Wrangellia—A displaced terrane in northwestern North America

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A large terrane extending along the Pacific margin of North America, from Vancouver Island, British Columbia, to south-central Alaska, is characterized throughout by similar sequences of Triassic rocks. These rocks, including a thick pile of tholeiitic flows and pillow lava (Nikolai Greenstone and Karmutsen Formation) capped with inner-platform carbonates (Chitistone Limestone, Whitestripe Marble, Kunga Formation, and Quatsino Limestone), overlie an upper Paleozoic andesitic arc sequence and Permian argillite and limestone. This coherent terrane, herein named Wrangellia, is juxtaposed against unlike sequences of Triassic and older rocks throughout its extent and is interpreted to be allochthonous. Paleomagnetic data obtained from the Nikolai Greenstone and published in a companion article by Hillhouse indicate that Middle and (or) Upper Triassic rocks in southern Alaska formed in low paleolatitudes, probably within 15° of the paleo-equator.

A possible southeastern extension of Wrangellia occurs in the Hells Canyon region of eastern Oregon and western Idaho. This area contains the typical Triassic sequence of Wrangellia and has been interpreted by other geologists as allochthonous. Paleomagnetic data are lacking, however, to document its original latitude.

Une vaste région s'étendant le long de la bordure du Pacifique en Amérique du Nord, de l'île de Vancouver en Colombie-Britannique jusqu'au centre sud de l'Alaska, se caractérise par des séquences semblables de roches triasiques. Ces roches, incluant un empilement de laves tholéiitiques épaisses et de laves en coussins (les roches vertes de Nikolai et la formation de Karmutsen) recouvertes de carbonates de plate-forme intérieure (le calcaire de Chitistone, le marbre de Whitestripe, la formation de Kunga et le calcaire de Quatsino) recouvrent une séquence andésitique d'arc datant du Paléozoïque supérieur et des argillites et calcaires du Permien. Cette région homogène, désignée ici sous le nom de Wrangellia, se juxtapose à des séquences dissemblables de roches triasiques ou plus anciennes dans toute son étendue et on l'interprète comme étant allochthone. Les données paléomagnétiques obtenues des roches vertes de Nikolai et publiées dans un autre article par Hillhouse indiquent que les roches du Trias moyen et (ou) supérieur du sud de l'Alaska se sont formées à basses paléolatitudes, probablement à moins de 15° du paléo-équateur.

Une extension possible de la région de Wrangellia au sud-est se rencontre dans la région de Hells Canyon dans l'est de l'Orégon et l'ouest de l'Idaho. Cette région contient la séquence triasique typique du Wrangellia et d'autres géologues l'ont interprétée comme étant allochthone. Les données paléomagnétiques manquent toutefois pour documenter sa latitude originale.

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Introduction

Geologic and paleomagnetic data suggest that a large terrane extending from Vancouver Island, British Columbia, to southern Alaska constitutes an allochthonous block of subcontinental dimensions that originated far to the south of its present position. This block is referred to as Wrangellia, because many of our data discussed herein were obtained from the Wrangell Mountains of southern Alaska. A detached fragment of Wrangellia may also occur in the Hells Canyon area of Oregon and Idaho, but paleomagnetic data are lacking to demonstrate its allochthonous nature.

The principal unifying characteristics of Wrangellia are provided by its Triassic strata, which include a thick Middle and Upper Triassic unit mainly composed of tholeiitic basalt that is disconformably overlain by calcareous sedimentary rocks whose deposition throughout the terrane commenced during late Karnian or earliest Norian time. Where exposed, older parts of the terrane consist dominantly of sedimentary and arc-related volcanic rocks that nowhere may be older than Pennsylvanian and, from indirect evidence, may have been, in part, deposited on oceanic crust. Triassic strata of Wrangellia contrast strongly with those in contiguous terranes, but overlying younger Mesozoic strata, where present, are less distinct. By late Mesozoic time the individuality of Wrangellia is no longer evident, and its subsequent history is shared with other terranes along the northwestern margin of North America.

The purpose of this report is to define the limits and nature of Wrangellia, to give a brief summary of the geologic evidence for its large-scale displacement, and to provide a geologic background for the new paleomagnetic data, which are presented in a companion article by Hillhouse (1977). His data were obtained from the Nikolai Greenstone (Middle and (or) Late Triassic) of the Wrangell Mountains and give strong support to the displaced nature of these rocks.

The concept that parts of what we now term Wrangellia have moved long distances is not new (Jones *et al.* 1976) and is discussed at length by Muller (1977), who uses the term 'Insular Belt' for these allochthonous rocks. However, as used by Muller the Insular Belt includes other terranes, such as the Alexander Terrane (Berg *et al.* 1972), which we regard as separate. Both paleomagnetic and paleontologic data have led Irving and Yole (1972) and Danner (W. R. Danner, personal communication, 1975; 1976) to suggest that Paleozoic and Triassic rocks of Vancouver Island originated in the southern hemisphere. Packer and Stone (1974) also have published paleomagnetic data that suggest Jurassic rocks in southern Alaska, some of which are part of Wrangellia, originated far to the south of their present position. None of these reports, however, has attempted to define the limits of the displaced terrane nor has any provided geologic data sufficiently compelling to support movements of this magnitude.

Character and Distribution of Wrangellia

Triassic rocks cropping out along the northwest coast of North America from Vancouver Island to south-central Alaska (Fig. 1) are remarkably similar throughout this distance of nearly 2000 km. Similarities, including basic stratigraphy, structure, position of unconformities, fossil faunas, and overall geologic histories, are summarized on Fig. 2. Although direct continuity cannot now be demonstrated between the major outcrop areas (Vancouver Island, Queen Charlotte Islands, Baranoff and Chichagof Islands, Wrangell Mountains, eastern Alaska Range, and Talkeetna Mountains, Fig. 1), the Triassic rocks throughout are so similar that these now disjunct areas must be regarded as formerly constituting one homogeneous, contiguous terrane. Brief descriptions of selected key areas are given below.

Wrangell Mountains, Alaska

Four formations of Triassic age are known from the Wrangell Mountains of east-central Alaska (loc. 1, Fig. 1), where they have been studied in detail by MacKevett and coworkers (see MacKevett 1976). The lowest unit of Middle Triassic (Ladinian) age has a limited distribution and comprises a thin sequence (100 m) 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 Lower Permian argillite and limestone of the Hasen Creek Formation and is overlain by the Nikolai Greenstone of Middle and (or) Late Triassic age.

Nikolai Gr. stone

The Nikolai Greenstone constitutes a vast, largely subaerial, but locally pillowed basaltic lava field that occurs throughout the Wrangell Mountains and the adjoining eastern Alaska Range and extends eastward into Canada, where it is an important element of the Mush Lake Group of Muller (1967). MacKevett and Richter (1974) report 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) indicate that the basalts generally are slightly quartz-normative tholeiites but also include some that are olivine normative. Amygdules are abundant and are mainly filled with chlorite and calcite and less commonly with quartz, epidote, prehnite, or zeolites, and native copper or copper-bearing ore minerals. Paleomagnetic data, reported separately by Hillhouse, were obtained from several sites within the Nikolai.

The Nikolai is disconformably overlain by a sequence of Triassic sedimentary rocks up to 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 (A. K. Armstrong and E. M. MacKevett, unpublished data). These inner-platform carbonate rocks of the Chitistone Limestone grade upward into more open platform limestones and then into the open platform or basinal limestones of the Nizina Limestone (Armstrong *et al.* 1969).

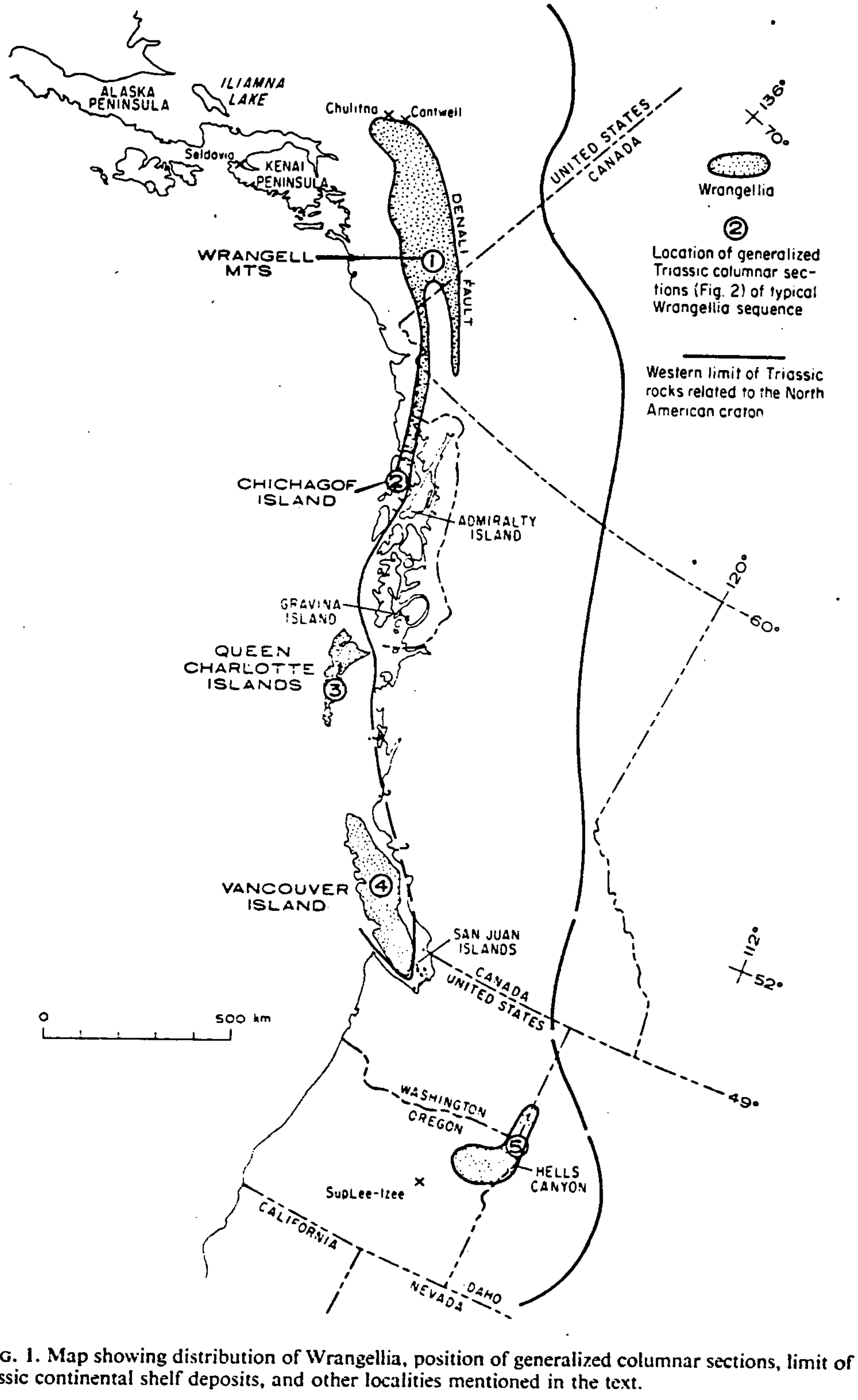

FIG. 1. Map showing distribution of Wrangellia, position of generalized columnar sections, limit of Triassic continental shelf deposits, and other localities mentioned in the text.

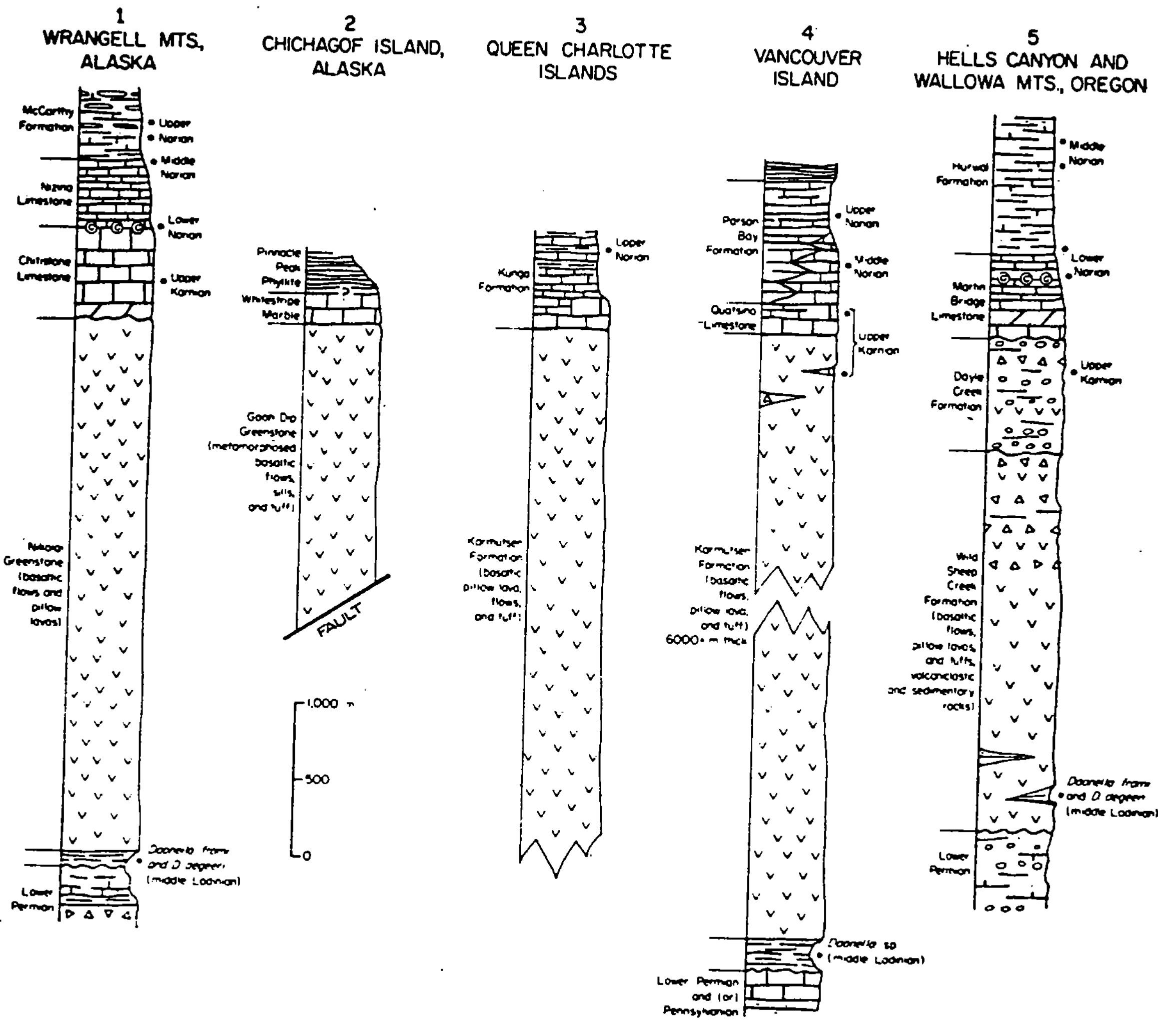

FIG. 2. Diagrammatic stratigraphic columns showing the Triassic rocks in representative sections belonging to, or possibly related to, Wrangellia. Numbers of columns refer to those of localities plotted on Fig. 1. Occurrence of age-diagnostic fossils indicated by black dots and assigned to Triassic stages abbreviated as follows: L, Ladinian; K, Karnian, and N, Norian. Coiled symbols show position of abundant and diverse molluscan faunas mentioned in text.

Some beds at the transition between the Chitistone and Nizina Limestones contain a remarkably diverse silicified fauna of lower 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. The significance of this fauna is discussed further on in the description of Wrangellia.

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.

Chichagof and Baranof Islands

A sequence of weakly metamorphosed greenstone, limestone, chert, argillite, and sandstone crops out in a narrow band on western Chichagof and northern Baranof Islands (loc. 2, Fig. 1). This sequence includes the Goon Dip Greenstone and Whitestripe Marble of Triassic(?) age (Loney *et al.* 1975) which are strikingly similar in lithologic attributes to the Nikolai

Greenstone and Chitistone Limestone of the Wrangell Mountains, as pointed out by Plafker *et al.* (1976). Also associated with the Goon Dip and Whitestripe is a distinctive amphibolite (metabasalt?) that has been traced by Plafker (G. Plafker, personal communication, 1976) as a nearly continuous band from south of the Wrangell Mountains through the Saint Elias Mountains to Chichagof and Baranof Islands, thus extending the older rocks of Wrangellia into southeastern Alaska.

Queen Charlotte Islands

The Karmutsen Formation, a thick sequence of basic lava probably more than 4000 m thick, crops out widely in the southern part of the Queen Charlotte Islands (loc. 3, Fig. 1) and has been studied by Sutherland Brown (1968). It consists of chloritized greenstone, massive amygdaloidal basalt, pillow lava, pillow breccia, aquagene tuff, and very minor amounts of lenticular limestone and other sedimentary rocks. The base of the Karmutsen is not exposed, nor are underlying older formations.

The Karmutsen is overlain by limestone of the Kunga Formation, the lowest member of which is a massive gray poorly fossiliferous limestone up to 200 m thick. This in turn is overlain by thin-bedded black flaggy limestone, containing abundant specimens of *Halobia* and *Monotis*, and by flaggy black argillite, the upper two-thirds of which contains Lower Jurassic ammonites (Sutherland Brown 1968, p. 57).

Vancouver Island

Triassic rocks are widespread on Vancouver Island (loc. 4, Fig. 1), where they have been recently studied by Muller *et al.* (1974). The lowest unit, designated by Muller *et al.* (1974) as the 'sediment-sill unit,' comprises up to 200 m of black silicified shale and siltstone that contain a Ladinian species of the bivalve *Daonella*. These sedimentary rocks are intruded by numerous thick basic sills. This unit overlies upper Paleozoic (Pennsylvanian or Early Permian) sedimentary rocks of the Sicker Group (see Muller *et al.* 1974, map 4) and is overlain by the basic lavas of the Karmutsen Formation.

Muller *et al.* (1974) divide the Karmutsen into three units: a basal member, over 2500 m thick, composed of pillow lava; a middle member, 600–1100 m thick, composed of pillow breccia and aquagene tuff; and an upper member, up to 3000 m thick, composed of basalt flows with minor amounts of pillow lava and some sedimentary layers.

Concerning the distribution of Karmutsen Formation on Vancouver Island and the Queen Charlotte Islands, Muller *et al.* (1974, p. 11) state, "The ubiquitous presence of piles of Karmutsen basalt flows on all of Vancouver Island except the southern tip, makes it apparent that the entire island region, as well as Queen Charlotte Islands consisted of great basaltic lava plateaus near the end of Upper Triassic time. The pillow lavas, aquagene tuffs, and breccias were poured out in (a) submarine oceanic environment, the bedded lavas perhaps accumulated as subaerial flood basalts, forming shield volcanoes."

The Karmutsen Formation of Vancouver Island and the Queen Charlotte Islands differs from the Nikolai Greenstone of Alaska primarily in containing a much higher percentage of pillow basalts and aquagene tuffs indicative of formation under water. The Nikolai does, however, locally contain some pillowed sequences near its base, so we do not deem this difference to be significant. On the basis of the chemistry of major elements, the rocks are remarkably similar (see Table 1).

The Karmutsen Formation on Vancouver Island is overlain by carbonate rocks whose age and stratigraphic relations are subject to different interpretation by Jeletzky (1970), Muller *et al.*

TABLE 1. Chemical analyses of the Nikolai Greenstone and the Karmutsen Formation

	Nikolai Greenstone[a]	Karmutsen Formation[b]
SiO_2	47.9	47.4
Al_2O_3	14.5	13.9
Fe_2O_3	5.2	4.1
FeO	6.4	6.5
MgO	6.9	7.7
CaO	9.4	10.5
Na_2O	3.1	3.5
K_2O	0.48	Tr
$H_2O(-)$	0.56 } = 3.76	3.8
$H_2O(+)$	3.2 }	
TiO_2	1.4	1.25
P_2O_5	0.16	0.10
MnO	0.18	0.17
CO_2	0.54	0.1

[a]From MacKevett and Richter (1974), arithmetic means (in weight percent) of major oxide components for 39 Nikolai basalts.
[b]From Muller *et al.* (1974, p. 11, Table 2, analysis no. 3). Selected because of H_2O content comparable to Nikolai specimens.
Tr, trace.

(1974), and Carlisle and Susuki (1974). All of these authors agree, however, in assigning the lower part of the post-Karmutsen limestone section to the Quatsino Limestone and in recognizing this as a shallow-water or carbonate-platform deposit. It is described as being thick-bedded and massive and as containing corals and other benthonic fossil debris, sparry coarsely bioclastic fabrics, and 'algal balls.' According to Carlisle and Susuki (1974, pp. 258–263), deposition of the Quatsino began during the early part of late Karnian time. In their view its gradation upward into the overlying Parson Bay Formation is about the same age within the upper Karnian at every known locality on Vancouver Island, aside from one place where exceptionally young fossils occur in limestone like the Quatsino. The Parson Bay contains pelagic fossils and is mainly dark laminated siliceous limestone in its lower part, but thin-bedded 'calcarenite' and feldspathic graywacke are more abundant in its higher parts. As interpreted by Carlisle and Susuki (1974), the Parson Bay ranges in age from late Karnian throughout the rest of the Late Triassic; upper Norian faunas, including those containing *Monotis subcircularis*, are well represented in the higher parts of the formation. Jeletzky (1970) and Muller *et al.* (1974) apparently define the Quatsino and Parson Bay Formations somewhat differently; they regard the lower limit of the Quatsino as latest Karnian in age and regard its upper limit with the Parson Bay as markedly diachronous within early and middle Norian time.

Possible Southeastern Extension of Wrangellia

Triassic rocks exposed in Hells Canyon of the Snake River (loc. 5, Fig. 1) and adjacent parts of eastern Oregon, western Idaho, and southeastern Washington show remarkable similarities, both lithologically and faunally, with those characteristic of Wrangellia on Vancouver Island and farther north, and we consider them to be a possible detached fragment of that terrane as does Muller (1977).

In the Hells Canyon area, the oldest of these Triassic rocks, along with rocks of Permian age, belong to the Seven Devils Group. As revised by Vallier (1974; and unpublished data), this group correlates with the Clover Creek Greenstone and the 'Lower Sedimentary series' (Smith and Allen 1941) that are exposed in or near the Wallowa Mountains of northeastern Oregon. In Hells Canyon, Triassic rocks of the Seven Devils Group consist of 2000–2500 m of basaltic flows, breccias, and aquagene tuffs, with some sedimentary intercalations, overlain by several hundred metres of predominantly conglomeratic volcaniclastic rocks (Fig. 2). The basaltic and volcaniclastic units are assigned by Vallier (1974) to the Wild Sheep Creek and Doyle Creek Formations, respectively. Concentrations of the bivalves *Daonella degeeri* and *D. frami* occur in sedimentary intercalations in the lower part of the Wild Sheep Creek Formation. Aside from their occurrence here and in beds beneath the Nikolai Greenstone of southern Alaska, congeneric bivalves resembling these two species are known only from localities in the Arctic and the western Pacific.

Overlying the Seven Devils Group with possible disconformity is the Martin Bridge Limestone, consisting of limestone and dolomite of early Norian and possibly also latest Karnian age. Like the correlative carbonate rocks of Wrangellia, the lowest part of the Martin Bridge is of inner-platform character, containing oncolitic beds and desiccation features. These inner-platform rocks then grade upward into more open marine limestones that locally contain a silicified highly diverse marine invertebrate fauna. In general biologic composition and specific taxa represented, this fauna from the upper part of the Martin Bridge in Hells Canyon and the Wallowa Mountains closely resembles the fauna of the same age from the transitional beds between the Chitistone and Nizina Limestones in the Wrangell Mountains of southern Alaska. In their present geographic locations, these two highly diverse yet taxonomically similar faunas seem to be unreasonably separated from one another latitudinally, and they show remarkably similar sedimentary and diagenetic histories, considering the great distance now separating them.

Conformably above the Martin Bridge Limestone in the Wallowa Mountains area (Nolf 1966) and upstream from Hells Canyon on the Snake River is the Hurwal Formation, which consists mostly of fine-grained generally calcareous marine clastic rocks containing exclusively pelagic halobiid bivalve and ammonoid faunas. As presently known, fossils from the Hurwal are of early and middle Norian and of Early Jurassic age; beds of latest Triassic age have not been recognized.

Further work is needed to establish the geographic limits of these Triassic rocks that resemble those of Wrangellia. It is significant, however, that although they are a considerable distance (about 400 km) inland, no other Triassic rocks are known between them and the present-day continental margin. It is possible that they were offset from the main mass of Wrangellia and moved southeastward along the trans-Idaho discontinuity of Yates (1968). Although their relation to age equivalent rocks in central Oregon, northern California, and northern Nevada remains to be established, Hamilton (1976) has already interpreted the Hells Canyon sequence to be allochthonous with respect to pre-Tertiary strata farther to the east. He recognizes a metamorphosed ophiolite belt preserved in the Riggins area of east-central Idaho as the suture zone between an accreted terrane including the Seven Devils Group and Precambrian rocks that are now greatly modified by emplacement of the Idaho batholith but were at the margin of the North American continent at the time of collision. Hamilton points out that this relation implies a late Paleozoic episode of continental rifting that removed the uppermost Precambrian and Paleozoic rocks that formed the continental shelf in the area of collision.

Boundaries of Wrangellia

The name Wrangellia is by definition applied only to areas that exhibit the characteristic Triassic stratigraphy, structures, and faunas described above. In many other parts of southern Alaska, British Columbia, Washington, Oregon, and Idaho, Triassic rocks are present, but these exhibit different stratigraphic sequences, structures, and faunas. These different areas are not part of Wrangellia, but some may also be allochthonous. Where differing sequences of Triassic rocks are in close juxtaposition to typical Wrangellia rocks, the limits of Wrangellia can be drawn quite easily, and several such critical areas are described below. Elsewhere, where unlike sequences are widely spaced, the precise limits of Wrangellia are more difficult to establish, and for such areas only arbitrary boundaries are shown on Fig. 1.

South-central Alaska

The northern limit of Wrangellia is readily established by the presence of the Chulitna sequence bordering the Chulitna Valley on the south flank of the Alaska Range (Fig. 1). There, a sequence of upper Paleozoic argillite, tuff, and limestone, Lower Triassic limestone, and Upper Triassic limestone and basalt, volcanic red beds, and Upper Triassic and Lower Jurassic marine sandstone and argillite (Hawley and Clark 1974) structurally overlies on the northwest a dismembered ophiolite (oceanic crust) containing conodont-age (A. G. Harris and B. Wardlaw, unpublished results, 1977). Rocks similar to the Nikolai Greenstone crop out about 25 km to the east in the northern part of the Talkeetna Mountains, as established by reconnaissance geologic mapping by Csejtey (B. Csejtey, unpublished data). Between the Chulitna sequence and the Nikolai Greenstone-like rocks occurs a newly recognized unit of massive siliceous bedded tuff and argillite, several thousand metres thick, of Late Triassic(?) and Early Jurassic (Sinemurian) age (R. W. Imlay, unpublished results, 1976, and unpublished data of D. L. Jones and N. J. Silberling). This unit contrasts strongly with both the coeval Wrangellia sequence and the Chulitna sequence, and shows that direct continuity could not exist between these three terranes in their present structural setting. Clark *et al.* (1972), Csejtey (1976), and Jones *et al.* (1976) have already called attention to the significance of the Chulitna district as possibly representing a suture zone along which unlike terranes have been juxtaposed, and recent fieldwork has substantiated this view (D. L. Jones *et al.*, unpublished data).

Farther east from the approximate position of Cantwell (Fig. 1), the northeastern boundary of Wrangellia is the Denali fault, which clearly separates southern Alaska into two distinctive terranes (Richter and Jones 1973; Richter 1976; Tempelman-Kluit 1976). A polymetamorphosed terrane (Yukon–Tanana upland) consisting of quartz mica schist, quartzite, marble, metaconglomerate, greenstone, and minor ultramafic rocks lies north of the fault, and Wrangellia lies to the south. This boundary prevails probably to south of Kluane Lake in the Yukon Territory (Muller 1967; Eisbacher 1976).

Alaska Peninsula and Kenai Peninsula

Triassic rocks crop out in a few places in the northeastern part of the Alaska Peninsula and also on the Kenai Peninsula near Seldovia. In neither place, however, has the characteristic Wrangellia sequence been recognized.

In the Iliamna quadrangle, Detterman and

Reed (R. Z. Detterman and B. L. Reed, unpublished data, 1976) have recognized three Triassic formations, the lowest(?) of which is a greenstone unit 300–600 m thick that consists of altered basic flows and tuffs, some of which are amygdaloidal. According to Detterman, the upper part of this unit appears to intertongue with massive fossiliferous limestone that in its upper part contains Norian fossils. This limestone contains abundant chert and is in turn overlain by thin-bedded dark limestone, tuff, and chert of middle to late Norian age.

To the south of the Iliamna quadrangle, near Cape Kekurnoi, Triassic rocks are well exposed and divisible into two formations (N. L. Johnson, unpublished results, 1967): a lower, massive crystalline limestone 125 m thick whose base is not exposed, and an upper unit of dark-gray to black thin-bedded siliceous limestone and shale 350 m thick that contains the Norian bivalve *Monotis*. Thin lenses of volcanic agglomerate occur in the middle of this formation.

On the Kenai Peninsula, Triassic rocks are known only near Seldovia, where they have been studied by Martin (1926; Martin *et al.* 1915). Two distinct sequences appear to be present: (1) a thick pile of pillow basalts capped by red radiolarian chert on Yukon Island that has yielded a Late Triassic radiolarian assemblage (E. A. Pessagno, unpublished results, 1975); and (2) a thick sequence of limestone, chert, and tuff containing *Monotis* (Norian) that underlies Jurassic volcaniclastic rocks in Port Graham. The relation of these two unlike sequences is not known, but they are probably separated by a major fault zone (G. Plafker, personal communication, 1975). The sequence of Port Graham is reported by Martin (1926, pp. 49, 50) to exceed 1000 ft (300 m) in thickness and comprises limestone, chert, tuff, tuffaceous conglomerate, and volcanic breccia.

In summary, the Triassic history of southwestern Alaska is poorly known because of the limited, widely spaced, and structurally complex exposures. However, Triassic rocks older than late Karnian appear to be absent, and volcanic activity seems to be mainly of Norian age. The presence of volcanic rocks equivalent in age to the Nikolai Greenstone has not been substantiated.

Moore (1974) and Moore and Connelly (1977) have interpreted these Triassic rocks to represent the first phase in the development of the widespread and very thick andesitic arc (Talkeetna Formation) and related plutons (Reed and Lanphere 1969) of mainly Early Jurassic age that extends from the Talkeetna Mountains to at least the middle of the Alaska Peninsula and perhaps beyond.

Paleomagnetic data obtained by Packer and Stone (1974) from Jurassic rocks of the Alaska Peninsula yield a mean paleopole position of 50° N, 295° E which is significantly different from the mean Jurassic paleopole position of North America and the present magnetic dipole. Packer and Stone (1974, p. 996) interpret this anomalous mean pole position as an indication that the Alaska Peninsula has moved northward and rotated clockwise since Jurassic time to reach its present position.

Two sites from near Nabesna in the Mentasta Mountains (in the northern part of Wrangellia) are also discussed by Packer and Stone (1974, p. 991). Samples for paleomagnetic measurements were obtained from probable Upper Jurassic sandstone that overlies the Nikolai Greenstone. Although the two sites (NBS-1 and NBS-3) are on opposite sides of the same creek and presumably are of the same age, they give widely divergent pole positions (NBS-1 = 54° N, 297° E; NBS-3 = 47° N, 1° E). The former lies very close to the mean paleopole position for Jurassic rocks of the Alaska Peninsula. The latter is widely discordant with respect to the Peninsula data. It is doubtful that both can be correct.

Paleomagnetic data could be very useful in helping to determine whether the presumed allochthonous rocks of the Alaska Peninsula moved with or independently of Wrangellia. Unfortunately, Packer and Stone's Nabesna data support both alternatives and hence cannot be accepted as meaningful without further corroborating evidence. This leaves the relation between the two terranes uncertain during Triassic and Jurassic time. Certainly by Cretaceous time they were joined, as faunas and stratigraphy carry through from one terrane to another (Jones 1963).

Southeastern Alaska

Triassic rocks are widespread in southeastern Alaska, and except for the deposits previously discussed on Chichagof and Baranof Islands, they differ markedly from the typical Wrangellia sequence. On Admiralty Island, and to the south on the Keku Islets and Kuiu and Kupreanof Islands, the oldest Triassic rocks are early or early late Karnian (Loney 1964; Muffler 1967) in age and directly overlie Paleozoic rocks. Hence, rocks equivalent in age to the Nikolai Greenstone, as well as to the underlying *Daonella*-bearing strata, are missing in the region east of Chichagof Island.

Throughout southeastern Alaska the Triassic rocks exhibit rapid changes in facies. All of these rocks are characterized by the presence of varying amounts of volcanic rocks, dominantly basalt. Only locally do minor amounts of andesite and felsite (= rhyolite?) occur.

Loney (1964) assigned the Triassic rocks of Admiralty Island to the Hyd Formation, which comprises four members: (1) a basal breccia consisting of chert fragments derived from underlying Permian strata; (2) an overlying limestone member, which includes light-gray-weathering poorly fossiliferous limestone, and brown-weathering fossiliferous limestone; (3) an upper argillite member composed of dark-gray to black argillite, chert, limestone, and graywacke; and (4) a volcanic member that intertongues with the other three. This member has a maximum thickness of 170 m and consists of altered spilitic volcanic flows in which pillows are commonly well developed.

The lowest Triassic unit immediately to the south on Kuiu Island comprises a lenticular mass of felsic flow rocks and flow breccias up to 300 m thick (Muffler 1967). These are overlain by the Hyd Group, which includes four formations similar to the four members of Admiralty Island.

Triassic rocks in the southern part of southeastern Alaska on Gravina Island have been recently studied by Berg (1973). Two formations are recognized, the Nehenta Formation and the overlying Chapin Peak Formation, both of which are of Norian age. The Nehenta includes a lower calcareous member that intertongues with altered basaltic pillow flows and an upper member composed of orange-weathering conglomerate containing large clasts (up to 2.5 m) of granitic rocks. The Chapin Peak Formation comprises intertonguing basaltic pillow flows, breccias, conglomerate, grit, siltstone, argillite, and limestone. Fossils collected from limestone blocks are latest Norian in age (Berg 1973, p. 24). The prevalence of Norian basalt in these sections is but one of the obvious distinctions between these rocks and those of Wrangellia.

Rocks underlying the Triassic deposits described above comprise a complex assemblage of Precambrian and Paleozoic sedimentary, volcanic, and igneous rocks referred to as the Alexander terrane (Berg *et al.* 1972). These rocks contrast markedly with the pre-Triassic rocks of Wrangellia in the Wrangell Mountains (lower part of the Taku–Skolai terrane of Berg *et al.* (1972)), and also with upper Paleozoic rocks lying to the east in British Columbia (Monger and Ross 1971). Because of these contrasts in Paleozoic rocks, Jones *et al.* (1972) suggested that the Alexander terrane may constitute a displaced continental fragment, perhaps derived from the south where the continental margin of North America is clearly truncated (Hamilton and Myers 1966; Burchfiel and Davis 1972).

The relation of Wrangellia to the Alexander terrane remains enigmatic. According to MacKevett (1975, p. 69; E. M. MacKevett, unpublished data, 1976), all known contacts between the two terranes are faults along which large-scale tectonic transport may have occurred. The presence of the unlike Triassic sequences suggests that juxtaposition of the two terranes took place after the Triassic.

Northwestern Washington and Southwestern British Columbia

The southern boundary of Wrangellia lies between the southeastern end of Vancouver Island and the northern tip of San Juan Island, less than 30 km to the east. Vancouver Island is characterized by the typical, widespread, and very thick Wrangellia sequence, whereas Triassic rocks of San Juan Island are restricted to one small patch on and immediately south of Davidson Head. There, the Haro Formation (McLellan 1927; Danner 1965) comprises 100 m or more of andesitic conglomerate and sandstone, together with a few thin (10–20 cm) beds of impure limestone containing abundant specimens of *Halobia* cf. *H. ornatissima* of Karnian to early Norian age. The structural setting of the Haro Formation is enigmatic, as it seems to be closely associated with a melange terrane that includes blocks of many different ages, ranging from early Paleozoic to Late Cretaceous (Whetten *et al.* 1976).

Farther north, in southwestern British Columbia, the boundary of Wrangellia is uncertain. Muller (1977) emphasizes the geologic differences between what he terms the Island Mountains tectonic belt on the west and the Coast Mountains tectonic belt to the east, with the contact between the two lying approximately along the Straits of Georgia. Rocks of the Island Mountains belt belong to Wrangellia and are absent in the Coast Mountains.

A more easterly position for this boundary is drawn by Monger (1975), who separates Triassic rocks in British Columbia into two assemblages, a western basaltic sequence (= Wrangellia of this report) and a complex eastern terrane composed of interfingering Upper Triassic basalt and basaltic andesite flows (augite porphyry), abundant pyroclastic rocks, and fine-grained sedimentary rocks. Monger (1975, p. 8) states that the boundary between these two Triassic belts appears to transgress the Coast Plutonic Complex of British Columbia, but its precise position is difficult to establish because of the presence of extensive young granitic rocks. His boundary seems to lie nearly 200 km too far to the east, however, as it places the andesitic rocks of the Haro Formation in the western belt.

Central Oregon

A thick sequence of Upper Triassic clastic, volcaniclastic, and volcanic rocks is exposed in the Suplee–Izee district and John Day region of central Oregon (Dickinson and Vigrass 1964, 1965; Brown and Thayer 1966). These rocks differ greatly from the Seven Devils Group and hence are not part of Wrangellia. They are assigned to several different formations that vary rapidly in thickness laterally, are thousands of metres thick at any one place, and comprise a wide variety of rapidly deposited sedimentary and volcanic rocks including conglomerate, slide breccia, graywacke, shale, mudstone, volcanic sandstone, andesite tuff, and local basaltic flows and breccias. These were deformed in early Early Jurassic time and are overlapped with angular unconformity by strata of late Early Jurassic (Pliensbachian) age. The oldest part of the Upper Triassic section is poorly dated but evidently is of Karnian age; higher parts of the sequence may represent most or all of the rest of the Upper Triassic and include lowermost Jurassic (Hettangian) beds at the top. Dating of this thick and variable succession is difficult in most places, owing to a scarcity of fossils and to abundant evidence that many of the more conspicuous fossils have been redeposited.

The older parts of this Upper Triassic sequence are reported to rest depositionally upon much deformed Paleozoic rocks, mixed with abundant serpentinite. However, at least some of the Paleozoic rocks occur in a melange that was tectonically accumulated in Triassic or later time and is in fault contact with the Upper Triassic strata.

Comparison with Cratonally Related Triassic Strata

None of the Triassic rocks that crop out near the various parts of Wrangellia, yet contrast lithologically with it, can be demonstrated to have originated in their present geographic positions relative to North America. For some there is evidence of substantial movement, either independently or attached to Wrangellia as part of a still larger plate. Consequently, our ultimate comparison of the Triassic rocks of Wrangellia is with those that unequivocally were deposited along the western and northern margin of the North American continent. As shown on Fig. 1, the western limit of cratonally related Triassic rocks is well inland; nowhere from Idaho to Alaska is it closer than 500 km to the present Pacific coast. At latitudes comparable to those of the rocks that typify Wrangellia, these rocks are mainly fine-grained clastic strata for which the source of terrigenous sediment was the craton (e.g. Pelletier 1965). Where marine, as most of the outcropping examples are, these sedimentary rocks are predominantly calcareous, but thick sections of relatively pure carbonate rock are poorly represented. Volcanic rocks are absent.

In keeping with their compositional character, well-developed benthonic shelly and coralline faunas do not occur in these cratonally related Triassic rocks. Their contrast with the warm water carbonate rocks found at high latitudes farther west in Canada, including those recognized herein as belonging to Wrangellia, has been attributed by Tozer (1970, p. 635) to substantial northward relative movement of the western rocks. Some Triassic marine invertebrate faunas show a similar pattern. For example, Middle Triassic ammonoid faunas dominated by parapopanoceratid and nathorstitid ammonoids and certain species of the abundant middle and upper Norian bivalve *Monotis*, such as *M. scutiformis* and *M. ochotica* described by Westermann (1962), characterize Triassic faunas of the North American and Asian Arctic and occur in the marine Triassic sequence at the craton margin at least as far south as east-central British

Columbia. In contrast, Triassic rocks of western Canada and southern Alaska, including those of Wrangellia, lack such 'arctic' faunas entirely.

Summary and Conclusions

A large terrane extending along the northwest continental margin of North America can be defined on the basis of similar Triassic stratigraphy, rock units, faunas, and geologic history. We have named this terrane Wrangellia and have identified a possible southeastern extension of it in eastern Oregon, western Idaho, and southeastern Washington.

Paleomagnetic data presented in a companion report by Hillhouse indicate that Triassic tholeiitic flows in the northern part of Wrangellia formed at low paleolatitudes (15° N or 15° S) and thus has been displaced northward a minimum of nearly 30°, based on a comparison of mean Triassic paleopole positions of Wrangellia and continental North America. Similar paleomagnetic results were obtained from coeval rocks by Irving and Yole (1972) and Symons (1971) from the southern part of Wrangellia (Vancouver Island).

Geologic data summarized herein support the notion of large-scale displacements. In places, Wrangellia is flanked by dissimilar Triassic rocks that may themselves be allochthonous but that formed in different environments than the rocks of Wrangellia.

Throughout this discussion, we have emphasized similarities and differences in Triassic rocks and have ignored the pre-Triassic rocks. A similar case for large-scale tectonic juxtaposition, however, can be made by contrasting these older rocks, and this has already been done by several geologists (e.g. Monger and Ross 1971; Jones *et al.* 1972; Muller, unpublished data). In brief, rocks underlying the Triassic sequence of Wrangellia throughout its extent from Alaska to eastern Oregon comprise a thick upper Paleozoic andesitic arc sequence overlain by Lower Permian fossiliferous limestone and argillite (Richter and Jones 1973; Bond 1973; Richter and Dutro 1975; Richter 1976; Muller *et al.* 1974; Vallier 1974). These rocks contrast with other Paleozoic terranes of Alaska and British Columbia (Monger and Ross 1971; Jones *et al.* 1972), which have also been interpreted as being allochthonous.

The time of arrival of Wrangellia at its present site is not definitely established. In the north, unpublished data derived from the Chulitna district suggest that by mid-Cretaceous time the various blocks, or terranes, were close together. To the south, in eastern Oregon, an earlier (Late Jurassic?) age seems likely for the suturing of disparate terranes (Jones *et al.* 1977). Movements of hundreds of kilometres along some of the major boundary faults, for example, the Denali, have been postulated for Cenozoic time (Forbes *et al.* 1974; Eisbacher 1976), and these movements, if real, may be related to the final suturing of Wrangellia.

A final point should be emphasized, which is that whether allochthonous or autochthonous, the enormous quantity of Triassic tholeiitic basalt that gives Wrangellia its particular character records an important but generally overlooked event in earth history. Volcanism commenced simultaneously throughout this large region and persisted for at least an estimated 5 000 000 years, during which time many tens of thousands of cubic kilometres of basalt were extruded to form one of the world's largest domains of nonoceanic tholeiitic basalt. Presumably rifting initiated this volcanism, but where this occurred and what was rifted remain enigmatic.

Volcanism was succeeded by slow but remarkably synchronous subsidence throughout Wrangellia, resulting in deposition over most of the area of inner-platform or even supratidal pure carbonate deposits, which then gradually gave way to deposition of mostly fine-grained detrital deep-water basinal deposits, again with remarkable uniformity. This synchroneity and similarity of deposition throughout imply a deep-seated control, perhaps in the mantle, that was absent in other areas that are now contiguous to Wrangellia.

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