UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MESOZOIC STRATIGRAPHY--THE KEY TO TECTONIC ANALYSIS OF SOUTHERN AND CENTRAL ALASKA

by

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OPEN-FILE REPORT
79-1200

ABSTRACT

Southern and central Alaska constitutes an enormous tectonic mosaic composed of separate structural blocks and fragments that accreted to North America during Mesozoic and early Cenozoic time. Some of these blocks are far traveled, as shown by paleomagnetic and paleontologic studies. More than 25 discrete tectonostratigraphic terranes now are known, each of which exhibits a characteristic internal stratigraphic sequence that differs markedly from that of neighboring terranes.

Lower Mesozoic rocks, which are widely distributed in these terranes, provide the most complete information for analyzing regional depositional and structural patterns. Sedimentary and volcanic facies of this age include: nonmarine red beds with minor intercalated basalt flows; extensive subaerial plateau basalt flows; shallow marine sandstone, conglomerate, and siltstone; inner to outer platform carbonate rocks; deep-water limestone, chert, cherty crystal tuff, and argillite; pillow basalt with associated deep-water volcaniclastic sedimentary rocks; and andesitic flows, tuffs, and volcanoclastic rocks with marine fossils. No systematic depositional patterns are perceived that indicate that these contrasting facies were deposited in their present structural positions; instead, large-scale tectonic juxtaposition is required.

The dominant structures produced during accretion were thrust faults that were modified by concurrent and later strike-slip faults. Some terranes may be enormous nappes, but much more detailed stratigraphic and structural studies are needed, with emphasis on the age and stratigraphy of deep-water siliceous and carbonate rocks, before the complex history of deposition and subsequent accretion can be adequately elucidated.

Introduction

Stratigraphic studies are so essential to tectonic syntheses of large areas that the two are impossible to separate. This report emphasizes the contribution that Mesozoic stratigraphic research has made to concepts of the tectonic evolution of western North America, particularly southern and central Alaska. We emphasize that an understanding of regional deposition and tectonic patterns can only be gained within a well-defined, precise, and readily available biostratigraphic framework. The key to geologic history is geochronology, and for Mesozoic and older rocks, biogeochronology because only rarely do pre-Cenozoic nonplutonic rocks yield accurate radiometric ages. The need for precise biostratigraphic dating is especially critical in the tectonically mixed terranes that are so abundant along the Pacific margin.

In this brief summary, we can illustrate with only a few examples how studies of Mesozoic rocks have played a key role in formulating important tectonic concepts. The examples are drawn from the diverse Mesozoic strata of southern and central Alaska that occur in a number of discrete tectonostratigraphic terranes constituting parts of a gigantic tectonic mosaic formed by the accretion of allochthonous blocks.

Tectonostratigraphic terranes of Alaska

Recent geologic and geophysical studies have shown that much of Alaska constitutes an enormous tectonic mosaic composed of separate structural entities termed tectonostratigraphic terranes (Jones, Silberling, and Hillhouse, 1977, 1978; Berg, Jones, and Coney, 1978; Churkin and Carter, 1979; Dutro and Jones, 1979). Each terrane is characterized by one or more distinctive, internally coherent stratigraphic sequences composed of rock units that can be linked through time by depositional relations and by recycled clasts derived from underlying units. Within terranes, normal facies changes are expectable and can be studied through application of well-known stratigraphic procedures. Between adjacent terranes, however, normal facies changes cannot be demonstrated, and totally dissimilar packages of rocks having radically different geologic histories commonly are closely juxtaposed. Thus, elucidation of the tectonic history of Alaska relies entirely on detailed stratigraphic studies that pinpoint discontinuities in facies trends or differences in depositional histories that require tectonic explanation.

Fig. 1 presents a simplified tectonostratigraphic terrane map of Alaska (exclusive of the Seward Peninsula and southeastern Alaska), on which 29 terranes are discriminated. Some terranes are too small to be portrayed at the scale of this map and have been omitted or combined with others. At least 50 terranes, blocks, and fragments have been recognized to date, but future work will undoubtedly require both division of some terranes and amalgamation of others, so that the total number of discrete structural entities cannot be predicted accurately at this time.

No attempt is made herein to describe each terrane or to summarize the complex tectonic and depositional histories recorded by the formation and accretion of each terrane. Rather, the emphasis is on the methodology and kinds of information that were required in order to perceive and discriminate the various terranes. Therefore, we concentrate on lower Mesozoic rocks of the southern and central parts of the state, where the stratigraphic sequences and age relations of most terranes are reasonably well understood.

Stratigraphic sequences characteristic of 10 tectonostratigraphic terranes extending from southern Alaska near the Canadian border to central Alaska are shown in Fig. 2, and the generalized location for each sequence is indicated in Fig. 1. Brief descriptions of each sequence are given in the following section, starting in the southeast corner of the state and proceeding generally northwestward.

Stratigraphic sequences of tectonostratigraphic terranes in southern and central Alaska

Wrangellia

Four formations of Triassic age are known in the Wrangell Mountains of east-central Alaska (loc. 10, Figs. 1 and 2), where they have been studied in detail by E. M. MacKevett, Jr., and coworkers (see MacKevett, 1976). The lowest unit, an unnamed unit of Middle Triassic (Ladinian) age, has a limited distribution and comprises a thin (100 m thick) sequence of grayish-black thin-bedded chert, siltstone, and fissile shale in which the bivalves *Daonella degeeri* and *D. frami* are locally abundant. This unit overlies argillite and limestone of the Lower Permian Hasen Creek Formation and is overlain by the Nikolai Greenstone of Middle and(or) Late Triassic age.

The Nikolai Greenstone constitutes a vast, largely subaerial, but locally pillowed basaltic lava field that extends throughout the Wrangell Mountains and the adjoining eastern Alaska Range and eastward into Canada, where it is an important element of the Mush Lake Group of Muller (1967). MacKevett and Richter (1974) reported that the Nikolai consists of intermixed aa and pahoehoe flows between 0.3 and 15 m thick and reaches a cumulate thickness exceeding 3500 m. Chemical analyses reported by MacKevett and Richter (1974) indicated that the basalt generally is slightly quartz-normative tholeiite but also includes some that is olivine normative. Amygdules are abundant and are filled mainly with chlorite and calcite and less commonly with quartz, epidote, prehnite, or zeolites, as well as native copper or copper-bearing ore minerals.

The Nikolai is disconformably overlain by a sequence of Triassic sedimentary rocks as much as 1400 m thick, commencing with limestone and dolomite that locally contain stromatolites, algal-mat chips, relicts of evaporites, and other indicators of deposition under sabkha conditions (Armstrong and MacKevett, in press). These inner-platform carbonate rocks, the Chitistone Limestone, grade upward into more open platform limestone and then into the open platform or basinal limestone of the Nizina Limestone (Armstrong and others, 1969). Some beds at the transition between the Chitistone and Nizina Limestones contain a remarkably diverse silicified fauna of early Norian invertebrate shells and skeletal fragments representing gastropods, bivalves, brachiopods, corals, spongiomorphs, cephalopods, and echinoderms. About 30 specifically distinct taxa of gastropods alone are represented.

Conformably above the Nizina are basinal deposits of calcareous shale, impure limestone, impure chert, and spiculite of the McCarthy Formation of Late Triassic and Early Jurassic age (MacKevett, 1976). Larger invertebrate fossils from the Triassic part of this formation are restricted to pelagic forms such as Monotis, Heterastridium, and ammonoids. Ammonites of Hettangian to late Sinemurian (Early Jurassic) age occur in the upper part of the McCarthy.

The Lubbe Creek Formation of Pliensbachian to late Toarcian (Early Jurassic) age conformably overlies the McCarthy Formation. This unit consists of 100 m of impure spiculite with lenses and beds of coquinoid limestone and minor chert. Disconformably above the Lubbe Creek is a sandstone unit as thick as 400 m, named by MacKevett (1969) the Nizina Mountain Formation, which consists of well-bedded reddish-brown-weathering feldspathic graywacke with minor shaly beds and fossiliferous limy lenses and concretions containing fossils of Bajocian and Bathonian (Middle Jurassic) age. The uppermost Jurassic unit, the Root Glacier Formation, includes 1200 m of mudstone, siltstone, graywacke, and conglomerate. Fossils range in age from early Oxfordian to late Kimmeridgian (Late Jurassic).

Deposition of Cretaceous rocks in the eastern Wrangell Mountains commenced in early Albian time, after a period of folding and faulting that affected older rocks as young as Late Jurassic (Jones and MacKevett, 1969). Nearly continuous deposition of clastic rocks and minor chert continued through the Cretaceous until late Campanian or early Maestrichtian time. In the western Wrangell Mountains, basal Cretaceous strata are as old as Hauterivian and Barremian(?). These strata are overlain unconformably by lower Albian beds similar to those of the eastern Wrangell Mountains; Aptian strata are absent.

Peninsular terrane in the Talkeetna Mountains

Mesozoic volcanic, plutonic, and sedimentary rocks exposed in the Talkeetna Mountains of southern Alaska constitute the northeast end of a long, nearly continuous belt--the Peninsular terrane (loc. 9, Figs. 1, 2)--that to the southwest forms the backbone of the Alaska Peninsula. Geologic mapping by Grantz (1960a, b, c; 1961a, b) and numerous paleontologic studies by Imlay (1953; 1961; 1962; 1964), Jones (1963, 1967), and Jones et al. (1965) have elucidated the basic stratigraphic framework of Mesozoic rocks of the Talkeetna Mountains.

The oldest exposed rocks are lava, tuff, and volcanogenic sandstone and siltstone of the Talkeetna Formation. This unit is more than 2000 m thick and ranges in age from at least early Sinemurian to late Toarcian (Early Jurassic) (Imlay and Detterman, 1973, p. 11). The Talkeetna is overlain unconformably by the Tuxedni Group, constituting 250 to 400 m of fossiliferous sandstone and siltstone of Middle Jurassic (Bajocian) age. Younger Middle and Late Jurassic rocks of Bathonian, Callovian, Oxfordian, and Kimmeridgian ages over 1000 m thick are subdivided into three unconformity-bounded formations: in ascending order, an unnamed tongue, the Chinitna Formation (Middle Jurassic), and the Naknek Formation (Upper Jurassic). Succeeding Cretaceous rocks range in age from late Valanginian (Early Cretaceous) to latest Campanian or early Maestrichtian (Late Cretaceous) and are entirely clastic. A distinctive calcarenite composed dominantly of comminuted Inoceramus shells (Jones, 1973) occurs locally at or near the base.

Susitna terrane

The Susitna terrane (loc. 8, Figs. 1, 2) consists of two mappable units: an Upper Triassic pillow basalt and clastic sedimentary rock unit and a Cretaceous flysch unit. The flyschlike rocks of the Susitna terrane, which are not known in detail, are dominantly fine grained with local interbeds of fine- to medium-grained graywacke. Bedding and slaty cleavage dip dominantly to the southeast, and many strata are overturned to the northwest. Fossils are extremely rare within the flysch of the Susitna terrane and are known from only two localities. Only one poor specimen of Inoceramus of probable Cretaceous age and a bed of Buchia-bearing limestone of Valanginian age have been found.

Two large sheets of basalt (some pillowed) with intercalated tuffaceous sedimentary rocks are structurally interleaved with the upper Mesozoic flysch. The sedimentary intercalations contain the late Norian (Late Triassic) fossils Monotis subcircularis and Heterastridium. The Triassic rocks are overturned to the northwest and comprise two parts: a stratigraphically lower part of pillow basalt several hundred or more meters thick, and an upper part of intercalated massive basalt flows, tuff, sandstone, and siltstone 300 to 400 m thick. The fossils were obtained from the upper part of this unit. In the past, these rocks have been loosely correlated with the Middle and(or) Upper Triassic Nikolai Greenstone of the Wrangell Mountains (for example, Jones et al., 1977), but the presence of the late Norian fossils demonstrates that these two basaltic units are dissimilar in age.

Upper Mesozoic flysch occurs both above and below this inverted slab of Triassic basalt. Depositional superposition of the flysch upon the Triassic basalt is possible, but the original nature of their contact is not known. The mapped distribution of the Triassic rocks suggests that they form a large thrust sheet or nappe that is isoclinally folded and overturned to the northwest.

West Fork terrane

The West Fork terrane (loc. 7, Figs. 1, 2) consists of three mappable fault-bounded units that are described below in descending structural order. We emphasize that stratigraphic relations have not been established, nor have the ages of certain rocks of this terrane been adequately determined.

Multiply deformed, isoclinally folded beds of argillite, chert, and sandstone form the structurally highest part of the West Fork terrane throughout most of its length. Gray to black chert locally predominates, but argillite and thin-bedded sandstone are the most common rock types; locally, massive graded siltstone and sandstone with interbedded argillite form the bulk of exposures. Several samples of chert have yielded well-preserved radiolarians of Late Jurassic age (Jones et al., in press).

Fault-bounded blocks and lenses of thick-bedded (as much as 1 m thick) fossiliferous phosphatic limestone, siltstone, sandy limestone, and limy conglomerate occur within the argillite, chert, and sandstone unit. These bodies range in size from about 50 to over 1000 m in length. Early Jurassic ammonites and bivalves found at five localities are all indicative of an early Sinemurian (Early Jurassic) age. Hence, rocks of Early and Late Jurassic age are juxtaposed without any apparent stratigraphic order.

A very thick unit of massive cliff-forming dark-grayish-green crystal tuff with minor fossiliferous sandstone and conglomerate lies in fault contact immediately southeast of the argillite, chert, and sandstone unit. Original relations between these two units are obscure, but several lines of evidence suggest that the massive tuff unit now structurally underlies the argillite, chert, and sandstone unit and may, in part, be the older of the two. Fragments and pebbles of crystal tuff in the argillite, chert, and sandstone unit suggest derivation from the massive tuff. Relatively coarse grained patches and layers of the tuff consist mostly of calcitized plagioclase crystals as large as 0.5 mm, along with mafic volcanic and indeterminate lithic grains, set in a cryptocrystalline impure siliceous matrix. Finer grained layers are mostly cherty matrix with sporadic crystals as large as about 0.1 mm.

Fossils of late Sinemurian (Early Jurassic age were found at one place within the massive tuff unit in 2- to 3-m-thick beds of conglomeratic sandstone that contain phosphatic pellets. These coarse clastic rocks are overlain by 30 m or more of dark-gray siltstone with minor beds of conglomerate, which are in turn overlain by fine-grained crystal tuff similar to that forming the bulk of the unit. These appear to be among the youngest exposed beds of the massive tuff unit, which may be several thousand meters thick.

The base of the massive tuff unit is unknown, as are the internal structure and age of the bulk of the formation. Because of its great thickness, we assume that some rocks of the tuff may be of Triassic age, but no fossils are available to prove this.

Chulitna terrane

The upper Chulitna mining district is characterized by a distinctive sequence of Paleozoic and lower Mesozoic rocks found nowhere else in Alaska (Hawley and Clark, 1974; Clark et al., 1972; Silberling et al., 1978; Jones et al., in press). This sequence, termed the Chulitna terrane (loc. 6, Figs. 1, 2), is complexly folded and faulted and structurally overlies dissimilar Mesozoic strata (including the West Fork terrane). The oldest rocks of the sequence include serpentinite, gabbro, diabase, pillow basalt, basalt breccia, and red radiolarian chert. This assemblage is believed to constitute a dismembered ophiolite of Late Devonian age (Silberling et al., 1978), on the basis of fossils obtained from the chert (Brian Holdsworth, written commun., 1976).

Rocks younger than the ophiolite include: Mississippian chert; Permian volcanic conglomerate and breccia, flysch, chert, and limestone; Lower Triassic limestone; Upper Triassic breccia composed of blocks of limestone in an argillite matrix; Upper Triassic red beds with interbedded basaltic and silicic volcanic rocks; Jurassic siltstone, sandstone, and chert; and Cretaceous argillite, chert, sandstone, and thin beds of cochinoid (Buchia) limestone. The Triassic part of this sequence is of particular importance because it contains a more complete record of early Mesozoic history than any other place in Alaska south of the Brooks Range. Therefore, the Chulitna terrane constitutes a key reference section with which other nearby terranes can be compared and contrasted.

Exposed Lower Triassic rocks consist of about 10 m of limestone with beds of secondary chert. The uppermost limestone bed contains abundant specimens of ammonites of Smithian age that show southern faunal affinities (Nichols and Silberling, in press). This bed is locally capped by 10 cm of cherty phosphatic argillite containing abundant fragments of fish bones and conodonts of lowest Spathian age, as determined by B. R. Wardlaw (written commun., 1978). These rocks are unconformably overlain by a few meters of sandy limestone, the base of which is conglomeratic, and then, above a covered interval, by several meters of greenish-gray argillite containing boulder-size blocks of limestone. Fossils from these blocks are Halobia, brachiopods, and conodonts of Karnian age (B. R. Wardlaw, written commun., 1978). The age of the matrix is unknown. Red mudstone with limestone blocks overlies the greenish-gray argillite and, in turn, is overlain by red conglomeratic sandstone with intercalated basalt flows.

Elsewhere within the terrane, these red beds are hundreds of meters thick and contain a few thin limestone units that have yielded ammonites and other fossils of Norian (Late Triassic) age. The character of the clastic detritus in the red beds indicates two discrete sources: the basalt, gabbro, serpentinite, and chert clasts were derived from the underlying oceanic Devonian ophiolite, as evidenced by identical radiolarian faunas in the in situ chert and in clasts; and the polycrystalline quartz, mica, metaquartzite, and schist clasts were derived from a metamorphic terrane of continental affinity. Clasts of similar composition are unknown in older conglomerates within the Chulitna terrane, which, instead, are entirely of volcanic and sedimentary origin. The source for the silicic detritus has not been identified, but its sudden appearance, mixed with ophiolite debris, indicates a major tectonic event occurred during Late Triassic time along a continental margin.

The Triassic red beds grade upward into marine sandstone and siltstone of latest Triassic and Early Jurassic age. The passage beds show numerous cycles of marine and nonmarine deposition before fully marine conditions were established. Shallow-water fossils, such as large heads of scleractinian colonial corals, Heterastridium, and diverse bivalves, are abundant.

The younger Mesozoic rocks consist of chert, argillite, sandstone, and minor limestone of Late Jurassic and Early Cretaceous age. Because these strata are complexly faulted and isoclinally folded, a detailed stratigraphy for this part of the section has not been established, and comparison with other terranes is difficult.

McKinley terrane

Rocks of the southern part of McKinley Park, north of the Denali fault, comprise a poorly understood structurally complex terrane--the McKinley terrane (loc. 4, Figs. 1, 2)--composed of interleaved clastic rocks (flysch and conglomerate), minor chert, and large masses of pillow basalt, breccia, tuff, diabase, and gabbro. No stratigraphic sequences have been established, and the ages of only a few rocks are known.

Hickman and Craddock (1975) determined an age of Permian and(or) Pennsylvanian for the bulk of these rocks, but suggested that older and younger rocks also may be present. Their age determination was based on two K-Ar analyses of gabbro, which gave ages of 307 m.y. and 139 m.y., and on several fossil localities that yielded Paleozoic fossils. We revisited two of their fossil localities; at locality UW1574 we recovered from limestone clasts in a massive conglomerate fossils of Devonian and Permian ages (J. T. Dutro, written commun., 1978); black chert pebbles yielded probable Mississippian radiolarians. The age of the conglomerate is post-Permian, probably Cretaceous. At locality UW1574 we found poorly preserved scraps of Buchia(?) in siltstone and Mesozoic radiolarians in chert; an Early Cretaceous (Valanginian) age for both seems likely.

Fossils from the volcanic rocks of the McKinley terrane are exceedingly scarce; only one small specimen is known, consisting of an incomplete example of Halobia, probably H. superba or H. cordillerana, which was found by Wyatt Gilbert on the west side of Polychrome Pass (University of Alaska loc. A-370). A late Karnian to middle Norian age is indicated. The relation of these rocks to the gabbros dated by Hickman and Craddock (1975) is unknown.

Dillinger terrane

A thick sequence of deformed Paleozoic sedimentary rocks in the central Alaska Range has been referred to as "sedimentary rocks of the Dillinger River" (Armstrong, Harris, Reed, and Carter, 1977; Reed and Nelson, 1977). These rocks consist of three units: interbedded lime mudstone and shale of unknown thickness; deep-water lime mudstone more than 900 m thick; and interbedded lithic arenite, shale, and limestone at least 700 m thick. Because of structural complexities, the relative ages and stratigraphic relations of these rocks are unknown, but both graptolites and conodonts of Silurian age are known from the limestone unit (Armstrong *et al.*, 1977, p. B62).

These lower Paleozoic rocks are overlain unconformably by a thin unit a few tens of meters thick of fossiliferous limy and phosphatic siltstone and sandstone of Sinemurian (Early Jurassic) age (R. W. Imlay, written commun., 1977). This unit is overlain by several meters of chert, siltstone, and limestone with abundant Buchias of Early Cretaceous (Valanginian) age. Triassic strata are absent. Both the Mesozoic rocks and the underlying Paleozoic rocks are here referred to as the Dillinger terrane (loc. 5, Figs. 1, 2).

Pingston terrane

A thick isoclinally folded sequence of interbedded laminated siliceous limestone, sooty-black shale, and calcareous siltstone crops out discontinuously north of the Denali fault in the northern foothills of the central Alaska Range. These rocks are referred to as the Pingston terrane (loc. 3, Figs. 1, 2). Southwestern exposures were mapped by Reed and Nelson (1977), who suggested a correlation with the lower Paleozoic strata. Late Triassic conodonts were reported from two localities by Hickman and Craddock (1975) in equivalent strata to the east in McKinley Park, and additional Late Triassic conodonts have since been found in numerous localities in and east of the park (D. L. Jones, N. J. Silberling, and B. R. Wardlaw, unpub. data; Paul Umhoefer, written commun., 1978). Lithologically similar but more highly metamorphosed strata are north of the Denali fault to the southeast near the Canadian border (Richter, 1976), but no fossils have been found there to substantiate the lithologic correlation.

Throughout its known and inferred extent, stratified rocks of the Pingston terrane are intruded by large masses of gabbro and diabase, but no volcanic rocks are known within the terrane. The age of the basic intrusive rocks has not been established but is probably Mesozoic. Neither the depositional top nor the base of the Triassic rocks of the Pingston terrane have been observed. The rocks lie in fault contact with upper Mesozoic clastic rocks and Triassic basalt of the McKinley terrane on the south, and with regionally metamorphosed Paleozoic rocks of the Yukon-Tanana terrane to the north, across the Hines Creek fault.

Nixon Fork terrane

A thick sequence of Precambrian(?), Paleozoic, and Mesozoic rocks in west-central Alaska is called the Nixon Fork terrane by Patton (1978) (loc. 2, Figs. 1, 2). The basal unit consists of mica schist and quartzite of probable Precambrian age, overlain along a sheared contact (Patton, Dutro, and Chapman, 1977, p. B39) by a thick sequence of platform limestone and dolomite of Ordovician to Devonian age. Similar rocks occur to the southwest in the Lime Hills region. Unconformably overlying the carbonate sequence is 60 m of sandy limestone, grit, limy sandstone and mudstone containing abundant Permian brachiopods (Patton, Dutro, and Chapman, 1977). Clasts of mica schist from the lowest unit locally occur in the basal part of this sequence.

Mesozoic rocks unconformably overlie the Permian rocks and consist of 50 m of limy sandstone, conglomerate, sandy limestone, and siltstone with *Monotis ochotica*, *M.* cf. *M. scutiformis*, and *Heterastridium* sp. of middle and late Norian age. These clastic rocks grade abruptly into a thick (100 m) unit of dark-gray bedded chert composed dominantly of sponge spicules with rare radiolarians. This unit, in turn, is unconformably overlain by sandy limestone, grit, coquinoidal limestone, sandstone, and siltstone of Valanginian and younger (Cretaceous) age. The occurrence in the Nixon Fork terrane of these particular species of the bivalve *Monotis* is of paleotectonic significance because they are characteristic of Triassic exposures in the Arctic and western Pacific. They are not found in any of the terranes that lie closer to the Pacific basin in southern Alaska, where the genus *Monotis* is represented by different, but partly coeval, species.

Innoko terrane

A thick, poorly exposed, and structurally complex assemblage of chert, volcanic and volcaniclastic rocks, minor limestone, and graywacke crops out in the Medfra and Ruby quadrangles of west-central Alaska. This assemblage, named the Innoko terrane (loc. 1, Figs. 1, 2) by Patton (1978), continues on to the northeast and may include rocks of the Rampart Group. The Innoko terrane also is known to extend to the southwest into the Ophir quadrangle (unpublished data of R. Chapman, D. L. Jones, and Brian Holdsworth).

The oldest rocks of the Innoko terrane consist of variegated cherts and argillite of latest Devonian and Carboniferous (Mississippian) age. The Mesozoic rocks include a thick sequence of tuff, volcanic conglomerate, breccia, and basalt, with intercalated radiolarian chert of Norian (Late Triassic) age. Much of the volcanic detritus appears to be intermediate in composition and probably represents andesitic-arc volcanism. Unconformably(?) overlying the Triassic volcanic assemblage is a thick unit of volcanic sandstone, conglomerate, and tuff of probable Early Cretaceous age.

Stratigraphic analysis

The basic stratigraphic data for 10 key terranes in southern and central Alaska have been briefly reviewed in the preceding section and are summarized in Fig. 2. The Triassic rocks provide the most meaningful information because important deposits of that age occur in 9 of the 10 terranes, and these deposits differ markedly in lithology, fossil content, thickness, and history from one terrane to another. In contrast, the Jurassic strata are well developed only south of the Denali fault, and only the Lower Jurassic rocks differ markedly between adjoining terranes. The Cretaceous rocks are generally similar in all terranes, although they do differ significantly in depositional history, thickness, and severity of deformation from place to place. Because of the relative abundance of the Triassic and Lower Jurassic rocks, the following analysis concentrates on the character and distribution of these strata.

As shown in Fig. 1, a wide variety of volcanic and sedimentary rocks characterize the early Mesozoic deposits of southern and central Alaska. Each terrane has an internally coherent stratigraphic sequence that records historical events unique to that terrane alone. For example, the Wrangellian sequence is characterized by an enormous outpouring of subaerial basaltic lava that abruptly ceased during late Karnian time, to be succeeded by inner-platform pure carbonate deposits. Later deposition records gradual sinking of this volcanic-carbonate edifice until deep-water basinal conditions were established that persisted until the end of Early Jurassic time. Because coarse clastic detritus is absent in the Alaskan exposures of this terrane its site of deposition must have been far distant from either volcanic or continental land masses.

In contrast, the Chulitna sequence totally lacks basaltic volcanic rocks of Karnian age but does contain basalt of Norian age intercalated with coarse clastic nonmarine and shallow-marine deposits. Because both locally derived and exotic (polycrystalline quartz and mica schist) detritus are in the red beds, proximity to a continental source is required. One possible source for the exotic material is the polymetamorphosed Yukon-Tanana terrane that occurs extensively in east-central Alaska and the adjoining Yukon Territory. The difficulty with this source is that the coeval Upper Triassic, but nonvolcanic, Pingston terrane, which borders the Yukon-Tanana terrane throughmost most of its extent in Alaska, is of deep-water facies and contains no recognizable coarse detritus that could have been derived from its metamorphosed neighbor to the north. Similarly, quartzose detritus is absent in the nearby Susitna terrane, which is characterized by pillow basalt and deep-water volcanogenic sedimentary rocks. Thus, with these terranes in their present positions, no area can be identified as the source of the Chulitna detritus, nor can a single depositional model relate these terranes to one another.

The Pingston terrane is in an anomalous position, with its southern terminus sandwiched between the Dillinger terrane to the southwest, which lacks Triassic rocks altogether, the Nixon Fork terrane to the northwest, which contains a thin sequence of nonvolcanic Norian sandstone, conglomerate, and chert, and the McKinley terrane to the south, which includes very thick units of Upper Triassic (Norian?) pillow basalt mixed with Mesozoic flyschlike rocks. No obvious connections between any of these terranes are apparent. Deep-water volcanogenic (andesitic) deposits with intercalated chert, also of Norian age, lie farther to the north in the Innoko terrane, but the relation of these rocks to those farther south is unknown.

The Lower Triassic limestone unit that underlies the Chulitna red beds likewise presents an anomaly because this is the only occurrence of rocks of that age in southern Alaska. Elsewhere, as in Wrangellia, Middle Triassic rocks lie directly on Permian strata with no discernible angular discordance.

As Nichols and Silberling (in press) point out, the ammonites from the Lower Triassic strata of Chulitna consist entirely of species described previously from localities in the western conterminous United States that were situated at paleolatitudes of about 10° north. The quite different species content of faunas from higher paleolatitudes implies that the Chulitna rocks have been transported northward from their point of origin in tropical paleolatitudes.

Marked contrasts are seen in Lower Jurassic strata between the east end of the Peninsular terrane in the Talkeetna Mountains and in coeval strata of Wrangellia: the former are entirely volcanic and volcanogenic, whereas coeval strata of the latter lack any evidence of volcanic activity. Likewise, as pointed out by Jones et al. (1977), Upper Triassic rocks that underlie the Jurassic volcanic rocks on the Alaska Peninsula lack Wrangellian affinities. Because of these differences, it cannot be demonstrated that the Peninsular terrane and Wrangellia shared a common early Mesozoic history. The similarity of later Jurassic and Cretaceous deposits of the two terranes implies a common history from at least Late Jurassic time to the present.

Other anomalous relations are apparent in the character and distribution of the Lower Jurassic strata. For example, the deep-water cherty crystal tuffs of the West Fork terrane have no known counterpart and contrast markedly with the shallow-water fine-grained limy clastic rocks of the nearby structurally overlying Chulitna sequence. On the other hand, the large blocks of ammonite-bearing phosphatic calcareous siltstone and conglomeratic sandstone of the West Fork terrane, mixed with deformed Upper Jurassic chert and argillite, are faunally and lithologically similar to Lower Jurassic strata of the Dillinger terrane to the southwest. Older rocks of these two terranes are totally dissimilar. The similarity between Lower Jurassic strata of the two terranes may signify their proximity during that time.

Tectonic analysis

The preceding brief review of Mesozoic stratigraphic relations reveals marked, abrupt discontinuities in stratigraphic sequence between adjoining terranes, discontinuities that cannot be explained by simple facies changes. These stratigraphic relations, coupled with paleomagnetic data indicating that some Mesozoic rocks formed at low paleolatitudes (Packer and Stone, 1974; Hillhouse, 1977; Stone and Packer, 1979), reinforce earlier interpretations that allochthonous fragments make up the bulk of Alaska and the adjoining Cordillera of Canada (Richter and Jones, 1971, 1973; Berg, Jones, and Richter, 1972; Monger and Ross, 1971; Jones, Irwin, and Ovenshine, 1972; Monger, 1977; Monger, Southey, and Gabrielse, 1972; Monger, 1975; Csejtey, 1976; Jones, Pessagno, and Csejtey, 1976; Jones, Silberling, and Hillhouse, 1977, 1978; Berg, Jones, and Coney, 1978; Davis, Monger, and Burchfiel, 1978; Monger and Price, 1979; Jones et al., in press; Stone and Packer, 1979). The only part of Alaska that is clearly autochthonous and that has remained part of North America since Precambrian time is a small area in the northeast corner of the state, bounded by the Yukon and Porcupine Rivers. Everything else, including the Brooks Range, has moved to some extent, although little agreement exists as to the nature, timing, and magnitude of most of these movements.

Because adequate paleomagnetic data exist only in the southern and southeastern parts of Alaska, only for these regions do we have quantitative measurements of the amount of movement involved in the accretionary process. Wrangellia is clearly far traveled because the paleomagnetic data indicate extrusion of Triassic lava flows at low paleolatitudes (Hillhouse, 1977). The Peninsular terrane likewise has moved north, on the basis of paleomagnetic data obtained from Jurassic rocks of the Alaska Peninsula (Packer and Stone, 1974). These data are not adequate to determine whether Wrangellia and the Peninsular terrane moved together or separately, but geologic evidence supports their separation until post-Early Jurassic time.

The loci of origin of the other terranes in southern and central Alaska discussed in this report are not known, although a southern origin for most seems required, particularly for the Chulitna terrane, because both the Upper Triassic red beds and the Early Triassic ammonite faunas show clear southern affinities.

The large quantities of basalt, both pillowed and in flows, that characterize Wrangellia as well as the McKinley, Chulitna, and Susitna terranes may be related to rifting events. If so, the age of the basalt is a critical indicator of the time of initiation of rifting. Wrangellia, which is clearly the most far traveled block, contains the oldest basalt (Ladinian to late Karnian); all the other terranes contain basalt of Norian age, by which time Wrangellia was quiescent with respect to basaltic volcanism. The Pingston terrane lacks extrusive volcanic rocks but is cut by enormous masses of gabbro and diabase of undetermined, but possibly post-Norian, age. If these mafic intrusions are also related to rifting, they may record the youngest such event in southern Alaska. Triassic basalt is absent in the Dillinger and Nixon Fork terranes--does this signify that these terranes were not subjected to massive rifting and thus have undergone only little movement during their history?

The mechanical process of accretion of these disparate geologic elements is poorly understood. Certainly, thrust faulting has played an important, and perhaps dominant, role. Structural superposition of adjacent terranes along major thrust faults has been documented in a few places (e.g., Silberling et al., 1978; Csejtey et al., 1978; Berg et al., 1978), and the Border Ranges thrust fault in southern Alaska separates Wrangellia and the Peninsular terrane from late Mesozoic accretionary deposits of the Chugach terrane (MacKevett and Plafker, 1974; Plafker, Jones, and Pessagno, 1977). If nearly flat faults (now locally folded) do indeed bound the bases of the major terranes, the scale of thrusting is unprecedented in North America. For example, the Yukon-Tanana terrane (Fig. 1) and related rocks form an allochthon of at least 400,000 km^2--an area equal to that of the state of California. A southwest-dipping thrust bounds the northeast edge of the Yukon-Tanana terrane in the Yukon (Tempelman-Kluit, 1979, and oral commun., 1979). A northeast-dipping thrust bounds rocks of the Tracy Arm terrane in southeastern Alaska (Berg et al., 1978), and this terrane may constitute a subdivision of the Yukon-Tanana allochthon. If so, and if these faults connect at depth, the entire allochthon would then constitute an enormous nearly flat, rootless slab. Geophysical data are required to test this hypothesis.

Whatever may be the role of major thrust faults, they certainly have been modified to some extent by extensive strike-slip faults, such as the Denali fault system. Minor offsets of Quaternary deposits are well documented in southern Alaska (Richter and Matson, 1971; Plafker, Hudson, Bruns, and Rubin, 1978; Grantz, 1966), but only a few major offsets of pre-Cenozoic rocks have been substantiated. Again, the key to analysis of any such lateral movements clearly lies within the nature and distribution of the various tectonostratigraphic terranes described in this report. In a few cases, disruption of a terrane by strike-slip faulting is apparent, but the amounts of these offsets are minimal (a few hundred kilometers at most). No examples of terranes completely severed and separated by great distances have yet been discovered in Alaska. On the other hand, the very process of large-scale northward displacement must have involved transform boundaries that separated the moving terranes from the stable continental block. Discrimination of older transform boundaries from younger faults related to neotectonic activities is not yet possible--in part, at least, because many young faults may simply be reactivations of older structures.

Despite these uncertainties in structural style and mechanics of emplacement, it is now apparent that the bulk of tectonic activity that formed the Cordilleran accretionary mosaic is confined to the Mesozoic. No evidence of accretion to North America during the Paleozoic is apparent from Alaskan data, although one instance of amalgamation of subterranes during the Permian is known from southeast Alaska (Berg et al., 1978). The final accreting events appear to have occurred during middle to Late Cretaceous time because Lower Cretaceous rocks locally are severely deformed and overridden by nappes (such as the Chulitna terrane). Elucidation of the long and complex history of accretion that followed Triassic rifting will require extremely detailed stratigraphic studies and structural analyses throughout the Cordillera, with emphasis on precise dating of sedimentary and volcanic sequences and correlations in space and time of major geologic events. Biostratigraphic controls, particularly of deep-water carbonate and siliceous rocks, will be mandatory because these rocks record depositional and tectonic events not necessarily apparent in shallow-water megafossil-bearing strata.

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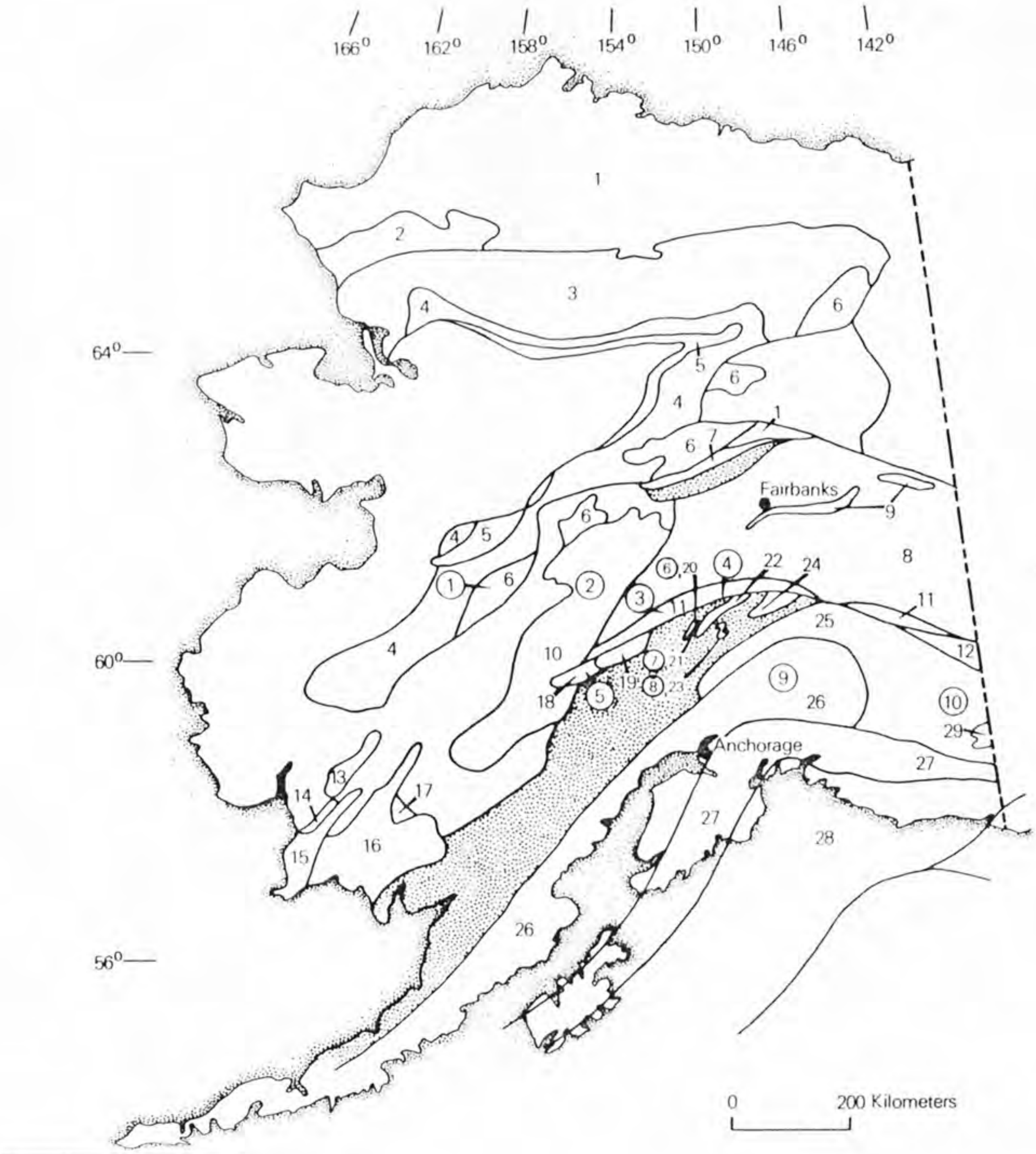
Fig. 1. Tectonostratigraphic terranes of Alaska (exclusive of the Seward Peninsula and southeastern Alaska).



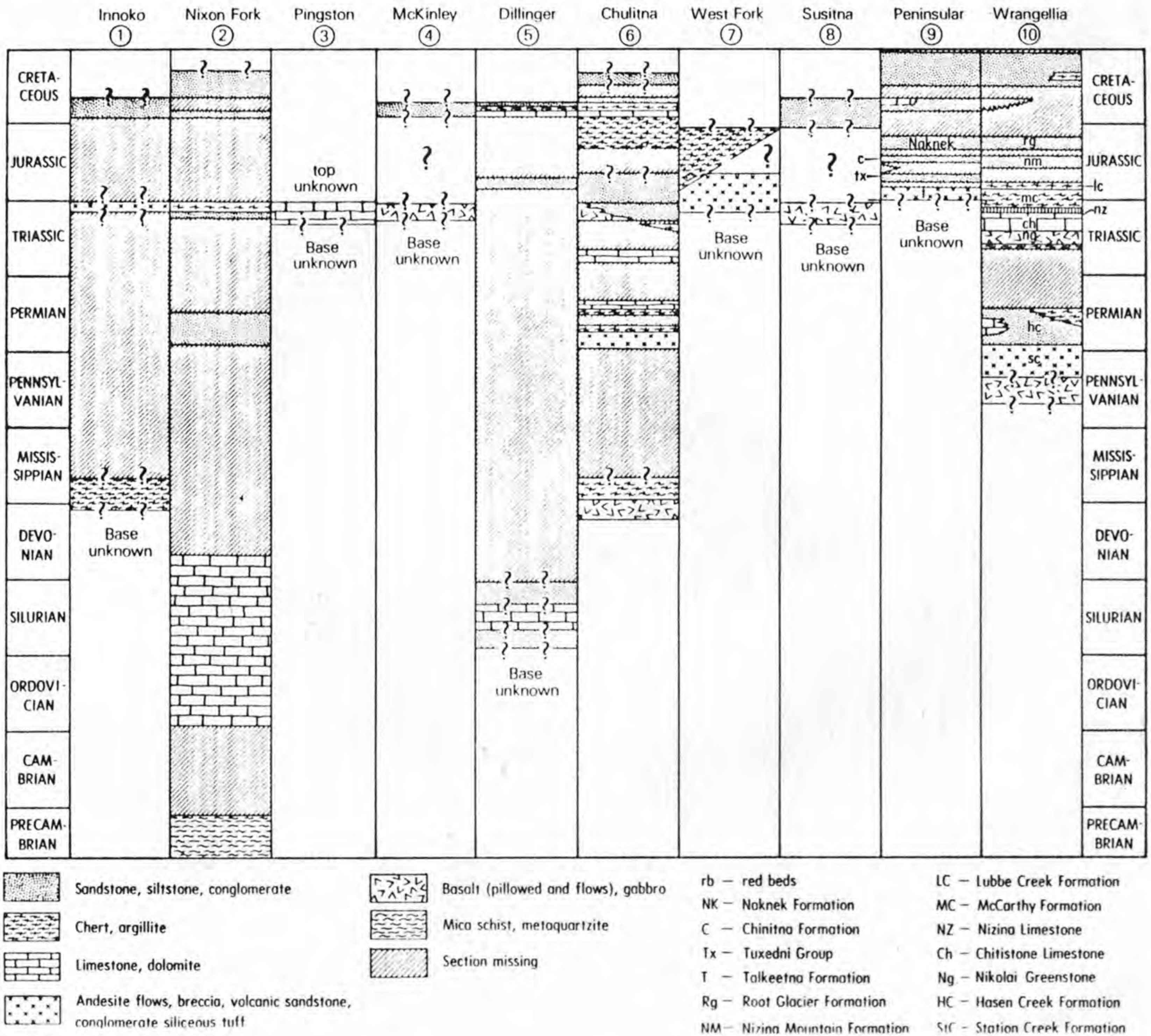
3 Key to terranes listed below

(1) Location of columnar section shown on fig 2

Tectonostratigraphic terranes (exclusive of the Seward Peninsula and S.E. Alaska)

- 1 North America
- 2 Kagvik
- 3 Endicott
- 4 Ruby
- 5 Angayucham
- 6 Innoko
- 7 Livengood
- 8 Yukon-Tanana
- 9 70 mile
- 10 Nixon fork
- 11 Pingston-McKinley, undivided
- 12 Mentásta
- 13 Nyack
- 14 Kilbuck
- 15 Goodnews
- 16 Togiak
- 17 Tikchik
- 18 Dillinger
- 19 Mystic
- 20 Chulitna
- 21 West fork
- 22 Broad Pass
- 23 Susitna
- 24 McLaren
- 25 Wrangellia
- 26 Peninsular
- 27 Chugach
- 28 Prince William
- 29 Alexander
- (stippled) Deformed upper Jurassic and Lower Cretaceous Flysch
- (blank) Undifferentiated Upper Cretaceous and Cenozoic deposits

Fig. 2. Columnar sections in selected tectonostratigraphic terranes of southern and central Alaska (See Fig. 1 for location).



Innoko ①
Nixon Fork ②
Pingston ③
McKinley ④
Dillinger ⑤
Chulitna ⑥
West Fork ⑦
Susitna ⑧
Peninsular ⑨
Wrangellia ⑩
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
top unknown
Base unknown
Noknek
c
tx
rg
nm
lc
mc
nz
ch
ng
hc
sc
Sandstone, siltstone, conglomerate
Chert, argillite
Limestone, dolomite
Andesite flows, breccia, volcanic sandstone, conglomerate siliceous tuff
Basalt (pillowed and flows), gabbro
Mica schist, metaquartzite
Section missing
rb — red beds
NK — Noknek Formation
C — Chinitna Formation
Tx — Tuxedni Group
T — Talkeetna Formation
Rg — Root Glacier Formation
NM — Nizina Mountain Formation
LC — Lubbe Creek Formation
MC — McCarthy Formation
NZ — Nizina Limestone
Ch — Chitistone Limestone
Ng — Nikolai Greenstone
HC — Hasen Creek Formation
StC — Station Creek Formation