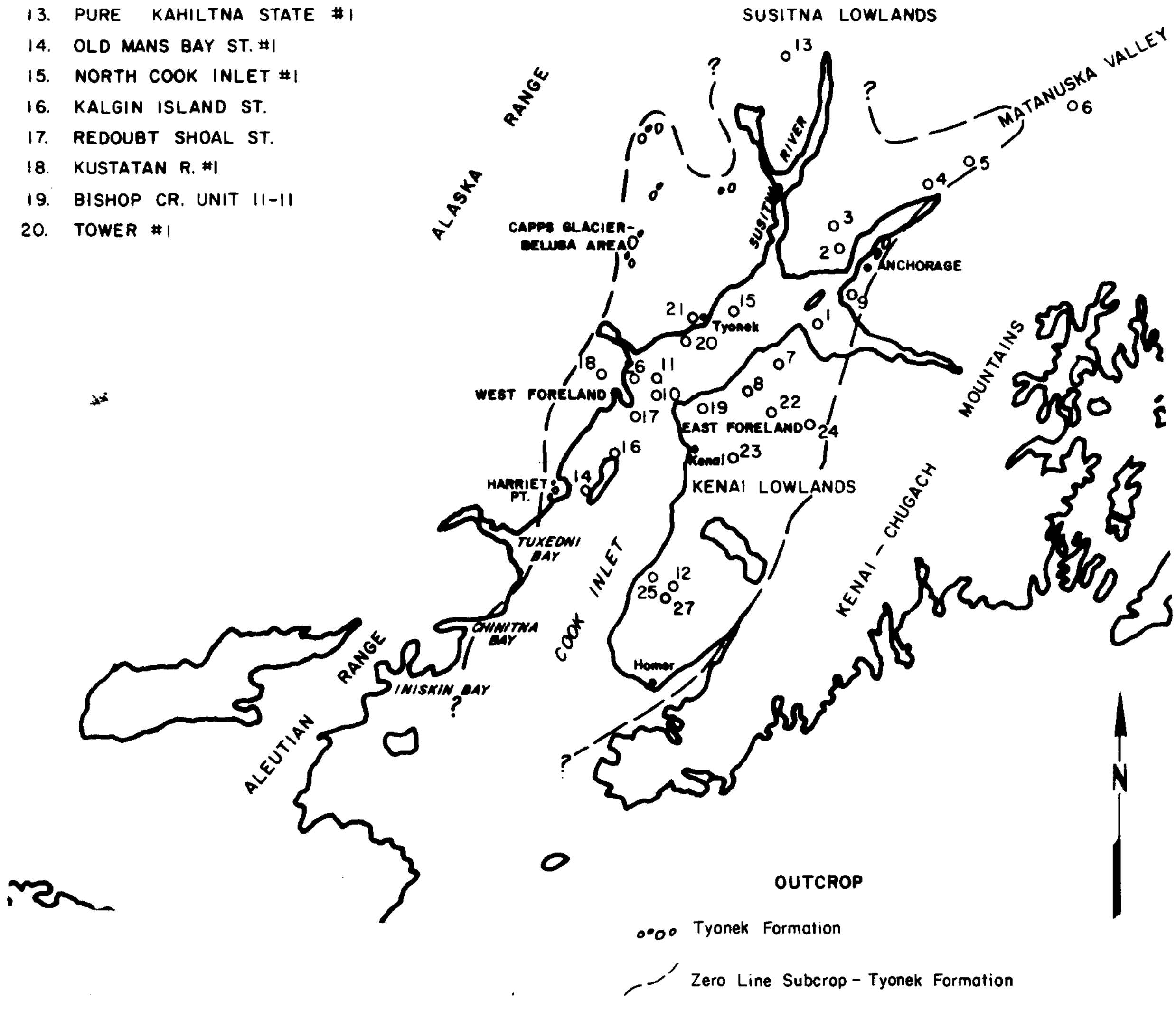
14. OLD MANS BAY ST. #1
15. NORTH COOK INLET #1
16. KALGIN ISLAND ST.
17. REDOUBT SHOAL ST.
18. KUSTATAN R. #1
19. BISHOP CR. UNIT 11-11
20. TOWER #1
21. TYONEK ST. 17587 #2
22. SUNRISE LAKE UNIT #1
23. STERLING UNIT 23-15
24. SWAN LAKE UNIT #2
25. NINILCHIK #1
26. WEST FORELAND #1
27. DEEP CREEK UNIT #1



Modified from Kirschner and Lyon (1973)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA

SCALE: 20 0 40 miles

DWN BY M.H. | REVISED
DATA BY C.C.
DATE 4/77

EXTENT OF TYONEK FORMATION

FIGURE 22

8X145

5,420-5,980	Claystone, light-gray, silty bentonitic. Interbedded with light-gray, fine- to medium-grained, silty sandstone, slightly calcareous, clay matrix; gray to dark-gray, argillaceous, some slightly calcareous siltstone; numerous coal beds as in overlying unit.
5,980-6,990	Sandstone, light-gray, fine-grained with some coarse grains and scattered pebbles, cemented with silty bentonitic clay matrix. Sandstones are in beds from a few feet to 60 feet thick interbedded with gray, argillaceous, calcareous siltstone; light-gray, silty, bentonitic claystone; lignitic and subbituminous coal beds up to 30 feet thick.
6,990-7,740	Sandstone, light gray, fine-grained, calcareous; dominantly quartz with some dark-gray rock fragments; scattered pebbles and thin pebble conglomerates. Interbedded with light-gray argillaceous, calcareous siltstone; lignitic and subbituminous coal.
7,740-8,840	Claystone, light- to dark-gray, silty, bentonite associated with light-gray claystone in lower half of unit; interbedded with siltstone, gray to dark-gray, calcareous; sandstone, light-gray, angular to subangular, predominantly fine-grained with streaks of coarse grains and scattered pebbles; cemented with benotonitic clay matrix; some thin limestone beds, gray to brown, argillaceous, silty; numerous lignitic and subbituminous coal beds up to 15 feet thick.
8,840-10,840	Sandstone, light- to medium-gray, fine- to medium-grained, angular to subangular, conglomeratic, cemented with bentonitic, silty clay matrix; beds up to 70 feet thick. Interbedded with medium- to dark-gray, silty, bentonitic claystone; medium- to dark-gray, argillaceous, slightly calcareous siltstone; dark gray to black, carbonaceous shale; and lignitic and subbituminous coal beds generally less than 10 feet thick but a few up to 30 feet.

10,840-11,950 Claystone, light- to medium-gray, silty, bentonitic; some siderite nodules. Interbedded with medium- to dark-gray, argillaceous siltstone, some beds slightly calcareous; light-gray, fine-grained sandstone, with scattered angular to subangular, calcareous pebbles cemented with silty clay matrix, some chlorite and biotite grains; lignitic and subbituminous coal. Coal beds are thinner, generally less than 5 feet and less numerous than in overlying units.

Base of Tyonek Formation
Hemlock Conglomerate

Common lithologies described in well logs consist of fine- to medium-grained, massively bedded sandstones and thick coal beds with interbedded siltstone and claystone.

The fine clastics of the Tyonek Formation contrast sharply with the conglomeratic character of the underlying Hemlock Conglomerate. More massive sandstones and thicker coal beds distinguish the Tyonek Formation from the overlying Beluga Formation.

In the Standard Oil Company of California Deep Creek No. 1 well (fig. 22, item 27), 6,189 feet of Tyonek Formation consist in part of a lower sandstone sequence similar to that in the underlying Hemlock Conglomerate (Adkison and Newman, 1973). Thin beds of argillaceous limestone occur in the lower third, and massive sandstone interbedded with siltstone, shale, and coal make up the remainder of the formation. The sandstone is typically fine-grained, gray, commonly subangular and in places, carbonaceous. Conglomerate is restricted to a few thin beds near the base of the formation. It consists of rounded quartz, chert, basalt, and metamorphic and granitic rock clasts up to 2 1/2 inches in longest dimension. In the upper 4,000 feet of the formation shale is prevalent as beds up to 30 feet thick. The shale is typically gray to black, carbonaceous, and commonly interbedded with coal stringers and sandy to silty lenses. Siltstone is gray, sandy, frequently carbonaceous and generally interbedded with shale. Coal occurs as thin beds (less than 3 feet thick).

In the Capps Glacier area five measured sections which include rocks of the Tyonek Formation have been described by Adkison (plate 84A, measured sections 1-5). The entire section of Tyonek Formation is not exposed, but it is believed to exceed 2,200 feet in thickness. The exposed stratigraphic sections consist of a lower conglomeratic sequence overlain by sandstone, siltstone and coal.

At measured sections 1 and 2, 835 feet of the lower part of the Tyonek is exposed in steep hillsides and cliffs. The exposures weather brown to brownish and consist of conglomerate, tuff, sandstone and siltstone. The conglomerate consists of pebble- and cobble-size clasts in a sandy matrix. The matrix is commonly silty, clayey and tuffaceous. Tuffaceous pebbles are common in the conglomerate. The other clasts were not identified, but according to Adkison and others (1975b), the conglomerate is generally similar to that of the underlying West Foreland Formation. The maximum thickness of conglomerate measured in the lower Tyonek Formation is 84 feet.

Several beds of tuff, ranging from 1 to 13 feet thick, occur in the lower part of the Tyonek Formation at measured section 2. The tuff is commonly gray, carbonaceous, and usually interbedded with thin sandstone and siltstone layers. Bentonite is usually above or below the tuff and in some cases, intermixed with tuff. One tuff bed, six feet thick, contains pebble-size clasts of grayish-orange devitrified fibrous tuff.

Gray to yellowish-gray weathering, fine- to medium-grained sandstone is predominant in the Capps Glacier area and ranges up to 29 feet in thickness. The sand-sized grains are generally poorly sorted and commonly subangular to angular in shape. Many of the sandstone beds are tuffaceous and silty and a few are iron-stained. Siltstone is gray to brown in color, ranges up to seven feet thick and is commonly tuffaceous, carbonaceous or both.

Tertiary volcanics cover much of the outcrop including the contact between the lower and upper Tyonek Formation. The volcanic deposit covers about 17 square miles and consists of several hundred feet of dark gray lapilli tuff and volcanic breccia that rest unconformably on strata of the Tyonek and West Foreland Formations.

Sedimentary rocks in the upper Tyonek Formation (plate 84A, measured sections 3, 4 and 5) are characterized by an abundance of coal beds (especially the 63 foot thick Capps coal bed). The stratigraphic relationship between the measured sections is uncertain. It is complicated by the presence of the Castle Mountain fault which lies between locations 3 and 4. Movement along the fault has resulted in both strike slip and vertical displacements. From well logs of nearby wells Adkison and others (1975b) have interpreted the sedimentary rocks at locations 4 and 5 to be structurally above those at location 3.

Total thickness of the upper Tyonek section measures 1,370 feet. The strata consist of sandstone, siltstone and coal beds. The sandstone is typically gray, poorly to moderately sorted, fine- to medium-grained and thick-bedded. Scattered coalified wood fragments are common as are other carbonaceous materials. Iron-staining and obscured bedding planes are present in the section. Some of the beds are tuffaceous, and in general, appear to be more quartzose than the sandstone of measured sections 1 and 2. Siltstone is gray, sandy to clayey, and contains carbonaceous material. Iron-staining, tuffaceous fragments, and ironstone concretions are present in a few of the siltstone beds. Coal beds range from thin lenses to 63 feet in thickness at measured section 3. Major coal beds at measured sections 4 and 5 are 20 feet or more in thickness. The coal is dull black in appearance and ranges in rank from lignite to subbituminous. It commonly contains lenticular partings of siltstone and carbonaceous shale.

Model of Sedimentation for the Tyonek Formation

The deposition of the Tyonek Formation took place during warm-temperate climatic conditions in an alluvial basin much like the present Susitna Lowlands. The basin was poorly drained and frequently occupied by extensive swamps, as indicated by the thick and abundant coal units. Sediment source was from the highlands to the west and north and from the emerging positive area to the southeast (fig. 20). Alluvial fans extended into the basin carrying coarse clastic material that was further transported by braided streams on the distal ends of the fans. It is probable that a through-going meandering stream occupied the basin to the east of the fan fronts in the lowest portion of the basin.

Heavy mineral studies (Hite, 1975) of surface and subsurface samples of the Tyonek Formation from the west side of the basin show that it is characterized by 65% garnet 5% epidote and 1% hornblende. In contrast, Kelley (1973) found that samples of the subsurface Tyonek Formation from the east side of the basin contained 15% garnet, 35% epidote, and 1% hornblende. The contrasting heavy mineral contents indicate that significant amounts of detritus were being supplied from positive areas on both sides of the basin. Size analysis studies show that the subsurface Tyonek Formation is coarsest on the west side of the inlet and grades laterally to sandy siltstone, claystone, and coal to the northeast, southeast and south. This indicates a source to the west.

Volcanism was not as active during deposition of the Tyonek Formation as in early Eocene time. Nonetheless, the tuffaceous character of some of the sandstone and conglomerate units as well as the tuffs themselves indicate that the contribution of volcanics to the sediments was significant.

Uranium Favorability

Many of the characteristics common to sandstone-type uranium deposits (table 4) are evident in the strata of the Tyonek Formation, especially the lower half of the formation with much less coal than the upper half. The depositional environment for much of the Tyonek Formation is considered to be fluvial. Sediments were supplied to the basin from the granitic terrane to the west and north. Metamorphic detritus was provided by the rising Kenai-Chugach complex. Kirschner and Lyon (1973) propose that a remote source provided much of the material supplied to the basin during the early Tertiary and through deposition of the Tyonek Formation. This theory is not disputed, but other evidence points to a nearby source for much of the sediment. The coarse texture of many of the facies in the West Foreland through Tyonek Formations, and the lithologic similarity between the sedimentary rocks and the rocks of local source areas support the hypothesis that the surrounding hinterlands were very significant contributors of sediment--probably more so than any remote provenance.

Unconformities separate the Tyonek Formation from its enclosing neighboring formations. The mineralogy of the Tyonek is not well described in available literature.

Having determined that the granitic highlands to the west were a source, it would then be logical to assume that the clastic facies on the west side of Cook Inlet are feldspathic or arkosic in part. Other favorable characterisitics are the quartzose nature of the upper Tyonek sandstone units in the area south of Capps Glacier and the tuff and widespread occurrence of tuffaceous sandstone and siltstone in Tyonek strata. In light of these characteristics, the Tyonek Formation is considered very favorable. Particularly favorable is the lower part of the Tyonek Formation that is west and north of Cook Inlet because of the proximity to the granitic highlands. It is not possible in this study to define certain stratigraphic horizons that are more favorable than others within the Tyonek Formation because the literature is too general for such an interpretation.

Gamma ray logs of 15 exploratory wells indicates that the normal radioactivity values of the Tyonek Formation average

43 API units. The values range from 24 to 50 API units and are not considered anomalous.

11.3.1.8 BELUGA FORMATION

The Beluga Formation of the Kenai Group is of late Miocene age. Exposures are present along the northern shore of Kachemak Bay and north of Homer where the unit forms low rolling hills (fig. 23). Beluga sediments are known to crop out on the west side of Cook Inlet near the village of Tyonek (plate 84A), but descriptions of these exposures are not available. The total area of combined exposures is approximately 40 square miles.

The Beluga Formation is widespread in the subsurface beneath the Cook Inlet Basin and covers an area of more than 4,000 square miles (fig. 23). Exposures of undifferentiated upper Tertiary sedimentary rocks near the north end of the lowlands suggest that the formation is probably present beneath the Susitna Lowlands. The unit thins to the north, west, and east with respect to the Cook Inlet Basin. It is absent from the wells along the eastern and northern margins of the basin. It is present as far west as the Kustatan River No. 1 well (fig. 23, item 18) where the formation is more than 1,100 feet thick. Plates 94B, 84B, and 85B show exploratory wells that bottom in sedimentary rocks of the Beluga Formation. Near the center of the basin and in the Tyonek-Beluga area the unit reaches a thickness of approximately 6,000 feet.

Calderwood and Fackler (1972) considered both the basal and upper contacts of the Beluga Formation to be unconformable. The formation is overlain by the Sterling Formation and underlain by the Tyonek Formation. Calderwood and Fackler (1972) have designated the interval from 3,610 feet to 7,760 feet in the Standard Oil Beluga No. 1 well as the type section. The following stratigraphic description is taken from their work:

Type section of the Beluga Formation

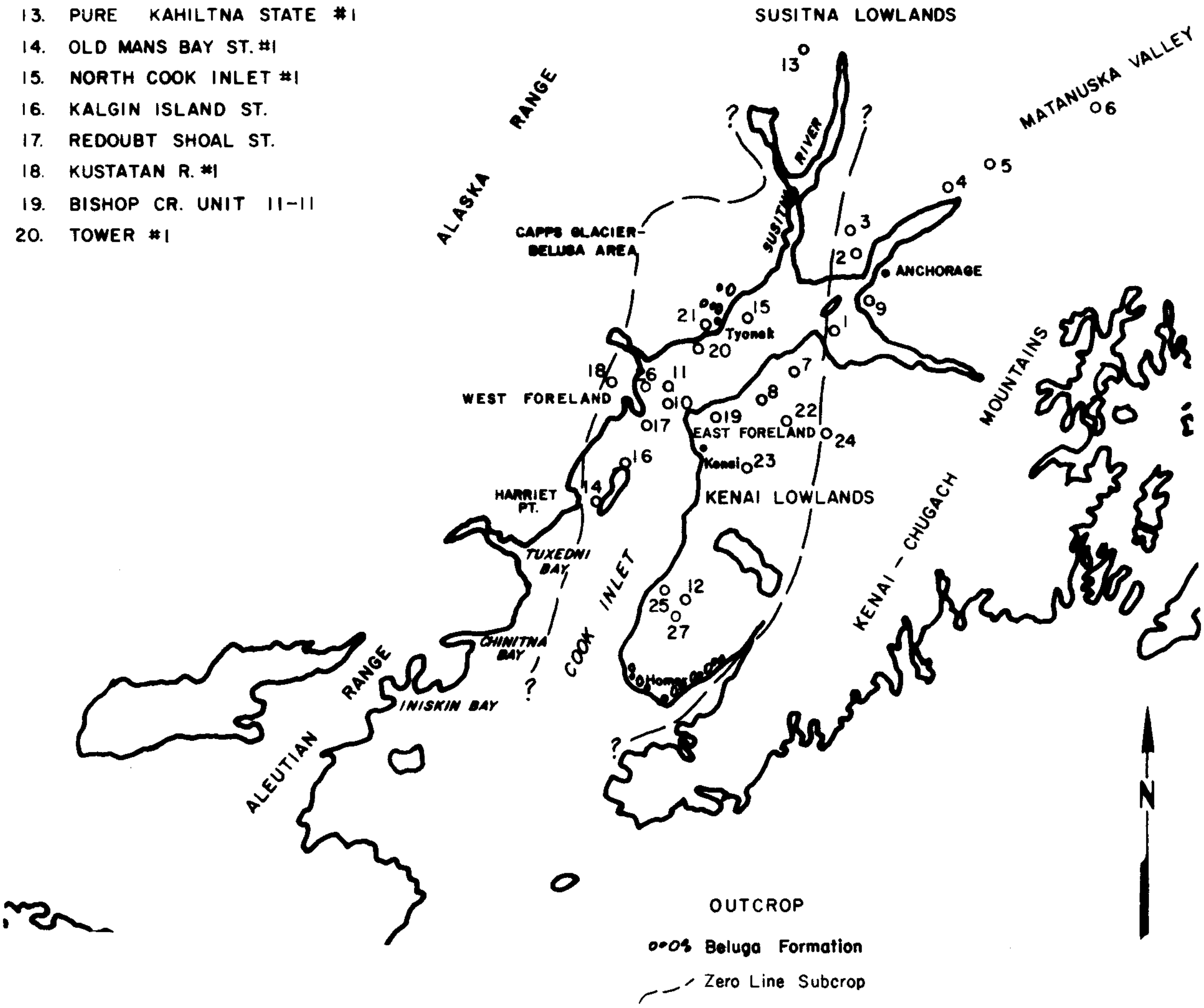
Sterling Formation.
Unconformity(?).
Beluga Formation.

<u>Depth</u>

3,610-4,660 Interbedded sandstone, claystone, siltstone, and coal. Sandstones are light gray, fine- to medium-grained, angular to subangular,

INDEX

1. TURNAGAIN ARM #1
2. LORRAINE #1
3. SUSITNA UNIT #1
4. PITTMAN UNIT #1
5. FISHOOK UNIT #1
6. CHICKALOON #1
7. POINT POSSESSION UNIT #1
8. SWANSON R. UNIT 34-10
9. CAMPBELL POINT #1
10. MIDDLE GROUND SHOAL 18746A-1
11. MIDDLE GROUND SHOAL A43-11
12. EDNA MAE WALKER #1
13. PURE KAHILTNA STATE #1
14. OLD MANS BAY ST. #1
15. NORTH COOK INLET #1
16. KALGIN ISLAND ST.
17. REDOUBT SHOAL ST.
18. KUSTATAN R. #1
19. BISHOP CR. UNIT 11-11
20. TOWER #1
21. TYONEK ST. 17587 #2
22. SUNRISE LAKE UNIT #1
23. STERLING UNIT 23-15
24. SWAN LAKE UNIT #2
25. NINILCHIK #1
26. WEST FORELAND #1
27. DEEP CREEK UNIT #1



Modified from Kirschner and Lyon (1973)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY M.H. DATA BY C.C. DATE 4/77	REVISED	EXTENT OF BELUGA FORMATION
SCALE: 20 0 40 miles			FIGURE 23 8X158

	silty, carbonaceous, soft clay matrix, thin-bedded in beds generally 10 feet or less thick. Claystones are medium gray, bentonitic, carbonaceous, and lignitic, thin-bedded as are sandstones. Siltstones are gray with thin streaks of coal and lignite. Coal beds range from thin stringers to 12 feet thick and are lignitic to subbituminous. Near middle of unit is a 50 foot thick light-gray, fine- to medium-grained, angular to sub-angular, silty, loosely consolidated, carbonaceous sandstone, with some thin lignitic coal stringers.
4,660-5,640	Sandstone, light-gray, fine- to medium-grained angular to subangular, silty, loosely consolidated, carbonaceous; beds range in thickness from a few feet to 40 feet and are separated by thin claystone, siltstone and coal interbeds. Coal beds are thinner than in overlying unit. Thicker sandstones are slightly calcareous in upper part of unit.
5,640-7,760	Sandstone and claystone. Sandstones are light gray, fine- to medium-grained, angular to subangular, silty, carbonaceous, loosely consolidated, and thin-bedded with beds generally less than 20 feet thick. Claystones are gray, soft, silty, bentonitic, and carbonaceous with thin coal laminae. Siltstones are dark gray, argillaceous, and slightly calcareous. Coal beds are lignitic to subbituminous, and generally less than 6 feet thick.

Base of Beluga Formation.
Unconformity.
Tyonek Formation.

Adkison and others (1975a) described and measured several sections of Beluga Formation in the Homer area. The section consists of more than 3,000 feet of sandstone, siltstone, shale and coal and dips gently (5° or less) to the north. The sandstone is typically very fine- to fine-grained, silty, and clayey. It is generally medium-gray in color and composed of subangular grains of relatively unweathered metamorphic detritus. Carbonaceous debris, fragments of plants and coal are common. Iron-staining occurs in many of the units, and ironstone nodules are present in many beds. Channel deposits are numerous. Coarse-grained basal units grade upward to finer, more silty laminae in the channel deposits. Cross-bedding and sharp basal contacts are common. Higher in the section above the channel sandstones, the sandstone is generally less clayey and calcareous. Beds of friable sandstone are more common in the upper part of the section than in the lower part.

The siltstone is dominantly medium-gray in color. A few thin siltstone beds are brown or brownish-gray. The units are sandy to silty and commonly carbonaceous. Locally, the siltstone is limy and in part iron-stained. Small scale cross-bedding is present in some units.

The shales and claystones are silty to sandy and poorly bedded. Carbonaceous debris is common and the units are locally iron-stained. Ironstone nodules, as much as 0.6 foot in diameter, occur in gray shale and siltstone. The shale is similar throughout the section with the exception of a thick unit in the upper portion. This unit is 53 feet thick and is characterized by a pronounced conchoidal fracture that produces distinctive outcrops upon weathering. Iron-staining is abundant on joints and fractures in the unit.

Coal beds, several of which are 3 to 5 feet thick, are abundant in the lower portion of the section. The coal is well indurated and more resistant to weathering than most of the other rocks. Partings of clastic rock are common in the thicker coal beds. Some of the partings consist of pyroclastic material. Coal beds are stratigraphically much more widely spaced in the upper portion of the section. Pyroclastic material is less common in the partings in these upper beds while plant fragments, coalified wood fragments, including flattened logs, are more numerous.

Additional information regarding the Beluga Formation exposures along the shores of the Kenai Peninsula and near Seldovia on the south side of Kachemak Bay is provided by Hayes and others (1975). Approximately 3,000 feet of the upper Beluga-lower Sterling section is included in their study. Sand grains and pebbles that comprise the coarser fraction of Beluga Formation consist of argillite, metagraywacke, chert, and metavolcanic fragments. The principal constituents of the finer sediments are crystalline euhedral chlorite and mica, indicative of relatively unweathered rocks. Porosity and permeability of the sandstone is low due to deformation and compaction of the soft, ductile metasedimentary rock fragments during burial. Large calcareous concretions (up to 6 feet in size) occur in the thicker sandstone units and make up several percent of the total volume of the Beluga sandstones.

Depositional features include low angle cross-bedding, ripple marks, trough sets, and an apparent lateral gradation from sand beds to siltier, thinner layers. Basal contacts of sandstone beds are sharp. The beds grade from fine- to medium-grained sand at the base to clayey silt at the top. Climbing ripples and parallel lamination occur in siltstone beds, some of which are penetrated by fossil plant roots. Coal beds are commonly underlain by root zones and, in places, fossil tree stumps remain upright.

Subsurface lithology of the Beluga Formation has been described by Adkison and Newman (1973) from samples and well log data from the Deep Creek No. 1 well (fig. 23, item 27). The formation is 3,520 feet thick in this well and is overlain by 2,464 feet of Sterling strata and 22 feet of Quaternary alluvium. The Beluga section consists of sandstone and interbedded shale, siltstone and coal. The sandstone is typically medium-gray in color, fine-grained, and commonly silty. Carbonaceous debris is present in some of the units as plant fragments and thin lignite stringers. Some beds are iron-stained and many are slightly micaceous and/or limy. Interbedded shales are generally medium-dark-gray and contain abundant carbonaceous material. Many of the shale units are silty, fewer are limy, and most show some degree of bedding. Adkison and Newman describe a shale bed located 50 feet below the top of the Beluga Formation as being 5 feet thick, brownish-gray, very carbonaceous, and containing scattered selenite(?) crystals. The siltstone in the Deep Creek well is gray, generally limy, and in places sandy and carbonaceous. Bedding is obscure in the siltstone units. Lignite, predominant in the upper strata, and coal are present throughout the section as thin units interbedded with sandstone and shale.

Elsewhere beneath Cook Inlet the Beluga Formation generally consists of thin, gray to white, fine- to medium-grained sandstone; silty gray claystone (bentonitic in part); gray to brown siltstone, in part carbonaceous; shale; and coal. Many of the sandstones are unconsolidated to loosely consolidated and are composed of subangular to subrounded sand grains. Coal occurs widespread as thin beds, but is less abundant than in the Tyonek or Sterling Formations. Claystone and shale are predominant in the Hunt Oil Kalgin Island No. 1 well (fig. 23, item 16) suggesting a fining of sediments to the south on the west side of the basin.

Model of Sedimentation for the Beluga Formation

Depositional conditions during Beluga time are shown in the paleogeographic sketch (fig. 20). The eastern source area had considerable topographic relief as a result of tectonic uplift. Abundant, relatively unweathered sediment consisting of metamorphosed Mesozoic marine sediments and volcanics were shed into the basin from the Kenai-Chugach

Range located to the east. Hayes and others (1975) envision a system of alluvial fans that extended from the east side of the basin and probably forced the major through-going drainage system to the west side of the basin. Any detritus contributed by the Alaska-Aleutian Range during this time was restricted to the far-west side of the basin.

Heavy mineral studies (Hite, 1975) indicate that the Beluga Formation contains high epidote (50%) and very low hornblende (4%) concentrations. This compares well with similar studies made by Hayes and others (1975) in the same general area of southern Kenai Peninsula. The weight percent of heavy minerals ranges from 0.1 to 0.3 percent for sandstones of the Beluga Formation. A study done by Kelley (1973) on the heavy mineral contents of the Kenai Group produced slightly different results for the Beluga Formation. Rocks for that study, taken from Standard Oil of California Deep Creek No. 1, show a marked decrease in epidote content (13%). The hornblende content was similar, however, to results of the other two studies.

Hayes and others (1975) interpret the Beluga Formation in the Homer area to represent alluvial fan deposits. Channel deposits are thin, generally less than 12 feet thick, and relatively narrow, suggesting a braided stream environment. A high energy flow regime is indicated by the horizontal and low-angle stratification of the sediments. Finer material, silt and clay, collected along the margins of the braided streams as sheet-flood deposits and near the distal ends of the fans where stream gradients were much more gentle. Textural examinations show a westward decrease in angularity and size of clasts suggesting an east to west stream flow. An increase in number and thickness of coal beds westward supports the evidence of a decrease in gradient to the west. Studies made by Hite (1975) support an easterly source as well as a dominantly fluvial process of deposition for the Beluga Formation.

Uranium Favorability

The Beluga Formation is considered to be unfavorable for sandstone-type uranium deposits mainly for lithologic reasons. Sediments derived from a predominantly metamorphic terrane are generally less favorable for sandstone uranium deposits than sediments derived from a mixed granitic and metamorphic source (tables 2 and 3). Tuffaceous material is not common in the Beluga Formation while known sandstone-type uranium deposits are commonly associated with tuffaceous units in the western United States. The compaction and consequent loss of porosity and permeability is another unfavorable feature of the Beluga Formation since it occurred relatively early after the formation was deposited.

Little can be said of the sedimentary rocks of the Beluga Formation that were deposited on the western side of the northern extension of the basin. The rocks have not been described in published reports. Western sections may prove to be much more favorable than equivalent rocks studied on the east side of the basin. Recent investigations of the Tertiary sedimentary rocks in the northern portion of the basin by the United States Geological Survey are nearing completion and should be available to the public sometime during 1977.

Gamma ray logs of six exploratory wells show that radioactivity values of the Beluga Formation average 46 API units. The values range from 30 to 65 API units. None are considered anomalous.

11.3.1.9 STERLING FORMATION

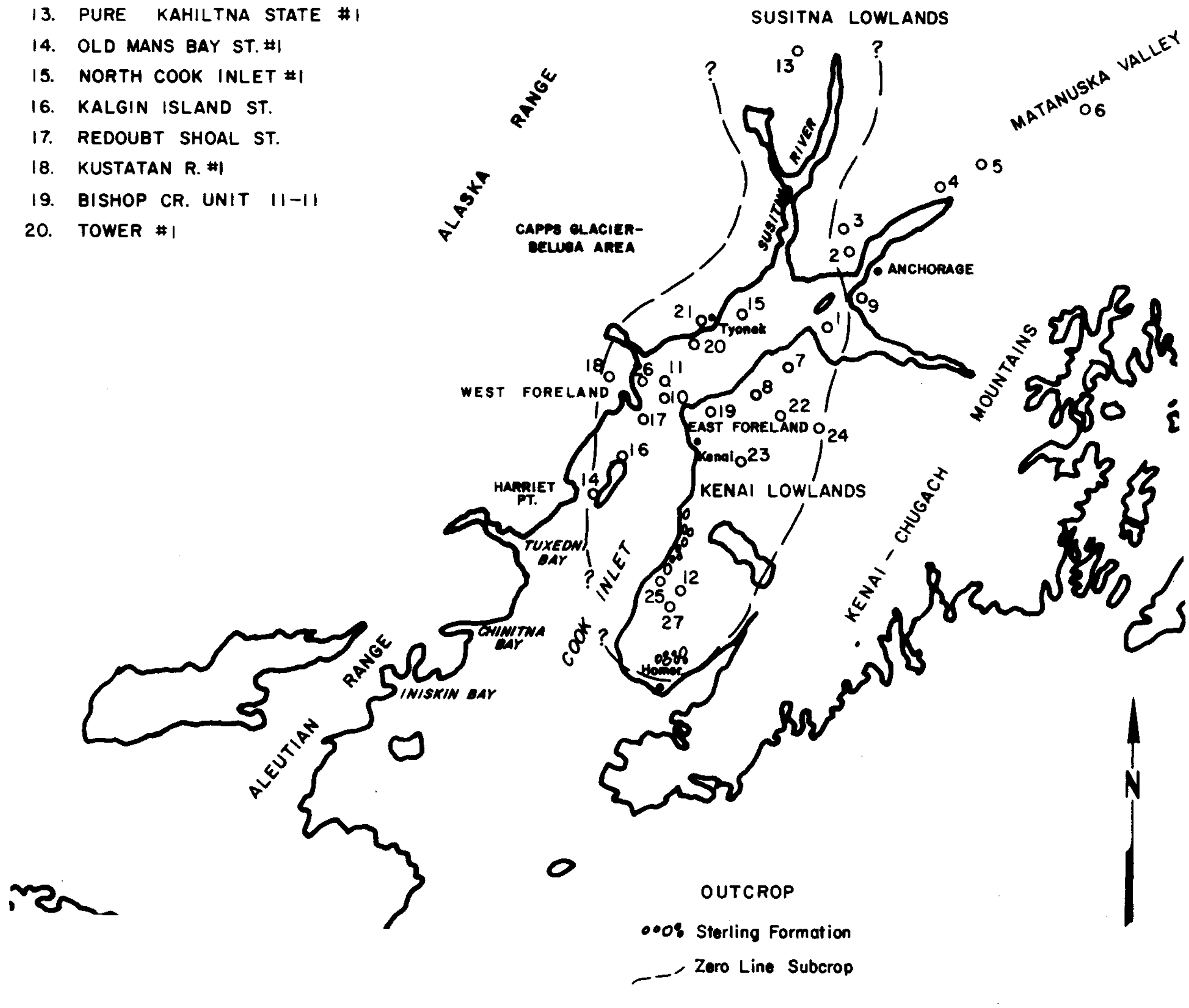
The Sterling Formation is the youngest of the Kenai Group. A Pliocene age has been assigned to the information based on paleonthological evidence (Wolfe, 1966).

The Cook Inlet Basin is underlain by more than 6,000 square miles of Sterling Formation (fig. 24). The formation thins toward the east and west until at the margins of the basin it is absent (fig. 19). Approximately 90 square miles of the Sterling Formation are exposed in the study area. Exposures of Sterling Formation are mapped and described for several areas on the east side of Cook Inlet. The lower 3,000 feet of the Sterling Formation is well exposed in sea cliffs along the western shores of the Kenai Peninsula and beneath the rolling hills north of Homer (plate 104A). Several of the measured sections described in the Homer area include Sterling Formation (Adkison and others, 1975a). In these areas, rocks of the Sterling Formation dip northwest at 3°-5°. Pleistocene gravels unconformably overlie much of the formation in the southern portion of the Kenai Peninsula. Recent efforts to compile the geology of the Alaska on a regional scale (Beikman, 1974) indicate that the Sterling Formation probably crops out in the northern portion of the Susitna Lowlands (plate 75A). If later studies prove that assumption to be correct then approximately 8,000 square miles of subsurface Sterling Formation can be added to the present known extent of the formation. Plate 94B shows several exploratory wells that were completed in sedimentary rocks of the Sterling Formation.

Sterling strata occupy two depositional troughs in the Cook Inlet Basin (fig. 19). The deepest depocenter, and consequently, the thickest section of Sterling Formation, is in the area beneath the east foreland north of Kenai. Here the Sterling Formation exceeds a thickness of 11,000 feet as

INDEX

1. TURNAGAIN ARM #1
2. LORRAINE #1
3. SUSITNA UNIT #1
4. PITTMAN UNIT #1
5. FISHOOK UNIT #1
6. CHICKALOON #1
7. POINT POSSESSION UNIT #1
8. SWANSON R. UNIT 34-10
9. CAMPBELL POINT #1
10. MIDDLE GROUND SHOAL 18746A-1
11. MIDDLE GROUND SHOAL A43-11
12. EDNA MAE WALKER #1
13. PURE KAHILTNA STATE #1
14. OLD MANS BAY ST. #1
15. NORTH COOK INLET #1
16. KALGIN ISLAND ST.
17. REDOUBT SHOAL ST.
18. KUSTATAN R. #1
19. BISHOP CR. UNIT 11-11
20. TOWER #1
21. TYONEK ST. 17587 #2
22. SUNRISE LAKE UNIT #1
23. STERLING UNIT 23-15
24. SWAN LAKE UNIT #2
25. NINILCHIK #1
26. WEST FORELAND #1
27. DEEP CREEK UNIT #1



Modified from Kirschner and Lyon (1973)

WGM INC MINING & GEOLOGICAL CONSULTANTS ANCHORAGE, ALASKA	DWN BY M.H.	REVISED	EXTENT OF STERLING FORMATION	FIGURE 24
SCALE: 20 0 40 miles	DATA BY C.C.			BX139
	DATE 4/77			

indicated by well and seismic data. To the southeast and east, another shallower trough trends north-south beneath the Kenai Lowlands. There the Sterling section probably exceeds 7,000 feet in thickness (Hartman and others, 1972). The formation thins along a linear trend of buried anticlinal structures that follow the eastern coast of Cook Inlet and form the structural oil reservoir for the Swanson River Field (plate 94A). A similar set of anticlinal structures is present near the western shore of Cook Inlet. The Sterling Formation appears to have been eroded or never deposited along the crests of those structures.

The Sterling Formation rests unconformably on the Beluga Formation. The top of the Sterling Formation is modified by glacial scour and fill. Formation thicknesses range from 1,100 feet to 6,270 feet in wells 12, 16, 18, 20, 22, and 24 (fig. 24). Wells 20 and 12 represent the minimum and maximum thicknesses, respectively. The formation is buried in wells 18 and 22 by 500 feet and 3,000 feet of Pleistocene and Quarternary gravels. The unit commonly reaches the surface on the west side of the inlet where it is covered by a few feet of unconsolidated gravel. Correlations of subsurface geology indicate that the Sterling Formation is generally overlain by more than 1,000 feet of loose gravel in the central and northern Kenai Lowlands. Calderwood and Fackler (1972) have designated the interval from 1,050 feet to 5,540 feet in the Union Oil Company Sterling Unit No. 23-15 well (fig. 24, item 23) as the type section. The following stratigraphic section is taken from their work:

Type section of the Sterling Formation

Unconsolidated Pleistocene and Holocene sediments.
Unconformity.
Sterling Formation.

<u>Depth</u>

1,050-3,170	Interbedded fine-grained sandstone and silty claystone with a few thin lignitic coal beds. Sandstone and claystone beds are generally less than 50 feet thick. Sandstones are light gray, very fine- to fine-grained, with subrounded grains, loosely cemented with clay matrix; some carbonaceous material and thin streaks of lignitic coal. Claystones are light to dark gray, silty, slightly bentonitic and carbonaceous, with some sandstone streaks and scattered pebbles. Coals are lignitic to subbituminous and range in thickness from thin streaks to beds generally less than 3 feet thick.

3,170-3,390	Sandstone, light-gray, very fine- to fine-grained, quartzose, moderately sorted, fair porosity, subrounded, with some silty soft clay matrix; carbonaceous and thin lignitic coal streaks.
3,390-3,820	Sandstone, light-gray, very fine- to fine-grained, moderately sorted, fair porosity, carbonaceous streaks throughout. Beds are generally 50-60 feet thick, with silty claystone interbeds usually 20-40 feet thick. Thin lignitic coal beds 1-3 feet thick are present at base of many sandstone units.
3,820-4,140	Sandstone, light gray, very fine- to fine-grained, subangular to subrounded grains, thick-bedded, bentonitic, silty claystone matrix, carbonaceous; some thin lignitic coal beds.
4,140-5,250	Interbedded sandstone and claystone. Sandstones are light gray, fine- to medium-grained, carbonaceous, subangular to subrounded grains; contains scattered pebbles. Beds 40-60 feet thick, interbedded with silty bentonitic claystone and some thin, fine-grained silty sandstones; numerous lignitic to subbituminous coal beds up to 8 feet thick. Coal beds are thicker and more abundant than in overlying units.
5,250-5,540	Sandstone, light-gray, fine- to medium-grained, subrounded grains, carbonaceous, bentonitic silty, shaly matrix, with some scattered pebbles. Silty bentonitic claystone 40 feet thick at base of unit.

Base of Sterling Formation.
Unconformity.
Belgua Formation.

Data from wells that have penetrated the Sterling Formation on the west side of the inlet indicate that the formation consists of sandstone, claystone, conglomerate, shale, coal and lignite. The sandstone is typically gray to white, fine- to coarse-grained, carbonaceous in part, and loosely consolidated to unconsolidated. Sand grains are generally subangular. The mineralogy was not described on the logs. Conglomerate, shale, and siltstone occur interbedded with the sandstone units. The claystone is generally gray, silty, and bentonitic or ashy in part. Beds of coal occur with greater frequency than in the underlying Beluga Formation.

The lithology of the subsurface Sterling Formation has been described more thoroughly on the east side of Cook Inlet than elsewhere in the basin.

Adkison and Newman (1973) described a section of Sterling strata in the Standard Oil Company Deep Creek Unit No. 1 well (fig. 24 and plate 104A). The formation is 2,442 feet thick in that well and consists of sandstone, shale, siltstone, and lignite overlain by 22 feet of Quaternary deposits. The sandstone is generally gray and consists of fine-grained, subangular fragments in a silty to clayey, in part micaceous, matrix. Some sand grains are feldspathic and red, green or gray in color. Pebbly sandstone consists of granitic and basaltic pebbles. Many of the units are carbonaceous and interbedded with thin siltstone and shale layers. The shale is gray to black, commonly carbonaceous to very carbonaceous, and silty. The siltstone is gray, commonly sandy to clayey, slightly micaceous and usually contains carbonaceous debris. One 16 foot section of siltstone and shale contains volcanic ash. Coal and lignite beds are generally thin and lignite is dominant.

Exposures of Sterling Formation consist mainly of sandstone and siltstone. Claystone, shale, and numerous coal beds are also included. The sandstone is typically medium-gray in color, thin-bedded and commonly iron-stained. The units are dominantly fine-grained, friable, and silty or clayey. Sand grains are generally subangular, but include subrounded shapes. Carbonaceous debris is common to abundant as plant fragments, coalified wood fragments and as thin laminations along bedding planes. The sandstones are cross-bedded and have gradational to sharp basal contacts. Many of the beds in measured sections 4 and 17 (plate 104A) are considered good examples of channel deposits (Adkison and others, 1975a).

Siltstone is generally clayey and partly sandy. Iron staining and carbonaceous debris are common. The beds are typically gray except in the upper part of the section where they have a bluish tint. Bedding in siltstone is obscure and many of the units are characterized by slabby weathering. Some beds are tuffaceous. Claystone is gray, silty, and generally displays obscure to poor platy bedding patterns. Shale is carbonaceous, gray, and often occurs close to or as partings within coal beds. Some of the claystone is tuffaceous.

Volcanic glass, tuff, and pumice occur as sand size grains in many of the units in the upper half of the section. One unit measuring approximately 1 foot thick and thickening locally to 5.5 feet is yellowish gray to yellowish brown in color, medium- to coarse-grained, and sandy. This unit was traced approximately 1 mile between measured sections 9 and 10 (plate 104A).

Coal beds in the lower part of the Sterling Formation closely resemble those in the upper part of the Beluga Formation. The coal is hard, and more resistant to weathering than many of the other rocks. The upper portion of the Sterling Formation contains thin, impure coal beds that, with partings, seldom exceed 1 foot in thickness. Thin units of shale or siltstone are common as partings in the coal and many of the partings contain pyroclastic fragments.

The mineralogy of sandstones in the Sterling Formation has been described in detail (Hayes and others, 1975). The sandstone is composed of angular volcanic grains, with lesser amounts of angular plutonic and metamorphic rock and mineral fragments. Locally abundant are such constituents as: monocrystalline and polycrystalline quartz; chert; twinned, untwinned, and zoned plagioclase; fresh and altered potash feldspar; fresh and devitrified grains of obsidian and pumice; biotite, hornblende, hypersthene, and epidote; and a wide variety of metasedimentary rocks. Most of the glass and pumice grains are clear, homogeneous, and isotropic, suggesting that very little weathering of the pyroclastic material took place and that deposition and burial was a rapid process.

Model of Sedimentation for the Sterling Formation

Based on the details of their study, Hayes and others (1975) proposed a model for the Sterling that best fits the data. The Sterling Formation was deposited by meandering streams that were large enough to produce 30- to 45- feet thick point bar sandstones. The major through-going streams paralleled the axis of the basin in the present area of the Kenai Peninsula (fig. 20). Western and northern source areas provided much of the volcanic and granitic detritus that covered the broad basinal areas by successive lateral migrations of a through-going meandering stream. Pyroclastic material was deposited as ash fall in fresh water lakes and swamps where it was left undisburbed by active streams. Elsewhere, ash accumulations were eroded from slopes and fans shortly after settling out of the atmosphere. The ash was redeposited along with granitic and other volcanic material by low gradient and low energy meandering stream systems. Swampy areas were common features of the topography as indicated by the numerous, but relatively thin beds of coal in the Sterling Formation.

The depositional environment in the Susitna Lowlands during this time was probably much the same as that to the south in the Cook Inlet area. Greater subsidence of the Cook Inlet Basin on the south side of the Castle Mountain fault, relative to the Susitna Lowlands, would have allowed sediments to accumulate at a faster rate and as thicker deposits. Thus, the strata north of the Castle Mountain fault system are not likely to be as thick as equivalent strata to the south. The vertical displacement along the east central portion of the fault during the Paleocene is thought to be on the order of several thousand feet (Grantz, 1966). Indications of movement along the fault system suggest that vertical displacement has been proportionately smaller during each period of the Tertiary, beginning with the Paleocene (Grantz, 1966).

Hite (1975) analyzed various size fractions of samples from surface and subsurface Sterling strata to determine probable modes of transportation for the sediments. Hayes and others (1975) did a similar study and reached similar conclusions. Hite determined that 94% of the samples studied were deposited by undirectional currents indicating a fluvial environment for Sterling strata. A bidirectional current was indicated by 4% of the samples and 2% were considered suspension deposits.

Hayes and others (1975) devoted their study primarily to the lower section of the Sterling Formation, which is well exposed on the southern Kenai Peninsula. The numerous sandstone intervals of the formation, ranging from 30 to 90 feet thick, are described as point bar deposits of meandering streams. The characteristic fining upward sequence of point bars can easily be observed in the Homer area.

Bedding features such as scoured basal contacts, horizontal laminations, tabular and trough sets of cross strata and current ripples are recognized in the sandstone units. Hayes and others (1975) interpret the interbedded mudstone, coal and thin sandstone that rest on the point-bar deposits to be flood plain or vertical accretion deposits, formed when flood water overflowed main channels. Rivers necessary to form the point-bar deposits of the Sterling Formation are thought to have been comparable in size to the Wabash River or the Red River in the central United States today (Hayes and others 1975). The Sterling sandstones are thicker and more continuous than Beluga sandstones which have been described as shallow shifting channel deposits of fan distributary systems.

Heavy mineral studies of samples from the Sterling Formation from the Deep Creek Unit No. 1 well (fig. 23, item 27) were made by Kelley (1973). The study indicates that the epidote content of sandstones and siltstones of the Sterling Formation ranges from 27% to 60%. The garnet content is low (5%) and hornblende content is considered to be very low (less than 1%). Similar studies (Hayes and others, 1975) of Sterling Formation exposed on the southern Kenai Peninsula show that the epidote content averages 20%, significantly less than an average of 40% as determined by Kelley. Hornblende content (50%) of the rocks studied by Hayes is substantially greater than the hornblend content of samples of Kelley's study. The garnet content of samples from the southern Kenai Peninsula is approximately 1% compared to 5% for the samples of Kelley's study. It should be noted that the samples analyzed by Kelley do not adequately represent all of the Sterling section and results are based on relatively few samples. The differences in heavy mineral contents between the two studies probably indicates local variations in the Sterling Formation. Hayes and others (1975) and Kirschner and Lyon (1973) note an increase in hypersthene in the upper Sterling Formation and attribute it to an increase in volcanic activity during deposition of the Sterling Formation. A study of heavy minerals by Hite (1975) of rocks from the east and west sides of the inlet gives slightly different results than those of the previously described studies. Hite's study characterizes the Sterling Formation as having a moderate epidote content (40%), and a hornblende content of 5%. Hypersthene is present at an average content of 7% and is found to be markedly lower in abundance in the sedimentary rocks on the west side of the inlet than in rocks of the same formation on the east side.

The mineralogy of the Sterling sandstone indicates that plutonic and volcanic source areas played a major part in providing detritus to the Cook Inlet Basin during deposition. The closest source area to fit that description is the Alaska-Aleutian Range, which borders the basin on the west and northwest. The subangular shape and relatively unweathered state of the sandstone grains suggest a nearness to source. Plutonic activity accompanied by volcanism is believed to have taken place during a middle Tertiary episode and it is quite probable that volcanism has been intermittent to the present time.

Uranium Favorability

Sedimentary rocks of the Sterling Formation appear to be favorable environments for sandstone-type uranium deposits (table 2). The rocks are Tertiary in age and the depositional environment of the formation is nonmarine. Specifically, the rocks are stream channel and/or alluvial fan deposits. The formation is bounded by unconformities. Provenance areas were dominantly granitic and at the same time volcanically active. Tuffaceous sediments are known to be widespread in the formation throughout the Cook Inlet Basin. Although reports of detailed mineralogy of the sandstones of the Sterling Formation are far from complete, the units are known to consist of grains of feldspar, quartz, and pyroclastic material at least locally. Thus, it appears that certain units of the Sterling Formation display the characteristic features listed in table 3.

This is insufficient public information available to determine which stratigraphic horizon may be more favorable than another. Exposures of the formation have not been recognized on the west side of the basin so there is no surface information on the formation in that area. At best it is possible to determine only that the Sterling Formation appears to be favorable.

Gamma ray logs from six exploratory wells show that radioactivity values of the Sterling Formation average 38 API units. The values range from 14 to 55 API units. None are considered anomalous.

12. COMPARISON WITH SANDSTONE-TYPE DEPOSITS AND OCCURRENCES IN SIMILAR CLIMATES

Sandstone-type uranium deposits are known to occur in many parts of the world. Areas where significant deposits exist include Europe, southern Africa, Japan, Pakistan, and the western United States. Although sandstone uranium deposits are not known to occur in latitudes as far north as Alaska, this section will draw comparisons between Mesozoic and Cenozoic sedimentary rocks in the Cook Inlet Basin and the host rocks of sedimentary uranium deposits found in Japan and northern Europe.

Because the deposits in the western United States have been studied in detail, they are often used as a model for comparison for all other sandstone-type uranium occurrences and deposits. It is difficult to obtain any information from the literature which is not already "biased", as most papers discuss the same similarities between deposits.

However, there are significant differences, primarily in age and genesis. The genetic model developed for the western United States deposits is the most widely accepted and is the most commonly applied to other sandstone-type occurrences.

Japan

Sandstone uranium deposits in Japan occur in Tertiary continental sediments directly overlying Cretaceous granitic rocks (Hayashi, 1970). Middle Miocene tuffaceous and carbonaceous sandstones of the Toki Group host deposits of uranium absorbed by zeolites, carbonaceous matter, and montmorillonite (Katayama and others, 1974). Coffinite, uraninite, and pyrite occur in the high-grade ores. Uranium calcite, and uranocircite are also reported from certain deposits.

Erosion channels in the Cretaceous granitic source rock partially controlled the migration of uranium-bearing ground water and the distribution of the deposits. Montmorillonized zones also controlled the groundwater conduit. Uranium migrating with the groundwater was absorbed in zeolites and montmorillonite and reduced in and around the carbonaceous material.

The uranium made available to the sediments was probably leached from the underlying granite and perhaps from the tuffaceous host rocks. There are no solution fronts or geochemical cells described, probably because the uranium has not migrated very far from its source rock.

Genetically similar deposits are being explored in British Columbia and at the Midnite Mine deposit in Washington.

Deposits of similar origin and geologic setting to those described above could occur in the Matanuska Valley or along the west side of Cook Inlet. The Tertiary Arkose Ridge Formation rests on an erosional surface cut in the granitic Talkeetna batholith. Thus, the basal units of the Arkose Ridge Formation where, in contact with granitic plutons, should be checked for similar type deposits. The West Foreland Formation overlies acidic plutonic rocks on the west side of Cook Inlet. It should also be examined for "Japanese-type" sandstone deposits.

Europe

The sandstone-type uranium deposits and occurrences in Europe are found in Carboniferous through Tertiary age rocks. The Permian deposits are the most important as they occur in mineable quantities in several European countries. Barthel (1974) has reviewed uranium occurrences in Permian sandstones in Europe and reports features similar to the deposits in the western United States.

Germany

Lower Permian sandstones in Germany have uranium occurrences at sandstone-claystone contacts. The deposits are associated with carbonaceous material and lenticular pyrite concentrations in the sedimentary rocks. Uranium mineralization consists of carburan, pitchblende, and coffinite. Pyrite, marcasite, and base metal sulfides accompany the uranium. Barthel (1974) suggests the uranium is epigenetic and was deposited in a reducing environment by circulating solutions.

France

Sandstone-type uranium mineralization around the Massif Central in France occurs in continental sediments of Lower Permian age. Volcanic ash horizons, abundant plant remains, and a tropical paleoclimate are characteristic of these sediments. The uranium, deposited as carburan and coffinite, was supplied by solutions generated from the weathering of the granitic Massif Central. Barthel (1974) feels the mineralization is syngenetic within a reducing environment that existed during sedimentation. Migrating hydrocarbons allowed subsequent enrichment along joints and in stratigraphic traps. Base metals, vanadium, molybdenum, and other metals are associated with the uranium deposits. Other uranium occurrences in France have been found where a change in coloration of the sediment occurs (generally from gray to red).

Italy

Some sandstone uranium occurrences in Italy occur in fluvatile and deltaic sedimentary rocks which exhibit depositional features such as; cross-bedding, poor sorting, ripple marks, and load casts. Epigenetic uranium mineralization occurs in horizons with carbonized wood and is accompanied by pyrite and base metal sulfides. Granite intrusives and acid volcanics, believed to be contemporaneous, are considered sources for the uranium.

Hungary

Upper Permian fluvatile sandstones in the Mecsek Mountains contain uranium concentrations. Uraninite was deposited during reducing conditions along a paleo meandering stream channel. Abundant carbonaceous material, arkosic sandstones, and high vanadium content characterize the mineralized zones. Barthel (1974) suggests epigenetic mineralization shortly after deposition of the sediments. Interbedded clay horizons contain little or no uranium due to their low permeability.

Other European Countries

Uranium in sandstones of Permian age also occurs in Czechoslovakia and Poland according to Barthel (1974). These deposits are similar in character and genesis to those presented above.

Summary

In summary, it appears that certain favorable features can be found in the Permian and Tertiary uranium occurrences of Europe, as well as in the sandstone uranium deposits in the western United States, that are similar in geologic setting and depositional history to the Cook Inlet sedimentary rocks. Continental sandstones deposited in a fluvial, deltaic, and/or lacustrine environment during a warm, moist climatic period are characteristic of both the Tertiary sequence of Cook Inlet and the Permian strata of Europe that host sandstone-type uranium occurrences.

Arkosic sandstones containing plant debris, pyrite, and volcanic ash and clay interbeds are also reported in both Alaska and Europe. Uranium was supplied to the mineralized sandstones in Europe by adjacent granitic intrusives. Granitic rocks are present along the western and northeastern margins of Cook Inlet and have contributed detritus to the basin. Tuffaceous sandstones with interbedded ash layers are reported in all three areas (Alaska, Europe and Japan) and could also be sources of uranium.

Because depositional conditions of the Permian sandstones of Europe and the Tertiary sedimentary rocks of Cook Inlet Basin are alike, it is possible that geochemical processes responsible for the formation of the European deposits may have developed in the Cook Inlet rocks. If this were the case, and if uranium ions were available, then it seems probable that uranium deposits like those described could occur in sedimentary rocks of the Cook Inlet Basin. There is not enough detailed information available about the Permian deposits in Europe to make a more definitive statement.

Japanese sandstone-type occurrences are restricted to continental sediments overlying Cretaceous granites. Similar geologic conditions occur in the Matanuska Valley and the Susitna Lowlands of the Cook Inlet Basin. This genetic type of deposit is untested in many parts of the world and in Alaska may prove to be of considerable importance as a guide for future uranium exploration.

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