The Geology of North America
Vol. G-1, The Geology of Alaska
The Geological Society of America, 1994

Chapter 9

Geology of southwestern Alaska

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INTRODUCTION

Southwest Alaska lies between the Yukon-Koyukuk province to the north, and the Alaska Peninsula to the south (Wahrhaftig, this volume). It includes the southwestern Alaska Range, the Kuskokwim Mountains, the Ahklun Mountains, the Bristol Bay Lowland, and the Minchumina and Holitna basins. It is an area of approximately 175,000 km^2, and, with the exception of the rugged southwestern Alaska Range and Ahklun Mountains, consists mostly of low rolling hills.

The oldest rocks in the region are metamorphic rocks with Early Proterozoic protolith ages that occur as isolated exposures in the central Kuskokwim Mountains, and in fault contact with Mesozoic accretionary rocks of the Bristol Bay region. Precambrian metamorphic rocks also occur in the northern Kuskokwim Mountains and serve as depositional basement for Paleozoic shelf deposits. A nearly continuous sequence of Paleozoic continental margin rocks underlies much of the southwestern Alaska Range and northern Kuskokwim Mountains. The most extensive unit in southwest Alaska is the predominantly Upper Cretaceous Kuskokwim Group, which, in large part, rests unconformably on older rocks of the region. Volcanic rocks of Mesozoic age are common in the Bristol Bay region, and volcanic and plutonic rocks of latest Cretaceous and earliest Tertiary age are common throughout southwest Alaska.

Two major northeast-trending faults are known to traverse southwest Alaska, the Denali-Farewell fault system to the south, and the Iditarod–Nixon Fork fault to the north. Latest Cretaceous and Tertiary right-lateral offsets of less than 150 km characterize both faults. The Susulatna lineament (or Poorman fault), north of the Iditarod–Nixon Fork fault, juxtaposes contrasting Early Cretaceous and older rocks and may have had significant Cretaceous

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Decker, J., Bergman, S. C., Blodgett, R. B., Box, S. E., Bundtzen, T. K., Clough, J. G., Coonrad, W. L., Gilbert, W. G., Miller, M. L., Murphy, J. M., Robinson, M. S., and Wallace, W. K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H. C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1.

lateral displacement. The Mulchatna fault, south of the Denali-Farewell fault system roughly corresponds to a pronounced aeromagnetic discontinuity and is likely to be a major basement fault.

The rocks of southwest Alaska (Fig. 1) can be grouped into three contrasting assemblages: (1) the predominantly Paleozoic continental margin rocks of the southwestern Alaska Range and northern Kuskokwim Mountains (Farewell terrane, defined below), (2) the predominantly Mesozoic accretionary rocks of the

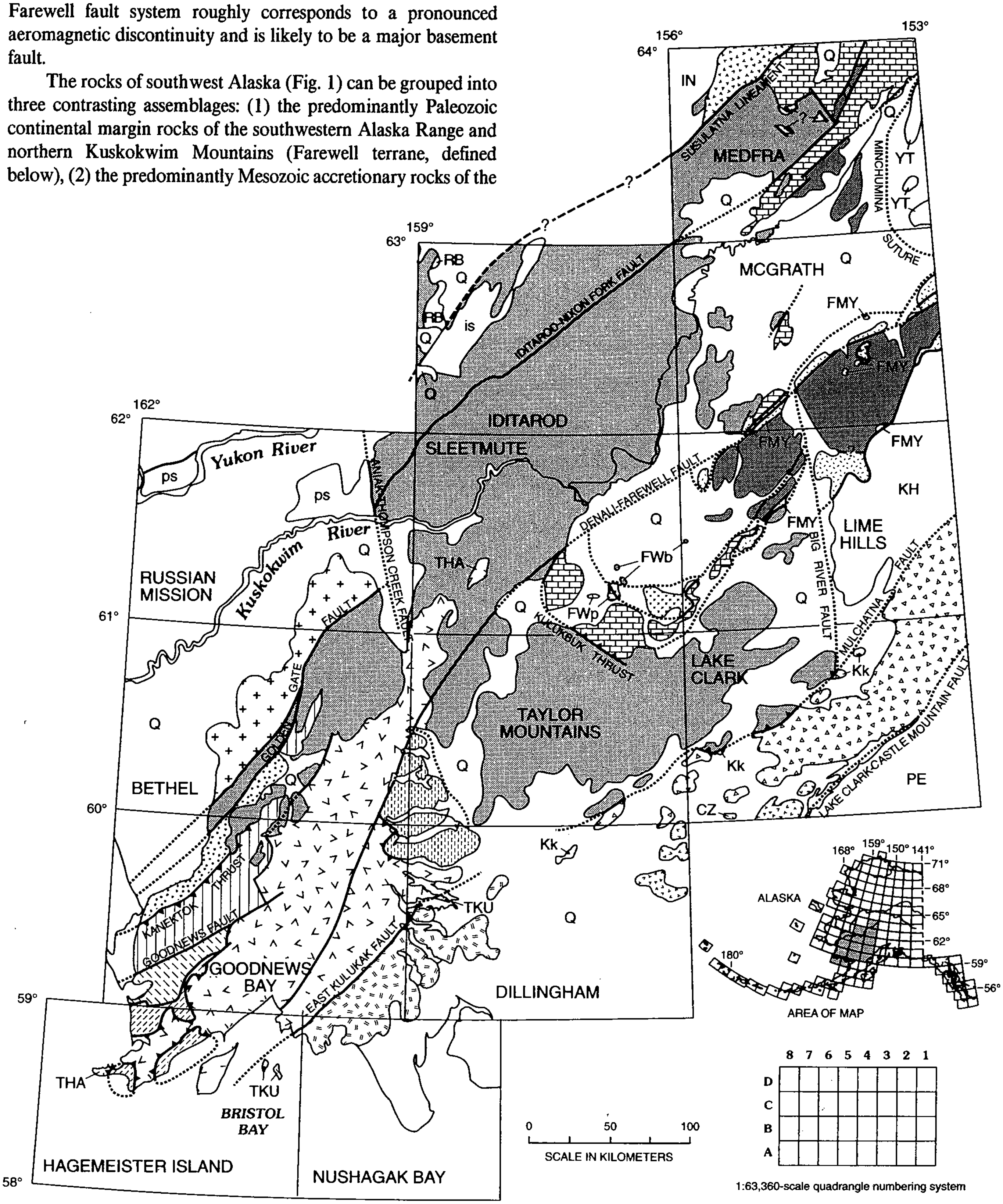


Figure 1. Tectonostratigraphic terrane map of southwestern Alaska showing the names of 1:250,000 scale quadrangles and the 1:63,360-scale quadrangle numbering system.

northern Bristol Bay region, and (3) postaccretionary clastic sedimentary rocks and mainly calc-alkaline volcanic and plutonic rocks that tie together assemblages 1 and 2. In order to establish a framework for discussion of these rocks, we have consolidated previously described tectonostratigraphic terranes (Jones and Silberling, 1979; Jones and others, 1981) in the southwestern Alaska Range and northern Kuskokwim Mountains, and subdivided the terranes of the Bristol Bay region. In the southwestern Alaska Range and northern Kuskokwim Mountains, sufficient stratigraphic information is now known to allow genetic relations to be established between previously defined terranes and to allow a more conventional stratigraphic approach to our discussion of the geology in this area. In the Bristol Bay region, however, many critical stratigraphic relations are unclear and our discussion of these rocks follows the tectonostratigraphic subterrane framework defined for this area by Box (1985). We believe that this somewhat different format for each area allows the best overall treatment of the geology of southwest Alaska.

EXPLANATION

OVERLAP ASSEMBLAGES

Q Quaternary Surficial Deposits

K Kuskokwim Group

Cz Cenozoic Deposits

TERRANES OF SOUTHWEST ALASKA

Alaska Range and Kuskokwim Mountains

Farewell Terrane

FMY Mystic Sequence

White Mountain Sequence

FWb Basinal Facies

FWt Transitional Facies

FWp Platform Facies

Bristol Bay Region

NY Nyack Terrane

Togiak Terrane

THA Hagemeister Subterrane

TKU Kulukak Subterrane

Goodnews Terrane

GNU Nukluk Subterrane

GTC Tikchik Subterrane

GPT Platinum Subterrane

GCP Cape Pierce Subterrane

KI Kilbuck Terrane

ADJACENT TERRANES

KH Northern Kahiltna Terrane

Kk Southern Kahiltna Terrane

MC McKinley Terrane

PE Peninsular Terrane

IN Innoko Terrane

PN Pingston Terrane

RB Ruby Terrane

YT Yukon-Tanana Terrane

UNITS OF UNCERTAIN TERRANE AFFINITY

is Idono Sequence

ps Portage Sequence

Contact

? Fault—Dashed where approximate, dotted where concealed, queried where uncertain.

Thrust fault—Dotted where concealed. Sawteeth on upper plate.

SOUTHWESTERN ALASKA RANGE AND NORTHERN KUSKOKWIM MOUNTAINS

The predominantly Paleozoic and Mesozoic rocks of the southwestern Alaska Range and northern Kuskokwim Mountains that are discussed in this chapter include parts of the Nixon Fork, Dillinger, and Mystic terranes, which Silberling and others (this volume) and Jones and Silberling (1979) originally defined as discrete, fault-bounded tectonostratigraphic terranes. Although these terranes have distinctive stratigraphies, several other authors have suggested that the Nixon Fork and Dillinger terranes consist instead of contrasting facies that were deposited within a single depositional basin (Bundtzen and Gilbert, 1983; Blodgett, 1983a; Blodgett and Gilbert, 1983; Gilbert and Bundtzen, 1983a; Blodgett and Clough, 1985), and that rocks of the Mystic terrane were deposited on rocks of the Dillinger terrane (Gilbert and Bundtzen, 1984). Recently, the identification of interfingering relationships and transitional or slope facies between the platform deposits of the Nixon Fork terrane, and the basinal deposits of the Dillinger terrane have been recognized in the White Mountain area (Gilbert, 1981; Blodgett and Gilbert, 1983), in the western Lime Hills and eastern Sleetmute Quadrangles (Blodgett and others, 1984; Clough and Blodgett, 1985; Smith and others, 1985), and in the Minchumina basin (M. W. Henning, written commun., 1985). Because genetic relationships exist among the Nixon Fork, Dillinger, and Mystic terranes, we herein redefine them as the Farewell terrane, comprising the White Mountain and Mystic sequences (Fig. 2).

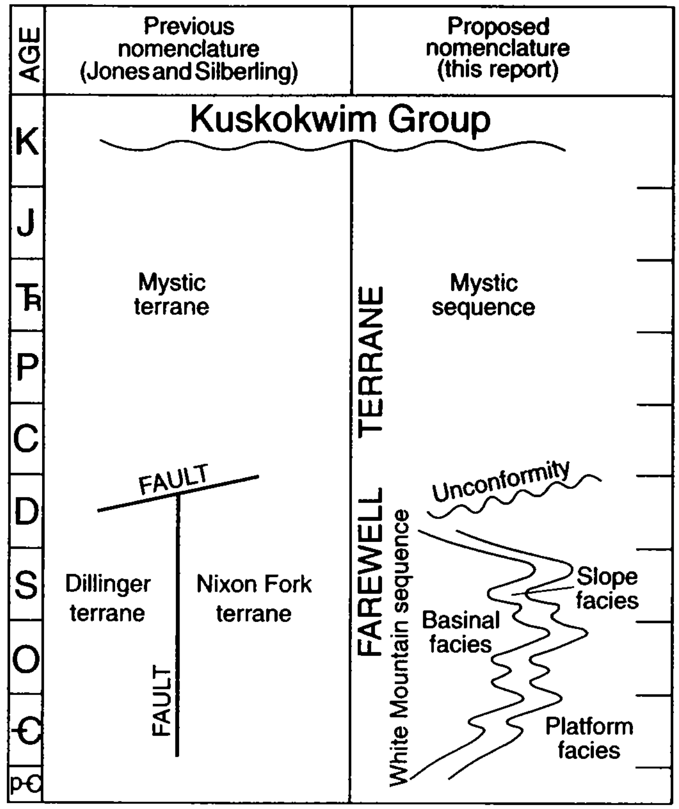


Figure 2. Farewell terrane terminology and relationships. This diagram compares the terminology proposed in this report with the terrane nomenclature of Jones and Silberling (1979). The figure schematically illustrates the genetic relations between the basinal facies (Dillinger terrane) and the platform facies (Nixon Fork terrane), and the unconformable relationship between the Mystic sequence and the White Mountain sequence. See text for discussion.

Farewell terrane

Definition. The Farewell terrane (Figs. 2 and 3) consists of a coherent but locally highly deformed lower Paleozoic through Lower Cretaceous continental margin sequence, deposited, in part, on Precambrian basement, and locally overlain by Cretaceous and Tertiary volcanic and sedimentary rocks. The Farewell terrane is divided into two distinctive sequences: (1) the White Mountain sequence, which consists of Middle Cambrian through Middle Devonian stable continental margin deposits; and (2) the overlying Mystic sequence, which consists of a highly variable assemblage of rocks of Late Devonian through Early Cretaceous age. We use the term "sequence" in roughly the same sense as "stratigraphic sequence" defined by Sloss (1963) and "depositional sequence" defined by Mitchum and others (1977). We define a sequence as a regionally extensive stratigraphic unit or body of rock bound above and below by unconformities or their correlative conformities.

White Mountain sequence. The White Mountain sequence is named for a well-exposed section near White Mountain in the McGrath A-4 Quadrangle. At White Mountain, three principal facies are recognized: a shallow-marine platform facies, a deep-marine basinal facies, and a transitional or slope facies. Historically, sections consisting predominantly of platform deposits have been called the Nixon Fork terrane (Patton, 1978; Jones and others, 1981) and sections consisting predominantly of basinal deposits have been called the Dillinger terrane (Jones and Silberling, 1979; Jones and others, 1982). In this chapter, we do not use the Nixon Fork and Dillinger terrane terminology; instead, we consider them together as comprising the White Mountain sequence.

Mystic sequence. The upper sequence is here designated the Mystic sequence. It includes rocks of the Mystic terrane of Jones and Silberling (1979) and age-equivalent rocks that overlie the White Mountain sequence. The Mystic sequence represents less stable tectonic conditions and more diverse local depositional environments than those in the White Mountain sequence. Facies relations between rock units within the Mystic sequence are poorly understood, but the upper and lower boundaries of the sequence are well defined. The Mystic sequence is stratigraphically bounded by the two most persistent units in southwest Alaska: the White Mountain sequence below and the Kuskokwim Group above. At most observed sites, the depositional contact between the Mystic and White Mountain sequences is an angular unconformity of Middle Devonian age, although apparently conformable relationships have been reported (Blodgett and Gilbert, 1983; Patton and others, 1984a). The upper boundary of the Mystic sequence with the Kuskokwim Group is a major angular unconformity of latest Early Cretaceous age that commonly cuts completely through the Mystic sequence into strata of the underlying White Mountain sequence. Further work may show that some of the wide variety of rocks we include within the Mystic sequence are tectonic slivers or independent terranes with no depositional link to rocks of the underlying White Mountain sequence. For this report, however, we include within the Mystic sequence all rock types of Late Devonian through Early Cretaceous age within the Farewell terrane that overlie the White Mountain sequence and/or underlie the Kuskokwim Group.

The main outcrop belt of the Mystic sequence (and type area of the Mystic terrane of Jones and Silberling, 1979) occurs in the Talkeetna Quadrangle (Nokleberg and others, this volume, chapter 10) where it is bounded on the north by the Denali-Farewell fault, and on the south by the Shellabarger fault (Jones and others, 1983). In this region, the Mystic sequence contains three fault-bounded assemblages (Jones and Silberling, 1979). The oldest, structurally lowest, and southernmost unit is a tectonic mixture (melange) composed of infolded and faulted blocks of typical White Mountain sequence lithologies, including Ordovician graptolitic shale, Silurian massive algal limestone, and pillow basalt (Bundtzen and Gilbert, unpublished 1983 field data). On the basis of stratigraphic and structural position, the melange most likely formed in post–Early Devonian time. To the north, structurally overlying these rocks, are strongly folded, partly coherent sanstone, gritstone, and limestone of Late Devonian age, phosphatic black radiolarian chert of latest Devonian and Mississippian age, and green chert and argillite of Pennsylvanian age (Jones and Silberling, 1979). The highest and most extensive unit is a thick, disrupted, flysch-like sequence containing minor chert, and thick, pebble to boulder conglomerate lenses containing clasts of limestone and black cherty argillite (Jones and Silberling, 1979). Permian plant fossils are known from one locality in the Talkeetna Quadrangle.

Description of key areas. *White Mountain area.* The White Mountain sequence (Fig. 3) is well exposed north of the Farewell fault in the Cheeneetnuk River area, near White Mountain in the McGrath A-4 and A-5 Quadrangles. There, Gilbert

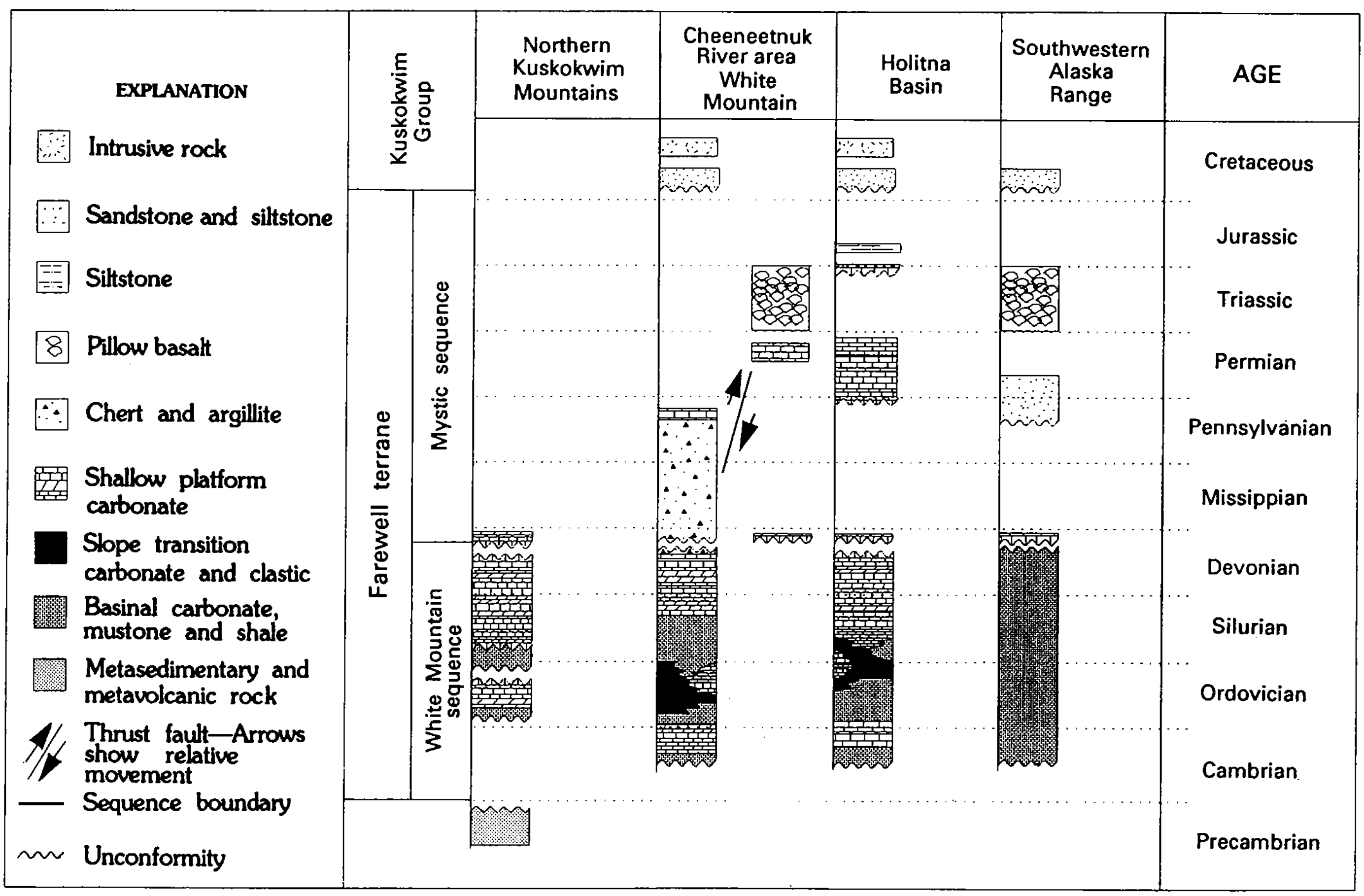


Figure 3. Generalized stratigraphic sections of the Farewell terrane showing the lithofacies variations within the White Mountain sequence. The Kuskokwim Group, the Mystic sequence, and the White Mountain sequence are separated by major interregional unconformities.

(1981) described a 6,000-m-thick sequence of Cambrian(?) through lower Middle Devonian rocks representative of marine shelf, slope, and basinal depositional environments. The oldest rocks in the Cheeneetnuk River area are of Cambrian(?) through Late Ordovician age and consist of oolitic limestone, banded mudstone, silty limestone turbidites, oncolitic algal limestone, and limestone breccia, representative of alternating deep-marine and shallow-marine depositional environments. The Upper Silurian through Middle Devonian strata consist of limestone and dolomite containing shallow-marine fauna, indicating relatively stable platform conditions. Fossils described from the region include Ordovician brachiopods (Potter and others, 1980) and Silurian conodonts (Savage and others, 1983) from White Mountain, and early Middle Devonian goniatites (House and Blodgett, 1982), sponges (Rigby and Blodgett, 1983), gastropods (Blodgett and Rohr, 1989), and the udotaecean alga *Lancicula sergaensis* Shuysky (Poncet and Blodgett, 1987) from the upper part of the Cheeneetnuk Limestone. Formal stratigraphic names remain to be applied in the White Mountain area, with the exception of the Cheeneetnuk Limestone (Blodgett and Gilbert, 1983), which is of Eifelian (early Middle Devonian) age in its upper part and forms the top of the platform carbonate succession in that area.

The White Mountain sequence in the White Mountain area is overlain by upper Paleozoic chert and argillite of the Mystic sequence. There the Mystic sequence consists of Middle(?) and Upper Devonian and Carboniferous deep-water argillite, siliceous shale, and chert, which depositionally overlie the platform carbonate rocks of the White Mountain sequence (Gilbert, 1981). Late Pennsylvanian trilobites occur in the McGrath A-5 Quadrangle and have been described by Hahn and others (1985) and Hahn and Hahn (1985). According to Blodgett and Gilbert (1983), the contact between the Cheeneetnuk Limestone at the top of the White Mountain sequence and the argillite and chert unit at the base of the Mystic sequence is abrupt, but apparently conformable.

Northern Kuskokwim Mountains. The White Mountain sequence in the northern Kuskokwim Mountains consists of a thick section of lower Paleozoic platform carbonate rocks that unconformably overlie metasedimentary and metavolcanic rocks of Precambrian age (Patton and others, 1984a; Silberman and others, 1979; Dillon and others, 1985). The metamorphic basement rocks consist of greenschist-facies pelitic schist, calc-schist, and metavolcanic rocks (Patton and others, 1984a). Dutro and Patton (1981) and Patton and others (1977), respectively, described stratigraphic sections for the lower and middle Paleozoic, and for the upper Paleozoic and Mesozoic in the White Mountain and Mystic sequences in the Medfra Quadrangle. Dutro and Patton (1982) later named four new formations with an aggregate thickness of more than 5,000 m (Novi Mountain, Telsitna, Paradise Fork, and Whirlwind Creek Formations) to encompass the Lower Ordovician through Devonian stratal sequence of the Medfra Quadrangle. As reported by Patton and others (1984a, p. 3–4). "Depositional environments range from mainly supratidal, characterized by laminated silty limestone in Lower Ordovician and Middle Devonian beds, to shallow marine, distinguished by a complex array of shallow-water carbonate facies that include reefoid bodies in the Upper Ordovician and Middle Devonian beds. Dark platy limestone and shale containing mid-Silurian graptolites indicate that deeper water paleoenvironments prevailed between Late Ordovician and Late Silurian time." Gastropods of late Early and early Middle Ordovician age (Rohr and Blodgett, 1988) and stromatoporoids of Middle or Late Ordovician age from the Medfra D-2 Quadrangle (Stock, 1981) support the shallow-water interpretation for rocks of these ages.

Rocks assigned to the Mystic sequence in the northern Kuskokwim Mountains include about 500 m of Permian, Triassic, and Lower Cretaceous (Valanginian to Albian) strata consisting of quartz-carbonate terrigenous sedimentary rocks and spiculitic chert beds that unconformably overlie metamorphic basement (Patton and others, 1984a). According to Patton and others (1984a, p. 4), "The relation of these terrigenous rocks [of the Mystic sequence] to the platform carbonate rocks [of the White Mountain sequence] is obscured by faulting. However, the debris which composes them clearly was derived, in large part, from erosion of the platform carbonate rocks."

Southwestern Alaska Range. The White Mountain sequence in the southwestern Alaska Range (Fig. 3) consists of a structurally complex assemblage of lower Paleozoic interbedded lime mudstone and shale, deep-water lime mudstone, and interbedded lithic sandstone and shale originally described by Capps (1926) along the Dillinger River in the eastern Talkeetna Quadrangle. In the southwestern Alaska Range, deep-marine strata correlative with the Dillinger River section occur south of the Denali-Farewell fault system in a wedge-shaped outcrop belt that broadens southwestward, where it grades into coeval slope facies, and platform carbonate rocks of the Holitna basin (Blodgett and Clough, 1985).

The following descriptions of stratigraphic relations within the White Mountain sequence in the southwestern Alaska Range are based on detailed field mapping by Gilbert (1981), Bundtzen and others (1982, 1985), Gilbert and others (1982), Gilbert and Solie (1983), and Kline and others (1986); and on measured sections by Armstrong and others (1977), Churkin and others (1977) and K. M. MacDonald (written commun., 1985). The presence of a rich graptolite succession allows for excellent biostratigraphic control.

The White Mountain sequence in the southwestern Alaska Range is a 1,400-m-thick section composed of five regionally persistent lithostratigraphic units: (1) Cambrian(?) and Ordovician rhythmically interbedded calcareous turbidites, shale, and minor greenstone; (2) Lower Ordovician to Lower Silurian graptolitic black shale and chert; (3) Lower and Middle Silurian laminated limestone and graptolitic black shale; (4) Middle and Upper Silurian lithofeldspathic sandstone turbidites and shale; and (5) Upper Silurian and Lower Devonian limestone, limestone breccia, sandstone, and shale (Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1983a; K. M. MacDonald, written commun., 1985). Collectively, these units represent a shallowingupward, deep basin to slope sequence (Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1983a, 1984). Twenty-one graptolite zones have been identified by Michael Churkin and Claire Carter (U.S. Geological Survey) from units 2, 3, and 4, which represents one of the most complete graptolitic successions in North America.

Middle Devonian through Lower Cretaceous rocks of the Mystic sequence occur locally throughout the McGrath and northern Lime Hills Quadrangles. These rocks vary widely across the region but, in general, include (1) upper Middle Devonian thick-bedded Amphipora-bearing limestone and massive dolomite, which interfinger with quartzose sandstone, (2) Upper Devonian shallow-marine limestone, (3) post-Devonian plant-bearing sandstone and limestone conglomerate, (4) Upper Pennsylvanian and Lower Permian fusulinid-bearing shallow-water clastic rocks, (5) Mississippian or Triassic chert and pillow basalt, (6) post-Carboniferous mafic intrusive and extrusive rocks, and (7) Triassic and Lower Jurassic clastic and mafic volcanic rocks (Gilbert, 1981; Bundtzen and Gilbert, 1983; Gilbert and others, 1982). This heterogeneous suite of post-Middle Devonian rocks is, in part, depositional on underlying rocks of the White Mountain sequence, indicating that the White Mountain and Mystic sequences form a single depositional succession (Gilbert and Bundtzen, 1984).

The White Mountain sequence in the southwestern Alaska Range is deformed by isoclinal to open folds with axes trending N10 to 40°E and is locally overturned to the northwest (Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1983b). Five major overturned isoclinal folds are responsible for at least 50 km of crustal shortening in the southeastern McGrath Quadrangle. Thrust faulting occurred concurrently with folding, but the amount of displacement along individual thrust planes is uncertain.

Holitna basin. The White Mountain sequence within the Holitna basin occurs in a broad, locally well-exposed outcrop belt in the Sleetmute, Taylor Mountains, and Lime Hills Quadrangles (Fig. 1). In the Sleetmute Quadrangle, it includes the Holitna Group (Cady and others, 1955), which is mapped in the Kulukbuk Hills and adjacent hills to the west and southwest. We estimate the White Mountains sequence to be at least 1,500 m and probably closer to 3,000 m thick. Cady and others (1955) recognized both Silurian and Devonian fossils in the upper part of the sequence, and suggested the undated lower part to be as old as Ordovician. Fossil collections made by the Alaska Division of Geological and Geophysical Surveys (ADGGS) during 1983 and 1984 establish the presence of Ordovician faunas in the Holitna basin (Blodgett and others, 1984). The oldest rocks in the basin are Middle Cambrian in age and are located along the axis of an anticline trending east-northeast in the southwestern corner of the Sleetmute A-2 quadrangle. Trilobites from these rocks were collected by Standard Oil Company and ADGGS geologists in 1984 from two closely spaced localities and are discussed in Palmer and others (1985). No Precambrian metamorphic basement rocks have been recognized in the Holtina basin.

A preliminary stratigraphic column for the White Mountain sequence of the Holitna basin is presented in Figure 3. In general, the oldest rocks (Middle Cambrian to Lower Ordovician) appear to be, at least in part, of deeper water character than the overlying Middle Ordovician to Middle Devonian carbonate succession. The deep-water nature of the older sequence is suggested by relatively thick intervals of graded carbonate debris flows, bedded chert, shale, and laminated lime mudstone lacking the abundant diverse benthic faunas typical of the overlying shallow-water platform carbonate sequence.

A Late Silurian to Early Devonian algal reef complex typically is developed along the outer edge of the carbonate platform (Blodgett and others, 1984; Blodgett and Clough, 1985; Clough and Blodgett, 1985). The reef complex is composed almost entirely of spongiostromate algae and locally is at least 500 m thick. Coeval cyclical lagoonal and peritidal environments were widely developed shoreward of the reef complex, and bear somewhat restricted faunas (Clough and others, 1984). The youngest Paleozoic fauna is of Eifelian (early Middle Devonian) age and is from the southeastern part of the Kulukbuk Hills (USGS collection 2688 mentioned in Cady and others, 1955, and recollected by the ADGGS). Fossils from this locality include brachiopod species also found in the upper part of the Cheeneetnuk Limestone of the McGrath A-4 and A-5 Quadrangles.

Along the Hoholitna River and in the vicinity of the Door Mountains, platform carbonate rocks appear to grade into coeval deeper water basinal rocks. This facies change is supported by (1) limestone debris flows that contain clasts apparently derived from the Late Silurian to Early Devonian algal reef complex, and (2) the close interdigitation of both shallow-water and deep-water facies near the interpreted outer edge of the carbonate platform.

Pennsylvanian and Permian brachiopods and Pennsylvanian foraminifera occur in coarse-grained fossil-rich detrital limestone interbedded with calcareous mudstone in the western Lime Hills Quadrangle (W. K. Wallace, unpublished data). These rocks are here considered part of the Mystic sequence. Late Triassic fossils have been collected from two localities in the Taylor Mountains Quadrangle, and are from units which most likely belong to the Mystic sequence. Rock units at these localities are silty lime mudstones bearing a diverse molluscan-rich fauna, accompanied by commonly occurring brachiopods (faunas identified by N. J. Silberling of the U.S. Geological Survey). Jurassic siliceous siltstone and volcanic conglomerate probably belonging to the Mystic sequence occur along the Stony and Swift Rivers in the western Lime Hills Quadrangle (Reed and others, 1985).

Minchumina basin. Within the Minchumina basin, a belt of the White Mountain sequence is exposed on several low rolling hills between the Iditarod–Nixon Fork and Denali-Farewell faults. Rocks within this belt consist mainly of laminated limestone and dolomitic limestone, dark gray chert, and siliceous siltstone, ranging in age from Ordovician to Middle Devonian (Patton and others, 1980). Platform carbonate rocks containing Late Ordovician (Ashgill) gastropods occur in the Lone Mountain region of the McGrath B-4 and C-4 Quadrangles (Rohr and Blodgett, 1985).

Poorly exposed sections of Mystic-like rocks cropout in low glacially scoured uplands north of the Farewell fault in the McGrath B-2, B-3, and C-1 Quadrangles. They consist of an undated clastic-carbonate sequence containing limestone breccia overlain by a fossiliferous Upper Devonian (Frasnian) limestone that is especially prominent at St. Johns Hill and immediately west of Farewell Mountain. The limestone units are overlain by bioclastic limestone of Permian age, then by chert-rich sandstone and ferruginous shale. The layered sequence is approximately 1,500 m thick, and is in probable fault contact with gabbro, pillow basalt, and chert, which yield both Mississippian and Triassic radiolaria (Kline and others, 1986).

Paleolatitude data

Sedimentological evidence from the White Mountain sequence of the Farewell terrane suggests that these rocks were deposited in warm, tropical latitudes. Evidence supporting this interpretation is primarily from the platform facies, and includes the presence of thick carbonate sections, the abundance of marine ooids in Ordovician and Silurian sedimentary rocks, and the presence of thick algal barrier reef complexes in Upper Silurian and Lower Devonian rocks. Supporting paleontological evidence includes the presence of green calcareous algae (Poncet and Blodgett, 1987) in shallow-water deposits. It also includes the paleobiogeographic affinities of the Alaskan Devonian faunas with those of the Cordilleran and Uralian regions of the Old World Realm (Blodgett, 1983a, 1983b; Blodgett and Gilbert, 1983), which are interpreted to have been located in equatorial climatic zones (Boucot and Gray, 1980, 1983). In addition, the Devonian gastropod are highly ornamented, as are present-day warm-water gastropod faunas, in contrast to the generally plain ornamentation of cold-water faunas.

Location of the Farewell terrane during Late Silurian and Early Devonian time in an equatorial humid belt, rather than in subequatorial arid to semiarid belts is suggested by the absence of evaporite deposits. The proposed low paleolatitudinal origin of the Farewell terrane is in agreement with similar positioning of the northwestern part of the North American continent based on Devonian lithofacies patterns (Heckel and Witzke, 1979; Boucot and Gray, 1980, 1983). However, the presence of distinctly Siberian faunas in the Middle Cambrian section of the Holitna basin (Palmer and others, 1985) suggests eastward longitudinal transport since Cambrian time, although the strongly Cordilleran affinities of the Lower and Middle Devonian faunas (Blodgett, 1983a) suggest that by that time, the Farewell terrane was affixed or closely adjacent to North America. This proximity during the Devonian is especially borne out by the Eifelian gastropod faunas of interior Alaska (known from rocks of the Farewell and Livengood terranes). These faunas belong to a single biogeographic entity, termed the Alaska-Yukon subprovince by Blodgett and others (1987), and are most closely allied with coeval faunas of western Canada and the Michigan basin.

Paleomagnetic data (Hillhouse and Coe, this volume) from Ordovician rocks of the White Mountain sequence have been discussed by Plumley and Coe (1982, 1983) and Vance-Plumley and others (1984). Their data suggest that the Farewell terrane had little or no major latitudinal displacement with respect to North America. This is concordant with our view, based on paleobiogeography and lithofacies trends. However, this does not discount the possibility of large-scale longitudinal transport.

Interpretation

Similarities between the major lithostratigraphic units of the Farewell terrane and rocks of the Selwyn basin and Mackenzie platform of northern Canada noted by Bundtzen and Gilbert (1983) suggest that the White Mountain sequence was part of a coherent Paleozoic passive continental margin that lay upon a Precambrian continental crystalline basement (Churkin and others, 1984; Gilbert and Bundtzen, 1983a) to form an extension of the Paleozoic North American continent (Blodgett and Clough, 1985).

Present-day lithofacies patterns have been complicated by the disruption of this Paleozoic continental margin by major right-lateral faults such as the Iditarod–Nixon Fork, Kaltag, and the Denali-Farewell faults (Fig. 4). Along the Denali-Farewell fault, right-lateral separation of 145 to 153 km (90 to 95 mi) is indicated by correlation of truncated trends of the Late Silurian and Early Devonian algal reef complex in the northeastern Kulukbuk Hills with exposures of the same complex in a similar paleogeographic setting (outer edge of carbonate platform) on the north side of the Denali-Farewell fault in the vicinity of White Mountain, McGrath A-4 Quadrangle (Blodgett and Clough, 1985). Bundtzen and Gilbert (1983) suggest right-lateral separation of about 60 km (37 mi) of an Upper Devonian (Frasnian) limestone and Triassic greenstone section along the Cheeneetnuk River south of the Denali-Farewell fault from a nearly identical section at Farewell Mountain to the northeast, north of the fault.

Rock sequences and the ages of major interregional unconformities within the Farewell terrane fit nicely the stratigraphic framework developed for northern Alaska and the Canadian Arctic by Lerand (1973). The White Mountain and Mystic sequences correspond respectively with Lerand's Franklinian and Ellesmerian sequences. The pre-Mississippian unconformity that separates the Franklinian and Ellesmerian sequences roughly correlates with the Middle Devonian unconformity which separates the White Mountain and Mystic sequences. In southwest Alaska, the Kuskokwim Group and related rock units occupy the same stratigraphic interval as the Brookian sequence in northern Alaska. The Early Cretaceous unconformity which separates the Ellesmerian and Brookian sequences corresponds to the Early Cretaceous unconformity between the Mystic sequence and the Kuskokwim Group.

In the southwestern Alaska Range, rocks of the Farewell terrane have undergone subisoclinal folding that postdates deposition of Triassic clastic rocks. Similar deformation, though with local variance in vergence, occurs in the adjacent Kahiltna terrane

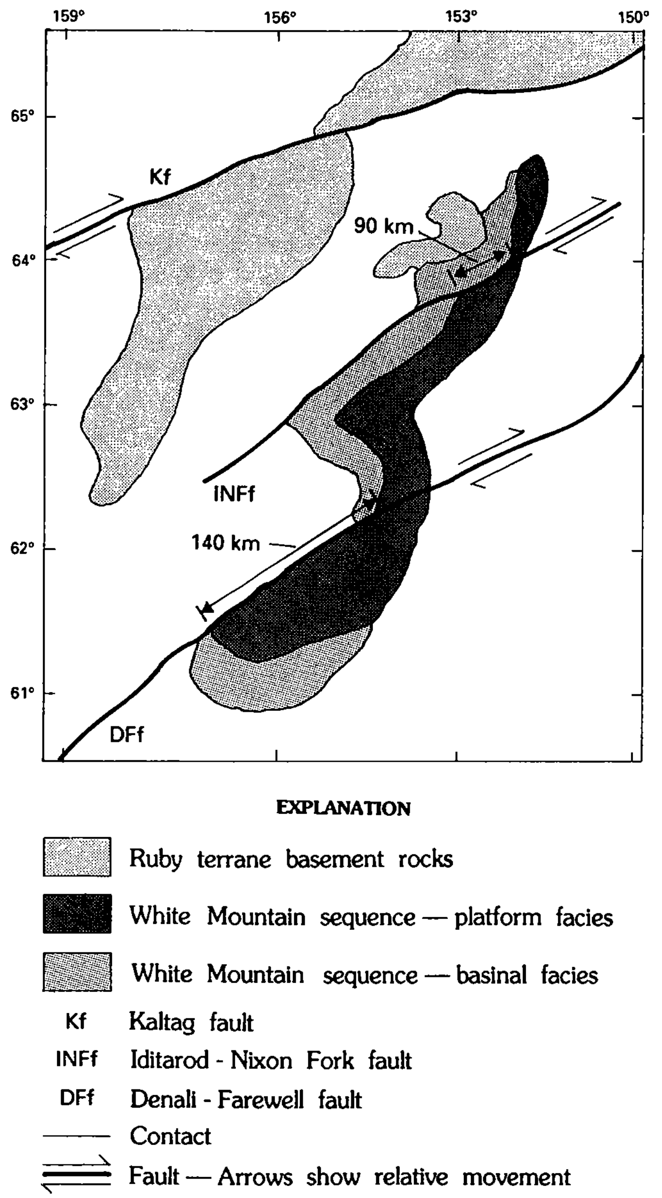


Figure 4. Generalized geologic map showing the offset of the White Mountain sequence along major faults. If the proposed offsets are removed, basement, shelf, and basin facies trends become contiguous and result in a consistent paleogeographic relationship.

to the southeast and apparently resulted from the same tectonic event. The timing of deformation in the Kahiltna terrane is bracketed in age by deformed Lower Cretaceous flysch and undeformed Late Cretaceous and Paleocene igneous rocks, which suggests that juxtaposition of the Farewell and Kahiltna terranes was completed by Late Cretaceous time. Although the contact between the Farewell and Kahiltna terranes is generally considered to be a fault, we cannot rule out the possibility that Jurassic and Lower Cretaceous flysch of the Kahiltna terrane was derived from and/or deposited on Farewell basement. In the McGrath A-1 quadrangle, facies relations within clastic rocks of the Kahiltna terrane suggest that the sediment was derived locally from a northern source (T. K. Bundtzen and W. G. Gilbert, unpublished field data). Conglomerate clasts, in part, resemble similar lithologies within the Farewell terrane. Granitic clasts also occur, however, and have no known local source.

TERRANES OF THE BRISTOL BAY REGION

The tectonostratigraphic terranes of the northern Bristol Bay region, named by Jones and Silberling (1979) include, from southeast to northwest, the Togiak, Goodnews, Kilbuck, and Nyack terranes (Fig. 5; Silberling and others, this volume). The Tikchik terrane of Jones and Silberling (1979) is considered here to be a subterrane of the Goodnews terrane. Extensive early mapping by Hoare and Coonrad (1959a, b, 1961a, b, 1978a) established the geologic framework of the region and provided the basis for the original terranes defined by Jones and Silberling (1979). Recent detailed mapping by Box (e.g., 1982, 1983b, 1985) along a coastal transect reveals a geologic history for these terranes reflecting episodic magmatism and accretion across an intraoceanic volcanic arc complex (Fig. 6), culminating in arc-continent collision and postcollisional strike-slip faulting. The terranes, and their respective subterranes, are described below in order of their interaction with the developing arc system. Unless otherwise noted, the subterrane nomenclature and descriptions used in this chapter for rocks of the Bristol Bay region are from Box (1985).

Togiak terrane

The Togiak terrane is composed of volcanic flows, coarse volcaniclastic breccias, tuffs, and associated epiclastic rocks of Late Triassic through Early Cretaceous age (Hoare and Coonrad, 1978a). Rocks of the Togiak terrane underwent only low-grade metamorphism (up to prehnite-pumpellyite or lower greenschist facies) and generally lack a penetrative metamorphic fabric. The Togiak terrane is divided into two northeast-trending subterranes, Hagemeister and Kulukak, that differ in sedimentary facies and structural style, but are linked by common provenance and stratigraphic history. Both subterranes record evidence for three deformational episodes accompanied by uplift and erosion: late Early Jurassic, latest Jurassic, and late Early Cretaceous. Volcanic episodes preceded each deformation event.

Hagemeister subterrane. *Definition.* The Hagemeister subterrane consists of Upper Triassic through Lower Cretaceous basaltic to dacitic volcanic and volcaniclastic rocks deposited on Upper Triassic ophiolitic rocks. The volcanic pile built upward, reaching sea level by Early Jurassic time. Rugged volcanic island topography resulted in a complex distribution of interfingering deep- and shallow-marine to subaerial facies.

Description. The Hagemeister subterrane includes three stratigraphic sequences separated by unconformities. The rocks within these sequences are generally not foliated, but record evi-

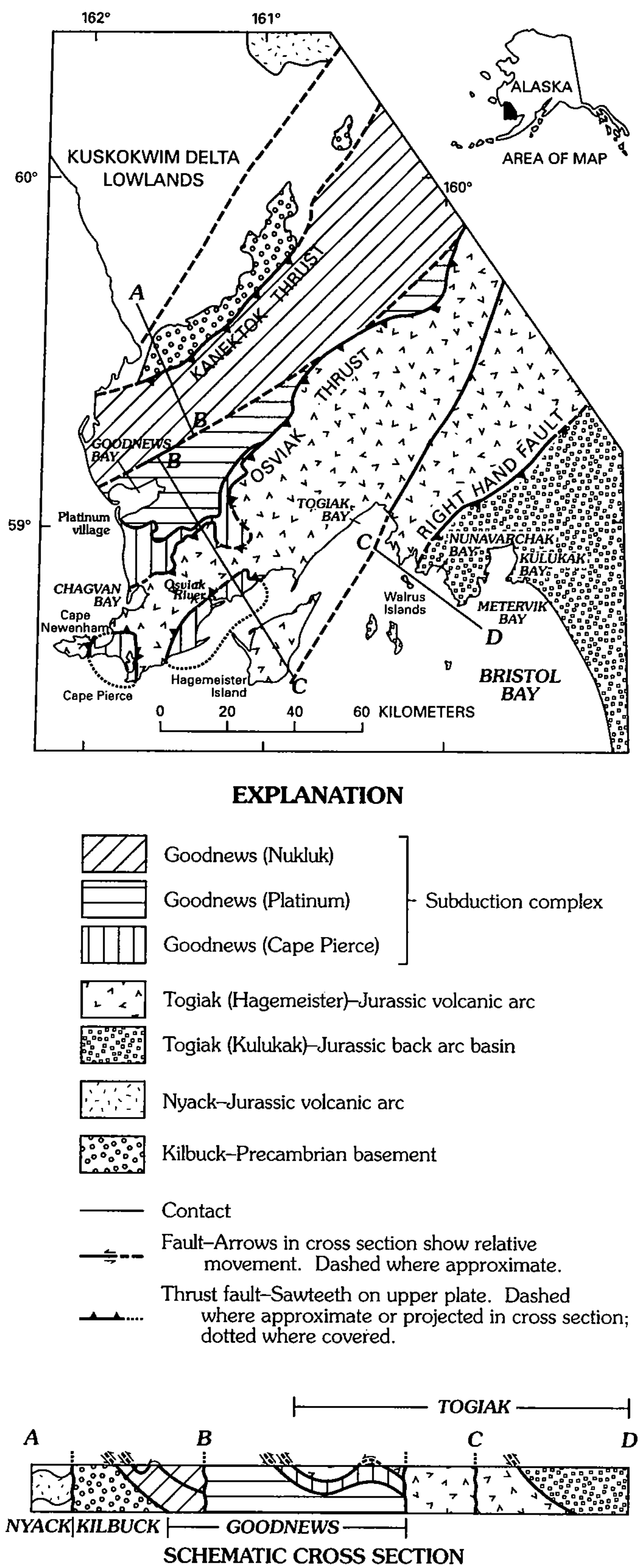


Figure 5. Terranes and subterranes of the Bristol Bay region showing the location of major faults and geographic features (Box, 1985).

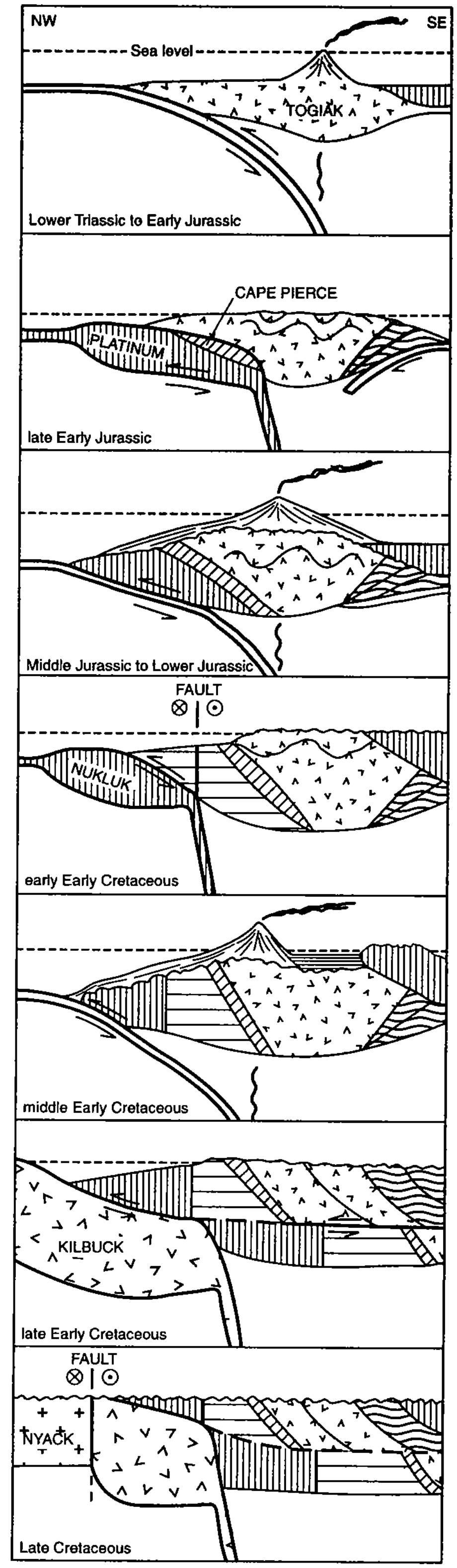


Figure 6. Amalgamation history of terranes and subterranes of the Bristol Bay region (Box, 1985). See Figure 5 for explanation of symbols. This diagram shows the successive accretion of terranes in the Bristol Bay region from Late Cretaceous to Late Triassic time. Arrow indicates direction of relative movement.

dence of up to prehnite-pumpellyite or lower greenschist-facies metamorphism, and moderate to severe deformation. The following description is based on coastal exposures of this subterrane (Box, 1985). Its application to the entire subterrane is untested.

The lowest sequence grades upward from an ophiolitic basement, containing Upper Triassic radiolarian chert, through thick volcanic breccia, into Lower Jurassic shallow-marine volcanogenic sandstone. This sequence records pre–Middle Jurassic deformation inferred by Box (1985) to relate to underthrusting by part of the Goodnews terrane from the northwest. The thrust contact (Osviak thrust) between the Goodnews and Togiak terranes is crosscut by Early to Middle Jurassic zoned mafic to ultramafic plutons, thus stitching these terranes by Middle Jurassic time. Elsewhere, a Middle Jurassic granitic pluton intrudes the lowest sequence.

The second sequence consists of Middle and Upper Jurassic (Bajocian to Tithonian) marine to nonmarine volcanic and volcaniclastic strata that, at least locally, rest with angular unconformity on the lowest sequence. Conglomerate from the second sequence locally contains clasts derived from the Middle Jurassic granitic pluton that intrudes the first sequence.

The third sequence consists of four widely separated belts of Lower Cretaceous (Valanginian to Albian) volcanic and sedimentary rocks (Hoare and Coonrad, 1983; Murphy, 1989) known in a few places to rest with angular unconformity on both the Togiak and Goodnews terranes. These belts record sedimentation in shallow- to deep-marine settings with locally derived, restricted provenances. Because no genetic relations are known to occur that link the four belts to a single depositional basin, we consider each belt to be part of the terrane it overlies.

Kulukak subterrane. *Definition.* The Kulukak subterrane consists predominantly of Jurassic volcaniclastic turbidites. In general, vertical changes in sandstone compositions and in turbidite facies record the partial unroofing of a volcanic terrane and the progradation of submarine fan environments. Although provenance links have been suggested by Box (1985), no direct depositional relationship with the Hagemeister subterrane has been observed.

Description. The Jurassic strata of the Kulukak subterrane consist of two informally named structural units, juxtaposed by a southeast-dipping thrust fault (Right Hand fault): the Nunavarchak structural unit, to the northwest; and the graywacke of Metervik Bay, to the southeast.

The Nunavarchak structural unit is characterized by structurally disrupted argillite displaying an anastomosing scaly fabric. The unit is assigned an Early(?) Jurassic age based on its structural and stratigraphic position, and on Jurassic or Cretaceous radiolaria (D. L. Jones, oral communication, *in* Box, 1985). Development of the structural fabric probably began in pre–Middle Jurassic time because angular clasts with distinct slaty cleavage that were most likely derived from the Nunavarchak structural unit occur in graywacke of the upper structural unit.

The graywacke of Metervik Bay consists of a basal unit composed of channelized volcaniclastic conglomerates (with minor angular slate clasts) and associated channel-margin facies, and three structurally higher units recording progradation of a submarine fan complex. Facies represent, from base to top, outer fan, midfan, and inner fan depositional environments. The fan complex ranges from Bajocian to Oxfordian in age, and shows a minor upsection increase in plutonic clasts, probably reflecting unroofing of an adjacent volcanic arc.

Goodnews terrane

The Goodnews terrane is a collage of variably metamorphosed blocks of laminated tuff, chert, basalt, graywacke, limestone, gabbro, and ultramafic rocks, in roughly that order of abundance. Devonian, Permian, and Upper Triassic limestones, and Mississippian, Upper Triassic, and Lower and Upper Jurassic cherts occur as fault-bounded blocks. Their original stratigraphic relations are uncertain. Box (1985) divided the Goodnews terrane into three subterranes with distinct stratigraphies and/or amalgamation histories. These subterranes, the Cape Peirce, Platinum, and Nukluk, were all linked with the Togiak terrane by earliest Cretaceous time; amalgamation of the Cape Pierce and Platinum subterranes with the Togiak terrane was completed by Middle Jurassic time. We interpret the Tikchik terrane of Jones and Silberling (1979) as a subterrane of the Goodnews terrane based on its similarities in age, lithology, and deformational style with rocks of the Platinum and Nukluk subterranes.

Cape Peirce subterrane. *Definition.* The Cape Peirce subterrane consists of foliated metamorphic rocks that are exposed in three separate outcrop belts in the Cape Newenham–Cape Peirce area (Fig. 1). These metamorphic rocks were probably derived from protoliths of probable Permian and Triassic ages (Box, 1985).

Description. The foliated metamorphic rocks of the Cape Peirce subterrane are in three nappes separated by low-angle faults. The structurally highest nappe is composed of mafic schist, the middle nappe is composed of metaclastic rocks, and the lowest nappe is composed of interbedded marble, slate, and mafic schist. Each nappe contains retrograded high-pressure mineral assemblages, and each low-angle fault zone contains structural blocks of nonfoliated mafic and ultramafic intrusive rocks. Protoliths of the highest nappe are similar to those of the structurally overlying, nonfoliated Hagemeister subterrane, and those of the lowest nappe are similar to the structurally underlying Platinum subterrane. Protoliths of the middle nappe are clastic rocks apparently derived from the Hagemeister subterrane.

The two lowest nappes record a premetamorphic deformation (D1) reflected by tight isoclinal folding, irregularly accompanied by axial-planar cleavage, or foliation. All three nappes record three later deformational events, including: (1) Late Triassic to Early Jurassic folding of the early isoclinal fold hinges and development of glaucophane- and lawsonite-bearing (Hoare and Coonrad, 1977, 1978b) high-pressure mineral assemblages (D2); (2) Late Jurassic(?) development of crenulation cleavage resulting from subhorizontal west- to northwest-directed stresses (D3);

and (3) post–Late Jurassic open folding of earlier fabrics along subhorizontal northeast-trending axes (D4).

Platinum subterrane. *Definition.* The Platinum subterrane consists of Lower and Middle Jurassic nonfoliated mafic flows, tuff, and volcaniclastic rocks metamorphosed to the prehnite-pumpellyite metamorphic facies. It occurs to the north of and structurally beneath the Cape Peirce subterrane in a wedge-shaped belt tapering to the northeast (Fig. 1).

Description. Rocks of the Platinum subterrane are interpreted by Box (1985) as the nonfoliated and less intensely deformed equivalent of the lowest schistose nappe of the Cape Peirce subterrane. Permian fossils occur in calcareous tuff interbedded with mafic volcanic rocks, and in limestone blocks within the fault zone between the Cape Peirce and Hagemeister subterranes. The Cape Peirce and Platinum subterranes both are intruded by zoned mafic-ultramafic plutons of early Middle Jurassic age (Southworth, 1984).

Platinum placer deposits at Goodnews Bay, America's largest source of this metal, are derived from one such pluton at Red Mountain. Hoare and Coonrad (1978a) suggested that the Red Mountain Pluton is part of a dismembered ophiolite belt of Jurassic age. However, the Red Mountain Pluton has a dunite core, pyroxenite border, and high-temperature contact zones, and may be analogous to the Alaskan-type of zoned ultramafic complex known in southeastern Alaska and in the Ural Mountains of Russia (Bird and Clark, 1976; Southworth, 1984).

Nukluk subterrane. *Definition.* The Nukluk subterrane is a structurally disrupted unit (mélange) containing blocks of diverse size and lithology ranging in age from Ordovician through Late Jurassic, locally set in a scaly argillaceous matrix. The blocks and matrix fabric of this mélange contrast with the more coherent nature of the Cape Peirce and Platinum subterranes. Deep-marine sedimentary rocks called the Eek Mountains belt by Hoare and Coonrad (1983) are of Early Cretaceous (Valanginian) age (Murphy, 1989) and rest with angular unconformity on older rocks of the Nukluk subterrane.

Description. Coherent limestone blocks of Ordovician, Devonian, and Permian age are distinctive constituents of the Nukluk subterrane, but constitute less than 5 percent of the outcrop area. The remaining area is underlain by radiolarian chert of Mississippian, Late Triassic, and Early and Late Jurassic age, laminated green or black mudstone, and basalt. At least two Devonian limestone blocks contain algal mounds indicative of a shallow water origin. Limestones containing Permian *Atomodesma* commonly are intercalated with amygdaloidal basalt flows; some are oolitic, indicating formation in a shallow-water environment. Massive limestones and basalts generally retain structural coherence, whereas laminated cherts, tuffs, and mudstones are more commonly highly tectonized.

A few elongate bands of serpentinite occur within this subterrane, at least one of which has an aeromagnetic signature indicative of a southeasterly dip (Griscom, 1978). Northwest-vergent overturned folds and stratigraphic facing directions in southeast-dipping blocks suggest imbrication along southeast-dipping thrust faults. Scattered occurrences of greenschist- to blueschist-facies schists along the northwestern edge of this terrane indicate high- to medium-pressure metamorphism of uncertain age in rocks adjacent to the fault boundary with the Precambrian Kilbuck terrane. Elsewhere, prehnite-pumpellyite facies metamorphic assemblages are sporadically developed. Penetrative deformation is reflected by the development of the scaly matrix fabric and the variable development of slaty cleavage within the more coherent blocks.

The northwestern boundary of the Nukluk subterrane is a southeast-dipping thrust fault that places the Nukluk subterrane on metamorphic rocks of the Kilbuck terrane (discussed below). Mid-Cretaceous (Albian) clastic rocks that overlie both assemblages are overturned along the fault. A latest Cretaceous pluton postdates deformation along this boundary. If the mid-Cretaceous clastic rocks are synorogenic deposits, deformation spanned the mid- and Late Cretaceous intervals.

The Eek Mountains belt (Hoare and Coonrad, 1983) is the westernmost of four coeval belts of Lower Cretaceous (Valanginian) marine clastic rocks. All four belts strike northeastward, reflecting underlying postdepositional structural trends, but not necessarily original basin geometries. The Eek Mountains belt is exposed along the crest of the doubly plunging, northeast-trending Eek Mountains anticline.

The Eek Mountains belt is a broken formation (Hsü, 1968) composed predominantly of siltstone and shale, and minor graywacke and conglomerate. In the northernmost Eek Mountains the belt is in fault contact with rocks of the Nukluk subterrane. A southeast-dipping structural fabric overprints all pre-Kuskokwim Group (pre-middle Albian) rocks but produced little metamorphic recrystallization of rocks within the Eek Mountains belt. The Kuskokwim Group overlaps older units with an angular unconformity preserving submarine canyon cut-and-fill (Murphy, 1989). Pre–Eek Mountains belt rocks have been metamorphosed to the prehnite and pumpellyite facies, while clastic rocks of the Eek Mountains belt and overlying Kuskokwim Group contain only detrital metamorphic minerals.

Petrographically, sedimentary rocks of the Eek Mountains belt are lithologically distinct from older rocks of the Nukluk subterrane, but are nearly identical to rocks of the Kuskokwim Group. Older rocks are entirely volcanogenic, while Eek Mountains belt rocks are polymictic. Clast components include metavolcanic and metasedimentary grains derived from the Nukluk subterrane, and, in the northern Eek Mountains, metamorphic clasts derived from the Kilbuck or distant Ruby terrane (Murphy and Decker, 1985). Previously, Kilbuck terrane detritus was presumed to be present only in Kuskokwim Group strata (Box, 1985). The presence of high-grade metamorphic clasts in sandstones of the Eek Mountains belt implies that the Kilbuck and/or Ruby terranes were in place relative to the Goodnews terrane by Valanginian time (Murphy, 1987).

Tikchik subterrane. *Definition.* The Tikchik [sub]terrane (Silberling and others, this volume) was named by Jones and Silberling (1979) and defined by Jones and others (1987). It occurs in the northern Tikchik Lakes area, southeast of the Togiak-Tikchik fault (Denali-Farewell fault system). The Tikchik subterrane is a structurally complex assemblage (melange) of clastic rocks, radiolarian chert of Paleozoic and Mesozoic age, Permian limestone and clastic rocks, Permian or Triassic pillow basalt and graywacke, and Upper Triassic clastic and mafic volcanic rocks. Ordovician radiolaria have also been identified from chert within the Tikchik subterrane (Hoare and Jones, 1981; D. L. Jones, J. M. Hoare and W. L. Coonrad, unpublished data), but the stratigraphic significance of the chert is unclear.

Description. Little more than what is described above is known about the Tikchik subterrane. The Tikchik subterrane is an apparently chaotic assemblage of blocks, particularly chert, of Ordovician, Triassic, Jurassic, and Early Cretaceous age, and of limestone of Permian age. The matrix is mainly graywacke, argillite, tuff, and mafic volcanic rock, although blocks of different ages commonly are juxtaposed without intervening matrix. Some of these blocks are quite large (kilometer-scale) and are structurally and stratigraphically coherent. The age(s) of deformation is uncertain, but predates deposition of the unconformably overlying clastic rocks of mid-Cretaceous age (W. K. Wallace, unpublished field data 1983).

Kilbuck terrane

Definition. The Kilbuck terrane, named by Jones and Silberling (1979), consists of multiply deformed, upper amphibolite- to granulite-facies metagranitic and metasedimentary rocks of Precambrian age (Hoare and Coonrad, 1979). These rocks appear to be folded into a large anticlinorium, with a high-grade gneissic core overlain by folded lower grade rocks.

Description. Hoare and others (1974), Hoare and Coonrad (1979), and D. L. Turner and others (unpublished data) provide the most detailed descriptions of this metamorphic complex. Their mapping indicates that the terrane is composed of a high-grade central zone flanked by lower grade schist. The central zone of layered biotite-hornblende gneiss with intercalated pyroxene granulite, garnet amphibolite, kyanite-garnet-mica schist, orthogneiss, and rare marble and quartzite record upper amphibolite- to lower granulite-facies metamorphism, partly retrograded under greenschist-facies conditions. In contrast, this high-grade core is flanked by schists recording greenschist-facies metamorphism. These rocks include chlorite schist, epidote-quartz-biotite schist, micaceous quartzite, marble, calc-phyllite, and metaconglomerate.

Geochronological studies by Turner and others (1983, and unpublished data) have yielded 2,050 Ma U-Pb and Pb-Pb zircon ages reflecting orthogneiss protolith crystallization, while coexisting sphene indicates a 1,800-Ma reset age recording the high-grade metamorphic event. A 1,800-Ma Rb-Sr whole-rock isochron also confirms this metamorphic event. K-Ar ages in both the high-grade core and low-grade carapace cluster in the range from 120 to 150 Ma, and may record uplift following the greenschist-facies metamorphic overprint. This metamorphic event is attributed to the underthrusting of the Kilbuck terrane beneath the northwest margin of the Goodnews terrane (Box, 1985). Postmetamorphic cataclasis in rocks along the southeastern boundary of the Kilbuck terrane record the return of this terrane to a shallower crustal level.

Boundaries between the Kilbuck and adjacent terranes are faults. Near the coast, the southeast-dipping Kanektok thrust (Fig. 5) places northwest-vergent greenschist- and blueschist-facies Goodnews terrane rocks over greenschist-facies rocks of the Kilbuck terrane (Box, 1982). Inland along strike, the Kanetok thrust places northwest vergent mid-Cretaceous clastic rocks and low-grade basalt and chert of the Goodnews terrane over amphibolite facies rocks of the Kilbuck terrane. The northwestern boundary of the weakly magnetic Kilbuck terrane may be defined by the sharp magnetic gradient along the southeastern flank of the Nyack terrane (Griscom, 1978). Where exposed, the Golden Gate fault (Fig. 5) juxtaposes the Kilbuck and Nyack terranes, but the sense of fault displacement is not clear.

Nyack terrane

Definition. The Nyack terrane (plate 3) is the least well known terrane in southwest Alaska. As originally defined by Jones and others (1981), the Nyack terrane consists of a Jurassic arc-related volcanic and volcaniclastic assemblage.

Description. Rocks of the Nyack terrane include andesitic, basaltic, and dacitic volcanic and volcaniclastic rocks interbedded with graywacke, siltstone, impure limestone, and conglomerate. It contains sparse marine fossils of Middle and Late Jurassic age (Hoare and Coonrad, 1959a, b). In the Nyack area, a granitic pluton intrudes the Jurassic volcanic rocks, and has yielded K-Ar ages of 108 to 120 Ma (Shew and Wilson, 1981; Decker and others, 1984a; Robinson and Decker, 1986). The rocks are unfoliated, but contain chlorite-epidote mineral assemblages of probable lower greenschist metamorphic facies (Hoare and Coonrad, 1959a, b).

The southeastern boundary of the Nyack terrane with the Kilbuck terrane is discussed above. The northwestern boundary is not exposed, but the irregular aeromagnetic pattern that characterizes the Nyack terrane is truncated along a linear, northeast-trending magnetic gradient that roughly follows the lower Kuskokwim river meander belt (Dempsey and others, 1957). In addition, the occurrence of rocks perhaps correlative with the Goodnews terrane (Portage sequence, discussed below) northwest of the Kuskokwim River suggests a concealed terrane boundary near there. The linearity of both the northwestern and southeastern boundaries of the Nyack terrane suggests that they are probably steep faults, but their amount and sense of displacement are unknown.

Enigmatic rocks

Two rock units of unknown terrane affinities occur in the Russian Mission and Iditarod Quadrangles (Fig. 1). Predominantly volcanic and sedimentary rocks exposed along the Kuskokwim River near Portage Mountain in the Russian Mission Quadrangle are here called the Portage sequence. Metamorphic rocks in the vicinity of VABM Idono in the Iditarod Quadrangle are called the Idono sequence. The southern Kahiltna terrane, exposed mainly in the Lake Clark Quadrangle, occurs between the Mulchatna and Lake Clark–Castle Mountain faults and constitutes a third enigmatic unit.

Portage sequence. Rocks of the Portage sequence occur in cutbank exposures of the Kuskokwim River near the village of Aniak, and in the vicinity of Portage Mountain in the Russian Mission Quadrangle (Fig. 1). These rocks were originally mapped by Hoare and Coonrad (1959b) as part of the undivided Gemuk Group. They were assigned to the Ruby and Innoko terranes (Silberling and others, this volume) by Jones and others (1981). Exposures along the river consist of volcanic flows, lahar deposits, green cherty tuff, volcanic breccia of probable andesitic and basaltic composition, altered diabase, graywacke, mudstone, calcareous conglomerate, and limestone (Hoare and Coonrad, 1959b; J. Decker and J. M. Hoare, unpublished field data, 1980). The unit is highly deformed and generally has a melange-like internal fabric. Nearest the projected location of the Aniak–Thompson Creek fault, river bluff exposures are highly shattered, moderately altered, and tightly to isoclinally folded. Fossils of Permian (Smith, 1939) and Triassic (U.S. Geological Survey, unpublished fossil report, 1963) age have been obtained from limestone within the Portage sequence. Hoare and Coonrad (1959b) suggest a Permian or Triassic age for these rocks based on correlation with similar rocks elsewhere in the region.

To the south, the Portage sequence may be correlative with rocks of the Nukluk subterrane; to the north and west, it may be correlative with the Innoko or Tozitna terranes.

Idono sequence. Gemuts and others (1983) first described a poorly exposed belt of augen gneiss and amphibolite in a 400-km^2 elliptical outcrop area in the central Iditarod Quadrangle (Fig. 1) and called them the Idono sequence. To be consistent with published nomenclature, we will also call these rocks the Idono sequence, although it does not strictly conform with our usage of the term "sequence" as defined earlier in this report. K-Ar ages of three samples led Miller and Bundtzen (1985) to tentatively correlate rocks of the Idono sequence with polymetamorphic rocks of the Ruby terrane exposed in the Kaiyuh Mountains (Patton and others, 1977b). However, Early Proterozoic U-Pb data and Precambrian K-Ar data subsequently obtained by Miller and Bundtzen (unpublished data), now suggest a closer similarity to rocks of the Kilbuck terrane.

Petrographic and field studies by Miller and Bundtzen (1985) indicate a variety of metamorphic rock-types in the Idono sequence including: (1) sphene-epidote-calcic oligoclase-quartz-hornblende-garnet amphibolite, (2) apatite-plagioclase-biotite-muscovite-quartz schist, and (3) andesine-biotite-muscovite quartzose schist. Unpublished 1984 and 1985 field studies by those workers also indicate metamorphosed augen gneiss, garnet amphibolite, meta-hornblendite, and foliated quartz diorite rock-units. The presence of hornblende and calcic oligoclase or andesine in the inferred mafic protoliths indicate that metamorphic conditions reached the lower amphibolite facies of regional metamorphism. K-Ar ages obtained from rocks at VABM Idono range from 126 to 134 Ma (Miller and Bundtzen, 1985), consistent with metamorphic ages obtained from greenschist- and locally blueschist-facies metamorphic rocks in the Kaiyuh Mountains (Patton and others, 1984b) about 120 km northeast of the Idono sequence. However, the varied lithologies in the Idono sequence also are similar to those described in the Kilbuck terrane discussed earlier in this chapter.

The Idono sequence has been multiply folded, and several foliation or cleavage surfaces are evident in outcrop. In most outcrops that we observed, the youngest foliation dips gently to moderately to the north-northwest, but the generally poor exposures severely limit structural interpretation.

Southern Kahiltna terrane. The southern Kahiltna terrane occupies a tectonically significant position between the Peninsular terrane to the east, and the terranes of southwestern Alaska to the west (Plate 3). The northern part of the Kahiltna terrane is discussed by Nokleberg and others (this volume, Chapter 10). We describe the southern part here because it is separated by younger plutonic and volcanic rocks from the rest of the terrane, and its relationship to the remainder of the terrane is uncertain. The southern Kahiltna terrane is best exposed in the Lake Clark Quadrangle, but small parts also occur in the Iliamna, Dillingham, Taylor Mountains, and Lime Hills Quadrangles (Fig. 1).

Wallace and others (1989) divided the southern Kahiltna terrane into two major stratigraphic units (Fig. 7): Chilikadrotna Greenstone of Bundtzen and others (1979), and the overlying Koksetna River sequence of Hanks and others (1985). The Chilikadrotna Greenstone is only locally exposed and consists predominantly of Upper Triassic and Jurassic(?) volcanic rocks. The Koksetna River sequence consists of extensive Upper Jurassic and Lower Cretaceous turbidite deposits.

The Chilikadrotna Greenstone is described by Wallace and others (1989) as consisting of a lower interval of basaltic pillow lavas and massive flows and an upper interval of andesitic flows and tuff breccia. These two intervals locally are separated by limestone pods that have yielded Late Triassic conodonts and brachiopods (Wallace and others, 1989). Silurian fossils previously reported from the same rocks (Bundtzen and others, 1979) has caused an age conflict that has not yet been resolved.

The Koksetna River sequence appears to consist entirely of turbidites composed of interbedded volcanogenic feldspathic-lithic graywacke, siltstone, and mudstone. Facies associations, from southeast to northwest, indicate deposition in slope, inner fan, middle fan, and outer fan submarine environments, suggesting a southeastern sediment source. A Late Jurassic and Early Cretaceous age for the Koksetna River sequence is based on sparse megafossils, mainly *Buchia,* in Lake Clark Quadrangle (Eakins and others, 1978; J. W. Miller, written communication to W. K. Wallace, 1983; Wallace and others, 1989). The nature of the original contact between the Chilikadrotna Greenstone and the Koksetna River sequence is uncertain because of poor expo-

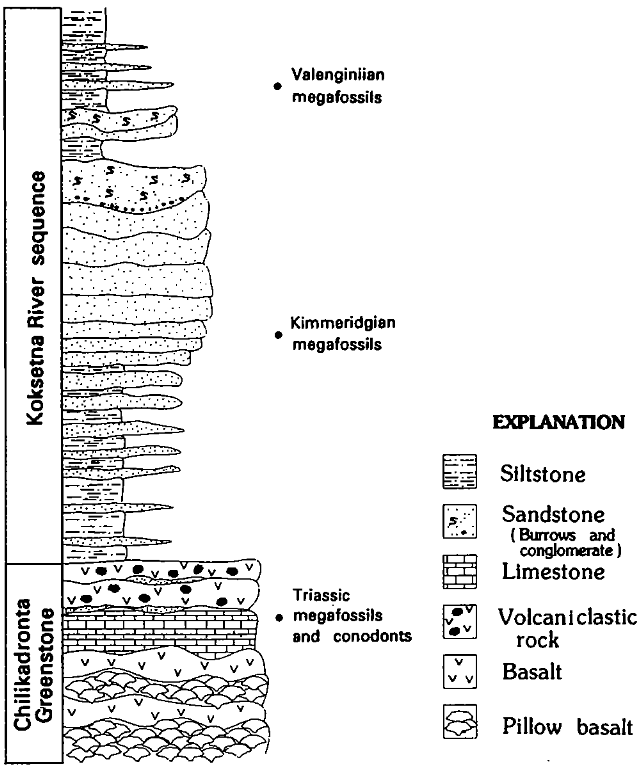


Figure 7. Composite stratigraphic column of the southern Kahiltna terrane showing points of fossil age control (Wallace and others, 1989).

sures and a strong deformational overprint. However, the Koksetna river sequence is younger, structurally higher, and locally contains distinctive detritus probably derived from the Chilikadrotna Greenstone, suggesting that the contact was probably originally depositional.

Rocks of the Koksetna River sequence superficially resemble those of the Kuksokwim Group to the west, and the two units thus were not distinguished in maps of the region published by Eakins and others (1978) and Nelson and others (1983). However, we believe that the two units can be distinguished on the basis of degree of induration, distribution of facies, available age data, and most diagnostically, clast composition (Hanks and others, 1985; Wallace and others, 1989). Sandstones of the Kuksokwim Group are generally less indurated and more carbonaceous than those of the Koksetna River sequence. Facies associations in the Kuskokwim Group indicate basin-plain to outer fan environments to the southeast, and middle- to inner fan environments to the northwest (Decker, 1984a; Hanks and others, 1985; Moore and Wallace, 1985; Wallace and others, 1989), suggesting a source to the northwest. This contrasts with the inferred southeastern source for the Koksetna River sequence. The quartzose lithic sandstones of the Kuskokwim Group contain higher percentages of sedimentary rock fragments and mica than sandstones of the Koksetna River sequence (Decker, 1984b; Hanks and others, 1985; Wallace and others, 1989).

The contact of the southern Kahiltna terrane with the Peninsular terrane probably is a fault, although it is now obscured, mainly by Late Cretaceous and Tertiary intrusions (Eakins and others, 1978; Nelson and others, 1983; Hanks and others, 1985; Wallace and others, 1989). The age and character of the Chilikadrotna Greenstone suggest that it may actually be part of the Peninsular terrane to the southeast; and parts of the sequence contain lithologies and structures similar to, but not diagnostic of, a subduction complex (Wallace and others, 1989). The Jurassic magmatic arc of the Peninsular terrane is interpreted by Reed and others (1983) to have formed above a southeast-dipping (present coordinates) subduction zone. If the Chilikadrotna Greenstone is part of the Peninsular terrane, it thus may have been located in a forearc setting adjacent to the convergent margin of the terrane. Following this assumption, the Koksetna River sequence may then have been shed from the axis of the Peninsular terrane into a basin to the northwest (present coordinates; Wallace and others, 1989). Therefore, on the basis of similarities in geologic history, and on the provenance and sediment source direction of the Koksetna River sequence, it is permissible to interpret the southern Kahiltna terrane as a northwestern extension of the Peninsular terrane (Hanks and others, 1985; Wallace and others, 1989). On the other hand, no genetic link has yet been established between the southern Kahiltna terrane and the Kuskokwim Group, and the two are probably separated by a fault (Wallace, 1984; Hanks and others, 1985; Wallace and others, 1989).

Paleolatitude data

Sedimentological evidence from lower and upper Paleozoic limestone blocks in the Goodnews terrane suggests that these rocks were deposited in tropical latitudes. Such evidence includes the occurrence of algal boundstone and oolitic limestone in the Nukluk subterrane (Hoare and Coonrad, 1978a; Box, 1985). Lower Jurassic rocks in the Hagemeister subterrane contain a faunal assemblage (characterized by the pelecypod *Weyla* sp.) that occurs well north of its northern range boundary elsewhere in North America (D. L. Jones, personal communication *in* Box, 1985), suggesting post–Early Jurassic poleward displacement.

Paleomagnetic analyses from the Tikchik subterrane by Karl and Hoare (1979) are inconclusive because the age and bedding attitudes could not be constrained. More detailed work in the same terrane (Engebretson and Wallace, 1985, and unpublished data) has confirmed a primary magnetic component in well-bedded Permian or Triassic basalts. Significant northward displacement (about $18 \pm 10°$) and counter-clockwise rotation (about $38 \pm 12°$) are indicated, although more precise age control would greatly decrease the uncertainty. If the basalts are Triassic in age, the data would suggest greater northward displacement, while a Permian age, which would be consistent with the reversed polarity of most of the samples, would suggest greater counter-clockwise rotation.

Paleomagnetic data (Globerman and Coe, 1984) from 81 volcanic flows in the post-accretionary upper sequence (72 to 65 Ma) of the Hagemeister subterrane show evidence for as much as

52° of counter-clockwise rotation since deposition, but no evidence for latitudinal displacement. Thus an unspecified amount of post–Early Jurassic to pre-Tertiary displacement is suggested by presently available data.

Interpretation

Many interpretations of relationships and correlations are possible among the terranes of the Bristol Bay region. However, the geology of the region is not known in sufficient detail to determine which of the possible relationships and correlations are correct, and many of the possibilities are not mutually exclusive. The most plausible interpretations, based on current data, are discussed below.

The Kilbuck terrane is unusual in that it consists of Proterozoic crystalline continental crust, yet is located between Mesozoic arc terranes. Although the Kilbuck terrane may be an allochthonous sliver of a distant continent, it seems more likely to us that it is a part of the North American continental backstop against which the Mesozoic arc terranes were accreted. Gemuts and others (1982) interpret the Kilbuck terrane to be continuous in the subsurface with the Idono sequence to the northeast. Similar Proterozoic protolith ages of rocks in the Kilbuck terrane and Idono sequence support their correlation. Instead of their being continuous in the subsurface, however, we offer the alternative model that the Kilbuck terrane has been offset from the Idono sequence along right-lateral strike-slip faults. The Idono sequence occurs north of the Iditarod-Nixon Fork fault, whereas the Kilbuck terrane occurs south of the Golden Gate fault. We believe that these two faults were once continuous but are now displaced about 43 km along the left-lateral Aniak–Thompson Creek fault (Fig. 1).

According to Box (1984b, 1985), the Togiak and Goodnews terranes formed as an intraoceanic arc-trench complex during Late Triassic to earliest Cretaceous time (Fig. 8A) that collided with North America during mid– to late Early Cretaceous time (Fig. 8B and 8C). Using present-day geography as a reference, southeastward-directed subduction occurred on the northwest flank of the volcanic arc (Hagemeister subterrane), creating an imbricately stacked subduction complex of accreted oceanic plate lithologies (Goodnews terrane) as shown in Figure 6. The Kulukak subterrane, southeast of the Hagemeister subterrane, consists of volcaniclastic turbidites deposited in a back-arc setting. Box (1983a, 1984a) suggests that the Nyack terrane is a slice of the Togiak terrane "doubled-up" by post-accretionary strike-slip faulting. According to this model, volcanic arc rocks of the Togiak and Nyack terranes continue northward into the Yukon-Koyukuk province where similar rocks of Jurassic and Cretaceous age occur (Fig. 8D). However, since the Togiak and Goodnews terranes trend southwestward into the Bering Sea, the continuation of these terranes into the Yukon-Koyukuk basin requires the arc-trench system to have been bent back upon itself analogous to the modern Banda arc (Hamilton, 1979), or to have had its trend reversed by some other means.

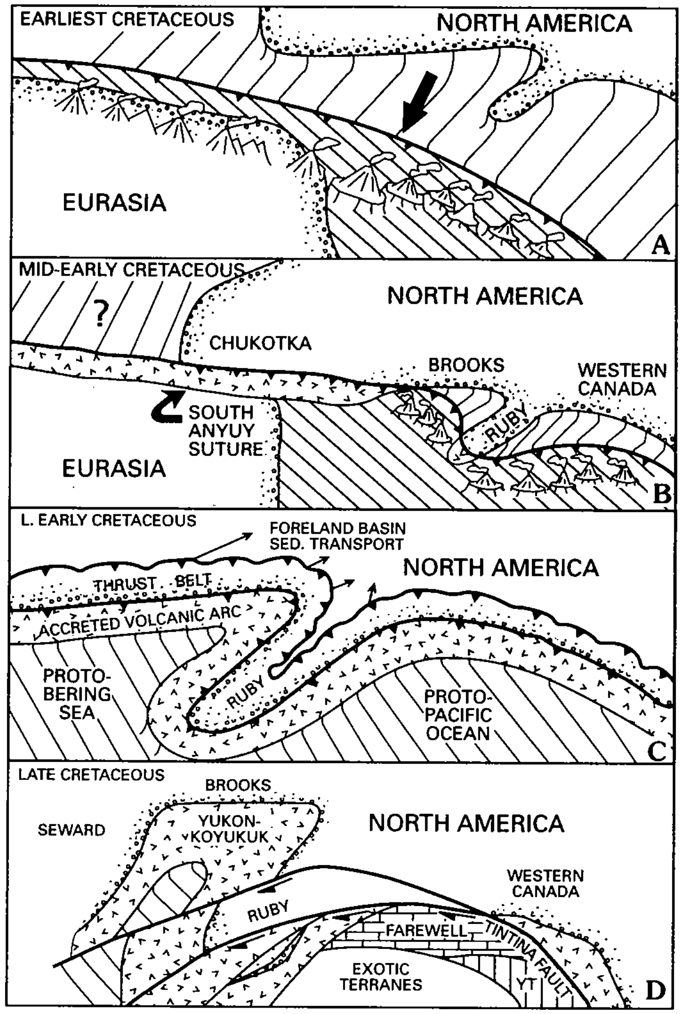


Figure 8. Schematic tectonic model of Box (1984a) showing correlation of Goodnews and Togiak terranes with terranes of Chukotka the Yukon-Koyukuk province. A, North America and Eurasia plate boundary (sawteeth on upper plate). Volcanic arc shown along plate boundary, large arrow indicates direction of relative movement. B, Development of the South Anyuy suture. Major mountain areas are labeled. Subduction boundary (large sawteeth on upper plate) and accreted volcanic arc complex (chevron pattern) along plate boundary. Uncertain terrane queried. C, Development of accreted volcanic arc and thrust belt along North American plate boundary. Arrows indicate direction of sediment transport. Sawteeth on upper plate. D, Major land areas in relation to accreted terranes. Arrows indicate direction of relative movement. Y-T = Yukon-Tanana terrane.

The southwestward projection of the Togiak and Goodnews terranes suggests that they may not be related to terranes onshore to the north and west, but instead continue offshore, possibly bending northwestward subparallel with the Bering Sea shelf margin (Marlow and others, 1976).

The Togiak and Goodnews terranes are also similar in many respects to the Peninsular and Kahiltna terranes to the south and east, suggesting a possible correlation (Wallace, 1983, 1984;

Decker and Murphy, 1985). However, paleomagnetic and geologic evidence (discussed below) indicates that any original relationship between the two pairs of terranes has been substantially modified by major displacement (Wallace and others, 1989). Although the two pairs of terranes probably formed in arc-trench settings, it is uncertain whether they were parts of a single continuous arc-trench system, or formed separately in the same tectonic setting. The latter relationship has been proposed by Wallace and others (1989) and is shown in Figure 9. This model assumes that the Yukon-Koyukuk arc, the Togiak arc, and the composite Peninsular-Wrangellia arc were separate but tectonically related magmatic arc complexes formed above a southwest-dipping subduction zone adjacent to North America in Middle and Late Jurassic time (Fig. 9A). During Late Jurassic and Early Cretaceous time, the volcanic arcs collided with North America, subduction stepped out beyond the arcs, and the subduction polarity reversed (Fig. 9B and 9C). Intermittent strike-slip faulting and subduction have modified the original relationships to the pattern that presently exists in southern Alaska (Fig. 9C to F).

The tectonic setting and paleogeography of the basin in which the Koksetna River sequence was deposited have important implications for the tectonic evolution of southwestern Alaska. Late Jurassic and Early Cretaceous turbidite-filled basins, including the Koksetna River sequence, the northern part of the Kahiltna terrane, and the Gravina-Nutzotin belt occur along the landward boundary of the Peninsular, Wrangellia, and Alexander terranes. It is generally agreed that these basins mark the suture along which the more outboard terranes of southern Alaska collided with North American. However, the basins are controversially interpreted to be precollisional (Jones and others, 1981, 1986; Csejtey and others, 1982, Coney and Jones, 1985) or postcollisional (Eisbacher, 1974; 1985; Decker and Murphy, 1985; Hanks and others, 1985; Wallace and others, 1989). The two interpretations differ with regard to basin configuration, timing and location of collision, and cause of deformation of the basinal rocks. If the basins were precollisional, they were probably relatively wide and floored by oceanic crust, and deformation of the basinal deposits resulted from postdepositional collision of the basins during or after Late Cretaceous time and near their present locations. If the basins were postcollisional, they were relatively narrow, were probably not floored by oceanic crust, and deformation of the basinal deposits resulted from late syntectonic compression followed by post-tectonic extension.

Paleomagnetic evidence (Stone and others, 1982; Hillhouse and Coe, this volume) suggests that there has been considerable northward translation of the Peninsular terrane since the Koksetna River sequence was deposited. Its depositional relationship with the Peninsular terrane thus requires significant tectonic transport of the southern Kahiltna terrane, whether the Koksetna River sequence was deposited in a pre- or postcollisional basin. On the other hand, the Farewell terrane and depositionally overlying Kuskokwim Group, which also rests depositionally upon the Goodnews and Togiak terranes (Wallace, 1983, 1984), does not appear to have been latitudinally displaced a significant amount since Paleozoic time (Plumley and others, 1981; Plumley and Coe, 1982, 1983). If the Koksetna River sequence was deposited on a part of the Peninsula terrane, the sequence therefore must be separated along its northwestern boundary from the Farewell, Goodnews, and Togiak terranes and from the Kuskokwim Group by a fault with considerable right-lateral strike-slip and/or thrust displacement. This contact is not exposed, but no pre–latest Cretaceous units have yet been correlated across it and field observations suggest that it is a major fault (Wallace, 1984; Hanks and others, 1985; Wallace and others, 1989).

POST-ACCRETIONARY ROCKS

Kuskokwim Group

The Lower and Upper Cretaceous (Albian to Coniacian) Kuskokwim Group consists of marine turbidites, and subordinate shallow-marine and fluvial strata, deposited in an elongate southwest-trending basin covering over 70,000 km^2 in southwestern Alaska (Bundtzen and Gilbert, 1983; Wallace, 1983; Decker, 1984b; Pacht and Wallace, 1984). The Kuskokwim Group is thickest (> 10 km) and displays the deepest water facies in the central part of the basin between the villages of McGrath and Aniak. Mixed marine and nonmarine sections are relatively thin (<3 km) and are restricted to the basin margins and local basement highs. Sandstone and conglomerate clast compositions throughout the Kuskokwim Group suggest that the sediment was derived from local sources (Bundtzen and Gilbert, 1983; Wallace, 1983, 1984; Crowder and Decker, 1985; Murphy, 1989). Facies relations suggest rapid deposition within a regionally subsiding continental trough (Hoare, 1961; Decker and Hoare, 1982; Bundtzen and Gilbert, 1983). The basement upon which the Kuskokwim Group was deposited is known only locally near the margins of the basin. In the thick central part of the basin, especially between the Denali-Farewell and Iditarod–Nixon Fork faults, the underlying basement rocks are unknown (Decker and others, 1984b). The Kuskokwim Group is generally deformed into broad open folds, but locally, especially near its southeast margin, overturned or isoclinal folds and thrust faults predominate (Decker, 1984a).

The Iditarod–Nixon Fork and the Denali-Farewell fault systems divide the Kuskokwim Group into three geographic basins: the Iditarod basin to the northwest, the central Kuskokwim basin, and the Nushagak basin to the southeast. The geological relations among these three basins are unclear, but because they are defined by such postdepositional faults, they do not necessarily correspond with the original depositional basins. For example, there is little contrast in facies and clast composition across the Iditarod–Nixon Fork fault (Bundtzen and Laird, 1982, 1983a), whereas sandstone clast compositions are significantly different across the Denali-Farewell fault system (Crowder and Decker, 1985). Sandstones within the central Kuskokwim basin, north of the Denali-Farewell fault, are composed predominantly of metamorphic and volcanic rock fragments derived locally from

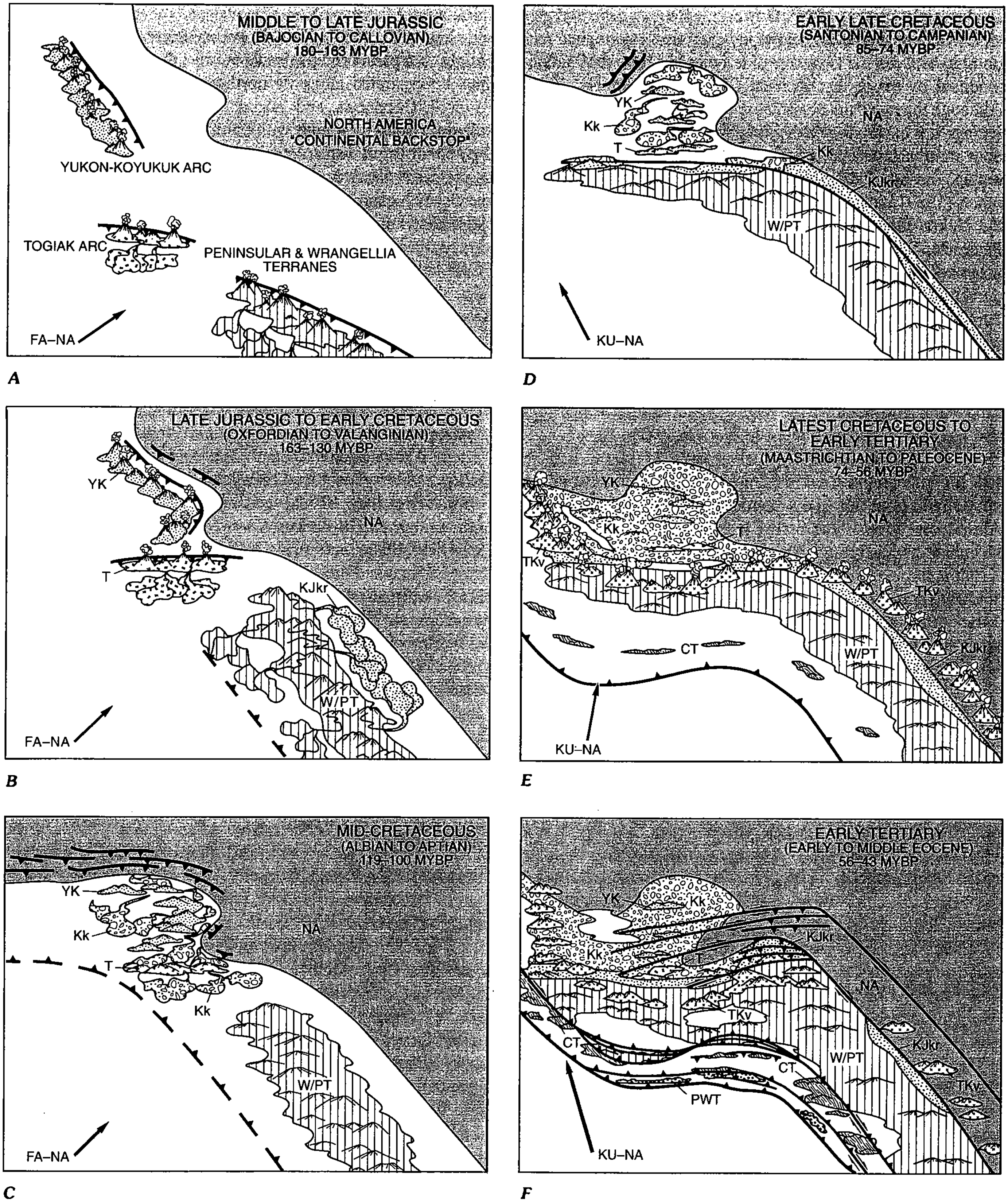
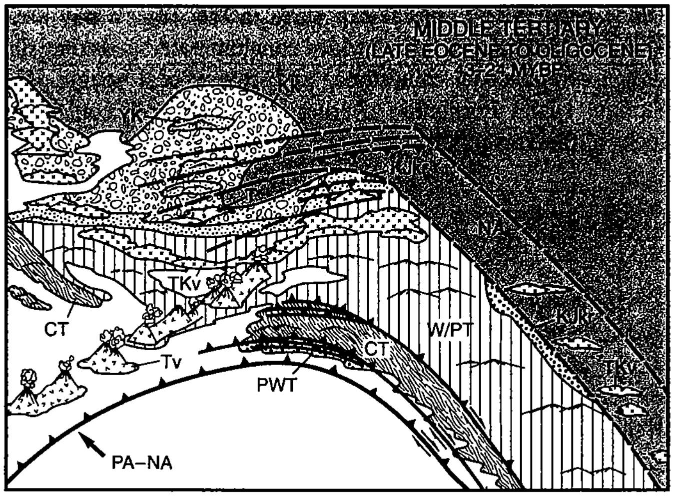


Figure 9. Schematic tectonic reconstruction of southern Alaska from Wallace and others (1989). This figure illustrates the possible paleogeographic affinities of the Goodnews and Togiak terranes with terranes of south-central Alaska. See text for discussion.



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EXPLANATION

TECTONOSTRATIGRAPHIC TERRANES

PWT–PRINCE WILLIAM TERRANE
Eocene accretionary rocks

CT–CHUGACH TERRANE
Early Cretaceous and Late Cretaceous accretionary rocks

W/PT–WRANGELLIA/PENINSULAR TERRANES
Paleozoic and Mesozoic sedimentary rocks and Early to Middle Jurassic island-arc rocks

T–TOGIAK ARC
Middle Jurassic to Early Cretaceous island-arc rocks

YK–YUKON KOYUKUK ARC
Middle Jurassic to Early Cretaceous island-arc rocks

NA–NORTH AMERICA CONTINENTAL BACKSTOP

CRETACEOUS AND TERTIARY MAGMATIC ARCS

Tv–LATE EOCENE TO OLIGOCENE
Arc volcanic and intrusive rocks

TKv–LATE CRETACEOUS TO PALEOCENE
Arc volcanic and intrusive rocks

SUCCESSOR BASIN DEPOSITS

Kk–KUSKOKWIM GROUP
Late Early to Late Cretaceous clastic rocks

KJkr–JURA-CRETACEOUS FLYSCH
(Koksetna River sequence) Late Jurassic to Early Cretaceous deep-water clastic rocks

FAULTS–Solid during times of major displacement; dashed during times of minor displacement. Arrows indicate direction of relative movement.

SUBDUCTION ZONE–Dashed where existence is inferred from model and plate-motion vectors. Sawteeth on upper plate

Plate motion vector indicates motion of oceanic plate (FA–Farallon, KU–Kula, PA–Pacific) with respect to North America (NA). Length of plate motion vector proportional to convergence rate

various source terranes, but are noticeably poor in unmetamorphosed sedimentary rock fragments. Sandstones in the Nushagak basin, on the other hand, are characterized by sedimentary rock fragments.

Assuming that the Kuskokwim Group formed in one contiguous marine embayment, the Kuskokwim Group then stitches together most of the terranes of southern and western Alaska by Albian time. Kuskokwim strata of the Iditarod basin depositionally overlie rocks of the Ruby, Innoko, and Farewell terranes, and in the central Kuskokwim basin depositionally overlie rocks of the Farewell, Kilbuck, Goodnews, and Togiak (Hagemeister subterrane) terranes. Kuskokwim strata of the Nushagak basin depositionally overlie rocks of the Tikchik and Farewell terranes. The only terranes in or adjacent to southwestern Alaska not clearly overlain by the Kuskokwim Group are the Nyack, Kulukak subterrane of the Togiak, southern Kahiltna, and Peninsula terranes.

Igneous rocks

Igneous rocks of latest Cretaceous and earliest Tertiary age (45 to 80 Ma) are widespread throughout southwest Alaska (Wilson, 1977; Shew and Wilson, 1981; Robinson and Decker, 1986; Bergman and others, 1987; Wilson and others, this volume). These rocks have been divided by Wallace and Engebretson (1982, 1984) into two parallel northeast-trending belts, the Kuskokwim Mountains belt to the northwest, and the Alaska Range belt to the southeast. Only rocks within these two belts are summarized below; for additional information about Upper Cretaceous and Cenozoic volcanic rocks of southwest Alaska, see Moll-Stalcup (this volume).

The Kuskokwim Mountains belt consists of volcanic fields, isolated stocks, and volcano-plutonic complexes that vary widely in composition (Moll and others, 1981; Moll and Patton, 1982; Bundtzen and Laird, 1982, 1983a, b; Robinson and others, 1984a, b, 1986; Reifenstuhl and others, 1984; Robinson and Decker, 1986; Moll-Stalcup, 1987; Decker and others, 1990). Eleven volcano-plutonic complexes in the Iditarod and Ophir Quadrangles described by Bundtzen and Swanson (1984) chiefly consist of elliptical outcrop areas of andesite and basalt that overlie and flank alkali-gabbro to monzonite stocks, and are spatially associated with volumetrically minor garnet-bearing peraluminous rhyolite sills and chromium-enriched mafic dikes. Compositionally and temporally similar rocks occur to the north in the Medfra Quadrangle (Moll and others, 1980). A similar magma series is described by Robinson and others (1984a) in the southern Sleetmute Quadrangle, where granodiorite to quartz monzonite plutons intrude and are flanked by a bimodal suite of flows, tuff, lahar deposits, and hypabyssal rocks of basaltic andesite and rhyolite composition. A thick volcanic sequence consisting mainly of calc-alkaline basaltic andesite flows, tuff, and breccia are described on islands in the northern Bristol Bay region by Globerman and others (1984). Magmatic rocks of the Kuskokwim Mountains area intrude and/or overlie the Innoko, Ruby, Farewell, Kilbuck, Nyack, Goodnews, Togiak, and Tikchik terranes, and the Kuskokwim Group.

The Alaska Range belt consists of three longitudinal segments of magmatic rocks: a northeastern segment consisting of scattered batholiths and stocks with sharp discordant contacts, a central segment consisting of extensive elongate and concordant batholithic complexes with dynamothermally metamorphosed country rock, and a southwestern segment consisting of extensive volcanic fields and scattered hypabyssal plutons (Reed and Lanphere, 1973, 1974; Wallace and Engebretson, 1984). Intrusive rocks generally are tonalite, quartz-diorite, and granodiorite, and subordinate gabbro, syenite, quartz monzonite, and monzonite (Solie, 1983); volcanic rocks range from basalt to rhyolite and occur as flows and pyroclastic deposits (Reed and Lanphere, 1973, 1974; Solie and others, 1982; Wallace and Engebretson, 1984). The Alaska Range belt intrudes and/or overlies the Farewell, Kahiltna, and Peninsular terranes, and the Kuskokwim Group.

Moll and Patton (1982) and Bergman and Doherty (1986) combine the Kuskokwim Mountains belt and the Alaska Range belt into one province extending from the Alaska Range to the Yukon-Koyukuk Province. Bergman and Doherty (1986) and Bergman and others (1987) present age distribution and geochemical data on the 45- to 80-Ma igneous rocks in southern Alaska. They feel that the data for the 60- to 80-Ma rocks are consistent with subduction-related magmatism occurring in a 400- to 600-km-wide province. On the other hand, on the basis of trace element and isotopic data Bergman and others (1987) believe that the 45- to 60-Ma magmatism in the region resulted from post-subduction processes characterized mainly by crustal lithospheric melting (also see Hudson, this volume).

Upper Cretaceous and Tertiary sedimentary rocks

Nonmarine conglomerate, sandstone, shale, and coal occur in a series of small fault-bounded sedimentary basins that formed along the Denali-Farewell fault system in the McGrath Quadrangle (Gilbert, 1981; Dickey, 1982; Gilbert and others, 1982; Solie and Dickey, 1982; Kirschner, this volume). The rock assemblages in these basins are similar to those in the Usibelli Group in the Healy Quadrangle (Wahrhaftig and others, 1969; Wahrhaftig, 1987). In the McGrath Quadrangle, quartz and argillite clasts from the lowest unit were derived primarily from the polycrystalline basement rocks of the Yukon-Tanana terrane to the northeast (Dickey, 1984). Pollen ages for the quartz-argillite clast unit range from Eocene to middle Oligocene (unpublished company data cited in Dickey, 1984). Limestone-clast and felsite-clast units overlying the quartz-artillite unit are probably late Tertiary in age and were probably derived from the Farewell terrane in the Alaska Range to the south (Dickey, 1984). Coal in the Tertiary rocks in the McGrath Qaudrangle range in thickness from 1 to 20 m and in BTU rank from subbituminous C to A (Solie and Dickey, 1982).

Uppermost Cretaceous (Maestrichtian) nonmarine sedimentary rocks of the Summit Island Formation (Hoare and others, 1983) occur along coastal exposures in the Togiak Bay area. These rocks consist of thick-bedded conglomerate, sandstone, siltstone, carbonaceous mudstone, and sparse coal seams. The Summit Island Formation overlies with angular unconformity rocks of the Togiak terrane.

CONCLUSIONS

Southwest Alaska is composed of the predominantly Paleozoic continental margin rocks of the southwestern Alaska Range and northern Kuskokwim Mountains region (Farewell terrane), and of the predominantly Mesozoic accretionary rocks of the northern Bristol Bay region (Fig. 10). The Farewell terrane (together with the Kilbuck terrane and Idono sequence) probably formed a significant part of the North American continental backstop against which the Mesozoic terranes of southern Alaska were accreted. Although its contact with the Farewell terrane is not exposed, the Togiak-Goodnews arc-trench complex (here interpreted as a single terrane at least since Early Cretaceous time) has been amalgamated with the Farewell terrane at least since Albian time, when deposition of the Kuskokwim Group across the terranes in both regions began (Fig. 10; Cady and others, 1955; Hoare, 1961; Hoare and Coonrad, 1978a; Wallace, 1983). South of the Denali-Farewell fault, the suture zone between the Farewell terrane and the Togiak and Goodnews terranes probably is covered by the Kuskokwim Group and by younger deposits in the low-lying Nushagak Hills. North of the fault, the suture probably occurs within the centrak Kuskokwim Mountains, where it also is buried by the Kuskokwim Group and younger deposits.

The southern Kahiltna terrane has been juxtaposed against the Farewell terrane at least since latest Cretaceous to Paleocene time, when magmatism of the Alaska Range belt occurred within and northwest of the southern Kahiltna terrane (Wallace, 1983, 1984; Wallace and Engebretson, 1984; Wallace and others, 1989). The boundary between the southern Kahiltna terrane and the Farewell probably is a major suture zone (Fig. 10) along which the far-travelled terranes of southern Alaska (such as Wrangellia and the Peninsular terranes) were juxtaposed against North America. Considerable postcollisional northward translation of at least some of these terranes may have occurred by strike-slip displacement along this suture. The suture is generally buried by overlap deposits, intruded by post-accretion plutons, or modified by more recent faulting. The locations of the suture at depth may correspond with a pronounced aeromagnetic discontinuity (Decker and Karl, 1977) at the position of the Mulchatna fault at the surface. Considerable rearrangement of southwestern Alaska has occurred by strike-slip and thrust-faulting since deposition of the Albian and latest Cretaceous to Paleocene overlap strata. The disruptions, however, probably have been insignificant compared to the amount before amalgamation, as indicated by the fact that the Kuskokwim Group and the Alaska Range magmatic belt still are geologically relatively coherent.

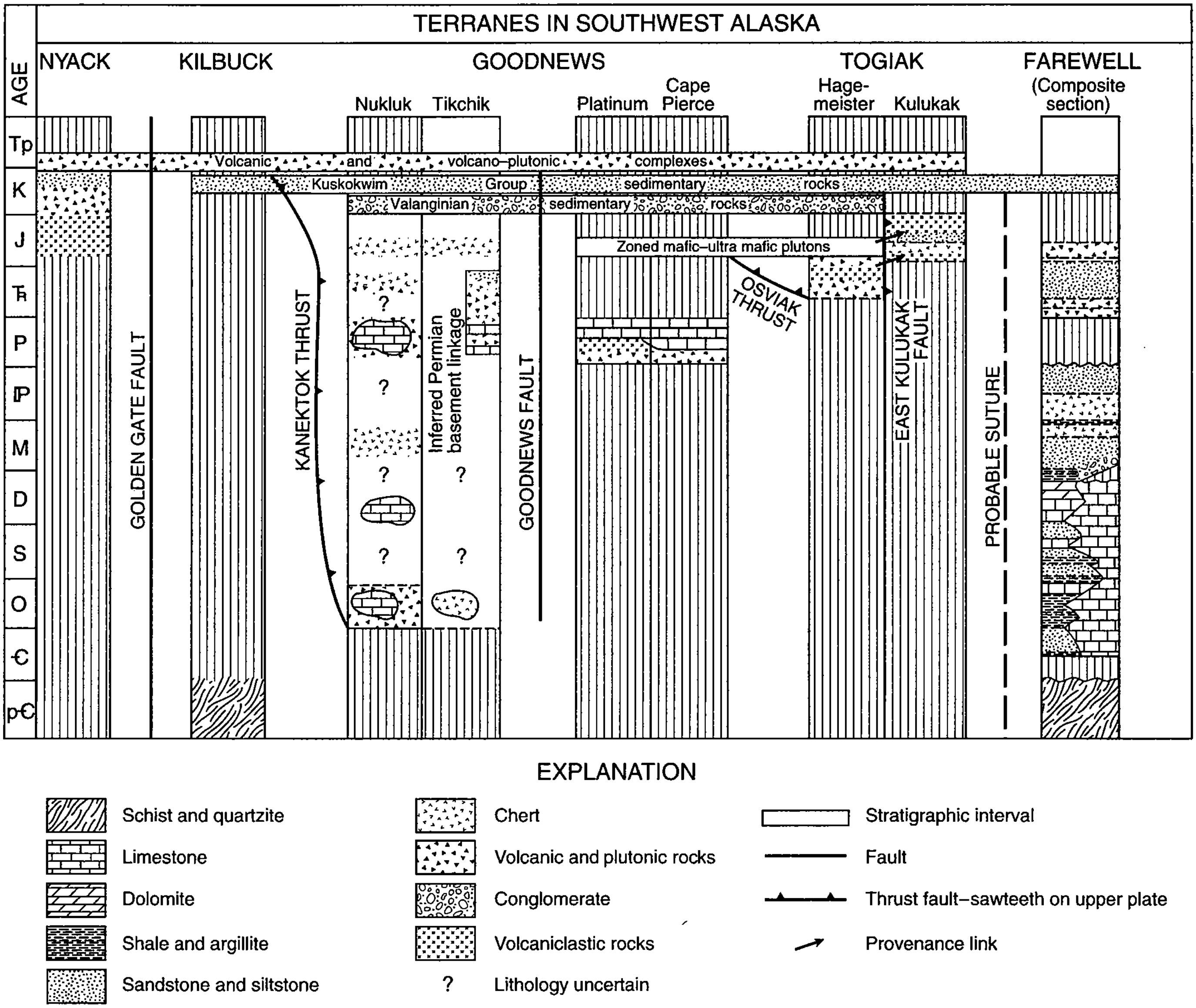

Figure 10. Diagram showing amalgamation history of terranes in southwest Alaska.

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MANUSCRIPT ACCEPTED BY THE SOCIETY NOVEMBER 16, 1990

ACKNOWLEDGMENTS

Most of what is known about the geology of southwest Alaska is from systematic field mapping by J. M. Hoare, W. L. Coonrad, W. H. Condon, and S. E. Box in the Bristol Bay region, by W. M. Cady, J. Decker, J. M. Murphy, M. S. Robinson, and R. R. Reifenstuhl in the southern Kuskokwim Mountains, by W. W. Patton, Jr., T. K. Bundtzen, M. L. Miller, J. T. Dutro, E. J. Moll, and G. M. Laird in the northern Kuskokwim Mountains, and by B. L. Reed, T. K. Bundtzen, W. G. Gilbert, J. T. Kline, and D. N. Solie in the southwestern Alaska Range. Recent detailed mapping and topical studies, in large part by the authors of this chapter, and regional studies by D. L. Jones, N. J. Silberling, M. Churkin, and others, have contributed much to our current understanding of the geology of southwest Alaska. Discussions with geologists at the Alaska Division of Geological and Geophysical Surveys, in particular, D. B. Dickey, M. W. Henning, J. T. Kline, R. R. Reifenstuhl, T. E. Smith, and T. N. Smith have been very helpful, and we thank them for their coöperation.

This chapter was compiled by Decker, Murphy, and Robinson in 1984 and 1985, and was partially updated by Decker and Bergman in 1990 to include current references. The chapter was compiled from contributions on the southwestern Alaska Range and northern Kuskokwim Mountains by Blodgett, Bundtzen, Clough, Decker, Gilbert, and Miller; on the Holitna basin by Blodgett and Clough; on the Bristol Bay region and southern Kuskokwim Mountains by Box, Coonrad, Decker, Murphy, Robinson, and Wallace; on post-accretionary rocks by Bergman, Bundtzen, Decker, Robinson, and Wallace; and on the southern Kahiltna terrane by Wallace.

We dedicate this chapter to Joseph M. Hoare (1918 to 1981) for his pioneering contribution to the geology of southwest Alaska.

NOTES ADDED IN PROOF

Since the completion of the original draft of this chapter, the following relevant publications on paleontology and stratigraphy have appeared.

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Printed in U.S.A.