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Cover Photo: Fold in Cantwell Formation along East Fork Toklat River.

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CONTENTS

RECONNAISSANCE GEOLOGY ALONG THE VARIEGATED GLACIER, SAINT ELIAS MOUNTAINS

By B. Ronald Frost[1]

ABSTRACT

The metamorphic rocks occurring to the east of the Fairweather fault in the Variegated Glacier area of the Saint Elias Mountains can be divided into two principal units that are separated by the Mother Hubbard fault: gneiss and overlying metasedimentary schist occurring north of the fault, and a large body of orthoamphibolite with minor interfoliated pelitic schist south of the fault. Correlation of the gneiss with the continental Alexander terrane and the amphibolite with the oceanic older Chugach terrane is possible. However, rocks on both sides of the Mother Hubbard fault show a similar structural and metamorphic history, and large-scale displacement along the fault cannot be demonstrated.

INTRODUCTION

The Saint Elias Mountains are geologically one of the least known areas in Alaska. Only a large-scale map of the Tertiary rocks lying to the west of the Fairweather fault (Plafker, 1967) and as-yet-unpublished reconnaissance data on the crystalline rocks to the east of the fault (Plafker, personal communication) exist; no other geologic investigations are known to have been conducted in the central part of the Saint Elias chain.

This paper describes a small-scale reconnaissance geologic study along the Variegated Glacier, about 64 km northeast of Yakutat and immediately east of the Fairweather fault. The rocks in the area are medium-grade metamorphic rocks that have been divided into two groups by a major fault (herein named the Mother Hubbard fault) and intruded by postmetamorphic granitic rocks.

ROCK UNITS

There are three principal rock units in the area: a paragneiss-orthogneiss complex with overlying metasedimentary schist north of the Mother Hubbard fault, an orthoamphibolite with minor interfolded pelitic schist south of the fault, and postmetamorphic intrusive rocks.

The texture of the orthoamphibolite unit that dominates most of the ridge south of the Variegated Glacier (fig. 1) indicates that it formed from both basalt and gabbro. The rock shows a varying intensity of deformation with the major rock type, a well-foliated amphibolite, containing local pockets of metagabbro and zones of hornblende schist. Metamorphic grade is uniform throughout, being a lower amphibolite facies as indicated by the assemblage hornblende-andesine-epidote and local garnet.

Two portions of this amphibolite can be distinguished from the unit described above. One of these is a zone in which the amphibolite has been intruded by numerous dikes of very weakly foliated late-metamorphic quartz diorite. The dikes were intruded after the major deformation episode and hence retain their tabular aspect, but were metamorphosed to an assemblage consistent with that of the peak of metamorphism: quartz-andesine-epidote-garnet-hornblende. The other unit is a mile-wide zone adjacent to the Fairweather fault, within which the amphibolite has been strongly fractured.

Interfolded with the amphibolite is a pelitic schist. The schist contains the assemblage biotite-chlorite-muscovite-garnet-staurolite, which is consistent with the lower-amphibolite-facies grade of metamorphism found in the amphibolite. Because of the numerous periods of deformation these units have undergone, the original stratigraphic relation between the amphibolite and pelite could not be determined.

Bordering the Mother Hubbard fault on the north side is a complexly folded gneiss. This unit includes both quartz dioritic orthogneiss and quartz-biotite-andesine-garnet-epidote-paragneiss. The gneiss is overlain by a metasedimentary sequence containing dominantly graphitic schist with lesser amounts of para-amphibolite and minor marble. The metamorphic grade of both the metasedimentary schist and the gneiss is that of lower-amphibolite facies.

Postmetamorphic intrusive rocks occur high on the ridge north of the Variegated Glacier; however, poor weather precluded investigation of them. Samples collected from lateral moraines along tributary glaciers indicate that these rocks range from quartz diorite to granodiorite and are associated with fine-grained dikes of a border facies. Although they show strong evidence of retrogression, textures indicate that these plutonic rocks were emplaced after the regional metamorphism. The intrusion is probably related to the late Mesozoic to

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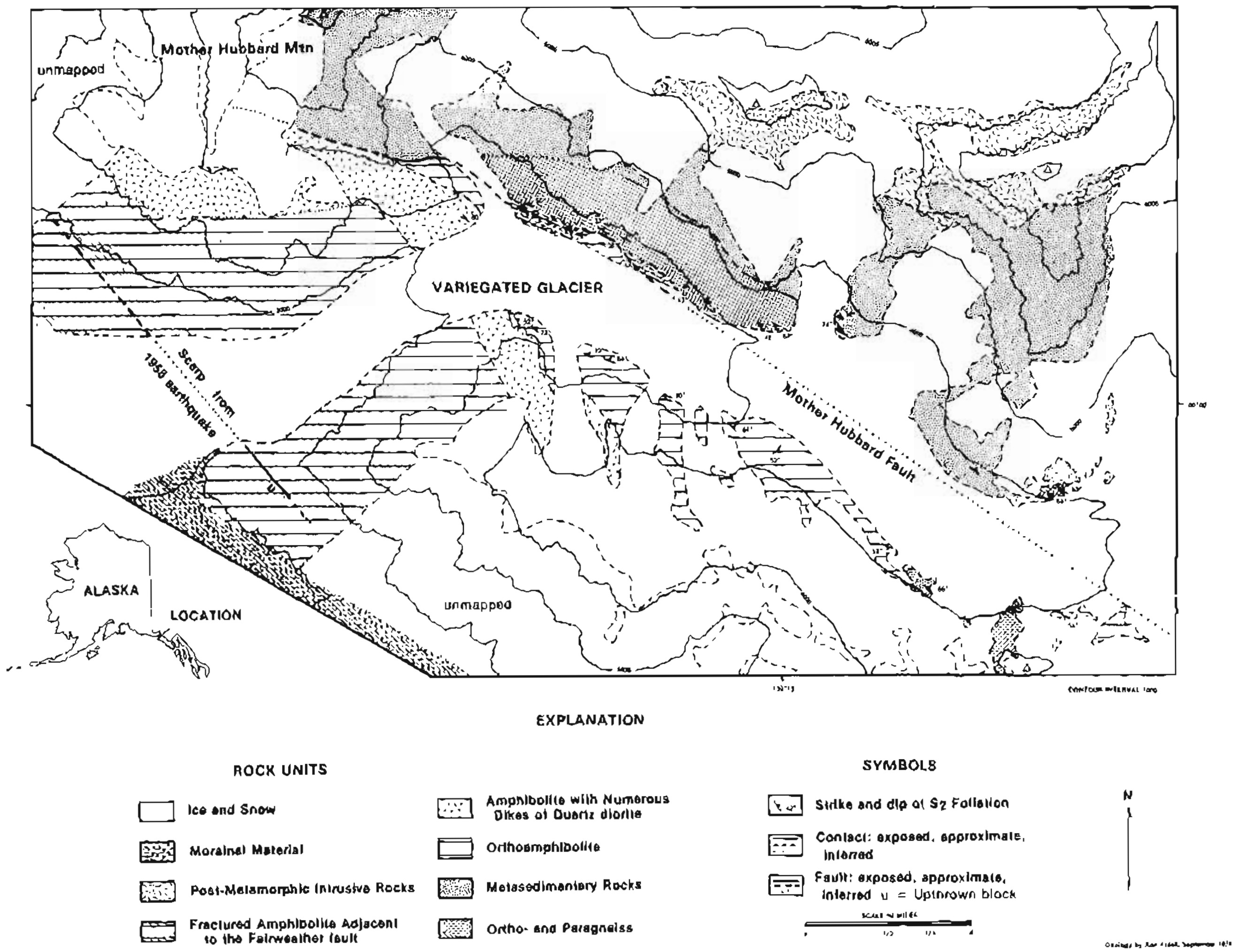

Figure 1. Geologic map of the Variegated Glacier area. Topography from U.S. Geological Survey 15' quadrangles Yakutat D-3 and D-4, and preliminary sheets for St. Elias A-3 and A-4.

early Tertiary plutonism that occurred throughout southeastern Alaska.

STRUCTURE

Small-scale structures are best displayed in the orthoamphibolite, where two penetrative schistosities can be recognized. An earlier schistosity, S_1, has been folded into tight isoclinal folds and only persists in isolated fold hinges. S_2 has formed parallel to the axial surfaces of the isoclinal folds and contains a hornblende lineation parallel to the axial trend of these folds. This lineation is not uniform throughout the orthoamphibolite but spreads across a stereographic plot in a manner suggesting that it was deformed by later cylindrical folding.

The structural history of the rocks north of the Mother Hubbard fault is difficult to interpret. The metasedimentary schist seems to show a structure similar to those seen in the amphibolite, although early isoclinal folds are less commonly preserved. There does not seem to be any fault separating this unit from the underlying gneiss, and the fact that the orthogneiss bodies do not intrude into the schist sequence suggests that the gneiss might underlie the metasedimentary unit. This relation is uncertain, as no detailed structural analysis of the gneiss was attempted and the latest, lower-amphibolite-facies metamorphism seems to have obliterated any trace of previous metamorphism in the few samples of gneiss studied in thin section. Whatever the original age of the gneiss, its major foliation is clearly synchronous with the latest metamorphism and is the same as S_2 in the overlying schist.

One of the major structures in the area is the Mother Hubbard fault, which separates the amphibolite-pelite unit from the gneiss and graphitic schist. The fault is spectacularly exposed on the southeast face of Mother Hubbard mountain, where it strikes approximately N. 70° W. and dips 54° N E.; however, it lies beneath the Variegated Glacier over most of its length, and is only approximately located on the eastern part of the map (fig. 1). Associated with the fault is greenschist-facies retrogression. Similar retrogression along with zones of mylonite were found in metagabbro in one location on the southeast edge of the map. The trace of the fault through this area has been drawn on the basis of this single outcrop. It is not known whether the body of paragneiss shown on figure 1 lying to the south of the inferred trace of the Mother Hubbard fault is a large fault sliver or if it is continuous with the pelitic schist and amphibolite that are adjacent to it.

The other major structure in the area is a fault scarp that shows signs of its recent activity and lies totally within fractured orthoamphibolite (fig. 1). The scarp has been traced on airphotos for more than 3 km and is well exposed on the south side of the glacier, where it crosses a saddle; there the fault has offset talus slopes by as much as 3 feet vertically and the scarp has dammed a small creek. The apparent recent age of the fault suggests that it formed during the earthquake of July 10, 1958, an event that was associated with major surface faulting along the Fairweather fault, 185 km to the south (Toder and Miller, 1959).

DISCUSSION

Because of the limited geologic data on the Saint Elias Mountains, correlation of the units found around the Variegated Glacier with others mapped elsewhere is difficult. Plafker (personal communication) indicates that the orthoamphibolite can be traced along the eastern margin of the Fairweather fault as far as Glacier Bay, more than 160 km to the southeast, where it has been mapped by Rossman (1963a,b) and by MacKevett and others (1971). The unit seems to continue south to Chichagof Island, where it may be Triassic to Jurassic in age (Reed and Coats, 1941; Rossman, 1959).

Berg and others (1972) have divided the pre-Tertiary rocks of the Saint Elias Mountains into two geologic terranes. The Alexander terrane, which is the dominant terrane in the Alexander Archipelago of southeastern Alaska, is of continental affinity and contains Paleozoic to early Mesozoic rocks that have been intruded by plutons as old as Silurian; this terrane occupies most of the interior of the Saint Elias Mountains (Berg and others, 1972). The early Mesozoic rocks of Baranof and Chichagof Islands and their continuation into the Saint Elias Mountains are considered by Berg and others (1972) to be part of the older Chugach terrane, which they interpret as oceanic sedimentary and volcanic rocks that were deposited directly on oceanic basement and later faulted against the Alexander terrane.

According to this interpretation, the gneiss and metasedimentary schist north of the Mother Hubbard fault would be correlative with rocks in the Alexander terrane, and the orthoamphibolite on the south side of the fault would be part of the older Chugach terrane. The Mother Hubbard fault, therefore, would be a major structural feature separating these two geologic provinces.

Because of the insufficient amount of information, there are several problems in establishing this correlation. First, as shown in figure 1, it cannot be demonstrated within the study area whether the Mother Hubbard fault separates the amphibolite-pelite from all the gneiss bodies or actually transects contacts between them. Second, as the units on both sides of the fault show similar structural and metamorphic histories, there is no direct evidence for large-scale displacement on the fault. Therefore, while it might be tempting to extend the terranes of Berg and others (1972) to the rocks of the Variegated Glacier area, the question of the regional significance of the Mother Hubbard fault must await further detailed investigations.

ACKNOWLEDGMENTS

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EVIDENCE FOR EARLY CENOZOIC OROGENY IN CENTRAL ALASKA RANGE

By Wyatt G. Gilbert[1]

ABSTRACT

Paleocene sedimentation and volcanism and Paleocene-Eocene folding, plutonism, and metamorphism strongly suggest that major orogeny affected the central Alaska Range during early Cenozoic time.

INTRODUCTION

Most summaries of Alaska's tectonic history emphasize the important events which involved welding arc-trench systems of southern Alaska to northern Alaska during Jurassic and Cretaceous time (for example, Berg and others, 1972; Grantz and Kirschner, 1975; Csejtey, 1976; Jones and others, 1976). These events are consistent with the timing of major orogenesis in the North American Cordillera, but as in other parts of the Cordillera, there is evidence that this major orogenic episode continued into early Cenozoic time (Coney, 1972; Monger and others, 1972; Burchfiel and Davis, 1975). The geology of the central Alaska Range, in particular, yields evidence for early Cenozoic orogeny. This evidence includes 1) the depositional history of the Cantwell Formation, 2) extrusion of calc-alkaline volcanic rocks, 3) strong folding, and 4) plutonism and metamorphism.

DEPOSITIONAL HISTORY OF CANTWELL FORMATION

During Paleocene time sandstone, siltstone, and conglomerate were deposited in a large continental basin or series of basins in the central Alaska Range (Wolfe and Wahrhaftig, 1970) (fig. 1). The stratigraphy of the formation reflects tectonic instability. Lower stratigraphic intervals suggest a shift from a northern to a southern source (Decker, 1975), and the upper part of the formation contains coarse volcanic detritus caused by renewed uplift (Gilbert and others, 1976).

CALC-ALKALINE VOLCANISM

The Teklanika Formation, which covers about 200 sq km in the central Alaska Range, is a series of calc-alkaline andesite, rhyolite, and basalt flows, and pyroclastic rocks that overlie the Cantwell Formation (Gilbert and others, 1976) (fig. 1). These rocks are typical of volcanic arc assemblages formed in orogenic belts (Green and Ringwood, 1968) and were extruded during late Paleocene time (Gilbert and others, 1976). The Teklanika Formation may be the extrusive manifestation of a Late Cretaceous-early Tertiary plutonic event described by Reed and Lanphere (1973).

EARLY CENOZOIC FOLDING

The Paleocene Cantwell Formation and the Paleocene Teklanika Formation are strongly folded into a series of northeast-trending folds with wavelengths from a few meters to several kilometers (Gilbert, 1975; Gilbert and Redman, 1975) (fig. 1 and front cover photo). In the Toklat River area, a flow of hornblende andesite unconformably overlies folded Cantwell sandstone (Gilbert and Redman, 1975). A hornblende concentrate from this flow yielded an age of 43.2 ± 2.6 m.y. (table 1). Thus, folding occurred after Paleocene deposition of the Cantwell Formation and before late Eocene time.

PLUTONISM AND METAMORPHISM

Sixty-nine plutonic K-Ar ages reported by Wilson and Turner (1975) from the central Alaska Range indicate that plutonism strongly affected the Central Alaska Range during Paleocene-Eocene time (figs. 1 and 2). Wilson and Turner also reported 25 metamorphic K-Ar ages from the eastern part of the Central Alaska Range. Although the ages range from Late Cretaceous to Oligocene, the younger ages may be partially reset by Cenozoic plutons.

CONCLUSION

Paleocene sedimentation and volcanism and Paleocene-Eocene folding, plutonism, and metamorphism strongly suggest that major orogeny affected the central Alaska Range during early Cenozoic time. It is not clear whether this orogeny was continuous with late Mesozoic orogenic events or represents a separate orogenic episode. Early Cenozoic orogeny in the central Alaska Range probably reflects the final consolidation of the main elements of northern and southern Alaska.

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Table 1. *Analytical data for hornblende andesite K-Ar age determination.*[1]

Rock type	Mineral dated	K_2O (weight percent)	Sample weight (grams)	$^{40}Ar_{rad}$ (moles/gm) x 10^{-11}	$\frac{^{40}Ar_{rad}}{^{40}K}$ x 10^{-2}	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Age (±2 m.y.)
Hornblende andesite	Hornblende	0.685	2.1468	4.42	0.2557	0.6965	43.2 ±2.6

[1]Constants used: $\lambda_\varepsilon = 0.586 \times 10^{-10}$ year^{-1}, $\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}, $^{40}K/K$ total = 1.19×10^{-4} mol/mol.

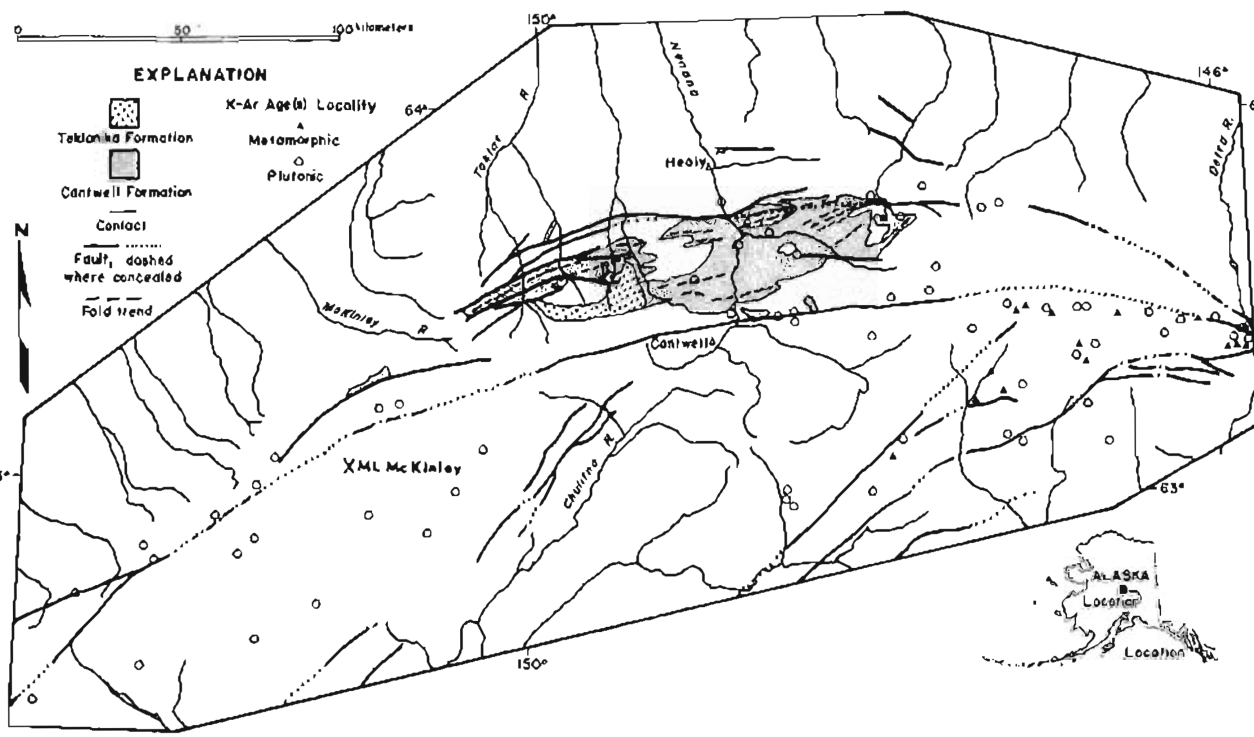

Figure 1. Map of central Alaska Range showing Paleocene Cantwell and Teklanika formations and location of K-Ar ages. Modified from Beikman, 1974; Gilbert and Redman, 1975; Hickman and Craddock, 1975; and Wilson and Turner, 1975.

ACKNOWLEDGMENTS

The K-Ar age of the hornblende andesite flow was provided by Donald L. Turner and Virginia M. Ferrell, Geochronology Laboratory, Geophysical Institute, University of Alaska.

Special thanks are due John E. Decker of DGGS and Thomas E. Smith of the University of Alaska Geology Department for discussion of the ideas in this report.

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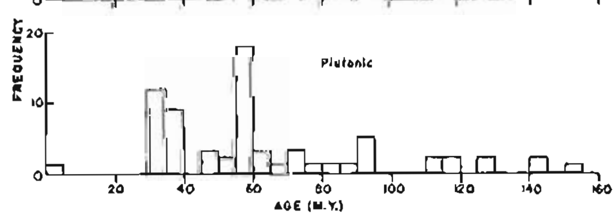

Figure 2. Age-frequency plot of plutonic and metamorphic K-Ar ages reported by Wilson and Turner, 1975, for area shown in figure 1.

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THE SHUMAGIN-KODIAK BATHOLITH—A PALEOCENE MAGMATIC ARC?

By Juergen Kienle and Donald L. Turner[1]

This paper presents four new ages of granitic intrusive rocks from the Sanak, Shumagin, and Semidi Islands on the Pacific side of the Alaska Peninsula. We discuss implications of these ages for the existence of an elongate batholith extending 760 km from the Sanak Islands to Kodiak Island and possibly also to the Kenai Peninsula.

Biotite granodiorite samples from Sanak, Nagai, Big Koniuji, and Chowiet Islands (fig. 1) were dated by the ^{40}K-^{40}Ar method at the Geochronology Laboratory at the Geophysical Institute, University of Alaska, Fairbanks. Our analytical techniques have been reported previously (Turner and others, 1973). Ages range from 57.8 to 60.5 $\pm$ 1.8 m.y. and are thus analytically indistinguishable from one another (table 1). Burk (1965) reported ^{40}K-^{40}Ar ages of 56 to 64 $\pm$ 5 m.y. for one biotite and two muscovites from two granodiorite samples from Nagai Island, and Berry and others (1976) recently reported a biotite ^{40}K-^{40}Ar age of 59.9 $\pm$ 1.8 m.y. from granodiorite or quartz diorite from the Sanak pluton. These ages are concordant with those reported here.

The close agreement of radiometric ages, petrographic similarity, and the occurrence along the same trend of these granitic intrusives strongly suggest that they may be contiguous at depth and thus part of an elongate batholith parallel to the Alaska Peninsula. This idea was originally proposed by Burk (1965), who pointed out that these plutonic rocks were petrologically similar and that they all intruded a Late Cretaceous slate and graywacke belt (fig. 1), a major flysch unit extending from the Sanak Islands to the Kenai-Chugach Mountains.

The slate and graywacke belt is identified as the Shumagin Formation on the Sanak and Shumagin Islands (Grantz, 1963; Burk, 1965), by the Kodiak Formation on Kodiak and Afognak Islands (Moore, 1969), and by the Valdez Group in the Kenai-Chugach Mountains (Schrader, 1900; Moffit, 1954). Evidence for the Late Cretaceous age assignment and correlation of these various parts of the slate and graywacke belt are discussed by Moore (1973) and Jones and Clark (1973). The sediments of this belt were shown by Moore (1972, 1973) to be turbidites which he believes were deposited in a trench bordering the continent in Late Cretaceous time that was superseded by the Aleutian arc-trench system.

Although radiometric dates have not been reported for the granitic rocks intruding the slate and graywacke belt on Kodiak Island (fig. 1), there are three lines of evidence suggesting these rocks are correlative with the dated Paleocene granitic plutons on the Sanak, Shumagin, and Semidi Islands: 1) the rocks on Kodiak Island are quartz diorite to granodiorite plutons with biotite as the dominant mafic mineral, as are the dated intrusives; 2) the Kodiak rocks intrude the slate and graywacke sequence that is correlated with the same sequence on the other islands; and 3) detritus from both the plutons and the slate and graywacke sequence is reported by Capps (1937, p. 151) in the nonmarine sediments of probable Eocene age on Kodiak Island (Burk, 1965, p. 111). The age of the Kodiak quartz diorite and granodiorite, therefore, appears to be bracketed between Late Cretaceous and early Tertiary, an age span that is in agreement with our biotite granodiorite intrusive ages from the islands.

We suggest that the above evidence indicates the existence of an elongate batholith of Paleocene age, herein named the Shumagin-Kodiak batholith, which extends from the Sanak Islands to Kodiak Island, and probably further (fig. 1). This batholith may extend as far northeast as the Nuka Bay—Blying Sound area, because small quartz diorite bodies intrude the slate and graywacke belt there (Johnson, 1915; Burk, 1965). These intrusives have not been dated radiometrically, but we know that they intrude Late Cretaceous rocks and are, therefore, of Late Cretaceous or younger age. We know of no paleontologic data that can be used to put an upper age limit on these rocks, and the determination of their ages must await future radiometric dating.

We propose that the Shumagin-Kodiak batholith represents the locus of a Paleocene magmatic arc similar to the Jurassic magmatic arc on the Alaska Peninsula (fig. 1). The trench sediments associated with this arc are likely to be found incorporated into the continental shelf edge landward of the present trench axis (Von Huene and Shor, 1969, p. 1897). Von Huene and Shor (1969) estimated the age of the present eastern Aleutian trench to be Pliocene. Their age evidence, together with our evidence discussed above, indicates a seaward migration of the trench at least through Late Cretaceous and Tertiary times.

Scholl and others (1975), Moore (1972), and Jones (1971) argue convincingly that the eastern Aleutian and

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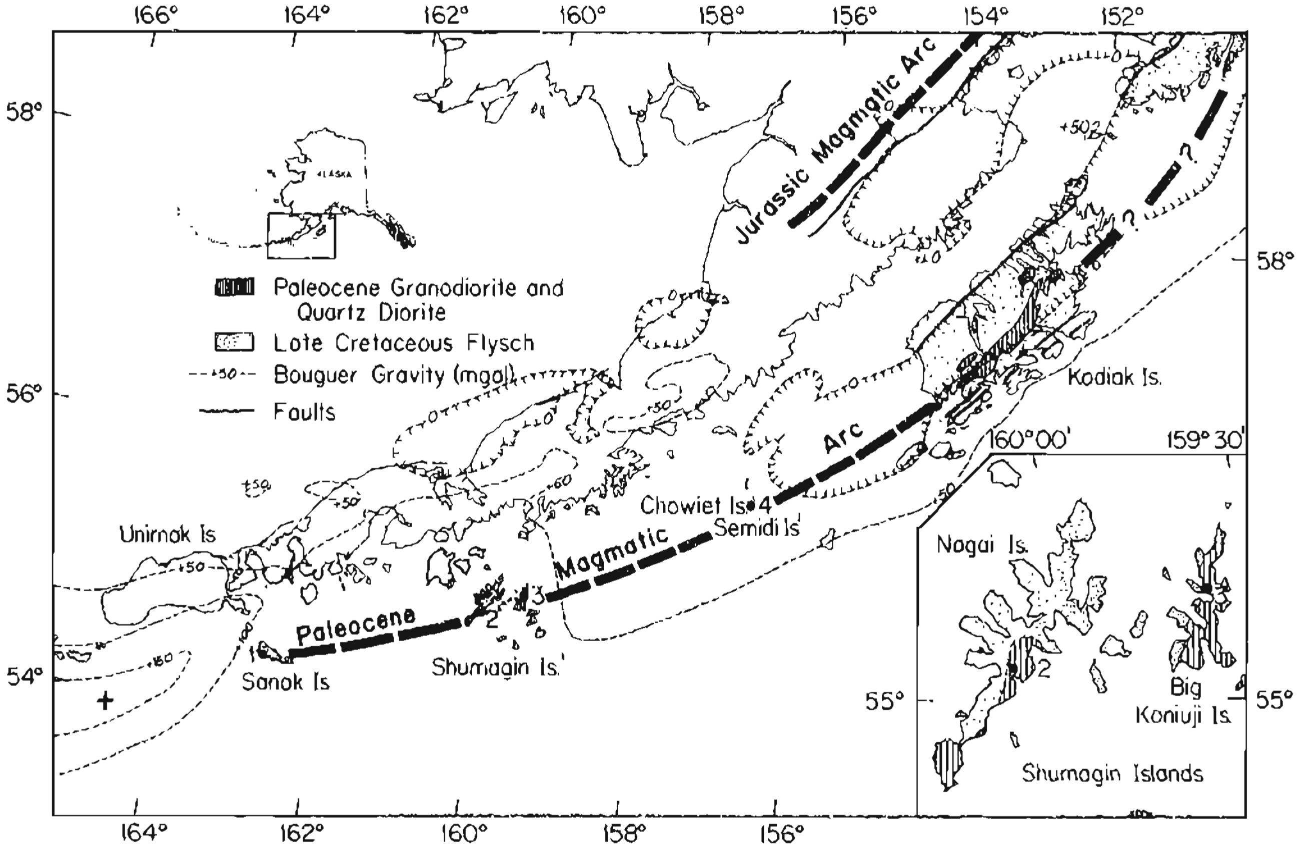

Figure 1. Locations of dated plutonic rocks, approximate axes of Paleocene and Jurassic magmatic arcs, and Bouguer gravity contours (generalized from Barnes, 1976).

Bering Sea region evolved by a two-step process: first, Mesozoic subduction in the Shumagin-Kodiak, Bering Sea and eastern Siberian (Koryak Mountains) shelves produced the trench sediments of the Late Cretaceous slate and graywacke belt; this was followed by an early Tertiary shift to more seaward subduction south of a newly emerging magmatic arc, the Aleutian ridge. The magnitude of this shift in the eastern Aleutian trench was about the width of the Cretaceous arc-trench gap, whereas the western Aleutian Trench jumped the entire width of the Bering Sea (Scholl and others, 1975, p. 8). This tectonic model, however, is at variance with paleomagnetic data (Stone and Packer, 1976), which suggest that the Alaska Peninsula drifted to its present position in early Tertiary time from a much more southerly position in Jurassic time.

The Late Cretaceous slate and graywacke belt extending from the Kenai Peninsula to the Shumagin Islands is outlined by a regional Bouguer gravity trough (Barnes, 1976; fig. 1), which terminates in the Shumagin Islands region. This gravity trough and its Shumagin cutoff are consistent with the two-step tectonic model outlined above in which the late Mesozoic subduction zones along the eastern Aleutian and eastern Siberian continental shelves were connected by a relatively narrow trench extending along the Bering Sea shelf edge.

We propose that the Shumagin termination of the gravity trough is due to this abrupt narrowing of the late Mesozoic eastern Aleutian trench, resulting in less sediment accumulation and a corresponding attenuation of the gravity anomaly.

In conclusion, concordant radiometric ages of granitic plutonic rocks, which outcrop on the Alaska Peninsula continental shelf in a narrow belt at least 400 and perhaps as much as 1,250 km long, date a regional magmatic arc. We believe that this arc, represented by the Shumagin-Kodiak batholith, is the result of Paleocene subduction landward of the present Eastern Aleutian Trench, where subduction began in Pliocene time.

ACKNOWLEDGMENTS

We thank Diane Duvall for laboratory assistance with mineral separations and potassium and argon analyses. R.B. Forbes, D.B. Stone, and J.R. Carden reviewed the manuscript.

Table 1. *Analytical data for K-Ar age determinations.*[1]

Sample	Rock type	Mineral dated	K_2O (weight percent)	Sample weight (grams)	$^{40}Ar_{rad}$ (moles/gm) x 10^{-11}	$\frac{^{40}Ar_{rad}}{^{40}K}$ x 10^{-3}	$\frac{^{40}Ar_{rad}}{^{40}Ar\ total}$	Age ± 1σ (m.y.)
(1) Sanak Is. (75089)	biotite granodiorite	biotite	7.516 7.492 $\bar{x}$ = 7.504	0.3543	68.198	3.598	0.844	60.5 ± 1.8
(2) Nagai Is. (75092)	do.	do.	8.252 8.244 $\bar{x}$ = 8.248	0.3298	73.335	3.520	0.918	59.2 ± 1.8
(3) Big Koniuji Is. (75088)	do.	do.	6.470 6.550 $\bar{x}$ = 6.510	0.3770	57.404	3.491	0.903	58.7 ± 1.8
(4) Chowiet Is. (75086)	do.	do.	6.325 6.353 $\bar{x}$ = 6.339	0.7014	54.958	3.432	0.910	57.8 ± 1.8

[1]Constants used: $\lambda_\epsilon = 0.585 \times 10^{-10}$ year^{-1}, $\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}, $^{40}K/K$ total = 1.19×10^{-4} mol/mol.

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SPECULATIVE TECTONIC EVOLUTION OF THE CENOZOIC SHELIKOF TROUGH, SOUTH-CENTRAL ALASKA

By Steve W. Hackett[1]

Recent integration of regional geologic and geophysical data over the Cook Inlet region, south-central Alaska (fig. 1) reveals new information on the probable Cenozoic history of the region (Hackett, 1976a). Regional gravity and magnetic anomalies can be related to known and speculated Mesozoic and Cenozoic tectonic elements in the upper Cook Inlet region. These regional geophysical anomalies help delineate major geological features and suggest the locations of inferred rock units.

The regional tectonic pattern of south-central Alaska was first delineated by Payne (1955). His study revealed five arcuate Mesozoic tectonic elements outlining the geologic setting of south-central Alaska (fig. 2). The Shelikof Trough is a major structure of Cenozoic age superimposed on Mesozoic geanticlines and geosynclines; it cuts across these Mesozoic features and seemingly is not influenced by them (Gates and Gryc, 1963). Carey (1958) and Grantz (1966) defined the arcuate Mesozoic features as part of the Alaska orocline.

Structural and stratigraphic data from geologic field studies and exploratory drill holes in the northeastern Alaska Peninsula, the Cook Inlet Basin, and the Copper River Basin outline major Cenozoic and Mesozoic rock units. Regional stratigraphic and structural trends have been identified in the Cook Inlet region, Alaska (Hackett, 1976a). K-Ar whole-rock age dates (Grantz and others, 1963a; Detterman and others, 1965; Reed and others, 1969, 1971, 1972, and 1973) and regional geologic compilations (Beikman, 1974) help identify major Mesozoic and Cenozoic plutonic bodies and associated rock types. Recent regional syntheses have documented the probable tectonic setting of portions of south-central Alaska and its influence on the accumulation of petroleum (Kirchner and Lyon, 1973; Grantz and Kirchner, 1975). Seismicity studies (Plafker, 1965, 1969; Davies and Berg, 1973, VanWormer and others, 1974) and regional implications of plate tectonics (Atwater, 1970; Grow and Atwater, 1970) have broadened our views about the probable importance of plate boundaries adjacent to and within south-central Alaska during Mesozoic and Cenozoic time.

Review of current geologic information indicates that Mesozoic rock units in south-central Alaska are offset in the upper Cook Inlet region (fig. 3). Regional gravity data imply that major geophysical anomalies are abruptly truncated in the Beluga Basin area between Lake Chakachamna on the west and the Matanuska Valley on the east (fig. 4). High positive Bouguer gravity values believed to be associated with the Jurassic rocks along the western edge of the Shelikof Trough are separated right laterally in the upper Cook Inlet region (Hackett, 1976b). This geophysical feature is believed to correlate with a similar anomaly defined by a relatively high Bouguer gravity trend in the Talkeetna Mountains and northern Copper River Basin (fig. 4). Distinct magnetic patterns associated with a Jurassic plutonic assemblage in the Talkeetna Mountains (T.E. Smith, pers. commun.) and magnetic patterns outlining Jurassic intrusive rocks along the western portions of the Cook Inlet (Grantz and others, 1963b) are also abruptly truncated in the Cook Inlet-Matanuska Valley region.

The Shelikof Trough (fig. 2) is postulated to be the result of transformation of a Jurassic magmatic arc system that was located in south-central Alaska during Mesozoic time (figs. 5 and 6). A dextral transform fault[2] (convex arc to convex arc) is believed to explain the apparent right lateral separation of two similar Jurassic terrains. The downthrown segment on the inside of the southern arc and on the outside of the northern arc is suggestive of the initial configuration of the Shelikof Trough. The transform geometry of the Jurassic Talkeetna geanticline in the Cook Inlet region apparently existed before Upper Cretaceous time. A large Jurassic-Cretaceous unconformity extending from southwest of Kodiak Island northwest through Cook Inlet Basin-Matanuska Valley to and possibly beyond the Copper River Basin is suggested (fig. 7). The position of this inferred Jurassic-Cretaceous contact suggests that the northern margin of Cretaceous shallow marine deposition was a growing transform boundary in the upper Cook Inlet-Matanuska Valley area.

Substantial block movements of translation and rotation are postulated to have occurred in south-central Alaska during Late Cretaceous and early Tertiary times (fig. 8). These block movements are believed to have been caused by a change from normal to oblique subduction between major plate boundaries during late Mesozoic or early Cenozoic time. Continued oblique rifting in the Cook Inlet region during the middle and

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[2]Transform - A junction where one feature (such as island or mountain arc) changes into another. An arc is described as being convex or concave, depending on which face is first reached when proceeding in the direction of relative motion (Wilson, 1965).

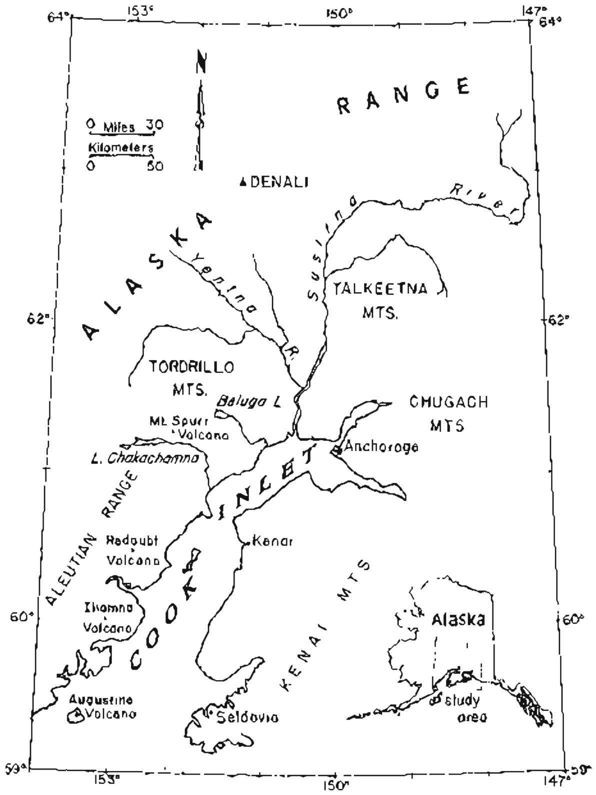

Figure 1. Index map of the Cook Inlet region, south-central Alaska.

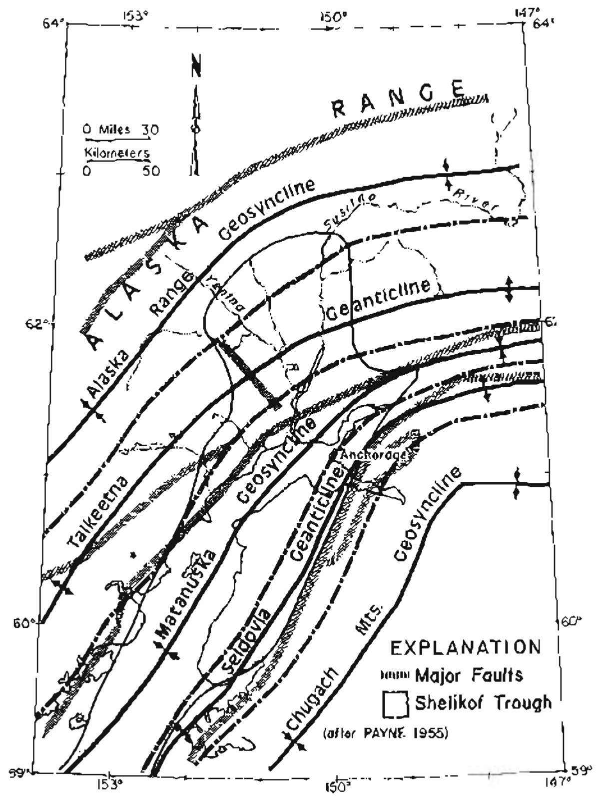

Figure 2. Mesozoic and Cenozoic tectonic elements in the Cook Inlet region.

late Tertiary further accentuated the formation of Tertiary rhombochasms[3] (Cook Inlet, Beluga, and Yentna basins) and sphenochasms[4] (Susitna basin and Matanuska Valley). The Tertiary basins enclosed within the upper Cook Inlet region (fig. 9) can be interpreted as a system of tilted horsts and grabens produced by continued extensional fragmentation of a pre-Tertiary basement.

The Shelikof Trough is postulated to be a pull-apart structure that resulted from rifting between the Pacific and North American plates since late Mesozoic time. Subduction of the Kula plate probably produced substantial northwest-southeast compressive stresses in south-central Alaska. Early Tertiary southeast-east ana northwest-west directed compressive stresses caused the rotation and translation of pre-Tertiary basement blocks to tilted positions bounded by high-angle reverse faults. Continued east-west underthrusting in the Aleutian trench (Plafker, 1969) and resulting block movements by strike-slip and reverse faulting in the Cook Inlet region have probably continued to the present. Structures within each Tertiary basin are believed to be related partially to oblique tensional and extensional fragmentation within a broad area of right-lateral movement and coupling between the Denali fault system to the north and the Aleutian Trench to the south (fig. 10). Translation and rotation of Cenozoic tectonic blocks in south-central Alaska are the result of the above-mentioned coupling.

Regional deformation in southern Alaska (Grantz, 1966; Freeland and Dietz, 1973; Gedney and others, 1975) is commonly characterized by nonpaired conjugate shear fractures. The Tordrillo block (fig. 8) (Hackett, 1974) shows strong evidence of right-lateral coupling. Bending of the Alaska orocline may be partially explained by counterclockwise movements between the Denali Fault system and the Aleutian Trench. The underthrusting of the Pacific plate also suggests substantial amounts of right-lateral coupling action in the central Aleutians (Grow, 1973).

To summarize, it is believed that translational and rotational Cenozoic block movements outlined the Shelikof Trough and its Tertiary subprovinces as we see them today (fig. 9). The exact evolution of each Tertiary basin within the Shelikof Trough cannot be determined from present geophysical and geological information, and more detailed investigations are needed for the accurate location of rock units, unconformities, basin depocenters, and structural trends.

[3]Rhombochasm - A parallel-sided gap in the crust and interpreted as a dilation. In dextral rhombochasms the crustal blocks have moved apart with a right-hand lateral component (Carey, 1958).

[4]Sphenochasm - A triangular gap separating two crustal blocks with fault margins converging to a point and interpreted as having originated by rotation of one of the blocks with respect to the other (Carey, 1958).

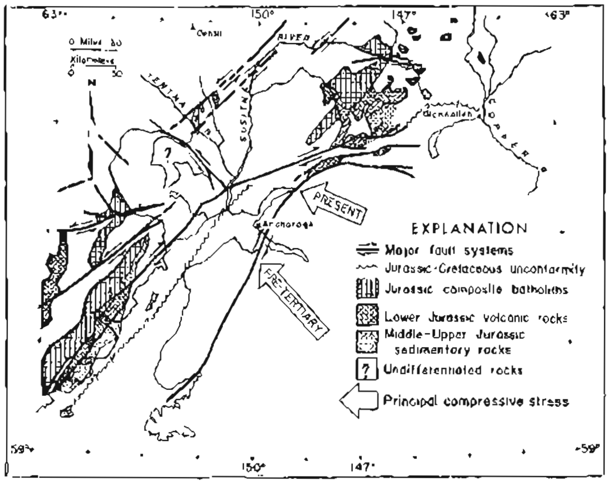

Figure 3. Outcrop map of Jurassic rocks, Cook Inlet region.

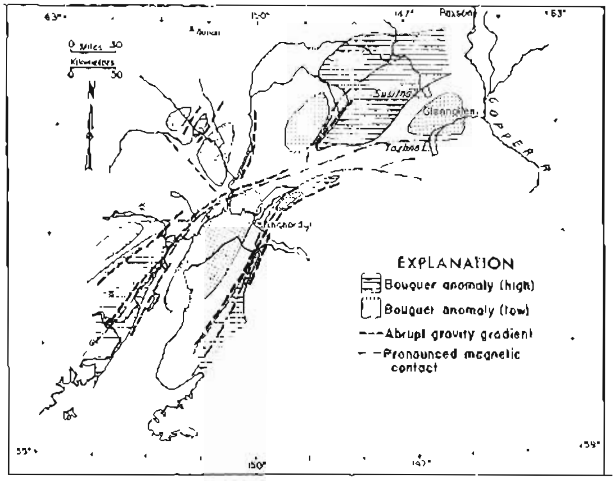

Figure 4. Geophysical interpretation of regional gravity and magnetic data, south-central Alaska.

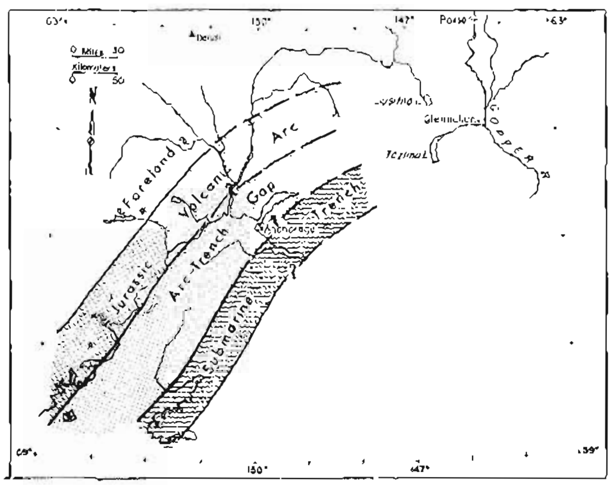

Figure 5. Reconstructed Jurassic island-arc system, south-central Alaska.

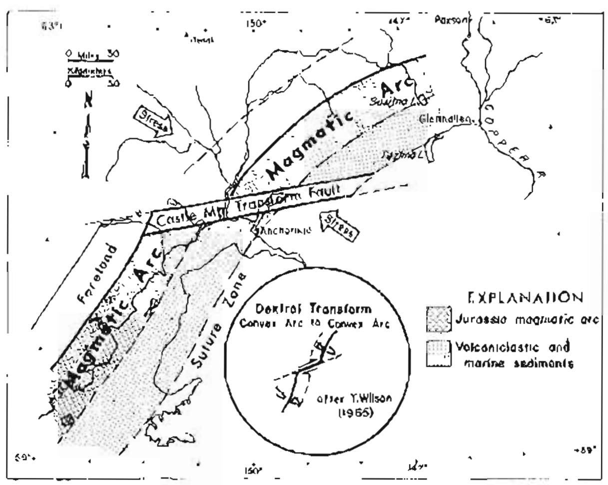

Figure 6. Speculative Mesozoic tectonic reconstruction, south-central Alaska.

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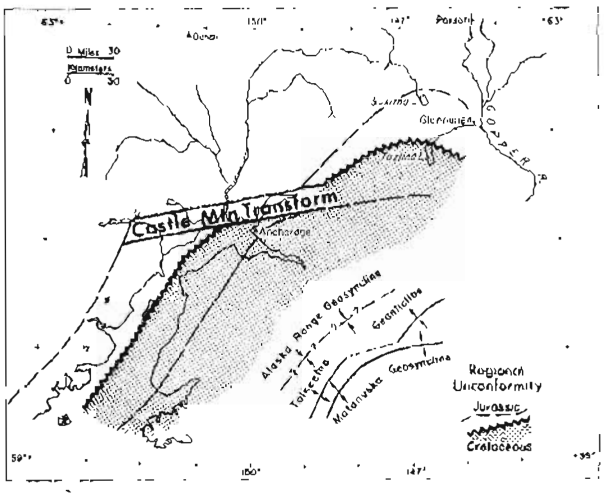

Figure 7. Speculative late Mesozoic sedimentary deposition, south-central Alaska.

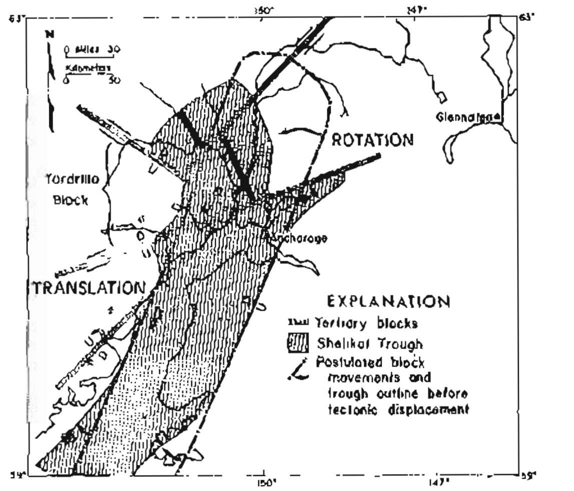

Figure 8. Cenozoic tectonic elements showing block outlines and postulated movements.

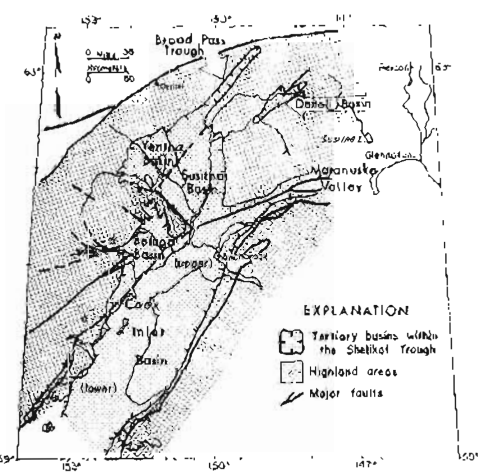

Figure 9. Outline of Tertiary basins enclosed within the Shelikof Trough, Cook Inlet region.

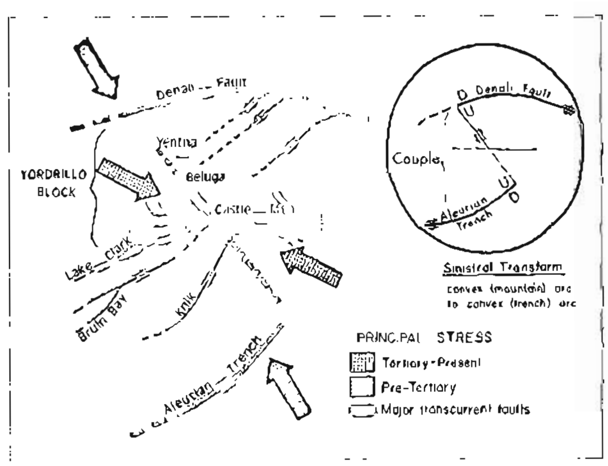

Figure 10. Generalized structural analysis showing postulated coupling movements and transformation in south-central Alaska.

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DISCOVERY OF BLUESCHISTS ON KODIAK ISLAND

By J.R. Carden and R.B. Forbes[1]

Metamorphic rocks containing sodic amphibole were first discovered on the southwest tip of the Kenai Peninsula over 50 years ago, when Martin (1915) noted their occurrence near Seldovia (fig. 1). Later, Forbes and Lanphere (1973) determined that the epidote-crossite blueschists and intercalated greenschists are in fault contact with a dismembered ophiolite complex composed of ferruginous cherts, pillow basalts, diabase, and small pods and stringers of serpentine.

Martin (1912), Maddren (1917), and Capps (1937) described chloritic schists and other metamorphic rocks cropping out with red cherts and pillow basalts on the northwest side of Kodiak Island between the old town of Uyak and Seven Mile Beach (fig. 2). Martin (1912) believed that the rocks in this area were correlative with similar rocks on the Kenai Peninsula, near Seldovia Bay.

Using this as a reference, we discovered blueschists intercalated with greenschists, graphitic quartz-mica schists, and marbles in several beach outcrops between Bear Island and Seven Mile Beach (lat 57°39'06" N., long 154°03'47" W.). The schists have an isoclinal overturned fold style, with fold axes that trend northeast and axial planes that dip steeply to the northwest. Compositional layering is still discernable in many of the outcrops, even though a pervasive axial-plane schistosity is well developed. The metamorphic rocks appear to be tectonically imbricated with virtually unmetamorphosed but highly deformed red cherts and argillites.

Typical blueschist metamorphic mineral assemblages include:

1) Crossite-epidote-stilpnomelane-sphene.
2) Crossite-lawsonite-chlorite-sphene.
3) Crossite-epidote-albite-chlorite-sphene.

Crossite constitutes 20-80 percent of the blueschists studied. It generally occurs as strongly pleochroic blades or bladed aggregates that define the schistosity. The needles are generally less than 0.24 mm long.

Iron-rich epidote is the dominant calcium aluminum silicate in both the greenschists and blueschists near Seven Mile Beach. It typically occurs as pleochroic subhedral porphyroblasts up to 1 mm in length. Lawsonite has been discovered in one blueschist outcrop, as determined by optical and X-ray diffraction analyses. The lawsonite in this rock is the only known in-situ occurrence known to exist in Alaska. In thin section, the mineral typically occurs as equant subhedral porphyroblasts, about 0.2 mm in diameter, set in a matrix of chlorite and sphene.

Chlorite occurs as pleochroic bladed aggregates which, along with crossite, also define the schistosity in many of these rocks. Accessory phases include albite, stilpnomelane, and sphene.

Relict phenocrysts of pyroxene and plagioclase occur in several specimens. The pyroxene, however, is partially altered to chlorite and the plagioclase is highly saussuritized. The groundmass of these rocks is made up of fine-grained crossite, chlorite, and epidote. This mineralogy, together with chemical data (table 1), indicates that the parent of these blueschists was a basaltic rock.

The presence of blueschists in at least three separate areas on the northwest side of Afognak Island has been confirmed by W. Connelly of the University of California at Santa Cruz (pers. comm.), indicating that the blueschist belt may be more or less continuous along the northwest side of the island.

The correlative mineral assemblages, associated rock types, and structural style of the Kodiak Island and Seldovia blueschist terranes suggest that these rocks may have once been part of an early Mesozoic convergent plate margin, which may also have been contiguous with other blueschist occurrences along the north flank of the Chugach Range. These localities include:

1) The Valdez C-2 locality (lat 61°30' N., long 144°30' W.).
2) The Hubbard Glacier locality (lat 60°04' N., long 139°38' W.) (G. Plafker, 1975, pers. comm.).

ACKNOWLEDGMENTS

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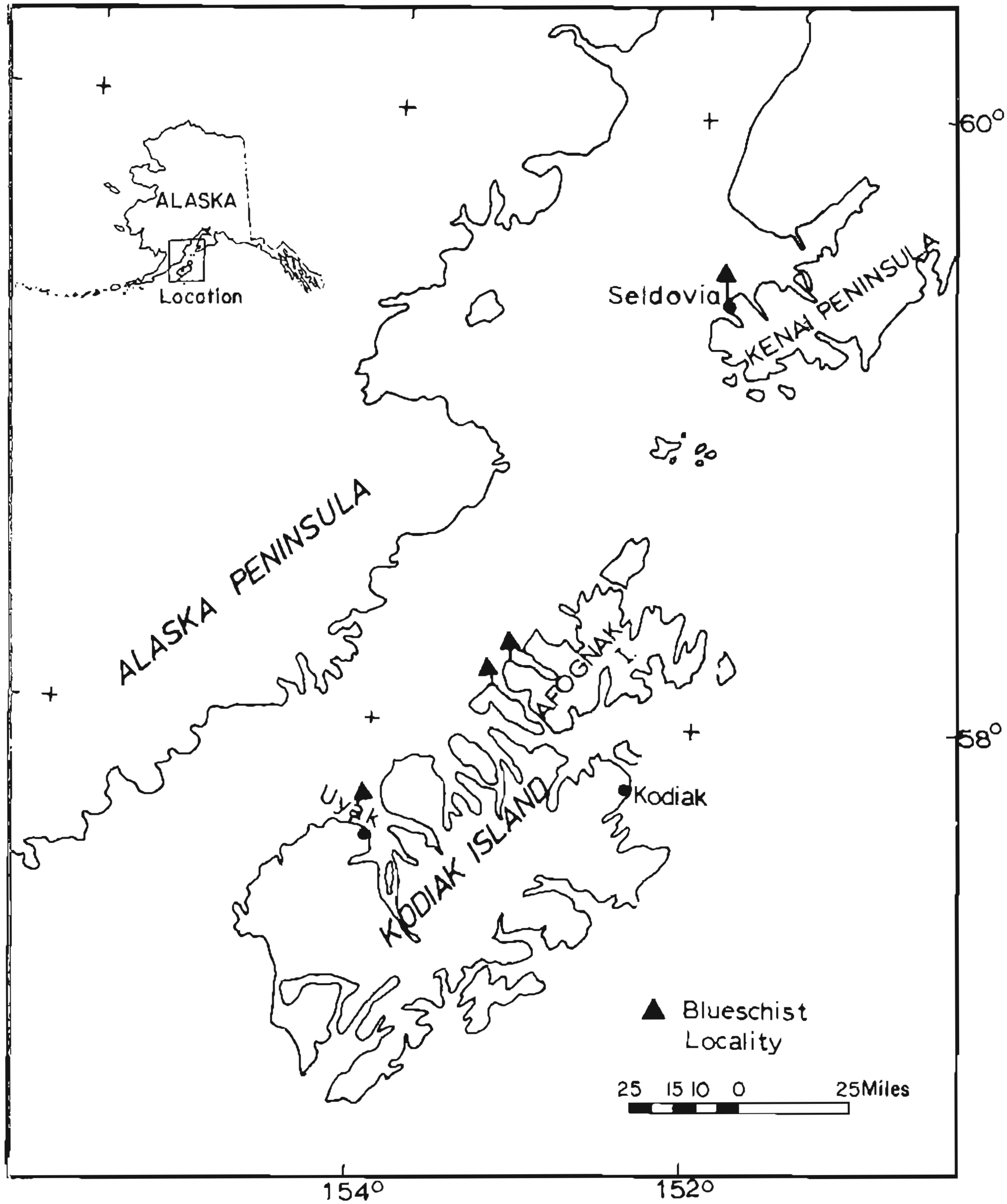

Figure 1. Location map of the Kodiak Island - Kenai Peninsula area showing occurrences of blueschist-facies metamorphic rocks.

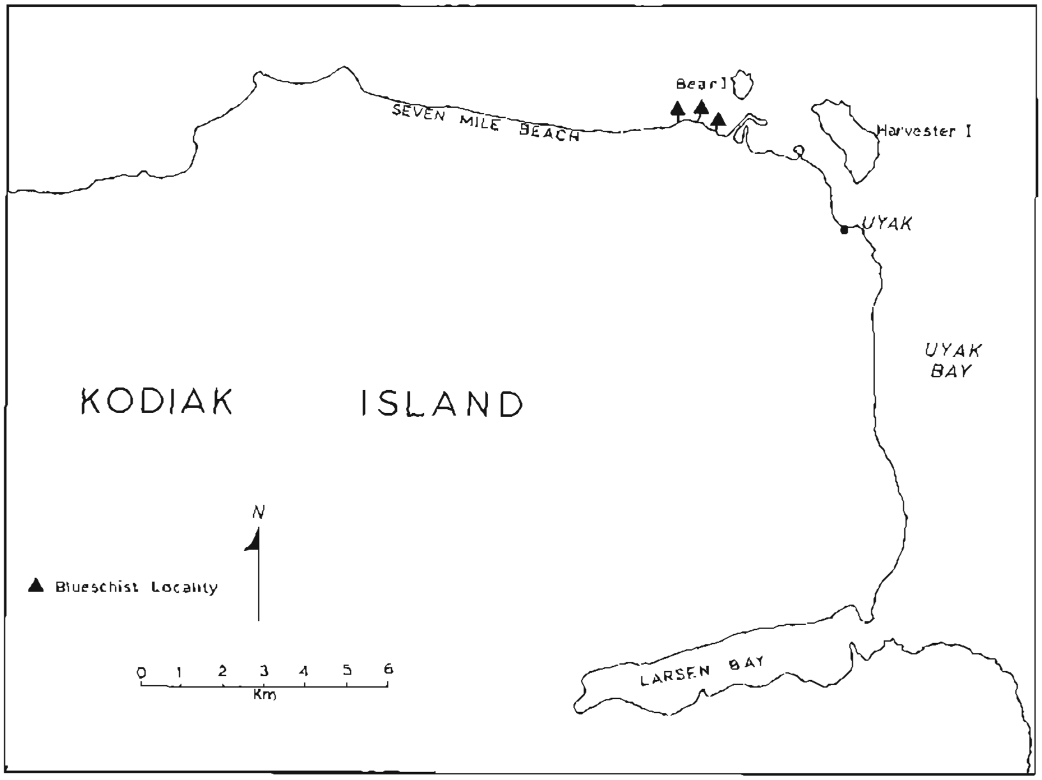

Figure 2. Location map of blueschist discoveries near Seven Mile Beach.

Table 1. *Chemical compositions and estimated modes of selected blueschists from Kodiak Island.*

Oxides	Sample (wt %) UK 23c	UK 23f	UK 19-20
SiO_2	53.2	47.5	47.1
TiO_2	0.11	2.9	2.9
Al_2O_3	6.2	12.8	12.6
Fe_2O_3	11.4	8.1	3.6
FeO	13.2	4.9	9.6
MnO	0.19	0.16	0.17
MgO	6.0	4.1	5.1
CaO	3.4	7.0	8.0
Na_2O	4.6	5.4	3.5
K_2O	0.38	1.2	0.77
P_2O_5	0.01	0.35	0.35
H_2O+	1.5	2.0	2.7
H_2O-	0.2	0.2	0.2
CO_2	0.1	0.1	0.8
Mineral			
Crossite	80	60	70
Epidote	10	5	--
Lawsonite	--	--	5
Chlorite	--	15	15
Albite	3	15	--
Stilpnomelane	5	--	--
Sphene	2	5	7
Secondary carbonate	--	--	3

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LARGE KAOLINITE CRYSTALS IN THE CHIGNIK FORMATION (UPPER CRETACEOUS), HERENDEEN BAY

By Don M. Triplehorn[1]

INTRODUCTION

A thin clay layer consisting of large kaolinite crystals has been found in a coal bed of the Chignik Formation (Upper Cretaceous) at Herendeen Bay on the Alaska Peninsula.

LOCATION AND DESCRIPTION

The outcrop occurs at Coal Bluff, on the east shore of Herendeen Bay, about 15 miles southwest of Port Moller (T. 74 W., R. 50 S., Port Moller 1:250,000 quadrangle).

The layer containing the coarse kaolinite occurs within a 2-foot bed of impure coal about 150 feet above the base of a sandstone-shale-coal section exposed in sea cliffs. It ranges from 1 to 3 inches thick and is continuous within the exposure (about 50 feet).

In hand specimen the parting is dark-chocolate brown, unlayered, with a granular appearance. On broken surfaces individual vermicular crystals up to 1.5 mm long are visible with a hand lens. The parting is overlain by a 1/2-inch layer of dark-gray carbonaceous claystone having some layering or fissility; this layer lacks the coarse kaolinite crystals but proved to be composed of kaolinite not significantly different in X-ray character or purity from the coarse-grained layer. The brown organic stain on the crystals is easily removed with hydrogen peroxide, leaving them with a pale yellow-brown color.

In thin section the rock appears as a mass of interwoven vermicular kaolinite crystals ranging in size from 0.25 to 1.0 mm with a mean size near 0.5 mm. A finer grained matrix, also kaolinite, occurs between the large crystals and constitutes perhaps 15 percent of the rock.

MINERALOGICAL COMPOSITION

Figure 1 shows X-ray diffraction patterns of this material. Patterns A and B are random powder mounts for the whole rock and for a relatively coarse-grained fraction (125μ - 63μ), respectively. The latter pattern consists of sand-sized kaolinite crystals obtained by the wet sieving of crushed, ultrasonically cleaned material. Note that the X-ray diffraction patterns are essentially similar: this suggests that the matrix is not significantly different from the large crystals. Such evidence is not conclusive because the matrix is a relatively small part of the whole rock.

Pattern C is for a fine-grained fraction ($< 8\mu$) obtained by timed withdrawal from a crushed clay dispersed in water and mounted as an oriented aggregate on glass. Only the first two orders of the basal reflection, at about 7Å and 3.56Å, are prominent. The third order, at 2.3Å, is barely detected.

The high purity of the kaolinite is indicated by the absence of diffraction maxima for minerals other than kaolinite. Despite the purity, a relatively low degree of crystallinity is suggested by the character of diffraction patterns A and B. Calculation of a "crystallinity index" by the method of Hinckley (1963) yielded values of 0.68 for the whole rock and 0.70 for a concentrate of coarse kaolinite crystals. For Georgia kaolins, Hinckley determined values from 0.25 (poorly crystallized) to 1.45 (well crystallized). On this scale the Herendeen Bay sample is moderately low.

The silt- and sand-sized heavy-mineral fraction is sparse, but consists predominantly of euhedral zircons (aside from an abundance of marcasite, which is probably of authigenic origin).

ORIGIN

I know of only two references of macrokaolinite in the United States. Isphording and Lodding (1968) described crystals up to 0.2 mm from the Kirkwood Formation (middle Miocene) of New Jersey. Asquith (1968) reported crystals up to 3 mm long in a 1- to 3-inch layer underlying a coal bed in the Almond Formation near Rock Springs, Wyoming.

In Europe, however, such occurrences are apparently common in kaolinitic clay partings (called tonsteins) in coal beds. Millot (1970, p. 166) gives a general discussion of these occurrences and notes that such crystals, once known as leverrierite, are now known to be a variety of kaolinite.

The parent materials for the tonsteins described by

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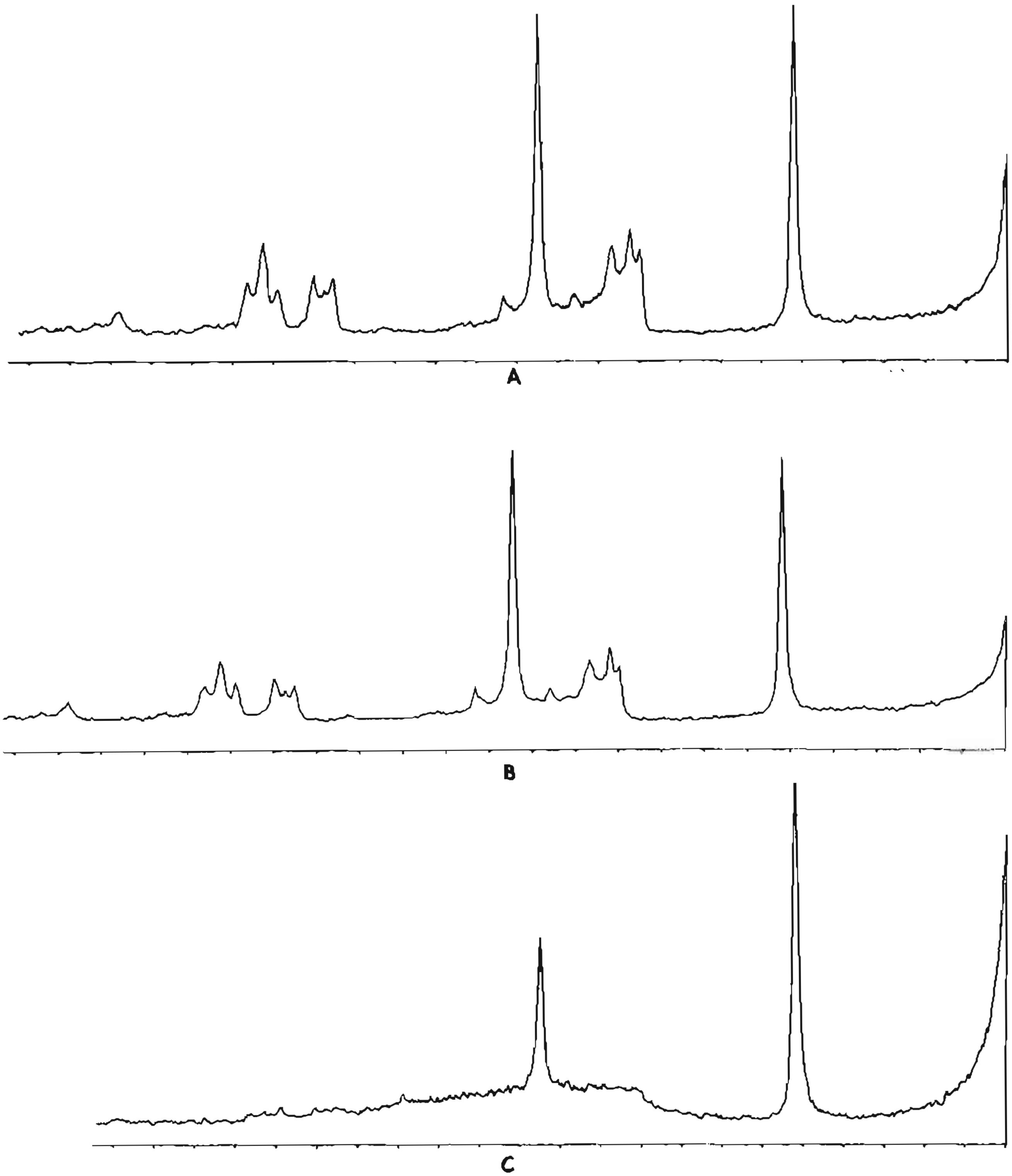

Figure 1. X-ray diffraction patterns. A - whole sample prepared as a random powder; B - 125μ- 63μ crystals prepared as a random powder; C - <8μ fraction prepared as an oriented aggregate.

Millot are now generally considered to be of volcanic origin. Thus the kaolinite crystals, sometimes of relatively large size, formed from vitric and crystal tuffs that were preserved as discrete layers by falling into coal-forming swamps. These kaolinitic layers tend to be relatively pure and contain minor silt- and sand-sized minerals notably different from those in water-laid terrigenous sediments.

The two U.S. examples noted above have been interpreted as products of intense leaching involving the removal of metallic cations and leaving an alumina-silica residue—perhaps gellatinous—that crystallized to relatively pure kaolinite. Such a process has long been advocated by W.D. Keller (1956, 1970).

The two suggested origins are not incompatible, since both imply extensive chemical alteration under acid leaching conditions. The tonstein case merely involves a particular kind of parent material that fell into a particularly favorable environment for kaolinite formation.

The Herendeen Bay macrokaolinite is in fact a tonstein and probably formed from volcanic ash that fell into a coal swamp and was diagenetically altered to kaolinite. The absence of other clay minerals, absence of terrigenous minerals such as quartz and feldspar, and the high content of euhedral zircons in the sand-silt fraction all support such an interpretation.

Still unanswered, however, is the question of why some tonsteins became coarsely crystallized and others did not.

SIGNIFICANCE

The Herendeen Bay macrokaolinite is noteworthy primarily because such occurrences are rare, at least in the United States.

Secondly, this occurrence is a variety of tonstein, a volcanic ash bed altered to kaolinite. A tonstein records a single event (volcanic eruption) and has the same time value wherever it is found. Tonsteins have proved useful for correlation of coal beds in Europe (Williamson, 1961, 1970); they are common in some Alaskan coals (Triplehorn, 1974, 1976) and thus may be useful stratigraphic markers.

ACKNOWLEDGMENT

This kaolinite was discovered while collecting coal samples with Cleland N. Conwell of DGGS while working under a U.S. Geological Survey grant (No. 14-08-001-G-207). I wish to thank J.T. Kline of DGGS for performing the mineral separations.

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OCCURRENCES OF SODIC AMPHIBOLE-BEARING ROCKS IN THE VALDEZ C-2 QUADRANGLE

By P.A. Metz[1]

INTRODUCTION

About 182 sq. km were mapped by the author during the 1974 field season in the Valdez C-2 quadrangle (Metz, 1975). The area of investigation is shown in figure 1. The mapping program resulted in the discovery of sodic amphibole-bearing rocks at 14 localities. Prior to this discovery, only one other sodic amphibole locality had been documented in south-central Alaska—at Seldovia (Martin and others, 1915). Since the Valdez C-2 discovery, three more localities have been documented (Moore and Connelly, 1976; Carden and others, 1976). These localities and their associated ultramafic rocks are located north and west of the Border Ranges fault (fig. 1). These recent discoveries supplement the hypothesis of MacKevett and Plafker (1974) that the Border Ranges fault represents a plate boundary.

REGIONAL GEOLOGY

The Chugach terrane of south-central Alaska extends from the St. Elias Mountains to Kodiak Island and is composed of metamorphosed graywackes, slates, and volcanic rocks. The metamorphic rocks are tectonically mixed with ultramafic rocks and are intruded by granitic rocks ranging from granodiorite to quartz diorite. The metamorphic rocks range from zeolite to granulite facies, but the greenschist-facies rocks of the Valdez Group constitute the bulk of the terrane.

North and west on the continental side of the Chugach terrane, the Gravina-Nutzotin terrane forms a high-temperature, low-pressure metamorphic belt (Berg and others, 1972) parallel to both the Chugach terrane and the Border Ranges fault. Preliminary evidence indicates that the belt is the result of a middle and upper Mesozoic termal event (Berg and others, 1972).

The Border Ranges fault is the major structural feature in the region, and extends 1,000 km from the St. Elias Mountains to the southwest end of Kodiak Island (MacKevett and Plafker, 1974). Numerous occurrences of ultramafic rocks are found north and west of the fault (fig. 1). This fault is interpreted by MacKevett and Plafker (1974) as a Mesozoic plate boundary.

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PETROLOGY AND MINERALOGY

The oldest rocks in the mapped area are regionally metamorphosed graywackes, slates, volcanoclastic rocks, and basalts that now contain greenschist and blueschist mineral assemblages. The metasediments show poorly defined compositional layering in thin section and lack lateral continuity in outcrop. There are no continuous marker beds, and the thickness of the metasedimentary units could not be determined. The metabasites, like the metasediments, display a complete lack of lateral continuity and cannot be followed for more than a few meters. Recrystallization is more complete in metabasites than in metasediments, and the original mineralogy cannot be determined with certainty. The rocks form isoclinal overturned folds with axial surfaces steeply dipping to the north.

The predominant mineral assemblage in the metasedimentary rocks is albite + chlorite + epidote + quartz, with less common muscovite, actinolite, crossite, stilpnomelane, carbonate, and sphene. The major assemblage in the metabasites is albite + epidote + actinolite + chlorite + crossite + quartz. The crossite was determined optically and verified by X-ray diffraction.

Incipient sodic amphibole first appears in the southern extreme of the map area (fig. 2), and the modal percent of crossite and the degree of recrystallization increase to the north. Although zeolite-facies assemblages have not been identified in the area, the above evidence suggests a progressively metamorphosed belt.

For 6.5 km west of Second Lake on the Edgerton Highway, near Chitina, a fault zone contains serpentinite, pyroxenite, and amphibolite. The mafic and ultramafic rocks are composed largely of antigorite, chlorite, and magnetite; relict diopside, plagioclase, hornblende, and garnet are also present. The fault zone along which the ultramafics are located extends for at least 40 km to the west.

The metamorphic terrane is intruded by several small plutons of quartz diorite. Preliminary radiometric dates indicate two periods of igneous activity: the earlier episode was about 100 m.y. ago, the latter about 45 m.y. ago.

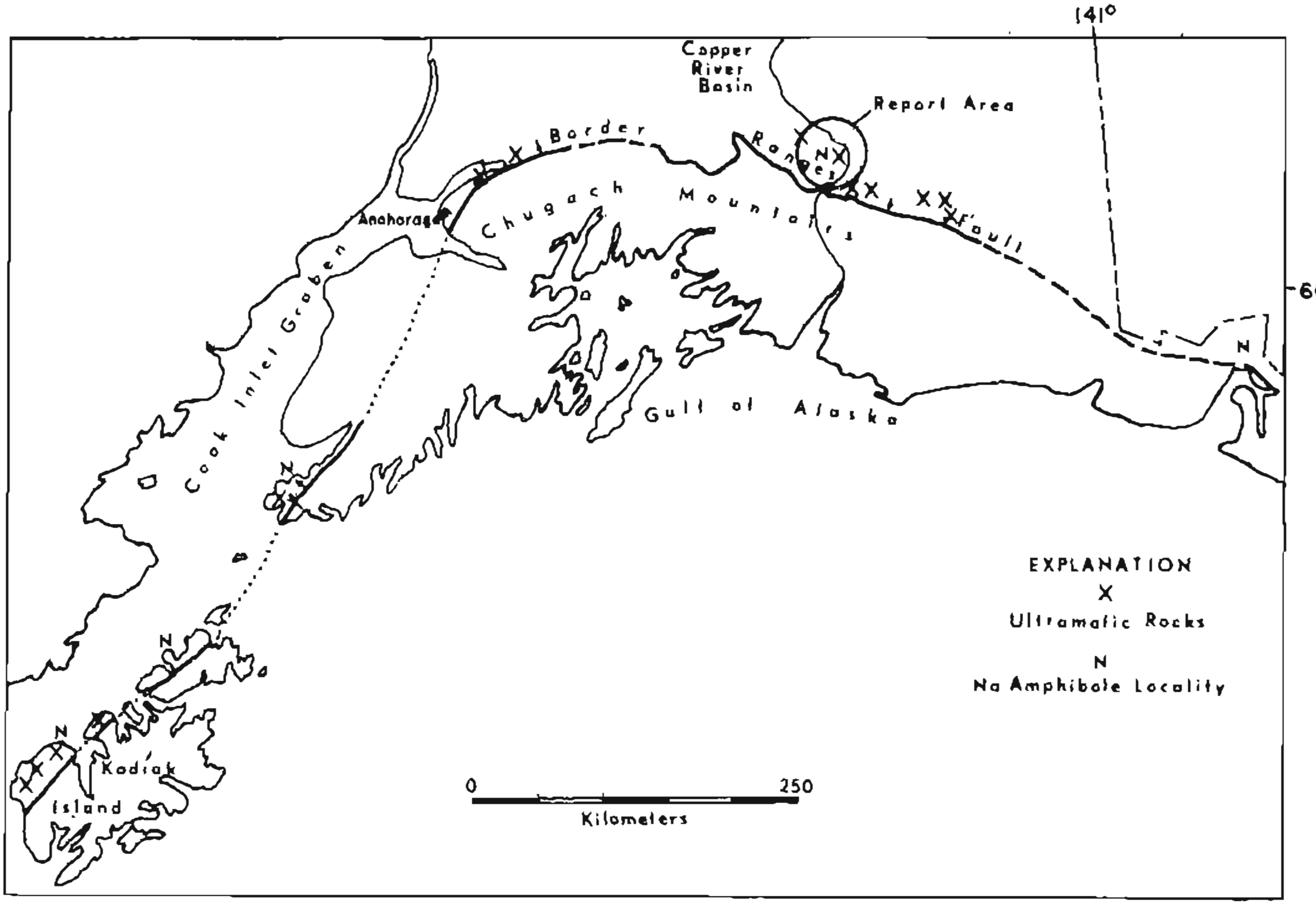

Figure 1. Location of this report and extent of Border Ranges fault (after MacKevett and Plafker, 1974) showing occurrences of ultramafic rocks and sodic amphibole localities north and west of the fault.

TECTONIC SIGNIFICANCE

The discovery of blueschist-facies metamorphism in the Valdez C-2 quadrangle, in the Seldovia area, and in the Kodiak-Afognak area provides additional evidence that the adjacent Border Ranges fault represents a major tectonic boundary junction; it also suggests the existence of paired metamorphic belts in south-central Alaska. Additional radiometric age dating and geologic mapping between the widely spaced localities must be accomplished before the age and continuity of the boundary can be substantiated.

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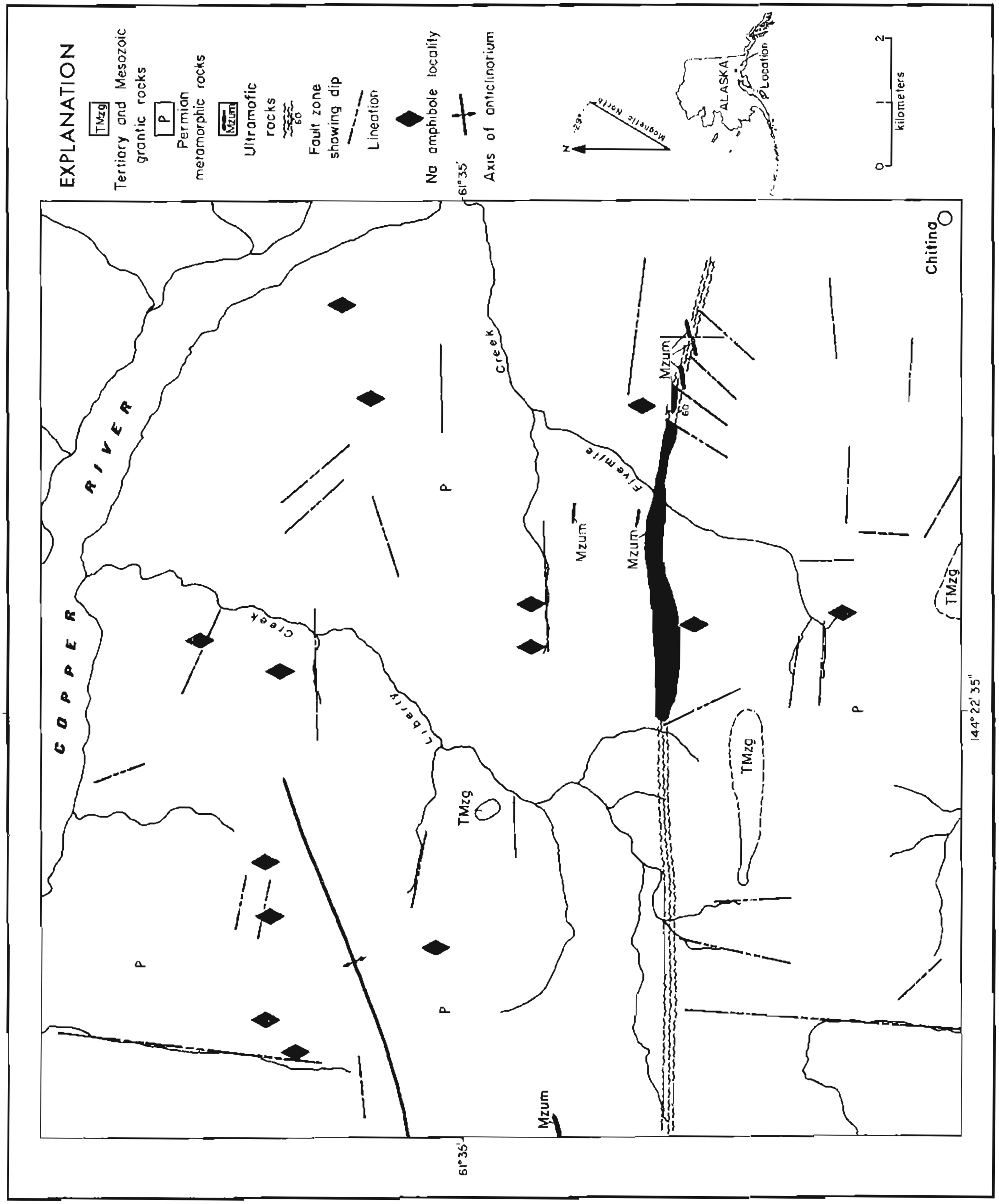

Figure 2. General geology and location of sodic amphiboles in the Valdez C-2 quadrangle.

HIGH-QUALITY COAL NEAR POINT HOPE, NORTHWESTERN ALASKA

By Cleland N. Conwell[1] and Don M. Triplehorn[2]

INTRODUCTION

Analyses of samples of Mississippian coal from northwestern Alaska confirm the occurrence of high-quality heating coal in an area extending from Cape Dyer southward to Cape Thompson (fig. 1). The coal has low moisture and ash, ranks semianthracite, and is an excellent heating coal. The bed at Kukpuk has a low ash (5 percent) and a high calorific value (13,748 Btu). The high rank and proximity to water transport make the field worth further study as a possible economic deposit.

The authors visited the area in June 1975 to collect samples for the U.S. Geological Survey national coal-resource-evaluation program. Financial support was in part provided by the USGS (contract 14-08-6001-G-207). The major oxide and trace-element analyses were performed by the USGS; other data were developed by the senior author.

GEOLOGIC SETTING

The coal-bearing formation occurs on the west flank of the Lisburne Hills in a belt about 35 miles long, from Cape Dyer on the west coast to Cape Thompson on the south coast (fig. 1). It also occurs in several fault blocks within the hills north of Cape Dyer (Tailleur, 1966).

North-trending imbricate thrust faults dominate the southern part of the Lisburne Hills (Campbell, 1966). Elsewhere, structural interpretations have been hindered by the ubiquitous tundra cover in lowland areas. However, Lathrum (1974), using ERTS images, found that the Ipewik-Kukpuk lowland area is structurally complex, more so than areas of comparable strata to the north and east.

The stratigraphic unit containing the coal is not well defined and combines all Early Mississippian rocks not part of the Lisburne Group into an unnamed mapping unit. It is primarily mudstone, sandstone, and limestone with minor conglomerate, including both marine and nonmarine deposits (Campbell, 1966). Total thickness is unknown. Campbell (1966) measured more than 450 feet in the southern area and suggested the possibility of 1500 feet. Tailleur (1966) measured nearly 2,200 feet of section south of Cape Dyer but indicated a possibility of repetition; furthermore, an undetermined amount of the upper part of the formation is not exposed here.

Coal is most abundant in the sea cliffs near Cape Dyer. It is least abundant at Cape Thompson, where Tailleur (1966) was unable to locate the coal reported by Collier (1906, p. 45); we found only one small exposure of crushed coal, apparently along a fault. Near Kukpuk between Cape Dyer and Cape Thompson, only one bed of significant thickness (6 feet) was observed and sampled (sample 75-cc-46).

In addition to the sample location (fig. 1), coal was exposed in the bank of a minor drainage about 1/2 mile to the west of the sample location. Many years ago a pit had been dug—apparently to expose a coal bed—about 1 mile south of Kukpuk (NE corner, sec. 21, T. 12 S., R. 60 W., Point Hope B-2 quadrangle). The sides of the pit had caved and the coal bed was no longer exposed; however, several small piles of coal had been left. Near Kukpuk, the bed apparently has a low dip or there are several beds, as indicated at Cape Dyer.

Poor exposures prevented further analysis of the structure and local stratigraphy. However, a resistant

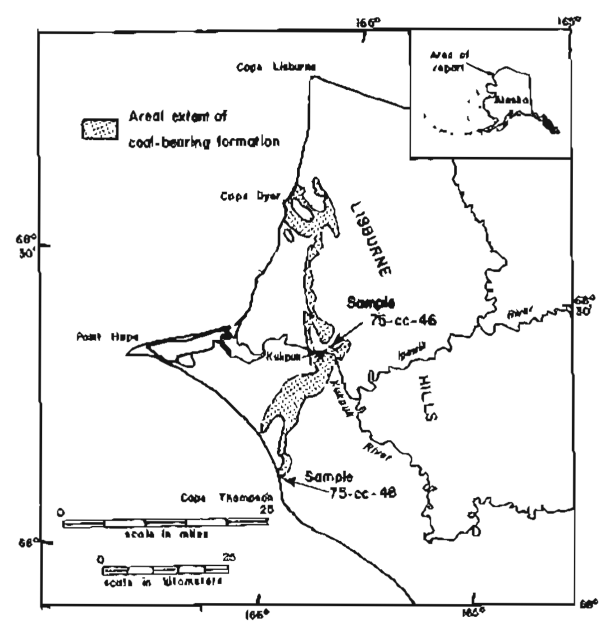

Figure 1. Location of coal samples.

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Figure 2. Sample location and approximate thickness of the coal bed near Kukpuk.

cherty limestone forms a prominent bluff between the coal outcrop and Iglupak Creek to the east; presumably this limestone overlies the coal bed.

Below about 2 feet, the ground is permanently frozen. Freezing may have resulted in some frost shattering because the coal crumbles to pieces generally smaller than 1 inch in diameter when thawed. On the other hand, the frozen condition inhibited oxidation and the coal shows little evidence of chemical weathering.

LOCATION AND DESCRIPTION OF SAMPLES

Sample 75-cc-46 was collected from a prospect pit (fig. 2) near Kukpuk on the Kukpuk River, about 1/4 mile west of the mouth of Iglupak Creek (fig. 1) (NW1/4 sec. 15, T. 12 S., R. 60 W., Point Hope B-2 quadrangle). The pit (fig. 2) is on a low knoll about 150 yards south of the river. About 2 feet of peat overlie about 6 feet of coal, which in turn overlies an underclay of undetermined thickness. The bed, which strikes east (magnetic) and dips 23° south; the top is not exposed. Hence, the true thickness is unknown. However, because the exposure is probably a stream-eroded cut with the coal as a resistant unit, the actual thickness is not likely to be much more than that observed.

At Cape Thompson, sample 75-cc-48 was taken 100 yards west of a high-angle fault mapped by Campbell (1966) along the west edge of NW1/4 sec. 22, T. 32 N., R. 32 W., Point Hope A-2 quadrangle. The sample was taken from an exposure where the coal was in a near-vertical bed about 1 foot thick. The coal unit has been squeezed by faulting, and slippage has apparently occurred along the coal bed. Another 100 yards further west, a coal bed 1 foot thick dips 30° NE. There appeared to be other thin coal beds present, and continuing west the coal-bearing unit is better exposed.

ANALYSES OF COAL AND WASHABILITY CHARACTERISTICS

Sample 75-cc-46 was analyzed in College for calorific value (13,748 Btu), moisture (1.2 percent), ash (6.0 percent, fixed carbon (82.05 percent), volatile matter (10.75 percent), and sulfur (0.52 percent); and separated into specific-gravity fractions. The ash was determined from the specific-gravity fractions (computed in table 1, rounded to one decimal point). The results of the sink-float tests on the raw coal from Kukpuk (table 1) indicates that 78.14 percent of the coal has a specific gravity between 1.4 and 1.5. Nearly 97 percent of the coal floats at a specific gravity of 1.6. The ash is 5.4 percent. This is a difference of only 0.6 percent from the raw coal. The washability characteristics of the raw coal (fig. 3) indicate that a float product at a specific gravity of 1.6 would not significantly reduce the ash content. However, separation at a 1.5 specific gravity would result in an unacceptable loss of combustible material in the sink fraction.

Samples 75-cc-46 and 75-cc-48 were analyzed by the USGS Denver laboratory for ash, major oxides, and trace elements.

Table 1. *Sink-float results on raw coal, Kukpuk River - Point Hope quadrangle, Alaska*

Specific gravity		Actual products		Cumulative float		Cumulative sink		+0.10 Sp. Gr.	
Sink	Float	Wt. (%)	Ash (%)	Wt. (%)	Ash (%)	Wt. (%)	Ash (%)	Material (%)	Ordinate D[1]
--	1.3	0.12	4.4	0.1	4.4	100.0	6.0	--	--
1.3	1.4	1.98	4.5	2.1	4.5	99.9	6.0	80.1	1.1
1.4	1.5	78.14	5.1	80.2	5.1	98.0	6.0	94.8	41.2
1.5	1.6	16.65	6.7	96.9	5.4	19.8	9.6	18.5	88.6
1.6	1.7	1.83	10.6	98.7	5.5	3.1	24.6	3.1	97.8
1.7	--	1.28	44.5	100.0	6.0	1.2	44.5	--	99.4
		100.00							

[1]Ordinate D is the percentage of ash in the highest ash particle in the corresponding specific-gravity fraction. It is calculated as follows:

Ordinate D= $A + \frac{B}{2}$ where

A = Cumulative weight-percent of float material down to but not including the specific-gravity fraction being considered.
B = Weight-percent of material in the gravity fraction.

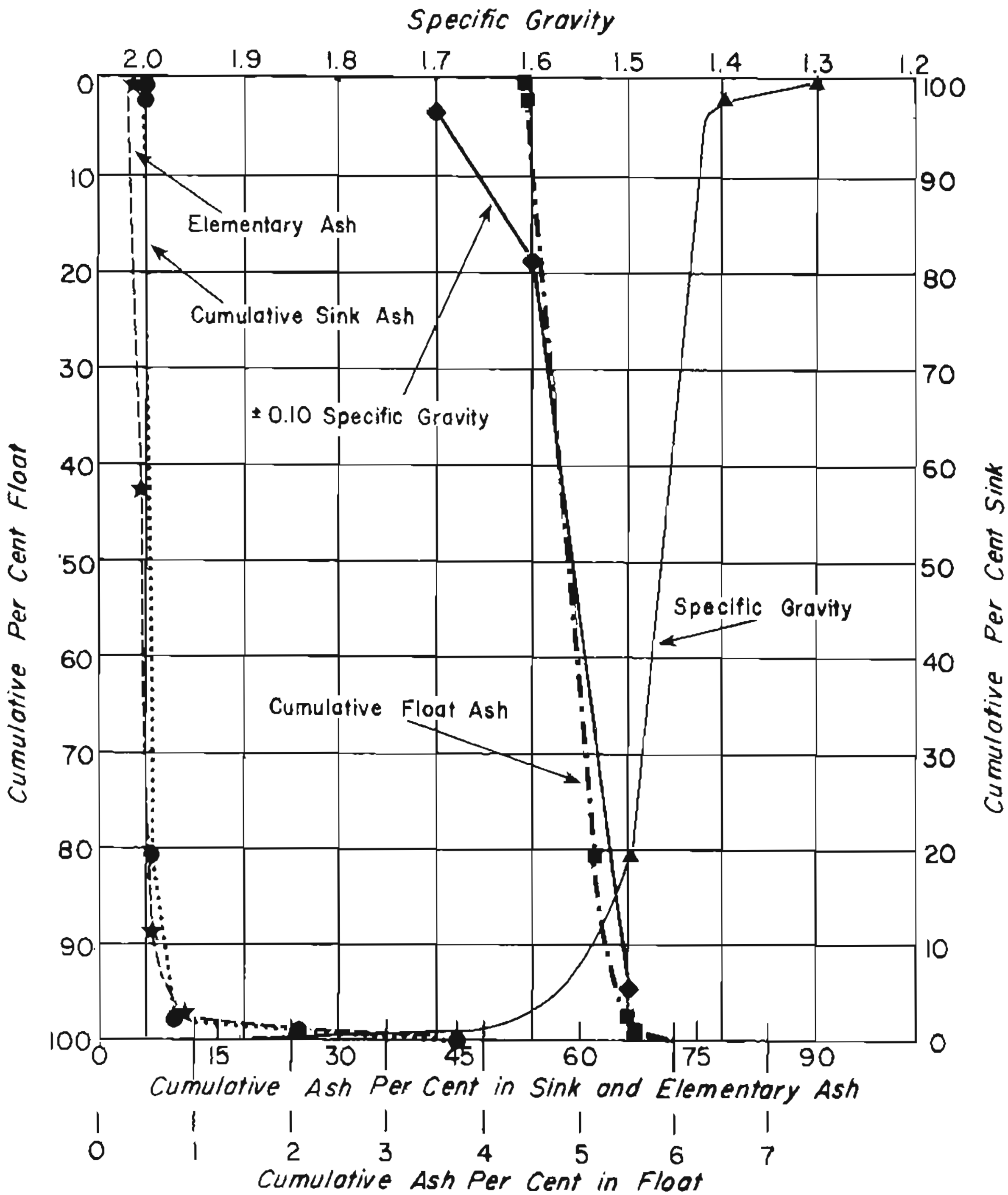

Figure 3. Washability characteristics of raw coal, Kukpuk River, Point Hope quadrangle.

Coal as Received

Sample	Ash (%)[1]	As[2] (ppm)	F[3] (ppm)	Hg[4] (ppm)	Sb[5] (ppm)	Th[6] (ppm)	U[6] (ppm)
75-cc-46	5.0	3.5	40	0.01	1.3	Missing	Missing
75-cc-48	27.8	21.0	120	0.27	2.1	4.8	12.1

Ash (%)

Sample	Al_2O_3[7]	SO_3[7]	Cl[7]	CaO[7]	SiO_2[7]	P_2O_5[7]	TiO_2[7]
75-cc-46	26	2.9	0.20	2.6	42	< 1.0	1.1
75-cc-48	24	0.52	0.20	0.19	55	< 1.0	1.1

Ash (%)

Sample	MnO[7]	K_2O[7]	MgO[8]	Na_2O[8]	Fe_2O_3[7]
75-cc-46	0.074	1.6	0.73	0.42	8.2
75-cc-48	0.050	2.1	0.69	0.85	6.2

Ash (ppm)

Sample	Se[7]	Cd[9]	Cu[9]	Li[9]	Mn[9]	Pb[9]	Zn[9]	Ag[10]	As[10]
75-cc-46	1.4	1.5	312	683	590	430	2650	N	N
75-cc-48	1.8	< 1.0	162	744	40	330	177	N	N

Sample	Au[10]	B[10]	Ba[10]	Be[10]	Bi[10]	Cd[10]	Co[10]	Cr[10]
75-cc-46	N	300	2000	70	N	N	300	500
75-cc-48	N	200	1000	15	N	N	< 10	300

Sample	Cu[10]	La[10]	Mo[10]	Nb[10]	Ni[10]	Pb[10]	Pd[10]	Pt[10]	Sb[10]	Sc[10]
75-cc-46	500	500	70	50	1500	700	N	N	N	200
75-cc-48	200	100	100	50	70	500	N	N	N	30

Sample	Sn[10]	Sr[10]	Te[10]	V[10]	W[10]	Y[10]	Zn[10]	Zr[10]
75-cc-46	N	2000	N	1500	N	300	3000	300
75-cc-48	N	200	N	1000	N	50	N	200

Sample	Ce[10]	Ga[10]	Ge[10]	Li[10]	Yb[10]	Pr[10]	Nd[10]
75-cc-46	700	150	30	700	30	< 200	500
75-cc-48	N	100	70	700	7	N	N

[1]Determined gravimetrically (ashed at 525°C) by G.D. Shipley.
[2]Determined by graphite furnace - atomic absorption method by G.O. Riddle and J.G. Crock.
[3]Determined by specific ion electrode method by J. Gardner.
[4]Determined by wet oxidation + atomic absorption method by J.A. Thomas and G.O. Riddle.
[5]Determined by Rhodamine-B method by G.T. Burrow.
[6]Determined by delayed neutron method by H.T. Millard.
[7]Determined by X-ray fluoresence by J.S. Walberg.
[8]Determined by atomic absorption by V. Merritt.
[9]Determined by atomic absorption by G.D. Shipley.
[10]Determined by semiquantitative six-step spectrographic analysis by J.C. Hamilton.
N Not determined or below detection.

There are anomalously high values of zinc, nickel, and vanadium in sample 75-cc-46 (from the Kukpuk River) and a high uranium value for a coal in sample 75-cc-48 (from Cape Thompson).

The coal is classified as semianthracite in accordance with ASTM designation D388-66 (using the Parr formula for calculating on a mineral-matter-free basis). P.D. Rao[3] measured the mean-maximum reflectance at 2.12 percent, further confirming the semianthracite rank.

[3]Mineral Industry Research Laboratory, University of Alaska, Fairbanks, 99701.

CONCLUSIONS

This report mainly confirms previous conclusions of Collier (1906) and Tailleur (1966), who stated the coal deposits have an economic potential that bears further investigation. However, our observations enlarge on the earlier work in two ways:

1. An analysis of the middle part of the coal-bearing area is in essential agreement with previous analyses from the northern end. This suggests that coal quality is high (low ash, high rank, low moisture) throughout the region. The analysis of the sample taken near Cape Thompson probably

indicates the effect of crushing and faulting on the bed.

2. Our analyses indicate a semianthracite rank, higher than the low-volatile subbitumious rank suggested by Tailleur (1966) for the northern part of the area. The analytical differences are small, and regional and stratigraphic variations in coal quality may be expected. Although outcrop samples do not necessarily reflect the true quality of the mined product, the establishment of the higher rank determination suggests the potential of commanding a premium price of this excellent heating coal.

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