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STRIKE-SLIP FAULTS IN ALASKA

By

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OPEN-FILE REPORT

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

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STRIKE-SLIP FAULTS IN ALASKA

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ABSTRACT

Long faults with large apparent right-lateral displacements and notably straight traces trend across Alaska from its south-eastern "panhandle" to the Bering Sea. They strike southeast in eastern Alaska and northeast in western Alaska, and several make up the Denali fault system, which crosses the State in a great arc that is convex to the north. These faults are a prominent feature of Alaska's geologic structure, and many are the loci of conspicuous rifts in its topography. Some have been active in Quaternary and historical times; most have a history of Tertiary displacement; and there is evidence that a few experienced Mesozoic and perhaps Paleozoic displacement.

Left-lateral faults are less prominent, but a few important ones are known in southwestern Alaska. Their strike is north or north-northwest, and where numerous, they seem to have acted with the right-lateral faults to reshape broad terranes of the State.

The position and trend of the known and suspected strike-slip faults, and the offsets along them, when viewed in relation to other geologic features, provide some support for a number of speculations about Alaska's tectonic evolution. These include the hypothesis (a modification of Carey's concept) that oroclinal bending deformed western Alaska during latest Cretaceous to early Tertiary time, that southwestern Alaska was shortened in mid-Tertiary time along an axis striking east-southeast, and that southeastern Alaska has been thrust against the Pacific Basin. If oroclinal bending did occur, its character has major implications for the nature of relative movements (continental drift) between North America and Eurasia.

INTRODUCTION

In recent years, the inferred displacement of real and of supposed large strike-slip faults in Alaska has been incorporated in tectonic hypotheses of circum-Pacific and even of global scope. But these hypotheses have made minimal use of specific geologic data concerning the character and displacement of these faults, for such data are meager and not readily available. Hence a compilation of the available field data seems timely. The present paper attempts such a compilation, and proposes in addition some generalizations about these faults. However, the material presented is incomplete and in part speculative, for much of the State is hardly known geologically and there are as yet few detailed studies. A number of faults and linear features about which little or no definite information exists have been included because they are long and straight and could possibly be strike-slip faults. The data are mainly from published sources and from the files of the Alaskan Geology Branch of the U.S. Geological Survey. Many of my colleagues on the Geological Survey assisted me by generously sharing unpublished data, for which I am most grateful. Specific acknowledgment is made at the relevant places in the text. The aid of Judith Terry in locating and assembling pertinent data was invaluable. Discussions with C. A. Burk, A. W. Bally, Clyde Wahrhaftig, and many of my co-workers on the Geological Survey, and with W. R. Dickinson, B. M. Page, and G. A. Thompson of Stanford University were also very helpful.

The present study is an outgrowth of detailed geologic mapping by the writer of four 15' quadrangles in the Nelchina area of south-central Alaska. This mapping, presented in the appendix, includes all or most of the Anchorage (D-1) and (D-2) quadrangles, the Talkeetna Mountains (A-1) and (A-2) quadrangles, and pieces of four adjoining quadrangles. It includes a geologic map in two parts at scale of 1:63,360, a geologic map explanation, a sheet of geologic cross sections, and a written summary of the evidence for the strike-slip character of the Castle Mountain fault system with a sketch map showing its western half. The fault system, with its many splay faults and associated compressional features, dominates the structure of the Nelchina area and is a principal factor in determining the distribution of its rocks. Mapping of this complex fault system in the Nelchina area led to a consideration of its regional extent and tectonic environment, and then to the present study of strike-slip faults throughout Alaska. The research originally planned included the detailed mapping of the Nelchina area presented in the appendix, but was to have emphasized the tectonic development of this area during Mesozoic and Cenozoic times. The present study, however, focuses upon the role of large strike-slip faults in the tectonic development of all of Alaska, rather than of the Nelchina area alone. The change in emphasis and scope seemed justified because large strike-slip faults are among Alaska's most notable geologic structures, and because their role in its tectonic development is a major unsolved problem.

An outline of the structural environment in which the strike-slip faults are found is followed by a descriptive summary of what is known about them, some generalizations concerning their age and displacement, and some speculations on their possible role in the broader deformations that affected Alaska. In the descriptive summary, conflicting data and concepts are resolved, where possible, to reach tentative conclusions about the character of each fault or other feature. For some of them, however, all that can be presented is a statement of some of the possibilities and problems and suggestions for further work. The speculations at the end of this paper arbitrarily assume that the descriptive data and the conclusions concerning the nature of each fault are in the main correct, even though many of the specifics are probably not. Hopefully, some of the relationships discussed will prove to be significant, but it is also important at this stage in Alaskan geologic studies to point out the possible tectonic significance of these faults and ways in which the speculations presented may be tested.

Actual strike-slip displacement can be proven on only a few of the faults discussed below; for the others, only lateral separations can as yet be demonstrated. Lateral separation designates the offset in plan along faults of geologic surfaces (generally contacts) where it cannot be definitely established that the offset was caused by strike-slip displacement. The proportion of these separations that is due to strike-slip is not known, and the figures given for lateral separation on the following pages should not be misconstrued as necessarily indicating such displacement. But where long, straight faults with prominent topographic rifts display large lateral separations in structurally complex terranes, these faults are likely to have experienced large lateral (or strike) slip. Where these faults are, in addition, accompanied by horizontal drag in the adjacent terranes, or where they merge with proven strike-slip faults, then it is considered likely that they, too, are strike-slip faults. Drag along some of the faults is spatially, and very likely genetically, related to them, and is on such a grand scale that it is appropriately termed regional drag.

STRUCTURAL ENVIRONMENT OF THE STRIKE-SLIP FAULTS

The known and suspected large strike-slip faults of Alaska appear to lie in the central part of the State, and to be bounded north and south by regions in which compressional (overthrust and island arc) tectonics were dominant during the Cenozoic. This confinement of larger strike-slip faults to the central parts of Alaska occurs where the connection between the continental masses of North America and Eurasia is narrowest and the Arctic and Pacific Ocean basins are least distant. Here also the Mesozoic tectonic elements of Alaska are most sharply bent. Elsewhere in the circum-Pacific region large strike-slip faults tend to occur closer to the rims of continents. In southeastern Alaska, which borders the main mass of North America, many of the larger strike-slip faults converge and strike toward the margin of the continent. In western Alaska, the relationship of the strike-slip faults to the margin of the continent is hidden by the Bering Sea.

The distribution of geologic units in Alaska, and to a considerable degree that of the large strike-slip faults, is influenced by two arcuate tectonic trends which intersect and are superposed in the southwestern and south-central parts of the State. The first trend is that of the major Mesozoic tectonic elements (Payne, 1955; Miller, Payne, and Gryc, 1959), which cross the State in parallel arcs that are convex to the north (see fig. 3). These arcs are similar to that of the Denali fault system (1A to 5 on figs. 1 and 4), but bend more sharply in south-central Alaska. The second, younger trend is followed by the Cenozoic Aleutian Arc,[1/] which is convex to the south and enters

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[1/] The present Aleutian Arc was formed in Tertiary time. Its

North America in southwestern Alaska. The main anticlinal ridge, depositional trough, volcanoes, and zone of epicenters of this arc, which are its principal features on land, all terminate in central Alaska near the northern apex of the arcs described by the Mesozoic tectonic elements (see fig. 3).

Within the domain of the Aleutian Arc, only a few strike-slip faults have been recognized. These include tear faults that are transverse to the arc and may include relict or superimposed features

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eastern half rests upon a continental framework of Mesozoic and Paleozoic volcanic, sedimentary, and plutonic rocks that extend far beyond the domain of the present arc; and the arc trends obliquely across the major tectonic trends and geologic boundaries in the Mesozoic rocks. The western half of the present arc, which consists of the Aleutian Islands that rise from oceanic depths, is probably also Cenozoic. The Cenozoic volcanic and volcaniclastic rocks of the present arc in the Aleutians rest discordantly on considerably more deformed and altered basaltic and andesitic volcanic, pyroclastic, and sedimentary rocks. These more deformed rocks are in part nonmarine and at one place on Adak Island, in the western "oceanic" half of the arc, yielded fossil plants of Pennsylvanian or Permian age (Coats, 1956a, p. 48-49).

If the late Paleozoic rocks of Adak formed in an island arc, it was ancestral to the present arc, for its rocks were considerably deformed and eroded before the present arc developed. However, other possibilities are raised by (1) inclusions of granite, quartz-bearing sandstone, and in part felsic schist, gneiss, and foliated granulite in some of the Cenozoic volcanic rocks in the western Aleutians; and (2) sialic erratics of assorted kinds, including schist and mica granite, in glacial deposits and on elevated wave-cut platforms on some only of these islands. (See Coats, 1953, p. 14-15, 1956b, p. 88-39, 1959, p. 487, and 1962, p. 93, and Powers and others, 1960, p. 544-5. Coats [1962, p. 93] gives additional references.) As stated by Coats, these occurrences suggest that the Aleutians may be underlain by continental rocks at depth, although alternative explanations (rafting in tree roots, origin in local marginal or sheared phases of Tertiary plutons) have been advanced (Fraser and Barnett, 1959, p. 231). To the writer the variety of sialic inclusions (some of which are quite potassic) and the localized occurrence of the erratics make the alternative explanations for the sialic rocks as difficult to accept as the local origin proposed by Coats. If the sialic rock inclusions and erratics of the Aleutian Islands are indeed local, then they and the late Paleozoic plant-bearing rocks of the Aleutians could be part of a former continental land mass that fragmented and/or foundered and subsequently was uplifted in the present (Cenozoic) Aleutian Arc, rather than an ancestral phase of the present arc. An additional argument for formed by processes unrelated to the arc. The main structures of the present arc appear to have been produced by late Cenozoic processes that acted normal to its trend rather than by processes involving strike-slip faulting parallel to its trend (Coats, 1962, p. 95-96). Fault-plane solutions for North Pacific and Aleutian Arc earthquakes suggest that the pressures producing most of these earthquakes were directed horizontally and normal to the arc (Hodgson, 1964, p. 122-123). In addition, large faults parallel to the arc on the Alaska Peninsula, such as the

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the presence of continental rocks beneath part of the western "oceanic" half of the Aleutian Arc was offered by Powers and others (1960, p. 549). They believe that the deformed pre-early Middle Tertiary andesitic marine volcanic rocks of Amchitka Island were deposited "... on a continental rather than an oceanic segment of the earth's crust, because all the igneous rocks of Amchitka resemble chemically the suites of andesitic rocks destributed around the margin of the Pacific Ocean." However, Coats (1962 and oral communication, 1966, based upon seismic work by Shor, 1960) believes that the sialic rocks at depth in the Aleutians are too scanty to explain the dominantly andesitic composition of the late Cenozoic volcanic rocks of the western part of the present Aleutian Arc. Therefore, Coats (1962) offered a tectonic explanation for these deep ocean andesites as an alternative to the commonly advocated origin of andesites by assimilation of sialic material in basaltic magma of subcrustal origin.

Seismic refraction studies by Shor (1964) show that low and intermediate velocity rocks are unusually thick and persistent along a single profile across the eastern Aleutian basin, the largest deep ("oceanic") basin in the Bering Sea. These consist of 3 km of material usually identified as unconsolidated sediment and soft sedimentary rock and 3 km of material usually identified as lithified sedimentary and/or volcanic rock. Shor proposes that these layers accumulated on typical oceanic crust behind the Aleutian Arc, which acted as a sediment trap. But the uniform and considerable thickness of these layers from the foot of the continental slope to the Aleutian Arc suggest the alternative that they may include the layer from which the late Paleozoic plant-bearing rocks and the sialic inclusions (and erratics?) of the Aleutian Islands were derived; and 3 km of irregular relief at the Mohorovicic discontinuity beneath the Aleutian basin (Shor, 1964, fig. 2) suggests that this boundary may there be unstable and undergoing important changes. These features of Shor's seismic profile, added to the occurrences of sialic inclusions and erratics, the late Paleozoic plant-bearing beds, and the discordance between the Cenozoic rocks of the Aleutian Arc and the Mesozoic and Paleozoic rocks upon which they rest, suggest that (1) the Aleutian Basin may represent "oceanizing" of continental crust rather than "continentalizing" of oceanic crust; (2) the present Alaskan continental slope in the Bering Sea is largely of Mesozoic or early

Bruin Bay fault (shown but not labelled on figure 1), are not strike-slip, but rather high-angle reverse faults with dominantly vertical displacement (Burk, in press).

Two areas in Alaska are dominated by overthrust and gravitational gliding tectonics and appear to lack large, through-going strike-slip faults. These areas border the State at its northern and southern margins. The intervening area does contain many reverse and thrust faults, but nowhere is their concentration and net transport on very low-dipping planes known to be as great as in the northern and possibly the southern belt. In the major thrust zone that encompasses the Brooks Range and the southern part of the Arctic slope, overthrusting occurred toward the north during the Early Cretaceous, the Late Cretaceous or early Tertiary ("Laramide"), and possibly the Pliocene (Lathram, 1965, Lathram and Gryc, 1966). The approximate southern boundary of this zone is shaded on figure 1. The southern zone occupies the mountainous coast of the Gulf of Alaska and some of its individual thrusts are also shown on figure 1. Thrusting here was toward the south, was related to Quaternary mountain building, and is probably still active. This thrust zone is bounded on the northeast by the Fairweather fault (16 on fig. 1), which has been active in historical times.

Tertiary age, that is, later than the late Paleozoic plant-bearing beds and earlier than the Tertiary rocks of the Aleutian Arc; and (3) there may be more sialic material available beneath the Aleutian Arc for the formation of andesite by assimilation in basaltic magma than was envisioned by Coats in 1962. But certainly more data are needed before these and other possible origins for the Aleutian Arc and basin can be conclusively evaluated.

KEY TO FAULTS AND LINEAR FEATURES SHOWN ON FIGURE 1

Denali fault system

(1A) to (1D) Denali fault

- (1A) Farewell segment
- (1B) Hines Creek strand
- (1C) McKinley strand
- (1D) Shakwak Valley segment

(2) Togiak-Tikchik fault

(3) Holitna fault

(4) Chilkat River fault zone

(5) Chatham Strait fault

Faults and lineaments in southwestern and central Alaska

(6) Castle Mountain fault system

(7) Iditarod-Nixon Fork fault

(8) Aniak-Thompson Creek fault

(9) Conjugate strike-slip faults in the Yukon delta region

(10) Kaltag fault

(11) Stevens Creek fault zone

(12) Porcupine lineament

(13) Yukon Flats discontinuity and fault

(14) Tintina fault zone and Tintina trench

(15) Kobuk trench

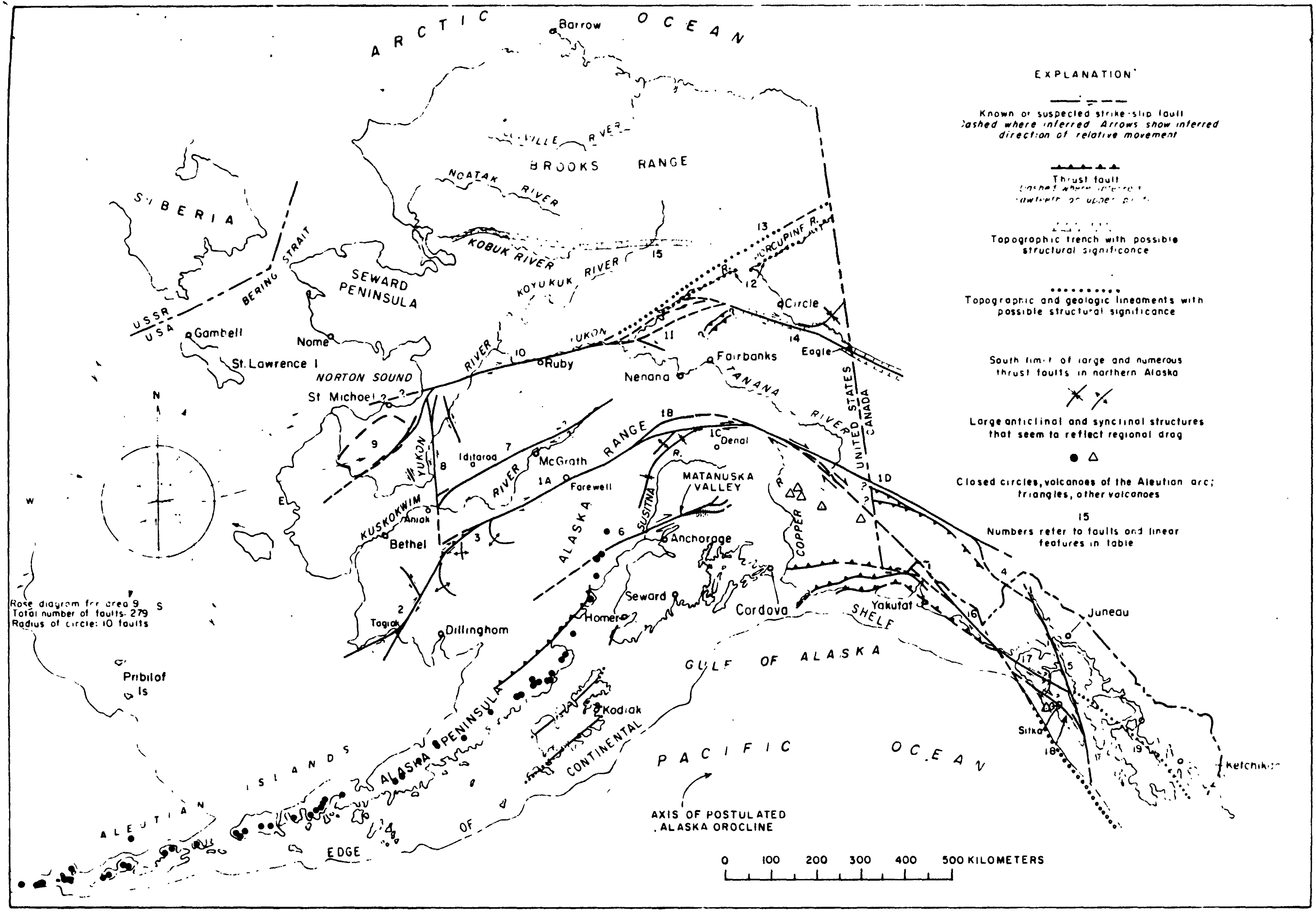
Faults and lineaments in southeastern Alaska

(16) Fairweather fault

(17) Peril Strait fault

(18) Chichagof-Sitka fault

([illegible]) [illegible] Strait lineament



MAP OF ALASKA SHOWING KNOWN AND SUSPECTED LARGE STRIKE-SLIP FAULTS AND SELECTED LINEAR FEATURES

FIGURE 1

DESCRIPTION OF STRIKE-SLIP FAULTS AND SELECTED LINEAR FEATURES

Denali fault and Denali fault system
(1-5 on map and in tables)

Nature of feature:	Major fault system; Cenozoic and perhaps older right-lateral strike-slip of undetermined amount inferred to be superimposed upon established faults of unknown but probably different character.
Synonyms:	Farewell fault, Shakwak Valley fault, Shakwak Lineament, Denali Lineament.
Length:	Denali fault, 1400 km Denali fault system, more than 2150 km
References:	Dutro and Payne, 1957; Muller, 1958a; St. Amand, 1957; and Twenhofel and Sainsbury, 1958.

The existence of this great Alaskan fault as a regional feature was simultaneously reported in abstracts by Sainsbury and Twenhofel (1954) and St. Amand (1954). The first detailed consideration of its regional extent and possible significance was presented by St. Amand (1957), who named it the Denali fault and proposed that it had perhaps 250 km of right-lateral strike-slip displacement. According to St. Amand, it extends from Bering Sea to British Columbia and connects with faults in southeastern Alaska that he believes are a northern extension of the San Andreas fault system of California.

In the present report, the Denali fault is restricted to the portion of St. Amand's fault that extends from the Kuskokwim River drainage east of Bethel to northernmost British Columbia. The term Denali fault system is proposed to include specifically the redefined Denali fault, and the Togiak-Tikchik (2), Holitna (3), Chilkat River (4), and Chatham Strait (5) faults, and it probably should include many unnamed subsidiary faults. The named faults apparently interconnect, as noted by St. Amand,

and many of them appear to have acted together structurally at times. The proposed Denali fault system is similar to St. Amand's Denali fault, but includes the Chilkat River and Chatham Strait faults and the Hines Creek strand, and does not include a fault that St. Amand thought extended from the Denali fault through the Kilbuck Mountains to Bering Sea.

The Denali fault is divided into three segments. The western (Farewell) and eastern (Shakwak Valley) segments are remarkably straight, but trend respectively northeast and northwest. The central segment, consisting of two strands, unites these divergently striking parts. The northern (Hines Creek) strand is older, topographically less prominent, and more sharply curved than the southern strand, and is a more fundamental geologic boundary. The southern (McKinley) strand is more nearly straight than the northern strand and joins the other segments at sharper angles. It is interpreted to have "short-circuited" the longer path of the northern strand. Only the southern strand was recognized by St. Amand and included in his Denali fault.

Right-lateral strike-slip is indicated by offset geologic and topographic features along the Denali fault, and such slip seems to be demonstrated for the apparently connected Holitna (3), Togiak-Tikchik (2), and Chatham Strait (5) faults. About 85 km of right-lateral separation of geologic lines on the Chatham Strait fault (5) appears to be due mainly to strike-slip offset (Brew, Loney, and Muffler, in press). On the Farewell fault (1A), right-lateral oroclinal drag and as much as 115 km of separation of Cretaceous contacts have been reported, but until the offset of geological lines is demonstrated, these relations do not conclusively prove lateral slip.

St. Amand's suggestion of about 250 km (150 miles) of right-lateral slip on the Denali fault is based upon the assumption that the Mount McKinley and the Mount Hess-Mount Hayes massifs of the central Alaska Range, now about this distance apart, were once united. These massifs lie on opposite sides of the McKinley (1C) strand of the fault; but both lie south of the Hines Creek (1B) strand, which marks the main lithologic discordance of the Denali fault in this area. The McKinley massif is composed principally of Mesozoic bedded and plutonic rocks, whereas the Mount Hess-Mount Hayes massif is composed of Paleozoic rocks (Dutro and Payne, 1957). Thus restoring 250 km of right-lateral slip does not lessen the differences between the geologic terranes juxtaposed at the McKinley strand, and leaves unchanged the major lithologic discordance across the Hines Creek strand. In addition to lithologic differences between the two massifs, the geomorphic history is difficult to reconcile with a 250 km topographic offset. In this area, the present Alaska Range was first uplifted during deposition of the Nenana Gravel (Wahrhaftig, 1958, p. 15-16), which is late Miocene or, more probably, Pliocene in age (Jack A. Wolfe, oral communication, 1966), and further uplift followed deposition and erosion of the Nenana Gravel. This would put the postulated 250 km (150 miles) offset of a once-united massif in the Pliocene and/or Quaternary, because the present mountains could hardly be older than Pliocene. Such large Pliocene to Quaternary displacement is in conflict with the evidence cited by Wahrhaftig (see p. 18-19 and 21-23), indicating that Pliocene or later slip on the entire Denali fault may not exceed about 3 km in the Nenana River area, and probably was not great in the Delta River area. Moreover, a restoration of 250 km of strike-slip creates some topographic anomalies. If Mt. Hayes is placed against Mt. McKinley, the high mountains near Mt. Kimball north of the fault are juxtaposed against Broad Pass to the south; if the displacement is increased to place Mt. Kimball as well as Mt. Hayes against the McKinley massif, then the plains north of the fault near the Nutzotin Mountains are brought against the high mountains near the Susitna and McClaren Glaciers. Thus, while St. Amand's postulated 250-km lateral displacement of the McKinley massif from the Hess-Hayes massif is an intriguing hypothesis, geologic evidence (as yet incomplete) seems to suggest smaller and mainly older displacement. As mentioned before, Cretaceous rocks seem to be offset about 115 km along the Farewell segment (1A) of the Denali fault.

The northern (Hines Creek) strand of the Denali fault was in existence by Paleocene (Cantwell Formation) time.2/ Metamorphic rocks north of this strand were juxtaposed against Paleozoic and Mesozoic bedded rocks south of this strand prior to deposition of the Cantwell Formation. Part of this pre-Cantwell displacement may have been of a type different from that of later displacement. Muller (1958a) believes that the Shakwak Valley segment marks a paleogeographic discontinuity, perhaps a former continental shelf break, or a lineament separating a geanticline from an active geosyncline. In his view, this break or lineament, associated normal faulting, and later thrusting might explain the geologic contrasts now observed along the Shakwak Valley segment.

2/The Cantwell Formation of the Alaska Range was considered by R. W. Chaney to be Cretaceous (and probably Albian) on the basis of plants from University of California Museum Paleontologic locality P3654 (see Imlay and Reeside, 1954, p. 235). These plants were recently re-examined by Jack A. Wolfe of the U.S. Geological Survey (written communication, 1966), who states that the flora is Paleocene on the basis of the following revised plant list:

Glyptostrobus? sp.
Metasequoia occidentalis (Newb.) Chan.
Sparganium antiquum (Newb.) Berry
Planera microphylla Newb.
Cocculus flabella (Newb.) Wolfe
Cissus sp., aff. *C. marginata* (Lesq.) R. W. Br.
Grewiopsis auriculaecordatus (Holl.) Wolfe
Dicotylophyllum flexuosa (Newb.) Wolfe

Farewell segment of Denali fault
(1A on map and tables)

Nature of feature:	Major fault zone, nature and history of displacement incompletely known, but probably with large right-lateral strike-slip displacement.
Synonyms:	Farewell fault, Denali fault.
Length:	350 km
References:	Cady and others, 1955; Condon, W. H., oral communication, 1965; Fernald, 1960; Hoare, 1961; Sainsbury and MacKevett, 196_ (in press); St. Amand, 1957.

The Farewell segment is a complex fault with many strands, and it is marked for much of its length by aligned hydrographic features, north- and south-facing fault scarps of Recent age, and locally by wide gouge zones. On the east it lies at the foot of a 2.4 km escarpment at the north face of the central Alaska Range; to the southwest it joins the Holitna fault. Locally, on the east end of the fault, post-Paleocene (Cantwell Formation) stratigraphic displacement, up on the north, exceeds 2.5 km; but mid-Tertiary nonmarine rocks that are at least in part late Oligocene or early Miocene[3], are in places relatively down-dropped to the north along the same end of the fault. The actual character of the displacements is not known. However, the long high escarpment of the north face of the Alaska Range and north-facing fault scarps of Recent age as much as $2\frac{1}{2}$ meters high indicate that at least a large component of the late Cenozoic displacement along the east end of the fault was up on the south. This uplift is related to the late Cenozoic elevation of the Aleutian-southern Alaska Range, an anticlinal

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[3] These beds contain Osmunda, Glyptostrobus, Salix n. sp., and Alnus n. sp. at U.S.G.S. Paleobotanical locality 11028. These plant fossils are probably of middle or late Oligocene age according to J. A. Wolfe of the U.S. Geological Survey (written communication, 1966).

extension of the Aleutian island arc on the Alaska mainland. This anticlinal uplift is an important structural feature with great lateral extent, and the fact that it terminates at the Farewell fault zone reinforces the suggestion that the fault zone is a major crustal feature. On the west end of the fault Late Cretaceous or younger stratigraphic displacement was up on the south.

Reversal of stratigraphic throw along the Farewell fault, roughly 100 (perhaps 115) km of apparent right-lateral separation of mid- late Cretaceous rocks on the western part of the fault, and regional drag of structures in the terrane south of the fault suggest large right-lateral slip displacement during late Cretaceous and Cenozoic time. Additionally, some large glaciers and glaciated valleys at the east end of the fault and on the adjacent McKinley strand of the Denali fault seem to be offset right-laterally about 5 km. These large valleys were probably in existence since early Pleistocene time. Smaller offsets (or none at all) are visible in progressively smaller valleys. Therefore, the topographic offsets may be mainly of early or mid-Pleistocene age. Such large offsets are not evident farther west along the fault, possibly because they diminish or because they are dissipated on more than one strand of the fault.

Hines Creek strand of the Denali fault
(1B on map and tables)

Nature of feature: Inferred to be the major strand of the Denali fault in the central Alaska Range; major Paleocene or older displacement. Nature and history of displacement incompletely known; may have large component of strike-slip.

Length: 375? km

References: Dutro and Payne, 1957; Reed, 1961; Sainsbury, C. L., written communication, 1958, and oral communication, 1965; Wahrhaftig, C., 1958, written communication, 1958, and oral communication, 1966.

The Hines Creek strand was recognized as a major through-going fault by C. L. Sainsbury. It has a wide gouge zone at Nenana River and there are great differences between the Mesozoic and older terranes that are separated by a simple arcuate projection of the fault from the Hines Creek area in the Nenana River valley. The difference in terranes is like that found to the east, across the major Shakwak Valley segment of the Denali fault. The Hines Creek strand is an older and more fundamental geologic break than the McKinley strand (1C) to the south, and it is probably the main strand of the fault in the central Alaska range. The Cantwell Formation (Paleocene[2/]) on the south side of the Hines Creek strand near the Nenana River Valley rests on Paleozoic and Mesozoic sedimentary, volcanic, and metamorphic rocks, yet it contains clasts of higher grade metamorphic rocks derived from the terrane north of the fault. The formation also overlaps the fault east of the Nenana River Valley. These relationships indicate that the great lighologic discontinuity at the Hines Creek strand, stratigraphically up on the north, was in existence by Cantwell time. Continued displacement, with more than 2000 meters of stratigraphic throw in the same sense, offset the Cantwell Formation in early Tertiary (but pre-Miocene) time from the Nenana River Valley west; but the Cantwell Formation still overlaps the fault east of the valley (Wahrhaftig, 1958, pl. 1, and oral communication, 1966). Smaller post mid-Pliocene vertical movements, also stratigraphically up on the north, have continued with a mid-Pleistocene pause into the Recent. Six meters of Recent stratigraphic displacement, up on the north, occurred on the Hines Creek fault near the Nenana River.

Important strike-slip displacement on the Hines Creek fault, which is an old and fundamental geologic boundary, must be considered because other parts of the Denali fault system appear to have large right-lateral slip. If such slip occurred it was pre-Cantwell Formation (Paleocene) because this formation overlaps the eastern part of the fault. However, direct evidence that the pre-Paleocene slip was lateral has not yet been obtained. The only displacements that can now be demonstrated are vertical.

McKinley strand of the Denali fault
(1C on map and tables)

Nature of feature:	Major fault zone with important right-lateral strike-slip.
Synonym:	Denali fault.
Length:	375 km
References:	Dutro and Payne, 1957; Reed, 1961; St. Amand, 1957; Wahrhaftig, C., 1958, and written communication, 1958.

The McKinley strand is marked by an impressively wide, deep, straight rift which crosses the high mountains of the central Alaska Range obliquely, and by fault scarps of Recent age. Large valleys are offset and all bedrock units are cut off at the fault, which lies wholly within a terrane of Mesozoic and Paleozoic bedded and intrusive rocks. It does not separate regions of grossly different rocks as does the northern (Hines Creek) strand, but at most places rocks on the north side of the fault are older.

The McKinley strand in its present configuration is post-Cantwell Formation (Paleocene[2]) in age, and therefore it is younger than the more northerly Hines Creek strand. Some geologic contacts in a broad belt south of the fault between 146° and 152° W trend into it in a manner that suggests right-lateral drag. The youngest rocks with this trend are nonmarine Tertiary sedimentary rocks of Broad Pass that are at least largely of probably middle Oligocene age[4], which implies that the drag and large right-lateral slip displacement may be Oligocene or later. However, available data do not rule out the possibility that the late Oligocene rocks were deposited and subsequently deformed in an already rotated or "dragged" trough.

Mid-Pliocene or later strike-slip displacement on the Denali fault near the Nenana River appears to have been no more than 30-40 km, and may have been much less, according to work by Clyde Wahrhaftig (written communication, 1958). The Nenana Gravel (mid-Pliocene) consists of debris that was shed northward from mountains in and south of the present Alaska Range. The Nenana Gravel contains clasts of an easily disintegrated biotite granite only within 30-40 km east and west of the Nenana River. The most likely source for these clasts is a similar

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[4] The Tertiary rocks of the Broad Pass area contain leaves at U.S.G.S. Paleobotanical locality 8291 on Colorado Creek to which J. A. Wolfe of the U.S. Geological Survey has assigned a probable middle Oligocene age (written communication, 1966). The taxa critical to this age are <u>Metasequoia glyptostroboides</u> Hu and Cheng, <u>Alnus</u> n. sp. aff. <u>A. evidens</u> (Holl.) Wolfe, and <u>Cercidiphyllum crenatum</u> (Ung.) R. W. Br.

granite in the drainage of Jack River (see Pogue, in Moffit, 1915, p. 56-57), almost directly south of the Nenana River Valley and across both the McKinley and Hines Creek strands of the Denali fault. If the provenance of the clasts is correctly identified, post-mid-Pliocene lateral slip on the entire Denali fault zone was probably about 30 km or less in this area.

Pleistocene displacement is indicated by many large glaciers and glaciated through valleys which jog right-laterally as much as 5 to 7 km (and in a few cases perhaps more) at the fault, probably due to right-lateral slip. Other, usually smaller, glaciated valleys and glaciers are similarly offset ½ to 4 km. Assuming that the larger valleys and glaciers were established early in Pleistocene time, the largest of these right-lateral offsets may represent accumulated right-lateral slip during most of Quaternary time. Recent lateral slip movement is suggested in places by small spur ridges and streams that are offset right-laterally about 0.05 to 0.2 km at the fault. Recent fault scarps along the McKinley strand stand as high as 6, and possibly 15, meters.

Shakwak Valley segment of the Denali fault
(1D on map and tables)

Nature of feature:	Major fault zone, possibly with older thrust as well as younger strike-slip displacement.
Synonyms:	Shakwak Valley fault, Shakwak lineament.
Length:	More than 600 km
References:	Bostock, 1952; Hanson, 1963; Kindle, 1953; Moffit, 1954; Muller, 1958a, b; St. Amand, 1957; Stout, 1965; Wahrhaftig, C., written communication, 1958.

The Shakwak Valley segment is a prominent topographic lineament which separates a terrane of Paleozoic or Precambrian schists and gneisses to the northeast from generally less severely metamorphosed and unmetamorphosed Paleozoic and Mesozoic bedded rocks to the southwest. Its trace is locally marked by Recent fault scarps and right-laterally offset topographic features. Great stratigraphic displacement along the fault, up on the north, may be a relict of pre-Laramide paleogeography modified by Laramide thrusting from the south as proposed by Muller (1958a). However, its straight trace and wide rift, as well as the laterally offset topographic features, suggest that the Shakwak Valley fault zone has also had significant lateral slip. In addition, the pattern of secondary faults south of the Shakwak segment in the Rainbow Mountain area (near Delta River) is compatible with right-lateral slip (Hanson, 1963, p. 66)

The great lithologic contrast at the Shakwak segment was established by Oligocene time, for isolated areas of nonmarine rocks of this age rest upon both of the contrasting terranes near the Delta River, at the west end of the fault. The vertical position of these nonmarine rocks on the south side of the fault near Gakona Glacier, about 15 miles east of the Delta River, with respect to the metamorphosed rocks in the mountains north of the fault, indicates that the north side there was relatively upthrown more than 1.5 km since the Oligocene.

Large Miocene to early Pliocene or later strike-slip displacement on the west end of the Shakwak Valley segment may be precluded by the course of the Delta River and the alignment of northerly-trending synclinal downwarps developed in Oligocene[5/] coal-bearing rocks on both sides of the fault near the river. These downwarps developed before the Nenana Gravel (Pliocene) was deposited; their position relative to the river and the fault are shown on figure 2. Clyde Wahrhaftig (written communication, 1958) points out that the alignment of the downwarps, which occur near Jarvis Creek north of the fault and near Phelan Creek south of the fault, more likely represent the remnants of the same broad downwarp of coal-bearing rocks than the chance alignment of unrelated structures because: 1) northerly structural trends are uncommon in the Alaska Range; 2) the coal-bearing beds near Jarvis Creek are part of the southernmost salient of such rocks in the Alaska Range on the north side of the fault, and the coal-bearing rocks near Phelan Creek are in one of only two such areas of structurally low Tertiary coal-bearing rocks now known from the Alaska Range south of the fault; and 3) the course of the Delta River and especially of its unusually broad valley across the Alaska Range is difficult to explain

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[5/] The coal-bearing beds south of the Shakwak Valley segment contain Metasequoia glyptostroboides Hu and Cheng, and Alnus n. sp. aff. A. evidens (Holl.) Wolfe near Gulkana Glacier (U.S.G.S. Paleobotanical locality 3021), according to J. A. Wolfe of the U.S. Geological Survey (written communication, 1966). He assigns them a probable middle Oligocene age. The age of the coal-bearing beds north of the fault is not definitely known, but is presumed to also be mid-Tertiary.

Figure 2

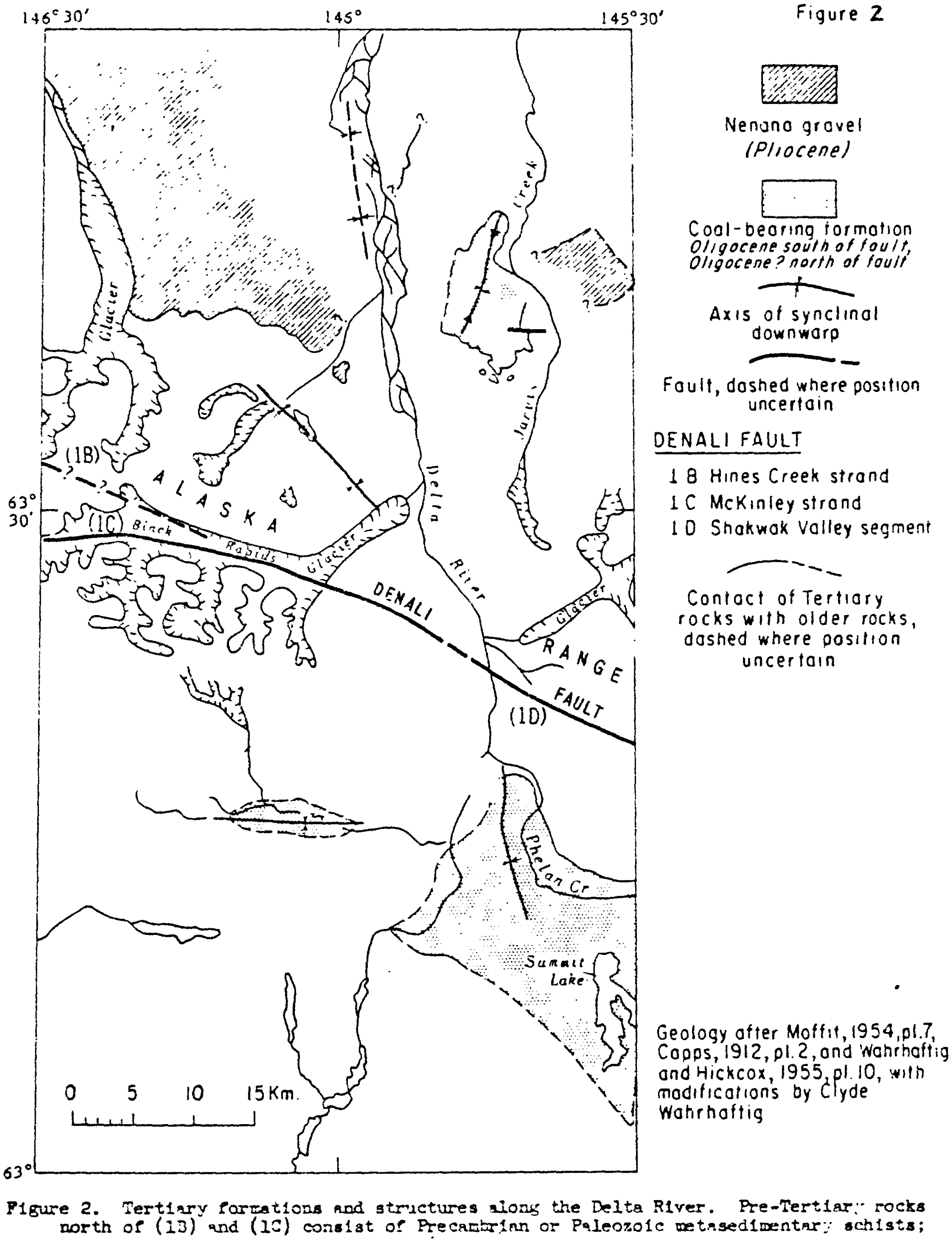

Figure 2. Tertiary formations and structures along the Delta River. Pre-Tertiary rocks north of (1B) and (1C) consist of Precambrian or Paleozoic metasedimentary schists; south of these faults they consist of generally less metamorphosed and unmetamorphosed Paleozoic and Mesozoic sedimentary, volcanic, and granitic rocks.

unless it was localized by the synclinal downwarp noted above or was antecedent to uplift of the Alaska Range. Another alternative, that the river was superimposed from some hypothetical terrestrial deposit that had "smothered" the Alaska Range seems improbable, but would also suggest considerable antiquity for its present course. If the river had been localized by the downwarp, then the fault has had no great net lateral slip since the Miocene or early Pliocene, when the downwarp was formed. If the river had been antecedent to the Alaska Range, the river was at about its present position since at least the Miocene or early Pliocene, when uplift of the range seems to have begun (see p. 12). Despite these constraints on large lateral slip near the Delta River, inspection of aerial photographs or of the U.S. Geological Survey Mt. Hayes (B-4) quadrangle strongly suggests that the broad, glaciated valley of this river has been offset right-laterally at the Shakwak Valley segment. The offset is about 2 km, and perhaps 5 or more km. Assuming that such a large glaciated valley has considerable antiquity, the offset probably represents slip that accumulated since early Pleistocene time. Similar offsets possibly exist along the fault east of the Delta River, but they are not so clearly displayed as those which occur along the McKinley strand to the west. Evidence of Recent right-lateral strike-slip displacement is present at many places along the west end of the fault, where small streams, spur ridges, and late Wisconsin and Recent glacial and alluvial deposits have been offset 0.05 to 0.2 km. The north slope of the Nutzotin Mountains may be a local late Cenozoic fault scarp with relative displacement up on the south, opposite to the stratigraphic displacement along the fault in that area. Numerous thrust faults occur in the terrane immediately south of the Shakwak segment in Canada and at least locally also in Alaska. However in Alaska such thrust have as yet been mapped only in a few places; Stout (1965) mapped thrusts which yielded southward in a small area south of the fault west of the Delta River, and Hanson (1963) mapped similar thrusts in a small area east of the river.

Togiak-Tikchik fault
(included with Holitna fault (3) by some writers)
(2 on map and tables)

Nature of feature:	Right-lateral strike-slip and high-angle reverse fault.
Length:	More than 250 km
References	Cady and others, 1955; Hoare, 1961.

Escarpments and rift valleys mark most of the straight trace of the Togiak-Tikchik fault, which dips 60 to 70° W at the north end. 20 to 30 km of right-lateral separation and associated regional drag in the rocks of the eastern block suggest right-lateral strike-slip displacement that is of latest Cretaceous to late Tertiary age. The south end of the fault displaces Plio-Pleistocene rocks.

Holitna fault
(included with Togiak-Tikchik fault (2) by some writers)
(3 on map and tables)

Nature of feature: Thrust and right-lateral strike-slip fault.

Length: 150 km

References: Cady and others, 1955; Hoare, 1961.

The Holitna fault is well marked by a topographic escarpment, and by fault scarps as high as 6 meters. Its overall trace is straight, but Cady and others (1955, p. 92) report that it dips 20° to 30° northwest. Stratigraphic throw, which is post-mid-Late Cretaceous, and displacement at the Recent fault scarps is up on the northwest. Right-lateral strike-slip displacement is suggested by regional drag and compression in the rocks of the southeast block, and by 20-30 km of right-lateral separation of Cretaceous contacts at the fault. Reportedly, streams and interfluves are not offset at the fault, indicating that lateral slip was pre-Recent. The Holitna fault has the same sense of drag as the Farewell and Togiak-Tikchik faults, which it joins.

Chilkat River fault zone
(4 on map and tables)

Nature of feature:	Possible northwest extension of Chatham Strait right-lateral strike-slip fault and/or southeast extension of the Duke Depression zone of mainly southwest-dipping thrust faults.
Length:	150 km in Alaska and British Columbia.
References:	Robertson, 1955; Watson, 1948.

Shear zones in pre-Tertiary rocks and roughly aligned in-faulted blocks of Paleocene to Miocene(?) nonmarine sedimentary and volcanic rocks suggest that an important zone of faulting may extend along and northwest from the Chilkat River. The character of the fault and the amount of displacement are not known, but if a fault exists movement may be partly late Early and Late Cretaceous, partly post-Paleocene to Miocene(?). The Chilkat River fault zone connects the Chatham Strait (5) and Shakwak Valley (1D) faults, and may have shared important displacements with them.

Chatham Strait fault
(5 on map and tables)

Nature of feature:	Right-lateral strike-slip fault.
Synonym:	Chatham Strait lineament.
Length:	More than 400 km, but may be continuous with the Chilkat River fault (4).
References:	Brew, Loney, and Muffler, in press; Lathram, 1964; Loney, Brew, and Lanphere, in preparation; Loney, R. A., oral communication, 1965; St. Amand, 1957; Twenhofel and Sainsbury, 1958; Wright and Wright, 1908.

The Chatham Strait fault is delineated by a long and strikingly linear fiord which separates regions of contrasting geologic character. Approximately 85 km of right-lateral separation was produced along the fault since mid-Early Cretaceous time, probably during the Tertiary.

Early(?) and Middle Devonian rocks along the fault may possibly be offset right-laterally an additional 130 km. In post-Oligocene time 2 km (and possibly as much as 10 km) of vertical uplift of the block west of the fault may have accompanied, or been superimposed upon, the lateral slip suggested by the right-lateral separations.

Castle Mountain fault system
(6 on map and tables)

Nature of feature:	Right-lateral strike-slip fault.
Synonym:	Lake Clark fault.
Length:	More than 450 km
References:	Barnes and Payne, 1956; Capps, 1935; Gastil, Gordon, cited in Karlstrom, 1964; Grantz, 1964, 1965, in Jones, 196_ (in press); Grantz, Zietz, and Andreasen, 1963; Ivanhoe, 1962; St. Amand, 1957.

Several km to perhaps a few tens of kilometers of latest Cretaceous to late Oligocene (probably Eocene to middle Oligocene) right-lateral strike-slip is inferred on the eastern half of the fault system (Grantz, 1965, and appendix of the present report). Large strike-slip displacement is indicated by juxtaposition of coeval but dissimilar sequences of Cretaceous marine sedimentary rocks along the eastern part of the fault (Grantz, ibid., and in Jones, 196_, in press). The sense of slip (right-lateral) is indicated by the geometry and distribution of secondary faults and folds relative to the Castle Mountain fault.

One eastern splay of the Castle Mountain fault has been inactive since the Eocene or Oligocene, but another had vertical displacement and possibly as much as 2 or 3 km of right-lateral strike-slip displacement in post-early Miocene time. Stratigraphic displacement reverses along the fault system but is consistently up several km on the north in the central section with respect to Mesozoic rocks, somewhat less with respect to Paleocene rocks, and by smaller and more variable amounts with respect to late Oligocene to early Pliocene rocks. Less than 3.1 meters of Recent dip-slip, also up on the north, is reported along the central part of the fault by Gordon Gastil (cited by Karlstrom, 1964, p. 21). Several rock units are thought by Ivanhoe (1962) to have been offset right-laterally at Lake Clark, along the inferred western extension of the Castle Mountain fault. The postulated displacement is several km, and possibly as much as 13 km. Ivanhoe's conclusions are based upon reconnaissance mapping by Capps (1935, pl. 2), which, in the writer's opinion, is not sufficiently detailed or complete in the Lake Clark area to be conclusive.

Iditarod-Nixon Fork fault
(7 on map and tables)

Nature of feature:	Major fault zone, probably with right-lateral strike-slip and some thrusting.
Length:	500 km
References:	Brown, 1926; Cady and others, 1955; Fernald, 1960; Mertie and Harrington, 1924; St. Amand, 1957.

The Iditarod-Nixon Fork fault dips steeply, and it is marked by aligned streams, by fault scarps of Recent age, and by contrasts in the geologic formations and degree of erosional dissection on the two sides. Stratigraphic throw reverses along the fault. Displacement is latest Cretaceous or Cenozoic, and the fault is still active. Large lateral slip is indicated by the great length and straightness of the fault, the reversals in stratigraphic throw, and by 110 km (but possibly only 35 km) or right-lateral separation of Cretaceous rocks along it. However, geologists have variously classed the fault as a thrust fault, a scissors fault, and a strike-slip fault.

The alternative lateral separations are based upon two very different interpretations of why Cretaceous rocks lie south of the main trace of the fault in the Nixon Fork country. The first alternative is based upon mapping by Brown (1926, pl. 5 and fig. 5), viewed in the context of the regional character and topographic expression of the fault. Brown places the Cretaceous rocks south of the fault in a fenster beneath a folded thrust; according to his interpretation these rocks belong with the main body of Cretaceous rocks north of the fault. The second alternative, based upon less detailed mapping by Fernald (1960, pl. 21), places the Cretaceous rocks south of the fault depositionally upon the older rocks; this would greatly reduce the lateral separation of Cretaceous rocks along the fault. The detail shown on Brown's map is convincing, however, and therefore the first alternative, which indicates the larger lateral offset (110 km) is favored.

Aniak-Thompson Creek fault
(8 on map and tables)

Nature of feature: Left-lateral strike-slip fault.

Synonym: Aniak fault.

Length: 300 km

References: Hoare, 1961; Hoare, J. M., and Condon, W. H., oral communication, 1965.

For much of its length the Aniak-Thompson Creek fault separates geologically unlike terranes, and locally bodies of serpentine occur at the fault. The fault trace is marked in places by springs, but Quaternary deposits do not seem to be displaced along it. 30-40 km of late Late Cretaceous or Tertiary left-lateral separation occurs at the fault, and splays at its north end show smaller offsets of the same type.

Conjugate strike-slip faults in the Yukon delta region
(9 on map and tables)

References: Hoare, 1961; Hoare and Condon, 196_ (in press); Hoare, J. M., and Condon, W. H., oral communication, 1965.

Recent geologic mapping and photogeologic studies by J. M. Hoare and W. H. Condon have demonstrated that a system of penecontemporaneous strike-slip fault sets, one right-lateral and the other left-lateral, has played a major role in the deformation of the Yukon delta region. Where best studied (the area designated (9) on figure 1) about 15 percent of the faults show 1 to 5 or more kilometers of lateral separation. The sense of displacement of these faults is almost uniform within each set, implying that at least many of the other faults in each set are similarly displaced. Lack of marker beds precludes measurement of separations along the other faults. The faults average 2-3 km apart and the aggregate displacement, and consequently the net distortion of the region, must have been very large.

The conjugate strike-slip fault system is later than the main deformation of the mid-Late Cretaceous and older rocks, and cuts rhyodacite intrusives that yielded potassium-argon ages of 67 m.y. However, it is older than the Plio-Pleistocene volcanic rocks of the region and is thus likely to be of mid-Tertiary age. The fault system shortened the region along a west northwest-east southeast axis, which is approximately normal to the nearest (northern) part of the Aleutian arc. However, more data on the geometry of strike-slip faults in other parts of southwest Alaska are needed before it can be determined whether this geometric relationship is sufficiently widespread and constant to permit conclusions to be drawn from it.

Kaltag fault
(10 on map and tables)

Nature of feature:	Right-lateral strike-slip fault.
Length:	400 km
References:	Dutro and Payne, 1957; King, P. B., unpublished tectonic map, 1966; Patton, W. W., Jr., oral communication, 1965; U.S. Geological Survey, 1961; Weber, 1959.

The Kaltag fault controls the course of a long reach of the Yukon River, and it is marked in places by rift valleys and Quaternary fault scarps. Cretaceous basin-margin deposits are apparently separated right-laterally about 140 km at the fault, which suggests large strike-slip displacement which must be of post mid- Late Cretaceous age. However, the possibility that part of the separation is due to a swing in the basin margin must still be admitted. Displacement of Pleistocene silts and Recent alluvium indicates that the fault is still active, but lateral displacement of these Quaternary deposits has not been reported and late Cenozoic volcanic rocks lie athwart the western extension of the fault in southern Norton Sound. Some displacement may possibly have been diverted from the Kaltag fault to the Chiroskey, Anvik, and related faults, which appear to join it obliquely from the southwest near Norton Sound. However, the character of the displacements along these faults has not yet been established.

The Kaltag fault cannot be traced east of the mouth of the Tanana River on the basis of presently available geologic mapping, but topographic alignments and isolated structural depressions with Oligocene[6/] nonmarine rocks along and near the Yukon suggest that 1) the fault may trend up the Yukon to join the Yukon Flats fault (13), and 2) splays of the Kaltag fault may swing obliquely into the Tintina fault. Late Paleozoic contacts along the postulated trend up the Yukon River are separated > 30 km and conceivable $\gg 30$ km right-laterally between the mouth of the Tanana River and the Yukon Flats. The relation of the fault to the Oligocene rocks is not known.

If these suggestions are substantiated by more detailed mapping (the area is hardly known geologically), some of the presumed right-lateral slip on the Kaltag fault may have veered to the southeasterly-striking Tintina (14) and Stevens Creek (11) faults in a manner analogous to the junction of the divergently striking Farewell and Shakwak Valley segments

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[6/] Small collections of fragmentary leaves from these beds (U.S.G.S. Paleobotanical localities 3246, 3247, 4708, and 4710) are probably of middle or late Oligocene age (J. A. Wolfe, written communication, 1966). The age is based on the occurrence of _Populus_ sp., _Carya magnifica_ Knowl., _Cercidiphyllum_ n. sp. aff. _C. crenatum_ (Ung.) R. W. Br., and _Vitis atwoodi_ Holl. at most of the localities, and of _Alnus evidens_ or _A._ n. sp. aff. _A. evidens_ at locality 4708.

of the Denali fault directly to the south. These systems of right-lateral faults follow similar trends, are almost parallel, change strike at about the same meridian, and probably both have more than one strand in the zone of intersection.

Stevens Creek fault zone
(11 on map and tables)

Nature of feature:	Right-lateral strike-slip fault zone.
Length:	> 50 km and possibly > 120 km
References:	Hopkins, D. M., oral communication, 1965; Mertie, 1937.

Late Cretaceous or younger movement produced 7 km of right-lateral separation along the parallel and adjacent Stevens Creek and North Fork faults; Recent movement along these faults, probably dip-slip, produced a shallow graben between them. The fault zone may be a splay of the Kaltag fault (10).

Porcupine lineament
(12 on map and tables)

Nature of feature:	Lineament of unknown origin.
Length:	Possibly 450 or more km in Alaska, extends into Canada
References:	Dutro and Payne, 1957; Williams, 1962; Brosge, W. P., oral communication, 1965.

The Porcupine River in Alaska and Canada, and the Yukon River between the Porcupine River and 150° W longitude in Alaska, maintain remarkably uniform and in general straight northeasterly courses despite abundant meanders and bends. If projected southwest the lineament these rivers define would strike into the Kaltag fault (10), which cannot at present be extended east of the mouth of the Tanana River. The uniform trend of the lineament, its parallelism to the Yukon Flats fault, and the fact that its projection meets the similarly striking Kaltag fault, suggests that it may be a related structural feature. But geologic formations appear to cross the lineament without offset along the Porcupine River, and the geology along the lineament near the Yukon is too poorly known to be pertinent. Geologic explanations for the Porcupine lineament may perhaps be found in 1) crush zones along the Porcupine River that parallel its general course; and 2) structural depressions with Tertiary nonmarine sedimentary rocks and late Cenozoic volcanic rocks that in places lie in or near the lineament along the Porcupine River. Some structurally controlled trenches, such as the Tintina trench (14), are locally filled or bordered with such deposits.

Yukon Flats discontinuity and fault
(13 on map and tables)

Nature of feature:	Fault and lineament of uncertain origin.
Length:	More than 200 km, possibly several hundred km
References:	Brosge, W. P., unpublished geologic map compilation, 1965; Wanless and others, 1965.

Devonian and Mississippian formations change abruptly in lithology, thickness, and trend across this discontinuity, suggesting that it may reflect an important paleogeographic or structural feature. Late Paleozoic formations are generally similar across the trend, and the discontinuity seems to strike into the granitic pluton near Old Crow, which has been dated radiometrically as late Paleozoic (Permian(?)) (Wanless and others, 1965). These relationships suggest that the discontinuity was active in late Paleozoic time. Reactivation in Jurassic or later time is indicated by a fault which displaces Early

Jurassic rocks along or close to the discontinuity, but the character of the Jurassic and later displacements is not clear from presently available information. Restoration of roughly 125 km of right-lateral displacement along the discontinuity and fault would serve to align the Kobuk and Tintina Trenches (see (15) below). The Yukon Flats structure parallels, and may strike into and join, the Kaltag right-lateral fault (10), but the Kaltag fault is latest Cretaceous or younger, while the Old Crow pluton, which seems to lie athwart the Yukon Flats structure, is reportedly late Paleozoic. Obviously more detailed work along this fault is needed before we will understand its displacement.

Tintina fault zone and Tintina trench
(14 on map and tables)

Nature of feature:	Tintina fault, large right-lateral strike-slip fault; Tintina trench, continuation of Rocky Mountain trench.
Synonym:	Eagle trough.
Length:	Tintina fault zone in Alaska, 350 km; Tintina trench, 1000 km (in Alaska, 250 km, including interruptions).
References:	Brabb and Churkin, 1964, 1965; Church and Durfee, 1961; Eberlein, G. D., oral communication, 1965; Green and Roddick, 1962; Hopkins and Tabor, in preparation; Mertie, 1937; Roddick, 1966.

A right-lateral strike-slip fault underlies the Upper Cretaceous or Paleocene to Pliocene(?) nonmarine sedimentary rocks which fill the Tintina trench in many places. Upper Precambrian and/or Cambrian metasedimentary rocks appear to be offset 80 to 100 km, and possibly 250 km in a right-lateral sense in Alaska and adjacent parts of the Yukon Territory, but the terrane south of the fault in Alaska is poorly known, and the separation may eventually be shown to be less. The Circle volcanics, of presumed late Paleozoic age, are offset between 60 and 90 km on the west end of the fault, but this may not include the offset on possible splay faults. The main displacement may have been late Cretaceous because 1) Neocomian and probably Albian (Lower Cretaceous) sedimentary rocks north of the fault in the Kandik area may be offset from a belt of generally similar and correlative rocks south of the fault about 120 km to the west, and 2) the oldest sedimentary rocks which overlie the fault in the Tintina trench are Upper Cretaceous or Paleocene. Movement of unknown type but with a large vertical component took place on faults adjacent and parallel to the Tintina fault in the Tintina trench. These faults cut beds as young as Eocene in the Upper Cretaceous or Paleocene to Pliocene(?) nonmarine sequence which fills the trench, and they may possibly post-date the entire trench fill and be of Pliocene(?) or early Quaternary age.

Much larger right-lateral displacement (about 400 km) is proposed for the Tintina fault by Roddick (1966), working in the Yukon Territory. His conclusion is based upon the apparent offset of upper Precambrian (and Cambrian?) clastic rocks (the Yukon Group) and other rocks. Roddick reports that the displacement is younger than Middle Jurassic shales which are truncated by the trench, and older than Paleocene rocks which lie within it, and that the displacement was more probably late Cretaceous than older. The age of the displacement reported by Roddick is in good agreement with the Alaskan data, but the amount of offset is much larger than seems apparent in Alaska. Perhaps the reasons for this discrepancy will be understood when the geologically poorly known terranes that lie south of the Tintina trench and adjacent to the west end of the Tintina fault are mapped in greater detail.

It is conceivable that the Kobuk trench may be an offset extension of the Tintina trench, yet the Tintina fault may have shared some lateral slip with the Kaltag fault (see discussion for features (10), (13), and (15)). This apparent discrepancy cannot be explained with available data, and indeed more detailed mapping may show that it does not exist, but such complexities would not be surprising in a system of intersecting large faults with a long history of activity. The details of the intersection of these faults and linears should be a principal objective of geologic research in central Alaska.

The thrust fault belt of the Brooks Range and the western part of the northern Ogilvie Mountains north of the Tintina fault bends into the fault in a manner compatible with regional right-lateral drag on the Tintina fault, and is there sharply deflected. The bend is of oroclinal proportions and encompasses other linears, and thus, if it represents a deformation, it is likely to be the result of broader distortions than displacement on the Kaltag-Tintina fault system alone (see p. 71). Some of the displacement on the Tintina fault may have been taken up by thrust faults in the rocks south of its west end, thus reducing the displacement on the Tintina fault in that area. This is suggested by the presence of large northeast-striking, southeast-dipping thrust faults in the White Mountains (Church and Durfee, 1961). These faults yielded to the northwest and parallel the geologic grain of the region; their extent is not yet known, but it seems likely that they will prove to be widespread and abundant.

Kobuk trench
(15 on map and tables)

Nature of feature:	Possibly an analogue of the Tintina and Rocky Mountain trenches
Length:	450 km (possibly 550 km)
Reference:	Payne, 1955.

The Kobuk trench may be an analogue of the Tintina and Rocky Mountain trenches, but its structural significance is uncertain because a major fault or fault zone has not been reported within it. However, to the writer, it seems likely that the trench will prove to be fault controlled. The Kobuk and Tintina trenches have similar trends and both end at the Yukon Flats, where they are separated by the Porcupine (12) and Yukon Flats (13) lineaments. These geometric relations raise the question as to whether the Kobuk trench is an offset extension of the Tintina trench.

Fairweather fault
(16 on map and tables)

Nature of feature:	Right-lateral strike-slip and reverse fault.
Length:	Probably 750 km in Alaska, Canada and the continental shelf, but may be much longer.
References:	Hamilton and Myers, in press and written communication, 1966; Miller, 1953; Plafker, George, oral communication, 1965; Stauder, 1960; Tarr and Martin, 1912; Tocher, 1960; Tocher and Miller, 1959.

The Fairweather fault has been definitely mapped only in the northern part of southeastern Alaska. However, Hamilton and Myers (in press, and written communication, 1966), using aerial photographs, have identified a possible extension of the fault in central Alaska. This possible extension is a zone of Recent right-lateral faulting which lies on the northeast flank of the Wrangell Mountains northwest of the White River and joins the Denali fault in the headwaters of the Slana and Chistochina Rivers. The position and trend of this zone of faulting are such that its projection would strike toward the essentially parallel Fairweather fault in southeastern Alaska. The zone of faulting may thus connect the Fairweather and Denali faults, but the connection cannot be followed across the rugged, glaciated St. Elias Mountains on aerial photographs. A regional fault has not yet been mapped along the zone of Recent right-lateral faulting, but such a fault or fault zone may well be present because the region has been mapped only in gross reconnaissance and because large faults have been recognized along parts of the zone of faulting. As pointed out by Hamilton and Myers (ibid.), continuity of Fairweather and Denali faults would have considerable significance for the Cenozoic tectonics of Alaska.

The block north of the Fairweather fault in southeastern Alaska has been uplifted more than 5 km, and the fault has undergone associated right-lateral slip of unknown magnitude, from late Pliocene or early Pleistocene to Recent time. During the July 9 (10), 1958 earthquake $6\frac{1}{2}$ meters of right-lateral slip and 1 meter of associated dip-slip (up on the south) occurred along the Fairweather fault. During the September 1899 earthquakes at Yakutat Bay and possibly during the July 9 (10), 1958 earthquake there was apparent lateral movement on the large splay of the Fairweather fault which crosses Nunatak Fiord. Gabbroic clasts in Pliocene sedimentary rocks southwest of the fault in southeastern Alaska could have been derived from layered gabbros in an adjacent terrane northeast of the fault, so post-Pliocene lateral slip there may not have been large.

The zone of Recent lateral faulting on the north side of the Wrangell Mountains, northwest of the White River, has displaced late Pleistocene and Recent land forms and small streams distances of 0.1 to 0.24 km right-laterally. The offsets occur on more than one fault strand in parts of the fault zone. The character of older displacements along the zone of Recent offsets is not revealed by presently available reconnaissance geologic mapping in that part of Alaska. If the zone of offsets marks a regional fault, however, that fault has down-dropped Upper Cretaceous nonmarine clastic rocks and Cenozoic volcanic rocks northwest of the fault about 1 km with respect to Paleozoic rocks southeast of the fault in the area between the White and Chisana Rivers.

The Fairweather fault is inferred to extend southeast along the continental slope off southeastern Alaska and northern British Columbia (see p. 74). It may thus connect the central part of the Denali fault with the right-lateral strike-slip fault zone of the west coast of North America.

Peril Strait fault
(17 on map and tables)

Nature of feature:	Right-lateral strike-slip fault(?).
Length:	180 km
References:	Berg and Hinckley, 1963; Brew, Loney, and Muffler, in press; Loney, Brew, and Lanphere, in preparation; Stauder, 1960.

Fiords and deep rift valleys mark the course of this fault. Possibly 30 km of right-lateral separation and considerable uplift of the northeast block have occurred along it since mid-Cretaceous time. Movement on the central and southeast parts of the fault may be mainly pre-Miocene. If the fault is part of the still-active Fairweather fault system (5) its history suggests that it is an ancestral branch of that system.

Chichagof-Sitka fault and its likely southeastern extension, the Patterson Bay fault (18 on map and tables)

Nature of feature: Right-lateral strike-slip fault.

Length: 200 km combined length

References: Berg and Hinckley, 1963; Brew, Loney, and Muffler, in press; Loney, Brew, and Lanphere, in preparation; Reed and Coats, 1941.

Lateral separations have not been demonstrated on the Chichagof-Sitka fault, but minor structures near it and movement on adjacent faults suggest right-lateral movement. The Patterson Bay fault had 4 km of right-lateral separation between mid-Eocene and late Oligocene, with vertical component not known. Post-mid-Early Cretaceous and pre-mid-Eocene movement with a strong or dominant component of uplift of the eastern block is probable.

Clarence Strait lineament (19 on map and tables)

Synonym: Clarence Strait fault.

Length: More than 350 km

References: Lathram, 1964; Muffler, L. J. P., oral communication, 1965.

If this lineament is a fault, the northeast side was uplifted at its southeast end and displacement decreased to the northwest. Evidence for lateral slip is not known. Fault displacement, if it exists, was probably late Early or Late Cretaceous.

AGE OF FAULTING

Fault displacements of Recent age are indicated by scarps and offset late Pleistocene and Recent deposits along 11 of the 17 faults, fault strands, and fault segments that have been included in the present compilation. These displacements have been reported only on the faults in central and western Alaska, and on the Fairweather fault (16). None have been reported for the faults in southeastern Alaska, but the surface traces of these faults are mainly under water. Historical displacement along the strike-slip faults has been recorded only on the Fairweather fault, the most vigorously active of the known or suspected strike-slip faults in Alaska during the Quaternary. During the July 9 (10), 1958 earthquake this fault slipped right-laterally about $6\frac{1}{2}$ meters, and a splay fault may also have moved during the earthquakes of September, 1899. In table 1 these and other data on the episodes of displacement on these faults are recorded in generalized form. Note that this table merely presents the incomplete data now available, and that it does not purport to present the displacement history of these faults.

Data on the sense of the Recent displacements are incomplete. In addition to historical and pre-historical Recent right-lateral slip on the Rairweather fault, there is geomorphic evidence of Recent right-lateral slip on parts of the McKinley (1C) and adjacent parts of the Farewell (1A) and Shakwak Valley (1D) faults of the Denali system. However, the Recent displacement on several other faults, including other parts of the Farewell and Shakwak Valley faults and other members of the Denali system, reportedly has been vertical.

Pleistocene displacements on the strike-slip faults may have been like those of the Recent, but Pleistocene glaciation has evidently masked much of the specific evidence. The Denali fault has bold

Table 1. Synopsis of the presently available evidence for episodes of displacement along the known and suspected large strike-slip faults of Alaska. The displacements recorded are not necessarily strike slip. Note that this table merely summarizes the incomplete data now available, it does not purport to present the displacement history of these faults.

	DENALI FAULT SYSTEM								SOUTHWESTERN AND CENTRAL ALASKA										SOUTHEASTERN ALASKA			
	DENALI FAULT																					
	Farewell segment	Hines Creek strand	McKinley strand	Shakwak Valley segment	Togiak-Tikchik Fault	Holitna Fault	Chilkat River fault zone	Chatham Strait Fault	Castle Mountain Fault	Iditarod-Nixon Fork Fault	Aniak-Thompson Creek Fault	Conjugate wrench faults in the Yukon delta region	Kaltag Fault	Stevens Creek fault zone	Porcupine lineament	Structural discontinuity in northern Yukon flats	Tintina fault zone and trench	Kobuk trench	Fairweather Fault	Peril Strait Fault	Chichagof-Sitka and Patterson Bay Faults	Clarence Strait lineament
	1A	1B	1C	1D	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
RECENT	X	X	X	X	X	X			X	X			X	X					△ X			
PLEISTOCENE	X	X	X	X	↑	↓							X?						X			
PLIOCENE	X	X	↑	↑					↑			↓	↓?				X?					
MIOCENE	↑							↑	↑				↑?									
OLIGOCENE		↓	↓	↓			↓?		↓								↑			↓	X	
EOCENE	↑	↑	↑	↑?			↑		↓? ↑?												↓	
PALEOCENE	↑	X ↓		X?	↑	↑			↑	↑	↑	↑	↑	↑			↓					
LATE CRETACEOUS							↑	↑									X			↑	↑	X?
EARLY CRETACEOUS																						
JURASSIC																↑	↑					
TRIASSIC																						
PERMIAN																						
CARBONIFEROUS																↓?						
DEVONIAN								X?								↑						
SILURIAN																						
ORDOVICIAN																						
CAMBRIAN																						

△ Historical displacement

X Evidence reported for displacement at about this time

↑ Evidence reported for displacement at this or a later time

↓ Evidence reported for displacement at this or an earlier time northerly-facing scarps of great height, and there are right-laterally deflected glaciers and glaciated valleys along the McKinley strand and adjacent portions of the Farewell and Shakwak Valley segments of the Denali fault. These features suggest large vertical and right-lateral Quaternary displacements along the Denali fault. Additionally, Pliocene and/or Pleistocene deposits are displaced along the Togiak-Tikchik (2), and Hines Creek (1B) faults of the Denali system, and along the Castle Mountain (6) and Fairweather (16) faults and possibly along the Tintina (14) fault.

Tertiary strike-slip displacement is indicated or suggested for several of the faults in central and southeastern Alaska, but the record of Tertiary displacement is limited by the restricted distribution of datable Tertiary rocks along the faults. Repeated Tertiary displacements with a vertical sense or a strong vertical component is indicated by the disposition of Tertiary sedimentary rocks along the Castle Mountain (6), Chatham Strait (5), and Chichagof-Sitka (18) faults, and for the Hines Creek fault (1B) west of the east side of the Nenana River Valley. On the Castle Mountain fault the major recorded episode of strike-slip (right-lateral) displacement was post-Cretaceous and pre-Miocene, and probably Eocene or Oligocene. There also appears to have been a little post-Miocene right-lateral slip. The Patterson Bay fault, an extension of the Chichagof-Sitka fault, had 4 km of mid-Eocene to late Oligocene right-lateral separation, and late Early Cretaceous to early Eocene lateral slip may have occurred. Strike-slip displacement on the Chatham Strait fault was likely Tertiary, although it also could have been late Early or Late Cretaceous; the conjugate strike-slip faults (9) of the Yukon delta region were most likely mid-Tertiary; and the Shakwak Valley fault (1D) experienced its major displacement in Oligocene or earlier time, followed by uplift of the terrane north of the west end of the fault in Oligocene or later time. The Farewell (1A) and McKinley (1C) strands have had major post-Paleocene (post-Cantwell Formation) displacement, as did the western part of the Hines Creek strand (1B). The eastern part of the Hines Creek strand, which is overlapped by the Paleocene rocks, also separates geologically dissimilar terranes. These relationships indicate that the Hines Creek strand had its major activity in Paleocene or older time. The lack of datable Tertiary rocks, and the widespread occurrence of Cretaceous rocks, along the Togiak-Tikchik (2), Holitna (3), Iditarod-Nixon Fork (7), Aniak-Thompson Creek (8), Kaltag (10), and Stevens Creek (11) faults have allowed their pre-Quaternary activity to be dated only as Late Cretaceous or Tertiary. For the Peril Strait fault (17) large strike-slip displacement must have been pre-Miocene. Strike-slip displacement greater than several kilometers on the eastern part of the McKinley strand and the western part of the Shakwak Valley segment occurred prior to Miocene or early Pliocene time, and anything greater than about 30 km on the central part of the McKinley strand probably occurred prior to late Miocene or early Pliocene time.

Late Cretaceous strike-slip displacement is suggested for the Tintina fault zone (14). However, until a critical comparison of the apparently offset Early Cretaceous rocks has been made an earlier Cretaceous or Late Jurassic age for the slip, based upon the offset of older rocks, must also be entertained. Late Carboniferous deformation, possibly faulting, occurred along the structural discontinuity in the northern Yukon Flats (15), and an episode of Early or Middle Devonian displacement has been suggested as a possibility for the Chatham Strait fault. The Hines Creek fault (1B) was already a well established feature in Paleocene time, and Muller (1958a) has suggested that the Shakwak Valley fault (1D) was an active tectonic feature during the Paleozoic.

The age data suggest that the Hines Creek strand (1B) of the Denali fault is older than the McKinley strand (1C), and the older fault is also more sharply bent. These relationships suggest that the McKinley strand "short-circuited" the older, more sharply curved Hines Creek strand under the influence of continued lateral slip. Similarly, the southernmost splay at the east end of the Castle Mountain fault, which has been inactive since early Tertiary time, is more sharply curved than the more recently active main northern splay.

The Peril Strait (17) and Chichagof-Sitka (18) faults seem to have experienced most of their displacement by mid-Tertiary time. They strike into, and are cut off by, the very young Fairweather fault.

MAXIMUM APPARENT LATERAL SEPARATIONS

The apparent lateral separations on the Alaskan faults are large, and in aggregate they represent a very considerable deformation. But they fall short of the largest lateral displacements that have been proposed for such notable strike-slip faults as the San Andreas and Alpine faults. This may be due, but only in part, to Cretaceous orogeny and sedimentation. Cretaceous events obscured older geologic features in much of Alaska, and the greatest lateral separations that can be measured are usually in rocks of this age. The data on the separations are summarized in table 2. Some of these may only be

Table 2.--Large lateral separations (in Km) measured along large known and suspected strike-slip faults in Alaska

FAULT		AGE OF ROCKS OR FEATURES UPON WHICH LARGE LATERAL SEPARATIONS WERE MEASURED						
		Late Pre-Cambrian or Cambrian	Devonian	Cretaceous	Eocene	Pleis-tocene	Historical	Unknown
Farewell (1A)	R[1]			115		5[2]		
McKinley (1C)	R					5-7+		
Shakwak Valley (1D)	R					2-5+[3]		
Togiak-Tikchik (2)	R			20-30				
Holitna (3)	R			20-30				
Chatham Strait (5)	R		215(?)	85				
Castle Mountain (6)	R			Few to few tens km				
Iditarod-Nixon Fork (7)	R			110(35?)				
Aniak-Thompson Creek (8)	L			30-40				
Conjugate faults, Yukon delta region (9)	R & L			1-5				
Kaltag Fault (10)	R			140				
Stevens Creek zone (11)	R			7				
Yukon Flats (13)	R?							125?
Tintina (14)	R	80-100 (250-400?)		120?				
Fairweather (16)	R					Several?	.0065	
Peril Strait (17)	R			30?				
Chichagof-Sitka (18)	R				4			

[1] R--Right lateral separation

L--Left lateral separation

[2] East end of fault only

[3] West end of fault only

apparent, for they are based upon geologic mapping by some of the earliest exploring parties in Alaska, and may disappear under the scrutiny of more detailed work. For others the evidence is strong that much or most of the separation is due to strike-slip displacement. Among the latter are the Chatham Strait fault, for which Brew and others (196_) have demonstrated that a number of Cretaceous and older rock units are offset about 85 km right-laterally. On the Castle Mountain fault juxtaposition of unlike Cretaceous facies, offset Mesozoic and Paleozoic rocks, and the geometry of related secondary structures indicate right-lateral slip of a few to a few tens of km. Cretaceous rocks seem to be separated right-laterally between 100 and 150 km along the parallel Farewell (1A), Iditarod-Nixon Fork (7), and Kaltag (10) faults, and along the Tintina (14) fault. Greater displacement for the Tintina fault is proposed on the basis of older rocks by Roddick (1966). He believes that late Precambrian (and Cambrian?) rocks are offset about 400 km along this fault, but evidence in Alaska suggests to the writer that at least there, the offset may turn out to be smaller. Numerous lateral separations of 1-5 km on the conjugate faults of the Yukon delta region indicate that their displacement is largely lateral.

Regional drag on the connected Togiak-Tikchik, Holitna, Farewell, and McKinley faults of the Denali system, and on the Tintina fault supports the evidence of large lateral separations that indicates important strike-slip on these faults. Other faults have rifts, offset topographic features, and secondary geologic structures to reinforce the interpretation that they underwent some strike-slip displacement. Of the latter, the Fairweather fault provides many surficial indications of the .0065 km of right-lateral slip that occurred along it in 1958, and there are many right-laterally offset topographic features along the McKinley strand and the adjacent parts of the Farewell and Shakwak Valley segments of the Denali fault.

SUPERPOSITION OF LATERAL SLIP UPON PRE-EXISTING FAULTS

Lateral movements on some of the large right-lateral strike-slip faults in Alaska, such as the Denali fault, may be relatively young strains imposed upon major pre-existing faults with different modes of displacement. This is suspected because for some of these faults even the greatest probable lateral separations (for example, 115 km right-lateral on part of the Denali fault) would not, if restored, eliminate great contrasts in geology across them. The contrasts across these faults may be due to a combination of right-lateral strike-slip displacement with something like the dip-slip or thrusting suggested for the Shakwak Valley fault by Muller (1958a). The lithologic differences across this fault, the Hines Creek fault, and perhaps the Tintina fault, may thus be due in part to differences in relative uplift and metamorphic grade.

Very young right-lateral slip was superimposed upon the Denali fault, and probably upon the Fairweather fault, during late Cenozoic time. This slip produced a zone of right-lateral offsets along the Fairweather fault that is inferred to extend from the Pacific rim to central Alaska (Hamilton and Myers, 196_), where it follows the adjacent western part of the Shakwak Valley segment and all of the McKinley strand of the Denali fault. This geologically young right-lateral slip is apparently absent from the central and eastern portions of the Shakwak Valley segment of the Denali fault, and thus it was superimposed upon only part of the pre-existing Denali fault.

HYPOTHESES INVOLVING THE STRIKE-SLIP FAULTS

The strike-slip faults of Alaska have important implications for its tectonic evolution, and their significance becomes especially apparent when their geometry and distribution is compared with other geologic features and trends in the region. However, data concerning the faults are quite incomplete, and in part contradictory, and their interpretation is highly speculative. Nevertheless, a few possible implications are discussed below.

It is striking that the known and suspected large strike-slip faults of Alaska are nearly all right-lateral, and that in the largest part of interior Alaska they conform to only two main trends. The faults strike mainly east-southeast in eastern central Alaska and east-northeast in western central Alaska, but there is some overlap northeast of the Tanana River (fig. 1). The significance of these trends is underscored by major lineaments such as the course of the Yukon and Porcupine Rivers above the Koyukuk and the course of the Tanana River and Valley, which also conform to these trends. The regularities and symmetries in trend and spacing of these faults indicate that they are related in origin to some of the same broad-scale tectonic processes.

Besides regularities in trend, spacing, and symmetry of the strike-slip faults, certain regularities in the distribution of the lateral separations also suggest that the faults are part of larger deformations. Thus, Cretaceous rocks seem to be separated about 100-150 km right-laterally on each of the parallel and adjacent Farewell (1A), Iditarod-Nixon Fork (7), and Kaltag faults (10). The right-lateral separations on the Tintina (14), and possibly the Yukon Flats

(13) faults are similar to that on the Kaltag fault, toward which they converge, and the connected Togiak-Tikchik (2) and Holitna (3) faults each have right-lateral separations of about 20-30 km. Along the parallel Tintina (14) and Shakwak Valley (1D) faults, which bound opposite sides of a large block of metamorphosed early Paleozoic and Precambrian (?) rocks, lateral separation is difficult to establish because of regional differences in metamorphic grade between the terranes juxtaposed at the faults.

The ratios of the largest apparent separations of Cretaceous rocks to the lengths of the fault segments along which they were measured also show a rough uniformity. These ratios for the fault segments whose lengths are approximately known lie between 0.1 and 0.3, and the mean is about 0.2. Of course, if the separations were compared with the length of the entire fault systems, the ratios would be much smaller. Thus for the entire Denali fault the ratio is about .08, and for the entire Denali system about .05. The fact that the ratios are grossly similar for the segments suggests that some sort of relationship may exist between the size of the offsets and the length of the respective straight fault segments. The relationship presumably reflects the character of the deformation that produced the faults, and perhaps some property of the earth's crust; and it is an additional suggestion that the faults are the result of the same broad deformations.

Relation to right-lateral slip along the Pacific Coast

The apparent connection between some of the right-lateral faults of central Alaska and an inferred right-lateral fault off the coast of Alaska and British Columbia (possibly an extension of the San Andreas fault system) has been the subject of speculation by St. Amand (1957) and other writers. St. Amand places this coastal fault just offshore in southeastern Alaska, but for reasons presented on page 74, the fault is thought to lie beyond the edge of the continental shelf. He infers that the Denali fault merges with the coastal fault at the mouth of Lynn Canal, and that the Castle Mountain fault (his suspected Lake Clark fault zone) may be connected with the coastal fault by the Fairweather fault and a suspected fault along the south side of the Chitina Valley. The Denali and coastal faults (the latter is considered to be an offshore extension of the Fairweather fault) may, in the past, have acted together, but their present angular junction, and other reasons presented in a following section, suggest that this association has now ended. Also, evidence is lacking for a fault in the Chitina Valley connecting the Fairweather and Castle Mountain faults, but the critical areas may not yet have been mapped in detail. Rather, as Hamilton and Myers (196_) suggest, the zone of Recent right-lateral slip on the coastal (Fairweather) fault very likely extends inland along that fault to join the Denali fault in central Alaska. Therefore, any former routing of coastal belt lateral slip into central Alaska along the now bent Denali fault system appears to have been superceded in late Cenozoic time by a more direct route to the interior along the Fairweather fault and its extension.

Clear evidence for Recent right-lateral slip on the Denali fault has not been reported beyond the east or perhaps the central portion of the Farewell segment. The coastal system of Recent right-lateral slip may thus become dissipated in the interior of Alaska, rather than cross it to reach the Bering Sea. If this is substantiated by more detailed geologic work along the western part of the Denali fault system, then the effect of the Recent (and Pleistocene?) lateral slip on the coastal fault has been to shove the northern Pacific basin and central and southwestern Alaska together (see St. Amand, 1957, p. 1365). However, internal rotation of Alaska was the apparent result of older slip on the right-lateral faults of Alaska.

Internal rotation of Alaska

The arrangement of the straight faults of central Alaska is such that if all are indeed right-lateral, then southern Alaska was deformed by internal dextral rotation about a vertical axis located in the western part of the Gulf of Alaska. The radius of a generalized arc through the outermost lateral faults is about 900 km. However, such rotation might be expected to produce a nest of simple concentric arcuate faults rather than the straight faults and interconnected straight fault segments that are actually observed. Thus the arcuate Denali fault system is composed of straight divergently-striking segments (the Togiak-Tikchik (2), Farewell (1A), Shakwak Valley (1D), and Chatham Strait (5) faults) that are connected by shorter east-trending strands in the Alaska Range south of Fairbanks and by the obliquely trending Holitna fault (3) and Chilkat River fault zone (4) in southwestern and southeastern Alaska, respectively. Two possible explanations for the straightness and arrangement of the faults are: 1) the faults were once straight but have since been bent as much as 50° along a northerly striking axial plane; 2) the apparent right-lateral rotation may have adopted favorably situated members of an old and extensive system of east-northeast and east-southeast trending deep faults or lineaments. In either case, continued right-lateral slip along the grossly arcuate Denali fault produced, in effect, internal dextral rotation in Alaska. In case 1, it could have been a continuation of long-established right-lateral slip or strike-slip displacement superimposed upon faults of a different character. In case 2, it would have been a younger strain superimposed on faults of unrelated origin.

Bending by regional compression

The bend between the Farewell (1A) and Togiak-Tikchik (2) faults of the Denali system, and possibly a bend in the later fault near Togiak Island, may possibly be due to east southeast-west northwest crustal shortening (compression) in southwestern Alaska. Such shortening may have been similar to, or part of, the deformation that produced the conjugate strike-slip faults of the Yukon delta region (9). Although both right- and left-lateral faults are only present in southwestern Alaska, the presence of a pervasive system of conjugate strike-slip faults has yet to be demonstrated outside of area (9). Such regional compression could have formed the bends in the manner that north-south regional compression in the Transverse Ranges of southern California produced a localized bend in the northwest-trending San Andreas fault. In addition, the deflection and probable offset of the western end of the Iditarod-Nixon Fork fault (7) seems to have been produced by interaction with the left-lateral Aniak-Thompson Creek fault (8). The position of the latter fault with respect to the junction of the Farewell and Togiak-Tikchik faults suggests that its left-lateral slip was part of the deformation that changed their trend at the junction.

Bending in an orocline

Mountain chains in most of Alaska follow east-west or southeast-northwest Cordilleran trends, but in the domain of the Aleutian Arc in southwestern Alaska the mountains trend northeast and north and are oblique to older tectonic trends (see figs. 3a and 3b). The union of these diversely trending and genetically distinct mountain systems in south-central Alaska has produced sharply curved orographic features which contribute to the great bend in the mountains of southern Alaska that Carey (1955, p. 270-271) has cited as the physical evidence in Alaska for an Alaskan orocline. The sharp change in trend of the Chugach Mountains near Anchorage, and the angular junction of the Aleutian-Southern Alaska R ange with the Central Alaska Range near Farewell, are examples of orographic "bends" that owe most of their form to the intersection and superposition of orogenic trends. If oroclinal bending did occur in Alaska, the evidence lies in the curved pattern of its faults and late Mesozoic tectonic elements, rather than in the more sharply curved but much younger present-day mountain ranges. Clyde Wahrhaftig (written communication, 1958) has pointed out that theories which seek to explain the curvature of Alaska's southern ranges by bending alone encounter the difficulty that the present mountains, of late Cenozoic age, are bent more sharply than the Mesozoic tectonic elements which, because they are older, should be at least as sharply bent. Another difficulty is that if the Castle Mountain fault (6) does extend with only slight flexure from the upper Matanuska Valley, in the domain of Cordilleran trends, southwest across the Susitna Lowland and the Aleutian-Southern Alaska Range, in the domain of Aleutian Arc trends, then the great oroclinal bending

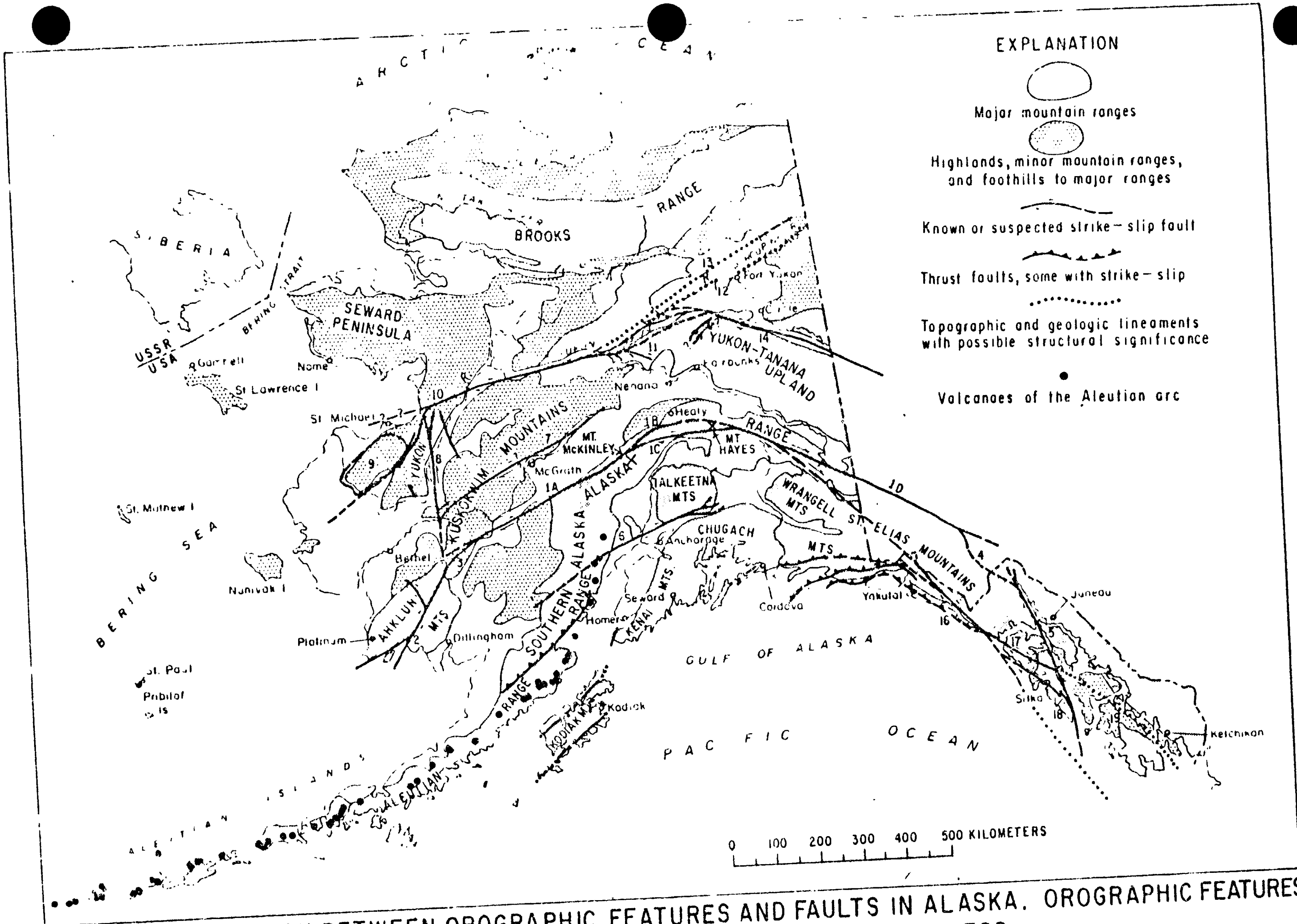

FIGURE 3A. RELATION BETWEEN OROGRAPHIC FEATURES AND FAULTS IN ALASKA. OROGRAPHIC FEATURES GENERALIZED FROM WAHRHAFTIG, 196—, IN PRESS

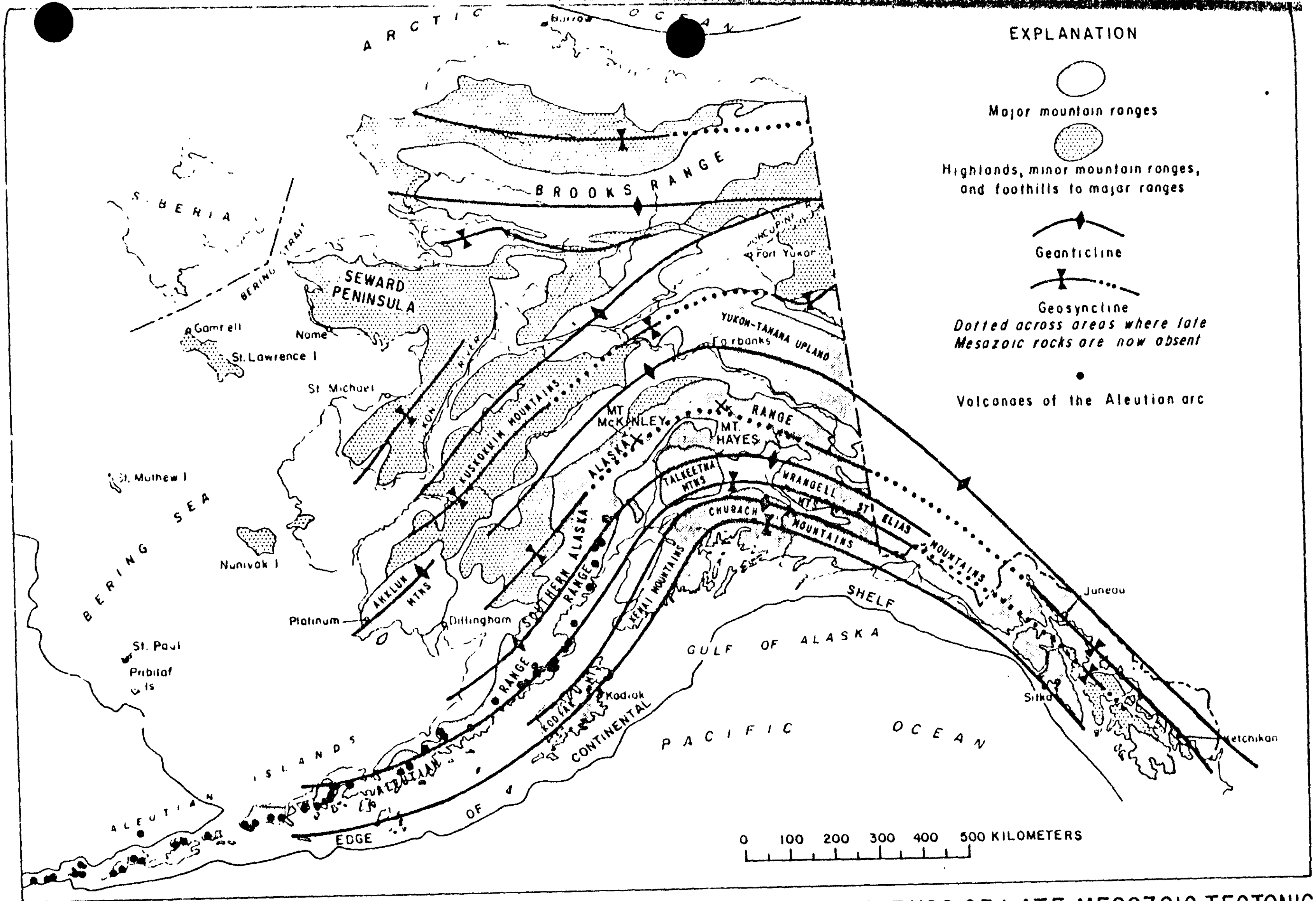

FIGURE 3B. RELATION BETWEEN OROGRAPHIC FEATURES AND THE TRENDS OF LATE MESOZOIC TECTONIC ELEMENTS IN ALASKA. THE TECTONIC ELEMENTS ARE ADAPTED FROM MILLER, PAYNE, AND GRYC, 1958, PL. 2, BUT HAVE BEEN CONSIDERABLY REVISED IN PLACES IN SOUTHERN ALASKA. THE AXES OF THE TECTONIC ELEMENTS ARE GROSS GENERALIZATIONS, AND HAVE DELIBERATELY BEEN DRAWN TO SHOW NO OFFSETS ALONG THE STRIKE-SLIP FAULTS.

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proposed by Carey was either pre-Miocene, or this pre-Miocene strike-slip fault was once semicircular and has since been straightened by oroclinal bending. Thus, while Carey's use of curved mountain ranges to indicate directly an Alaskan orocline is unwarranted, the present mountains are not likely to have formed without regard to earlier tectonic processes and structural features. Their curvature is a valid clue to the idea that folding of oroclinal proportions may have affected Alaska, but the possible orocline is much older and significantly less sharply curved than the bend formed by the present mountain ranges (see fig. 3).

The change in trend of the Denali fault and the possible junction of the Kaltag-Tintina faults near the meridian of Fairbanks in central Alaska may be due to bending of oroclinal proportions. The limbs of this bend would be defined by the straight faults and fault segments of central Alaska, and the axial trace would be an almost north-south line lying just west of 148° W longitude. Its straight limbs and sharp apex would make it a sort of chevron fold, and its dimensions would encompass more than half of Alaska. If the known and suspected strike-slip faults were active or subject to deformation during the hypothetical oroclinal bending, they could have acted to guide or accommodate some of the strain. In this event the bending could have proceeded by slip on the faults in an amount related to the degree of rotation of the limbs and the distance from the axial trace; there would be internal deformation of the inter-fault blocks; and there would be regions of intense compression in the axial region of the bend. And certainly the deformation should be recognizable in other regional geologic structures that existed at the time of the postulated bending.

The Denali, Tintina, and Kaltag faults are interpreted to have been well established before the postulated oroclinal bending occurred. Displacements generated on these established faults during the postulated bending would have been superimposed upon large pre-existing displacements, and they would have been confined to the active west limb of the postulated orocline. (Regional considerations discussed in a following section suggest that if oroclinal bending did occur, the east limb of the orocline, with its long, straight, pre-existing faults, was passive.) The Iditarod-Nixon Fork and Castle Mountain faults, which occur mainly or entirely west of the oroclinal axis, could have formed in response to the postulated bending.

Certain geologic features do offer some circumstantial support to the hypothesis of oroclinal bending, but many problems and contradictions remain. The strongest support is derived from the fact that other regional geologic structures, namely the late Mesozoic tectonic elements of southern central Alaska and the continental slope off central and southwestern Alaska, are bent in a similar manner and on a comparable scale (see figure 4). In addition, the axial trace of the bend defined by the tectonic elements is similar in strike and position to the axial trace of the bend described by the faults. This trace also intersects the continental slope at or very near the reentrant angle at which it changes trend from the easterly course that it follows in the Gulf of Alaska to the southward convex arc that it follows off southwest Alaska and beneath the Bering Sea. The tectonic elements are a little more sharply bent than the faults, and seem to have the form of a concentric rather than of a chevron, "fold" or "bend", but their plotted positions are only generalizations and the precise form of the "bend" which they define is not known.

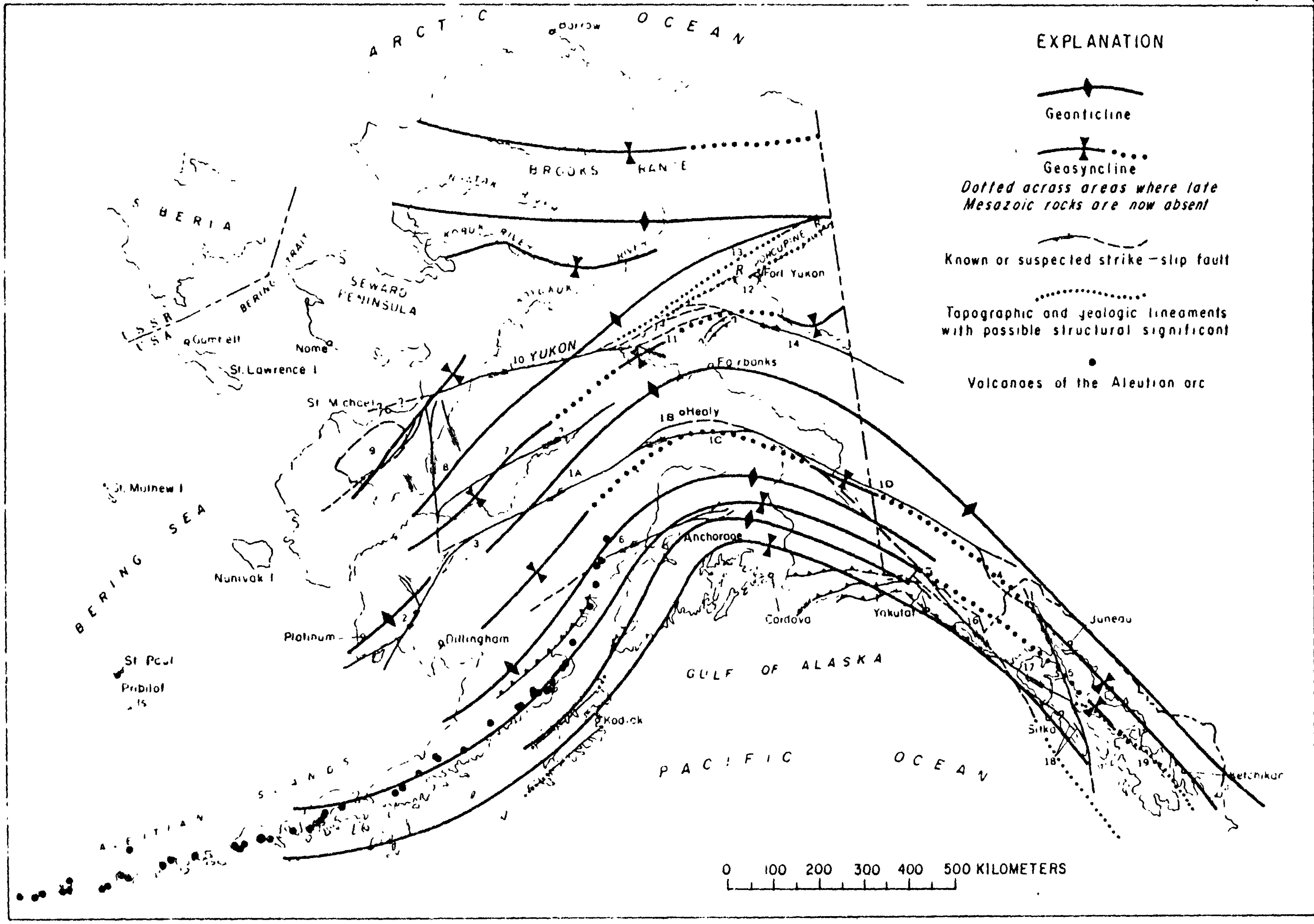

FIGURE 4. RELATION BETWEEN THE TRENDS OF KNOWN AND SUSPECTED STRIKE-SLIP FAULTS AND LATE MESOZOIC TECTONIC ELEMENTS IN ALASKA *(SEE CAPTION FOR FIGURE 3B)*

If oroclinal bending strained the crust in a manner analogous to chevron folding, the geometric requirements of the deformation should have created the diagnostic structural features outlined in the second paragraph of the present section of this report. Thus, a considerable deformation of the interfault blocks would have been created, possibly exemplified by features like the regional drag that has been reported within some of them. However, not enough is known about these features to demonstrate that they are necessarily a consequence of oroclinal bending. Another expected effect, local compression in the axial region of the bend, may be exemplified by such things as 1) the numerous faults and the intersecting systems of topographic linear features and faults in Prince William Sound (shown in part by Condon, 1965, and Condon and Cass, 1958); 2) the narrow, structurally compressed Matanuska Valley; and 3) the tight structure of Broad Pass. In chevron-like bending lateral displacement between the interfault blocks would increase with distance from the axial trace. Possibly this explains why the Castle Mountain (6) and Iditarod-Nixon Fork (7) faults seem to splay out or become lost in the axial region of the postulated orocline, and to apparently lack counterparts in the supposedly passive limb east of the axial region. A splay of the Castle Mountain fault (6) may, however, extend into the southern Copper River Lowland. Such bending could, perhaps, also explain why Paleocene rocks along the Hines Creek strand (1B) of the Denali fault are offset along the fault west of the axial trace of the postulated orocline, but not east of it.

The consistently right-lateral separations of Cretaceous rocks reported along the Farewell (1A), Iditarod-Nixon Fork (7), and Kaltag (10) faults are of a type and amount appropriate for slip related to chevron-like bending wherein the interfault blocks rotated more or less as units, and much of the adjustment between blocks occurred along the faults. Figures 5 and 6 show these faults and their lateral separations before and after restoration of the separations by rotation, using a simple mechanical model. Rotation sufficient to restore the separations rather closely aligns the faults along the trends of the homologous faults on the other limb of the "chevron fold". And rotation by the mediar amount (50°) needed to "restore" the lateral separations on the faults in the active west limb of the orocline also very nearly straightens out the curved late Mesozoic tectonic elements of Alaska (see fig. 7).

Alignment of the restored faults and straightening of the curved tectonic elements by a simplified mechanical manipulation does not, of course, compel belief in chevron-like oroclinal bending. The lateral separations must be better documented, the actual slip along the faults has not been determined, and the positions of the tectonic elements are only approximations. Furthermore, internal distortion and drag in the inter-fault blocks would have reduced the lateral separations along the faults, and non-oroclinal strike-slip displacement of earlier or later deformations on the same faults would have increased them. Hopefully, these and other factors "canceled out", but the available data cannot tell us whether they really did. In particular, non-oroclinal right-lateral slip on the Denali and Tintina faults is difficult to accomodate in the simplified model without additional assumptions. For example, one could assume that non-oroclinal right-lateral slip along the western part of the Denali fault was small in comparison with similar orocline-related slip, and that non-oroclinal right-lateral displacement on the Tintina fault followed

Figure 5

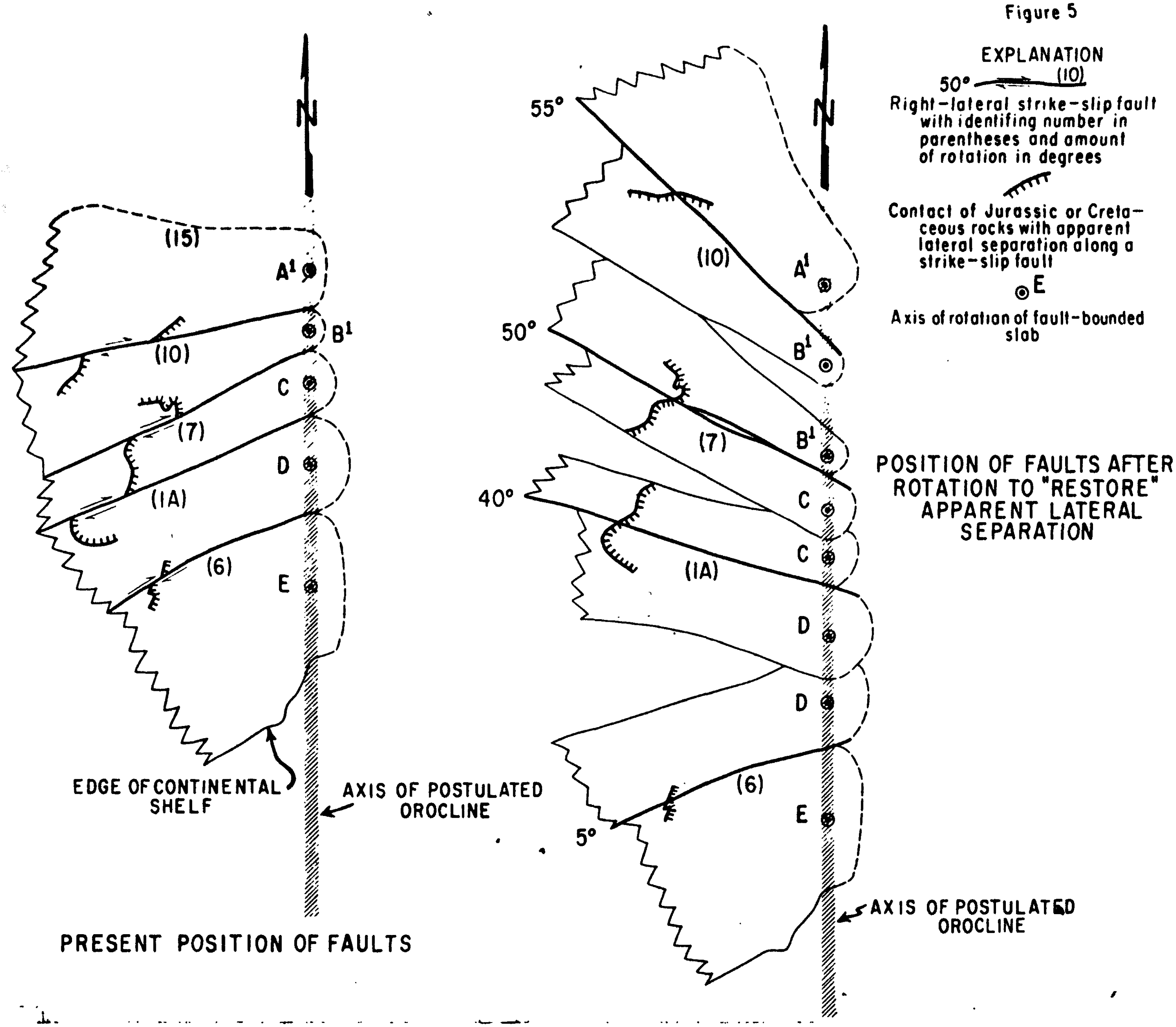

Figure 5. A simplified mechanical model to estimate the amount of rotation required to "restore" the apparent lateral separations found along the known and suspected large strike-slip faults in the active west limb of the postulated Alaska orocline. The west limb of the orocline in central Alaska is assumed, because of the straightness of the faults which help to define it there, to have deformed in a manner analogous to chevron folds. The lateral separations were "restored" by independently rotating the fault-bounded slabs adjacent to each fault until the offset along the fault was eliminated. The slabs were rotated about pivot points situated on the axial trace of the orocline halfway between the bounding faults. The pivot points were free to move along the axis of the orocline; their actual behavior could be represented only if the internal deformation of the interfault slabs could also be modelled. In the absence of known bounding faults, the northern and southern slabs were bounded by the Kobuk Trench and the continental slope.

Figure 6

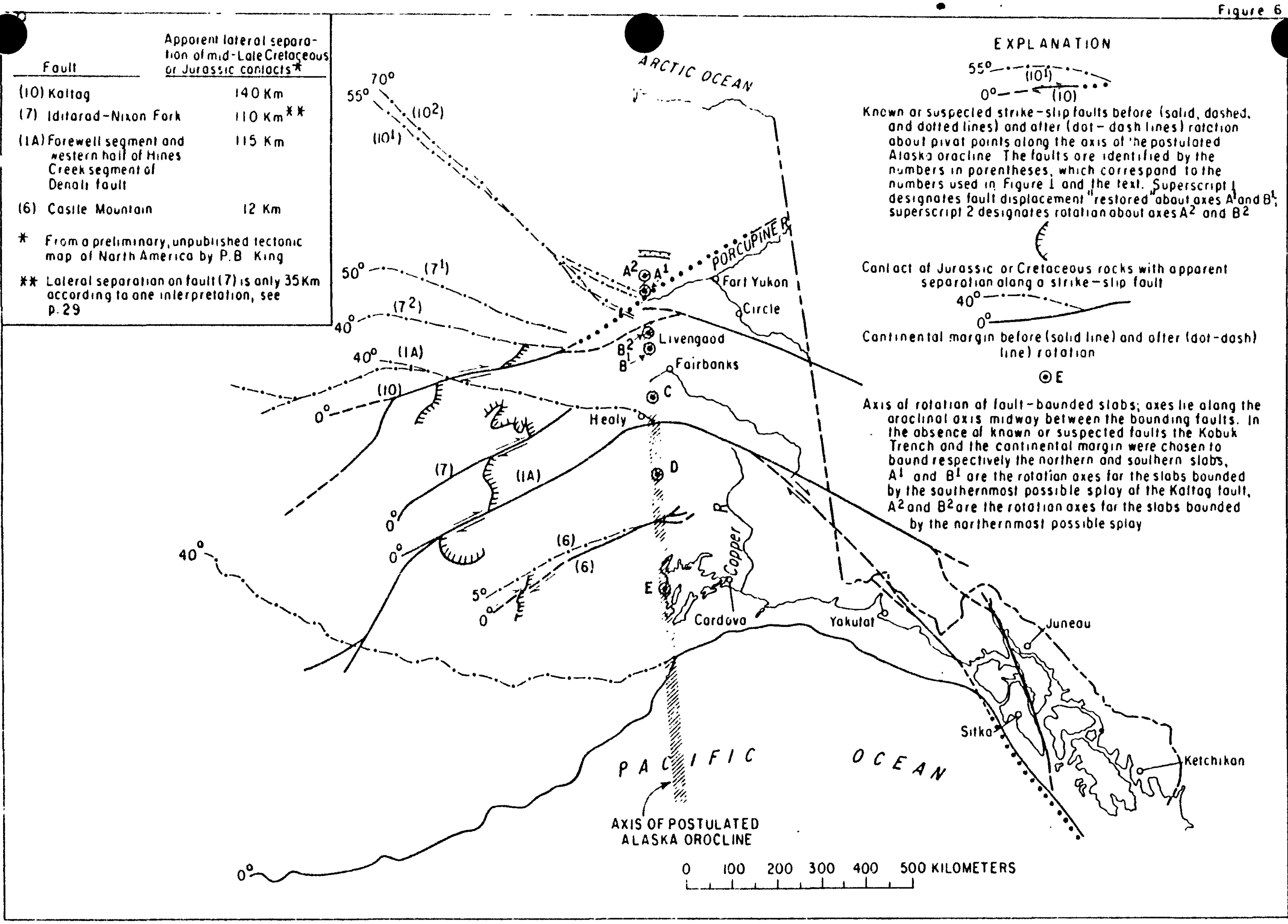

Figure 6. Position of known and suspected large strike-slip faults and of the continental margin in western Alaska before and after rotation in the active west limb of the postulated orocline, according to the model of chevron fold-like bending. Rotation was in the amount necessary to restore the apparent lateral separations of Jurassic or Cretaceous contacts along the faults. Figure 5 shows the simplified mechanical model by which the amount of rotation required to restore the apparent lateral separations was estimated to the nearest 5 degrees.

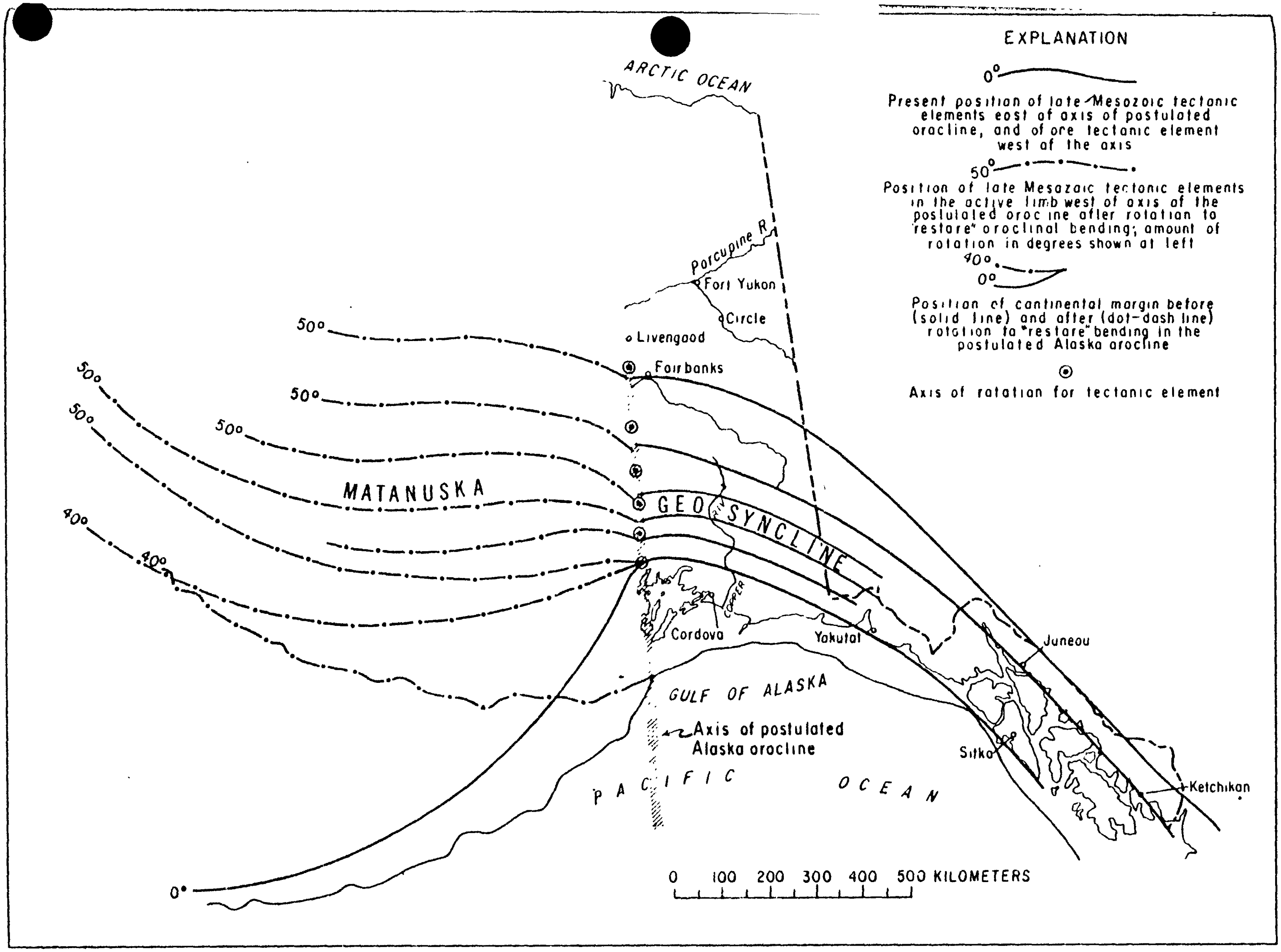

Figure 7. Position of late Mesozoic tectonic elements of southern central Alaska after rotation in the active west limb of the postulated Alaska orocline. Rotation of 50°, the median amount of rotation suggested by mechanical restoration of the apparent lateral separations along the faults, straightens the sharply curved Mesozoic tectonic elements, as well as the trend of the continental slope. The position of the late Mesozoic tectonic elements is after Miller, Gryc, and Payne (1959, pl. 2.). The present position of only the southernmost tectonic element is shown west of the postulated orocline axis; the present position of the other elements west of the axis is shown on figures 3 and 4. The Matanuska geosyncline is identified for reference.

the Kobuk trench or some other structure, rather than the Kaltag fault. However, data to evaluate these and other possible difficulties are not at hand. Accordingly, the simplified mechanical model is not presented to proclaim a theory of oroclinal strain, but merely to report a geometric observation which seems to relate a few of the presently available data on the large strike-slip faults of southern central Alaska.

There are also some inconsistencies within the data suggesting oroclinal folding, such as the relatively small lateral offset along the Castle Mountain fault. Perhaps this can be explained by assuming that this fault formed only during the last 7° of oroclinal rotation. Also, 39° of rotation (as on the Farewell fault, 1A) brings the Kaltag fault into better alignment with the homologous Tintina fault (14) than the 50° rotation suggested by the lateral separation along the Kaltag fault itself. This can be considered on one hand to be another difficulty, or on the other, to be evidence for continued post-oroclinal slip on the Kaltag trend which extended into the Yukon Flats. Also the presently recognized zones of tight structure (or compression) in the axial region of the postulated oroclinal bend are not located at the places of expected maximum compression on the south side of the fault-bounded rotated slabs, if the simplified mechanical model is taken literally. On the other hand, broad-scale oroclinal bending would likely have been accompanied by major inter-block deformation, and local stress concentrations may have been dissipated throughout the axial region. This dissipation of localized compressive stresses would be aided by the overall compression in the axial region implied by the model, and by major geologic inhomogenieties in the crust. Thus, the large batholiths of the Talkeetna Mountains may be ample explanation for the fact that the greatest Laramide compression in that region occurs south of the batholith, in the belt of thick Mesozoic and early Tertiary sedimentary rocks in the Matanuska Valley. Despite these and other discrepancies, however, a modified form of Carey's Alaska orocline is a hypothesis which deserves further consideration because it seems to relate a number of major geologic structures in Alaska.

The age of the postulated oroclinal bending would most likely have been late Cretaceous to early Tertiary. The faults west of the axial trace cut late Cretaceous rocks and one of them (the Castle Mountain fault) has a major branch which juxtaposes unlike Late Cretaceous facies, offsets Paleocene rocks, and is cross-cut by an intrusive plug of Eocene or Oligocene age. Another (the Hines Creek fault) cuts Paleocene rocks west of the axial trace of the postulated orocline, but is overlapped by them east of the trace. In addition, three of the faults are offset or deflected by faults of probable mid-Tertiary age in southwestern Alaska. The early Tertiary was a time of major paleogeographic change in Alaska, as elsewhere in North America, and a time of major thrust faulting in northern Alaska (Lathram, 1965). Early Tertiary virtual geomagnetic poles are also the youngest which fail to cluster within the present circumpolar region because the poles from some subcontinental areas are clearly divergent from those in others (Irving, 1964, p. 106-110).

Some implications of oroclinal bending.--If the postulated oroclinal bending occurred, it would have affected the entire crust and probably the upper mantle; and if it bent the late Mesozoic tectonic elements, it would also have bent the continental slope. Thus, if a substantial part of the present continental slope is basically as old as the postulated orocline, its form in plan should reflect oroclinal bending. This hypothesis has some implications which are worth exploring, provided the reader remembers its conjectural basis.

The continental slope between the Gulf of Alaska and Cape Navarin, which lies between the Gulf of Anadyr and the Bering Sea, follows a rather smooth semicircular curve that is convex to the south and is bounded east and west by reentrant angles in the trend of the continental slope (see fig. 8). The reentrant angle near Cape Navarin is similar to that in the Gulf of Alaska, although it bends a little more sharply, and a generalized Soviet tectonic map (Akademiya Nauk, 1963) shows some geologic units and faults near Cape Navarin and the Gulf of Anadyr that seem to follow the bend in the continental slope. Possibly these features are a clue to the existence of another oroclinal bend, complementary to the Alaska orocline, with an axial trace striking northerly and lying a little west of Cape Navarin. Such complementary oroclines could represent "hinge" zones between which the semicircular bulge of the continental margin between the Gulf of Alaska and Cape Navarin drifted southward over the Pacific basin and the oceanic crust (or "oceanized" continental crust) of the Aleutian basin of the Bering Sea. The possible existence of a complementary orocline near Cape Navarin has particular relevance to theories which incorporate the Alaska orocline into patterns of deformation presumed to be a consequence of continental drift. If the postulated Alaska orocline is an isolated feature, straightening of the bend would require 40°-50° of rotation of North America at the orocline. Only 28° of such rotation is necessary, however, to close the gap between Labrador and Ireland (Carey, 1955, p. 271-272). The larger rotation would be

Figure 8

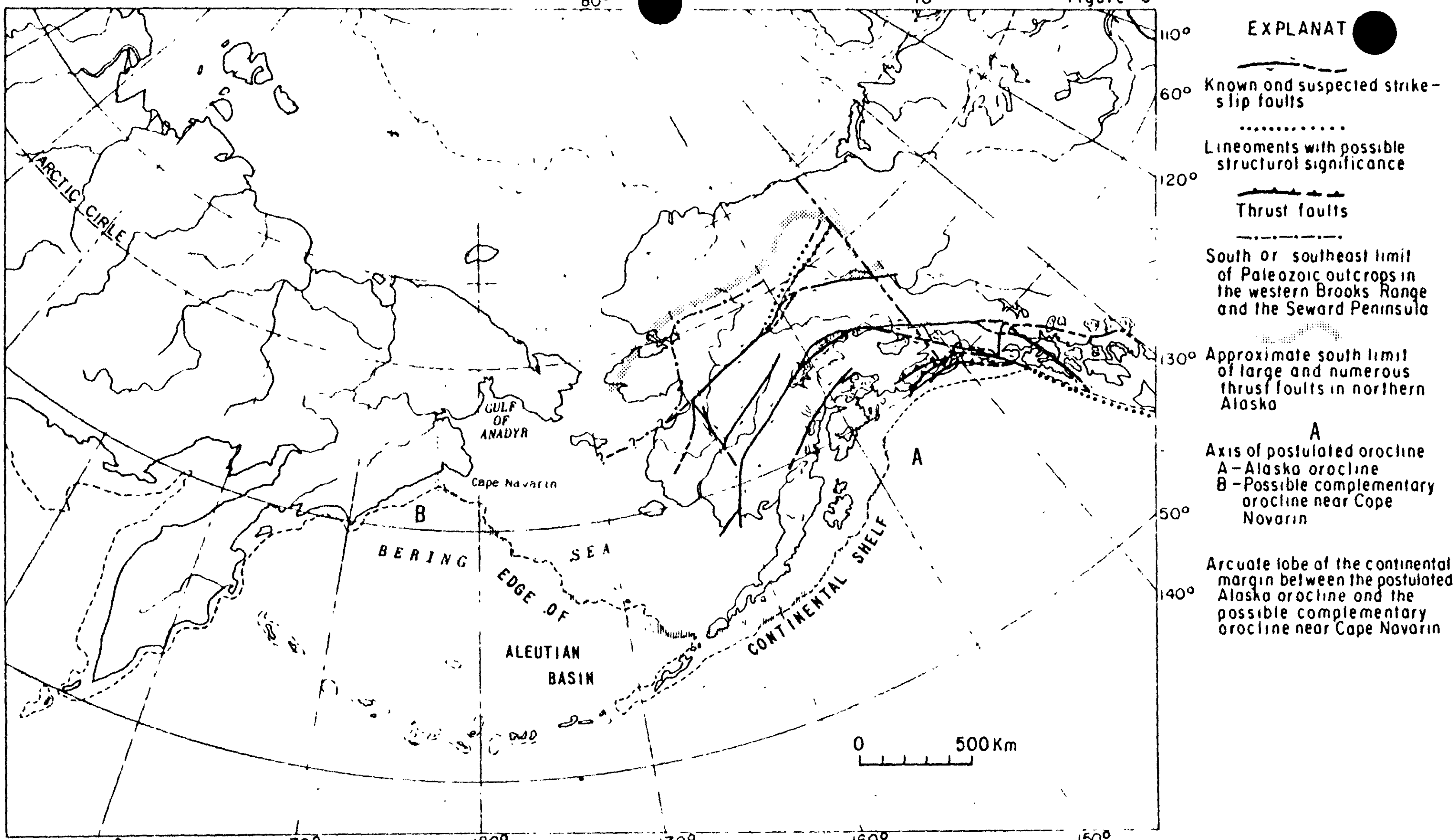

Figure 8. Relation of the postulated Alaska orocline to known and suspected large strike-slip faults in Alaska, deformation in northern Alaska that is possibly related to east-west shortening that would have accompanied development of the orocline, and the arcuate lobe of the continental margin between the Gulf of Alaska and Cape Navarin. Also shown is the position of a possible complementary orocline near Cape Navarin.

difficult to accomodate in any simple scheme of continental drift involving rotation. On the other hand, if a complementary and more or less contemporaneous orocline exists to the west, then the Alaska orocline would be but one limb of a relatively local buckle, rather than a bend whose limbs are entire continents. Such a buckle could have resulted from longitudinal drift of North America relatively toward Asia, and rotation of North America would not be a necessary consequence of oroclinal bending in Alaska. Such rotation would not be precluded, however, and it could well have accompanied local buckling. On the other hand, Moore (1965) attributes the bulge in the continental margin between Alaska and Asia to a "pucker" on the inside of a bend ("an Alaskan hinge") between North America and Asia.

A principal consequence of bending in the postulated orocline would be shortening normal to its axial plane. Therefore, the fact that the large faults and curved tectonic elements which suggest bending in southern and central Alaska appear to be absent in northern Alaska is a major difficulty[7/]. Some regional structural trends in northern Alaska possibly represent, however, east-west shortening of that area which is perhaps related to shortening in the postulated orocline. These features are shown on figure 8, and in part on figure 1. One is the south boundary of Paleozoic rocks in the Brooks Range, which is rather sharply kinked where it skirts the Seward Peninsula in western Alaska; the other is the south limit of large and numerous

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7/The identity and position of the late Mesozoic tectonic elements in northern Alaska, (as interpreted by Miller, Gryc, and Payne, 1955, pl. 2, see figure 3 of the present report) will have to be considerably revised, according to recent reports by Jones and Grantz (1964) and Lathram (1965). However it is thought that the revisions will not alter the conclusion that the trend of the tectonic elements of northern Alaska does not conform to the trend of the curved tectonic elements to the south.

thrust faults within the Brooks Range. Possibly the "kinked" contact and the path of the south limit of the thrusts (which in a general way also reflect the trend of other major geologic and topographic features across northern Alaska and northwesternmost Canada) represent east-west shortening. The relation of the thrust belt and other Brooks Range structures to the Tintina and Kaltag faults and to the Yukon Flats lineament and fault is suggestive of regional drag related to relative eastward translation on these faults, and the "kinking" of the Paleozoic contact could also represent east-west shortening associated with north-south extension. If these structures represent the postulated deformations, it could explain the change in tectonic style north of the Kaltag-Tintina fault zone. It also raises the question as to whether or not a structure which played an important role in the Laramide deformations of Alaska underlies the critically situated Kobuk trench.

An additional, although minor, consequence of the postulated oroclinal bending exists if the present continental slope off southwestern Alaska is, in general, as old as the orocline. In that case the narrowest part of the continental connection between Eurasia and North America, which lies along the oroclinal axis, was localized between the active limb of the orocline to the west, and the passive limb and the main mass of North America to the east.

Conjugate strike-slip fault systems

Yukon delta region.--The numerous conjugate right- and left-lateral strike-slip faults of the Yukon delta region (9) have acted to shorten this area along a west-northwest, east-southeast axis. The shortening ccurred between mid-Late Cretaceous and Plio-Pleistocene time, and is likely to have been of mid-Tertiary age. The axis of this shortening (see rose diagram, fig. 1) is normal to the adjacent portion of the Aleutian arc, which is considered to have been shaped by forces directed normal to its trend. If the parallelism of the axis of shortening in area (9) to a normal from the adjacent part of the Aleutian arc means that the conjugate faults and the arc were shaped by the same regional stress system, it would have important implications for theories of island arc tectonics. But it must first be demonstrated that the geometry and contemporaneity of the conjugate faults is widespread in southwestern Alaska, that their arrangement is in general compatible with shortening normal to the arc, and that the age of the conjugate faults indeed overlaps the time span of the arc.

Possible conjugate system of deep lineaments.--An alternative to the hypothesis of oroclinal folding to explain the trend of large faults across Alaska is suggested by the straightness of most of the faults and fault segments, and by the intermingling of east-southeast trending faults and east-northeast trending lineaments northeast of the Tanana River (see fig. 1). These lineaments are rather vague features; one (12) is physiographic and possibly reflects a deep structure beneath relatively undisturbed near-surface rocks, the other (13) is a fault and an old structural line that was apparently first active during the mid- or late Paleozoic. These lineaments occur in the area of east-southeast trending right-lateral faults in eastern central Alaska, but east-southeast trending counterparts have not been recognized in the area of east-northeast trending faults in western central Alaska.

The intermingling northeast of the Tanana might indicate that a conjugate set of faults or structural lines trending east-southeast and east-northeast lies within the crust of central Alaska, and that these faults or linears are expressed at the surface only locally, where trailed by later deformations. In this case the apparent bending of the present faults could merely be the result of selective trailing of suitably situated older faults or structural lineaments by younger "rotational" right-lateral slip, rather than the result of oroclinal folding. This model requires a long history of activity on these faults, which has indeed been demonstrated for many of them. However, intermingled diversely trending faults and lineaments must be recognized beyond the region northeast of the Tanana River before this hypothesis will have serious geologic support. It is possible that an old, conjugate fault and lineament system exists, but that it is disguised by Mesozoic and Cenozoic formations and deformations. On the other hand, of the features northeast of the Tanana which suggest intermingling, the Stevens Creek fault zone (11) may simply be a splay of the Kaltag fault (10), and the faulting along the Yukon Flats lineament (13) may be a northeastern continuation of faulting on the Kaltag trend that occurred at a late stage of regional (oroclinal) bending, possibly guided by Paleozoic structural lineaments in the Yukon Flats area. Evaluation of these and more elaborate alternatives, and of the possibility that the Kobuk trench is an offset extension of the Tintina trench, will require more modern geologic mapping than is now available in the large region between the lower Tanana River and the Brooks Range.

The Fairweather fault and the continental slope off southeastern Alaska

The Fairweather fault is the northeast limit of Cenozoic marine "soft" rocks along the Gulf of Alaska, and its inferred southeast extension seems to separate the wide continental shelf of the gulf, which is underlain by the Cenozoic sediments, from the narrow and rocky shelf off southeastern Alaska, which is underlain by hard Mesozoic and Paleozoic rocks. If this inference is correct, the southeastward extension of the Fairweather fault follows the straight continental slope off southeastern Alaska, and may cross-cut the important but older Chatham Strait strike-slip fault. The Chatham Strait fault must strike south from Chatham Strait to pass west of the Hazy Islands on the continental shelf, because these islands belong lithologically with the rocks in southeastern Alaska that lie east of the fault (L. J. P. Muffler, oral communication, 1965). Unless this strike-slip fault swings southeast seaward of the Hazy Islands, it must form an angular junction with the straight continental slope off Chatham Strait without offsetting it. The possibility that the Chatham Strait fault is cut off at the continental slope, together with the differences in geology, width, and trend of the continental shelf east and west of the Fairweather fault, suggest that during the late Cenozoic 1) very large lateral displacement along the inferred offshore extension of the Fairweather fault post-dated large lateral slip on the Chatham Strait fault; or 2) southeastern Alaska overthrust the North Pacific basin or the basin underthrust southeastern Alaska subsequent to large lateral slip on the Chatham Strait fault.

The first alternative is supported by Recent right-lateral slip along onshore portions of the Fairweather fault, but very large late

Cenozoic lateral slip has yet to be demonstrated. The second alternative seems to be supported locally by 5 km of late Pliocene to Recent uplift of the terrane northeast of the fault. However the uplift is related to late Cenozoic elevation and thrusting of the coastal mountains, which it follows around the Gulf of Alaska, rather than to the Fairweather fault, which trends into the interior near the east end of the gulf. Therefore a combination of thrusting related to processes at the continental margin, and not to uplift at the Fairweather fault, and right-lateral movement related to lateral slip on the Fairweather fault, appears to best explain the apparently angular junction of the Chatham Strait fault with the continental margin and the differences in the continental shelf east and west of Fairweather fault.

Possible sequence of fault-related deformations

The facts and speculations concerning the known and suspected strike-slip faults of Alaska can be fitted into a tentative, incomplete chronology of deformations spanning most of Cenozoic time. The chronology contains a large measure of speculation, but the implications of the inferences will be more apparent if they are arranged in historical order.

1. The great faults of central Alaska were in existence by latest Cretaceous and Paleocene time, and may have originated in part as paleogeographic features and faults with vertical displacements, or as a system of nearly straight, through-going strike-slip faults.

2. These faults may have been bent in an orocline from the Late Cretaceous to the Eocene or Oligocene. Concurrently, the late Mesozoic (including the latest Cretaceous) tectonic elements of Alaska and its southern continental margin, may also have been bent along the same axial trace.

3. Conjugate strike-slip faults in the Yukon delta region, and sinistral strike-slip faults in southwestern Alaska that acted with the through-going right-lateral faults, appear to have shortened southwestern Alaska along an east-southeast striking axis, and to have deflected or offset some of the through-going strike-slip faults.

4. The Aleutian arc was superimposed obliquely across already arcuately trending late Mesozoic tectonic elements in southwestern Alaska during the Cenozoic, and many of its prominent topographic features formed in Plio-Pleistocene time.

5. The present mountains of central and southern Alaska are Pliocene and Quaternary features that owe their arcuate form largely to superposition and intersection of Aleutian arc trends upon Cordilleran trends in south-central Alaska.

6. Late Cenozoic right-lateral slip from the Pacific margin reached interior Alaska by following the trend of the straight continental slope off southeastern Alaska and British Columbia, and was there superimposed upon the central portion of the Denali fault. This displacement takes the shortest, straightest path to interior Alaska from the continental shelf off southeastern Alaska by following the Fairweather fault and its inferred extension along the north flank of the Wrangell Mountains; and it "short-circuits" the longer route along the older faults that comprise the eastern part of the Denali fault system.

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