Continental Accretion: From Oceanic Plateaus to Allochthonous Terranes

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Summary. Some of the regions of the anomalously high sea-floor topography in today's oceans may be modern allochthonous terranes moving with their oceanic plates. Fated to collide with and be accreted to adjacent continents, they may create complex volcanism, cut off and trap oceanic crust, and cause orogenic deformation. The accretion of plateaus during subduction of oceanic plates may be responsible for mountain building comparable to that produced by the collision of continents.

Abundant geological and geophysical data obtained from work on land demonstrate tectonic complexities that seem far greater than those of the ocean floor, where the features are fairly well explained by plate tectonics. The tectonic evolution is particularly complex for the large cordilleran chains of the world. Although some of these mountain chains appear to be the result of classical plate collisions, the origin of others remains enigmatic. Many are known to be composed of numerous juxtaposed slivers with dramatically different tectonic and stratigraphic histories. At least some slivers appear to have originated far away from the stable cores of the continents. The term allochthonous terranes describes such regions; they are tectonically and stratigraphically distinct from adjacent regions, separated from adjacent terranes by bounding faults, and came to their present resting places from distant points of origin. For example, large parts of the mountainous regions of western North America are composed of such allochthonous terranes, some of which have migrated thousands of kilometers, to be added by accretion to the western continental United States, Canada, Alaska, Siberia, and other parts of the Pacific rim (*1*).

We suggest that modern analogs of many allochthonous terranes may be found in the oceans, in the puzzling topographic ridges, rises, or plateaus present on the ocean floor. We believe that some of the oceanic plateaus, which comprise about 10 percent of the ocean floor, are modern allochthonous terranes in migration, moving with the oceanic plates in which they are embedded and fated eventually to be accreted to continents adjacent to the subduction zones that ring the Pacific. The plateaus in the oceans and the allochthonous terranes on land may provide one of the major missing links in geodynamics: the link between hypotheses of plate tectonics in oceans and accretion tectonics in the continents.

What Are Oceanic Plateaus?

Oceanic plateaus are anomalously high parts of the sea floor that are not at present parts of continents, active volcanic arcs, or active spreading ridges. Included are rises that have been described as extinct arcs (*2*), extinct spreading ridges, detached and submerged continental fragments (*3*), anomalous volcanic piles (*4*), or uplifted oceanic crust. Figure 1 shows the locations of more than 100 present-day oceanic plateaus. Although particularly abundant in the western Pacific (*5*) and Indian oceans, they are found also in the Atlantic Ocean, the Caribbean Sea, and the Mediterranean Sea. Many of the large oceanic plateaus exhibit several common characteristic features.

Morphology. Most plateaus rise thousands of meters above the surrounding sea floor. Some, such as the Seychelles Bank, rise above sea level, whereas others, such as the Ontong Java Plateau, are 1500 to 2000 meters below sea level.

Crustal structure. Most of the plateaus for which seismic refraction and gravity data are available have estimated crustal thicknesses ranging from 20 to more than 40 kilometers, which are two to five times the thickness of usual oceanic crust (~ 8 km) (Fig. 2).

Crustal velocities. Some plateaus have an upper crust 5 to 15 km thick, where compressional wave velocities are in the range 6.0 to 6.3 km per second. This is typical not only of one of the layers of oceanic crust (layer 2c), but also of granitic rocks in the continental crust. The thickness of this layer is an order of magnitude greater than that of layer 2c in the basement of normal oceanic crust. Comparison of some typical oceanic and continental velocity structures (Fig. 3) suggests that the Ontong Java Plateau and the Seychelles Bank could be submerged continental fragments similar to the Lord Howe Rise, or anomalously thickened oceanic crust.

Magnetic lineations. Most plateaus exhibit weak or no magnetic lineations, suggesting that they are not formed as typical oceanic crust.

Gravity. Generally, the plateaus do not exhibit significant isostatic anomalies, implying more or less complete compensation.

Nature of margins. Various types of plateau margins have been identified, such as an ancient subduction zone at the northern margin of the Bowers Ridge (*6*) and a rifted margin at the eastern edge of the Ontong Java Plateau (*7*). The nature of most plateau margins, however, is not known.

Surface geology, drilling, and dredging. Several plateaus show strong continental affinities. For example, Precambrian granitic basement is exposed in the Seychelles Islands in the middle of the Indian Ocean. Granitic basement was found in the Paracel Islands in the South China Sea (*8*). Dredging of the Agulhas Plateau yielded Precambrian or Paleozoic granitic rocks (*9*). These observations suggest that parts of these plateaus are submerged continental fragments.

Other plateaus are of volcanic origin. For example, the Cocos and Carnegie ridges appear to be the result of a continuously active hot spot that extruded basaltic rocks onto the overriding Cocos plate (*10*).

Drilling into the Ontong Java Plateau revealed a few meters of Early Cretaceous basalt beneath more than 1 km of calcareous sediments, indicating shallow deposition since Early Cretaceous time (*11*). The nature of the rock underlying the Ontong Java volcanics is not known. Little is known about the composition at depth of most other plateaus.

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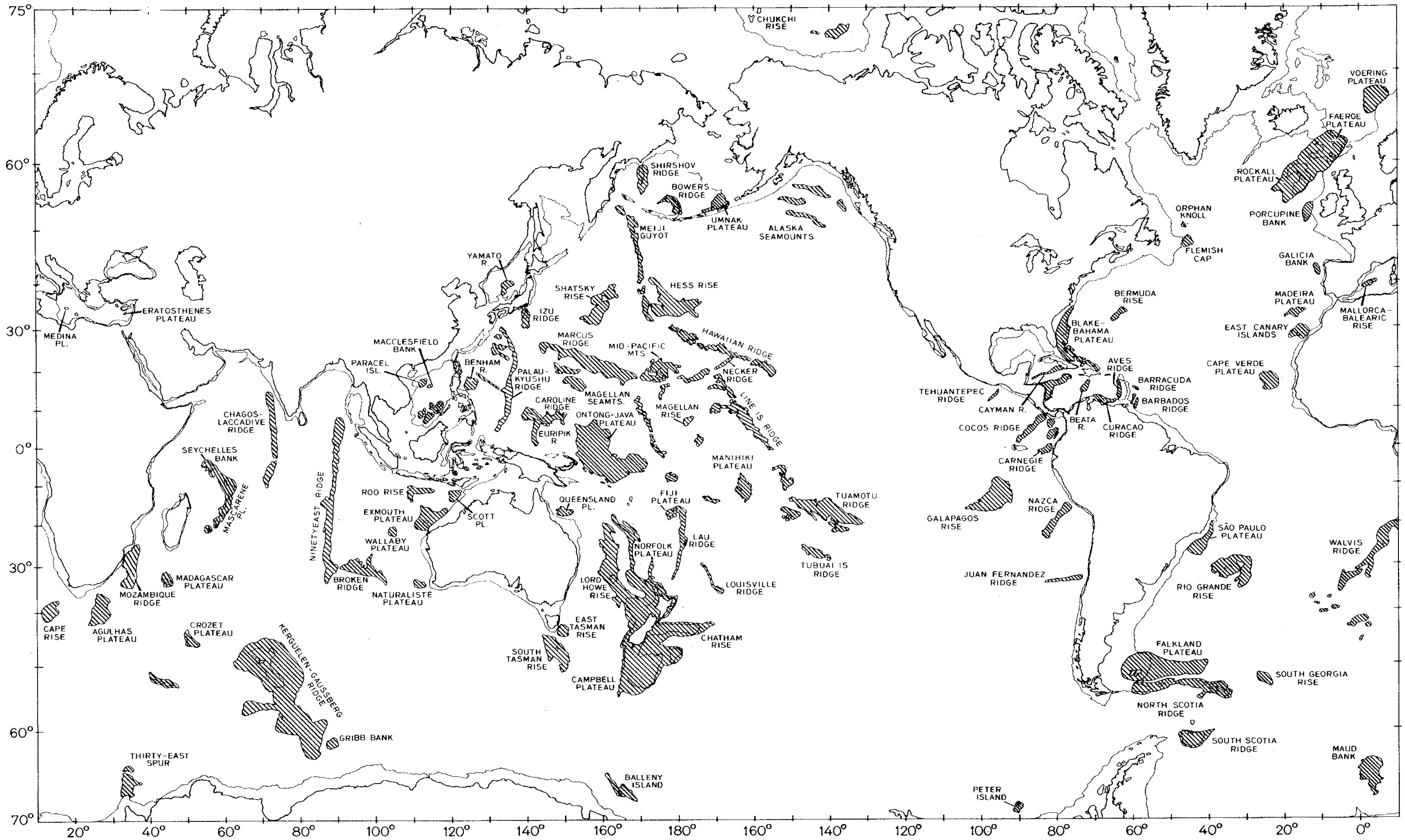


Fig. 1. Distribution of oceanic plateaus (shaded areas) in the world's oceans.

Relative motions. Measurements of magnetic inclination from cored sediments, from, for example, the Ontong Java Plateau, indicate substantial migration with time (*12*). These data are insufficient to determine relative motion between plateaus and surrounding oceanic crust, but seismic data suggest that little or no slip occurs at the margins, except perhaps during periods of collision. We assume, therefore, that most plateaus are moving with the oceanic plates in which they are embedded.

Consumption of Oceanic Plateaus

A small number of plateaus are being consumed at subduction zones, with profound geological effects that include reduced seismicity and shifts in volcanic activity (*13*). Furthermore, the distribution of oceanic plateaus (Fig. 1) suggests that new collisions will occur; for example, the Shatsky Rise may collide with Japan (Fig. 4). Consequently, it is reasonable to assume that the consumption of oceanic plateaus at plate boundaries was an important tectonic process in the past.

Eastern Pacific. Collisions between oceanic plateaus and subduction zones are occurring in the southeastern Pacific, where the Juan Fernandez, Nazca, Carnegie, and Cocos ridges are colliding with the western margin of South America. These collisions exert a remarkable control on the seismicity, volcanism, and morphology on the adjacent continent (*13*).

The internal structure and composition of these plateaus are not known in detail, but they may be volcanic in origin, possibly the result of a hot spot (*10, 14*). Since the ridges are in isostatic equilibrium, with deep, light roots, it is reasonable to assume that they do not sink with normal oceanic crust at subduction plate boundaries (*13, 15*).

Where the Nazca Ridge, towering more than 1500 m above the sea floor, collides with South America, the trench is greatly diminished in depth. For 1500 km north of this point, there is a gap in present-day volcanism, and the dip of the seismic plane is anomalously shallow in this zone. A similar volcanic gap is present farther south, just north of the point where the Juan Fernandez Ridge collides with the continent off the coast of Chile. A third gap extends south of the point at which the Cocos Ridge meets the continent in Panama (Fig. 5). Not only seismicity (*16–19*) and trench configuration but also volcanic activity in South and Central America are directly related to the oblique collision and consumption of the Juan Fernandez and Nazca ridges carried by the Nazca plate (*13*).

The oblique collision of the ridges may be responsible for the volcanic gaps. During subduction of normal oceanic lithosphere, typically dipping 30° to 45°, volcanic activity is continuous. The arrival of buoyant crust at the trench causes the cessation not only of subduction (*20*) but also of volcanism, perhaps because of the reduction in water supply needed for melting in the downgoing slab. The oblique orientation of the ridges, relative to the movement of the Nazca plate, causes the volcanic gaps to migrate along the plate boundary. As the fragments of the ridges become well embedded, the oceanic crust behind begins to be subducted again, forming first a new trench and then a new seismic slab seaward of the old one. This sequence of events leads to an apparent flattening of the active seismic zone (*21, 22*), eventually followed by renewal of volcanic activity and normal subduction of the oceanic plate.

In addition to transient effects, such as changes in volcanism during the accretion of oceanic plateaus, more permanent geological imprints may mark the process. The most likely imprints are the allochthonous terranes, many of which are embedded in the margins of continents, particularly in those that underwent orogenesis.

Northern and western Pacific. The transformation of oceanic plateaus into allochthonous terranes may take different forms depending on, among other things, whether tectonic stress is high or low. Seismicity implies that stress in the

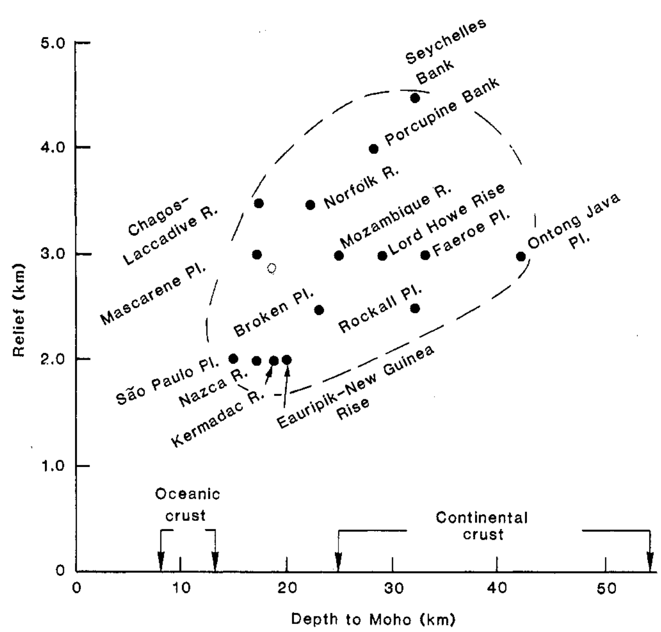


Fig. 2. Relief versus crustal thickness of several oceanic plateaus. Most have crustal thicknesses intermediate between oceanic and continental values.

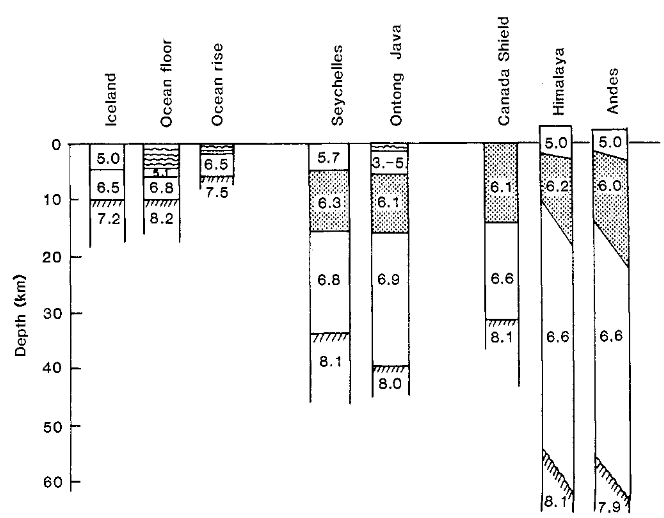


Fig. 3. Comparison of some typical oceanic and continental crustal structures (*36*). Although morphologically similar, the Ontong Java Plateau is structurally dissimilar to Iceland (*69, 70*) or to typical oceanic crust. It is, however, remarkably similar to a typical shield structure, where compressional wave velocity in thick upper crust is 6.1 km/sec, and to the Seychelles Bank, which is known to be continental (*71*). Typical orogenic roots like those of the Himalayas (*72*) and the Andes (*73*) are even thicker.

eastern Pacific is high; most energy released by earthquakes is measured there (*23*). Because of this high-stress regime, the disruptive effects of the consumption of ridges, such as the Nazca and Cocos, are only temporary, and the colliding ridges may undergo extensive deformation during accretion. However, the configuration of the plate boundary will be changed only by a modest migration of the trench toward the ocean basin, after which unimpeded subduction will resume.

In contrast, the plate boundary geometry may change significantly upon plateau collision in low-stress regimes, such as those bounding the west and north Pacific, where the subduction zones are adjacent to island arcs and marginal seas, not a continent. Subduction may reverse direction or the subduction zone may migrate to the oceanic side of the plateau (*13, 24*). The formation of several marginal seas around the Pacific can be explained in this way (*25*).

An example of a low-stress regime is the Bering Sea, which is thought to be a marginal sea formed by the Aleutian arc, which trapped a portion of the Kula plate (*26*). Before the formation of the Aleutian arc in the late Mesozoic or early Tertiary, subduction probably took place along the present-day continental margin of the Bering Sea (*26*). As the arc formed, subduction shifted to the Aleutian Trench some time before the change in motion of the Pacific plate 43 million years ago (*27*). This shift in subduction can be explained by the collision of an oceanic plateau with the Mesozoic subduction zone.

At present the Bering Sea has three large oceanic plateaus and ridges: the Umnak Plateau, the Bowers Ridge, and the Shirshov Ridge. Refraction data from the Bowers Ridge (*28*) and the Umnak Plateau (*29*) indicate that a thickened welt of crustal material is present beneath both features. The Bowers Ridge, with altered andesitic rocks, a positive magnetic anomaly over its crest, and a sediment wedge on its northern side, is probably an extinct island arc. Multichannel seismic profiles (*6*) reveal that there was a subduction zone on the northern side of the Bowers Ridge and that the Bering Sea margin was also a subduction zone. In the past, the Bowers Ridge must have moved toward the Bering Sea margin.

It is not clear whether the Umnak Plateau, now situated between the Bering Sea margin and the Aleutian Ridge, was formed in situ or not, but it is possible that, like the Bowers Ridge, it came from elsewhere. Thus, a possible scenario is that before formation of the Aleutian Ridge, the proto–Bowers Ridge and proto–Umnak Plateau moved into their present positions in the Bering Sea (*25*). The collision of the Umnak Plateau with the then convergent Bering Sea margin may have caused subduction to terminate and move southward, resulting in the formation of the Aleutian arc. Similarly, the Shirshov Ridge, separating the Aleutian and Komandorsky basins, could have been formed along a large transform fault that was active during the northward motion of the Kula plate (Fig. 6) or by rifting away from Kamchatka (*25*). Both mechanisms can explain why the Komandorsky Basin contains less sediment, has higher heat flow, and thus is probably younger than the Aleutian Basin.

A similar process may be responsible for the two distinct volcanic arcs around Japan. One is the northeast Japan arc, which includes the Kurile Islands and the northeast Japan and Izu-Marianas arcs; the other is the Ryukyu arc. In the past, one continuous subduction zone existed along the Japan arc from the Kurile arc to the Ryukyu arc (*30*). It has been suggested (*31*) that aseismic ridges originally located in the south moved north with the Kula plate and eventually collided with the Japan arc, causing the bend in the arc and the rotation of northern Honshu. We suggest further that it was the proto–Izu Bonin arc which came from the south and collided with the subduction zone. Subduction then shifted to the east, and two distinct arcs were formed, isolating parts of the Kula plate between the Ryukyu arc and the proto–Izu Bonin arc.

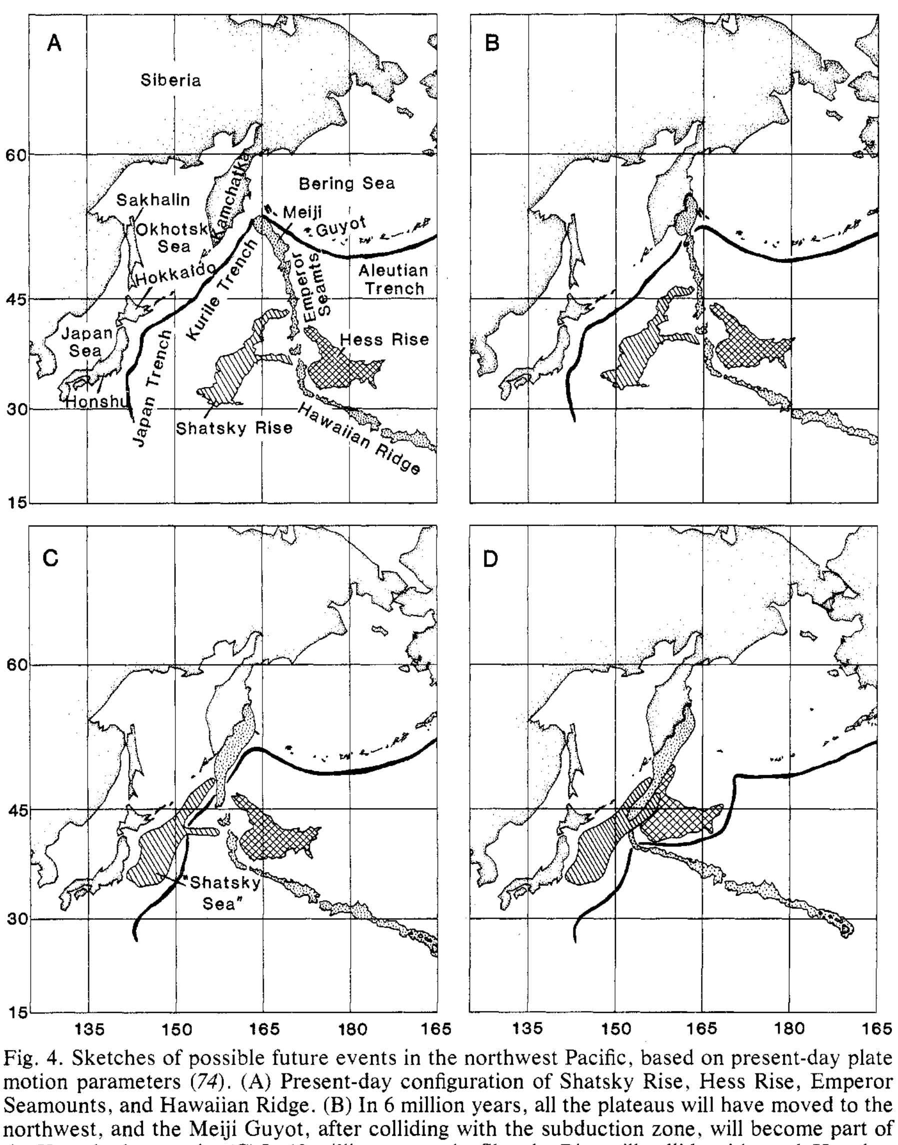


Fig. 4. Sketches of possible future events in the northwest Pacific, based on present-day plate motion parameters (*74*). (A) Present-day configuration of Shatsky Rise, Hess Rise, Emperor Seamounts, and Hawaiian Ridge. (B) In 6 million years, all the plateaus will have moved to the northwest, and the Meiji Guyot, after colliding with the subduction zone, will become part of the Kamchatka margin. (C) In 12 million years, the Shatsky Rise will collide with north Honshu, Hokkaido, and the Kuriles. At this stage the trench might move to the oceanic side of the plateau and a new marginal sea, the "Shatsky Sea," could form. (D) In 18 million years, the Shatsky Rise, Hess Rise, and Emperor Seamounts will be part of the Eurasia plate, and new plate boundaries will form in this region.

Allochthonous Terranes Along the Pacific Margins

Indirect geologic evidence indicates that plateaus similar to those that exist in ocean basins today also existed in ancient ocean basins. These ancient plateaus can now be recognized only by their remanents that have been incorporated into continental masses in the form of allochthonous terranes; their stratigraphy and paleomagnetism indicate distant origins. Figure 7 shows several allochthonous terranes along the northeast Pacific margin that were probably oceanic plateaus at some time.

Critical evidence for extensive migration of terranes comes from measurements of magnetic inclination (Table 1), which are used to decipher the latitudinal component of motion. Many of the North Pacific allochthonous terranes in Alaska and northeast Asia show migrations of several thousand kilometers over periods of tens of millions of years, with inferred velocities of about 5 centimeters per year (*32*). Paleomagnetic azimuths or declinations are commonly anomalous, suggesting that many terranes have also undergone substantial rotation (*33*). Episodes of accretion of allochthonous terranes have been suggested as an important part of the processes of crustal growth (*1*), crustal shearing (*34*), mountain building (*35, 36*), and the creation of marginal seas (*24, 25, 31*).

The nature, history, and character of allochthonous terranes along the Pacific margin are best understood in the northern cordillera of western North America (*1*), particularly in southern Alaska and British Columbia (Fig. 7). Among the best known allochthonous terranes in this region that may have been oceanic plateaus are Wrangellia (*37*) and Cache Creek (*38*).

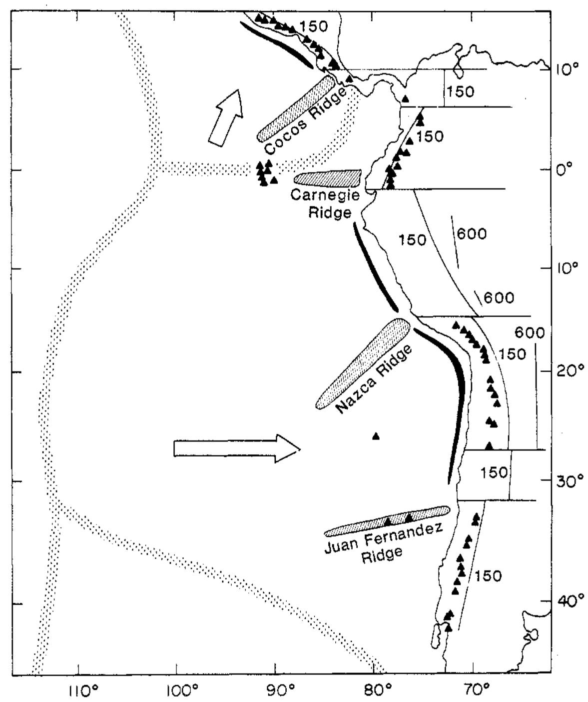


Fig. 5. Tectonic elements along the western South and Central America consumption zone (*15*): trench, active volcanoes, and seismicity. Numbers are depths in kilometers of the seismic planes. Arrows show direction of motion of oceanic plates. Several aseismic ridges are presently colliding with the continents, causing volcanic and seismic gaps on land.

Wrangellia terrane. Wrangellia is characterized by an enormous carapace of Middle(?) to Upper Triassic subaerial basalt, locally attaining a thickness of 6000 m, that overlies an upper Paleozoic volcanic arc assemblage with associated Permian and Triassic sedimentary rocks. Over the Triassic basalt is a thick carbonate sequence of Late Triassic age, which commences with inner platform limestone and dolomite and ends in basinal pelagic carbonates, siliceous argillite, and carbonaceous shale. Since continentally derived clastic material is wholly lacking in this sequence, deposition in an oceanic setting seems mandatory.

Two broad cycles of uplift and subsidence are recorded in the upper Paleozoic and lower Mesozoic stratigraphy of Wrangellia. The first is represented by shallow-water carbonate rocks with associated fossiliferous sandstone, shale, and conglomerate of Permian age, capped by a thin sequence of radiolarian chert that ranges from Permian to Middle Triassic in age. The subsidence may have been caused by cooling of the underlying upper Paleozoic volcanic arc. Rapid uplift is recorded by the sudden appearance above the cherty rocks of Triassic amygdaloidal basalt (locally pillowed at the base). This basalt erupted throughout Wrangellia with a total volume in the range of 100 to 200 km^3, and probably represents rifting related to the commencement of northward movement of the Wrangellian block from southern paleolatitudes (*32*). A second broad episode of subsidence is recorded by the thick Upper Triassic inner platform to basinal deposits that overlie the basalt.

Table 1. Paleomagnetic evidence for large-scale migration of allochthonous terranes now embedded in the Pacific margins.

Region	Position and age	Reference
East Siberia	*Sikhote-Alin.* Since the Permian, 40° poleward motion relative to Siberian platform. Since the Triassic, 20° poleward motion. Collision by Cretaceous. Moved 2000 kilometers in ~ 100 million years or at an average rate of 20 millimeters per year.	(*75, 76*)
Northeast Siberia	*Kolyma block.* Since the Permian, 20° poleward motion relative to Siberian platform. Since the Triassic, 13° poleward motion. Collision with Siberian platform by Cretaceous.	
Western Canada and southern Alaska	*Wrangellia terrane.* Formed either at 18°N or 18°S of equator in late Triassic; the southern latitude is more likely. Accreted by end of Cretaceous. Probably 6000 kilometers of northward displacement in 130 million years for average rate of 46 millimeters per year.	(*32, 76*)
	Stikine terrane. Northward displacement (13°) since late Jurassic.	(*77*)
	Alaska Peninsula–Shumagin Islands. Northward movement (~ 50°) since the Cretaceous or ~ 50 millimeters per year.	(*78*)
Japan	*Inner belt of central Japan.* In the Permian was situated near the paleoequator and was accreted to the Asian mainland by the late Mesozoic.	(*79*)
California	*Franciscan.* Northward movement (~ 20°) of seamounts relative to North America. Accreted in Franciscan mèlange in late Cretaceous or early Cenozoic.	(*80*)

This subsidence appears to follow a post-rifting cooling curve similar to that of rifted continental margins (*39*).

Cache Creek terrane. The Cache Creek terrane extends throughout much of the central part of the Canadian cordillera in a setting well inland from the present continental margin (Fig. 7). The presence within this terrane of non–North American Permian fusulinids belonging to the Tethyan faunal province led to the recognition of this terrane as allochthonous (*40*).

Characteristic rocks of the Cache Creek terrane (*41*) are mafic and ultramafic rocks (ophiolites), chert, argillite, pelite, volcanic sandstone and tuff, and thick piles of fossiliferous carbonate with minor lenses of basic volcanics. The assemblage of rocks in the Cache Creek terrane may represent deposition in an oceanic environment (*38*) in which locally thick (2000 m) carbonate banks formed plateau-like buildups that persisted from early Carboniferous until Late Permian time. Shallow-water fossils occurring throughout these banks indicate very slow progressive subsidence of the basement, with final termination of carbonate deposition in Triassic time. Coeval deposition of deep-water rocks in the Cache Creek terrane is demonstrated by the presence of radiolarian cherts ranging in age from Mississippian to Triassic. Slide blocks of shallow-water limestone occur locally in these deeper water facies (*41*). Possible modern analogs of the Cache Creek limestone banks are large atolls or the Bahama Banks (*38*).

Paleomagnetic data are not yet available to determine the paleolatitude of formation of the Cache Creek terrane, but paleobiogeographic analysis supports minimum movements of 30° northward for the Tethyan fusulinid-bearing limestones (*42*).

Continental Accretion

The role of continental collision in orogenesis has long been recognized for an area such as the Himalayas, where two land masses are juxtaposed along a major suture zone. The role of accretionary tectonics in a mountain belt such as the cordillera of western North America, which directly faces a vast open ocean, has only recently been recognized (*35, 43–46*). Although the North American cordillera and other mountain belts of the Pacific rim are widely recognized as products of accretion, little is understood about the processes involved or even the structures produced during incorporation of allochthonous terranes into the continental structure. Understanding this mechanism of continental growth remains one of the fundamental problems in geodynamics.

The gross structural relations in various parts of the cordillera indicate that thrust faulting played a dominant role in the historical development of the entire tectonic collage. A local structural style consisting of large-scale imbricated thrust sheets is well documented in southern Alaska (*47–49*), British Columbia (*50, 51*), northwestern Washington (*52–54*), the Klamath Mountains of northern California (*55–58*), central California (*59–61*), and southern California (*62*). The amount of local differential movement along some of the anastomosing thrust faults must certainly exceed several hundred kilometers, and movements taken up within the entire accretionary belt may well exceed 10,000 km. Most of the accreted material consists of blocks of thickened crust including arcs, seamounts, oceanic crust overlain by thick accumulations of sediments, plateaus, and continental fragments. Oceanic crust with thin sedimentary cover has mostly disappeared. Thus, subduction and underthrusting play key roles in this accretionary process, but how and where the thin thrust sheets are peeled off from their lower crustal substrata and are emplaced at supracrustal levels is not apparent. Many nappe-like bodies have been thrust onto the continental margin or onto previously accreted terranes, but there is no evidence of concomitant arc and subduction activity. This makes it exceedingly difficult to apply simple plate tectonic models to any specific locale as causes and effects within the entire system cannot yet be related.

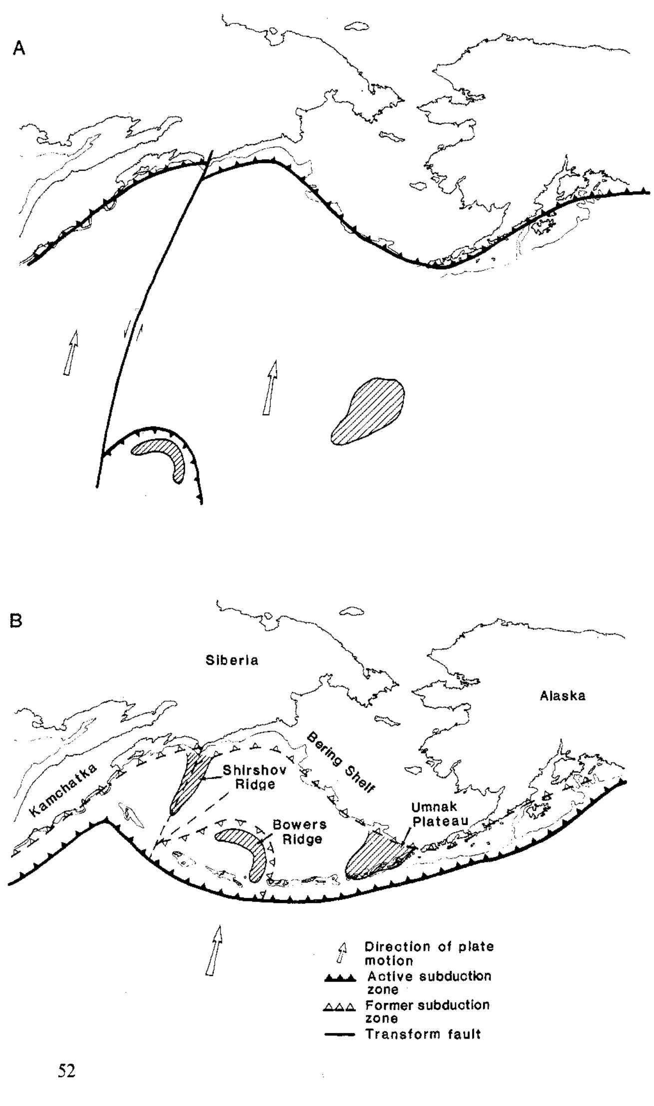


Fig. 6. Conceptual model for the formation of the Aleutian Ridge (*25*). Bowers Ridge and Umnak Plateau are thought to have come from the south with the Kula plate and Shirshov Ridge to have formed in place. (A) Late Mesozoic time and (B) early Tertiary.

Subduction Versus Collision Orogeny

For several decades, two types of mechanisms, collision and subduction, have been suggested for orogenesis. Collision is typified in the Alpine and Himalaya mountain chains. Subduction is typified by many of the circum-Pacific mountain chains, traditionally those in Alaska, western North America, east Siberia, and particularly the Andes in South America.

It now appears to us that Andean orogeny, in the sense of subduction of normal oceanic crust beneath a continent, has not been the underlying tectonic process at the northern Pacific rim. Wherever enough structural, stratigraphic, and paleomagnetic data have become available, it appears that allochthonous terranes are commonly present and that orogeny is intimately linked with the incorporation of these terranes. Although the occasional arc-continent collision orogeny has been recognized (*63*), we suggest that a very large fraction of all orogenic episodes are the result of collision. Aside from the Andean chain and perhaps the Sunda arc, almost all orogenies, or at least their deformation phases, are associated with such collisions. Little or no orogenic deformation occurs where only pure subduction of simple oceanic crust has taken place.

It is possible that allochthonous terranes actually played a role in the Andes comparable to their role in other parts of the Pacific rim, but the geological data for western South America are insufficient to determine whether the required allochthonous terranes are present. Nevertheless, evidence is accumulating that the orogenic history of the Andes is not as simple as that expected from simple subduction.

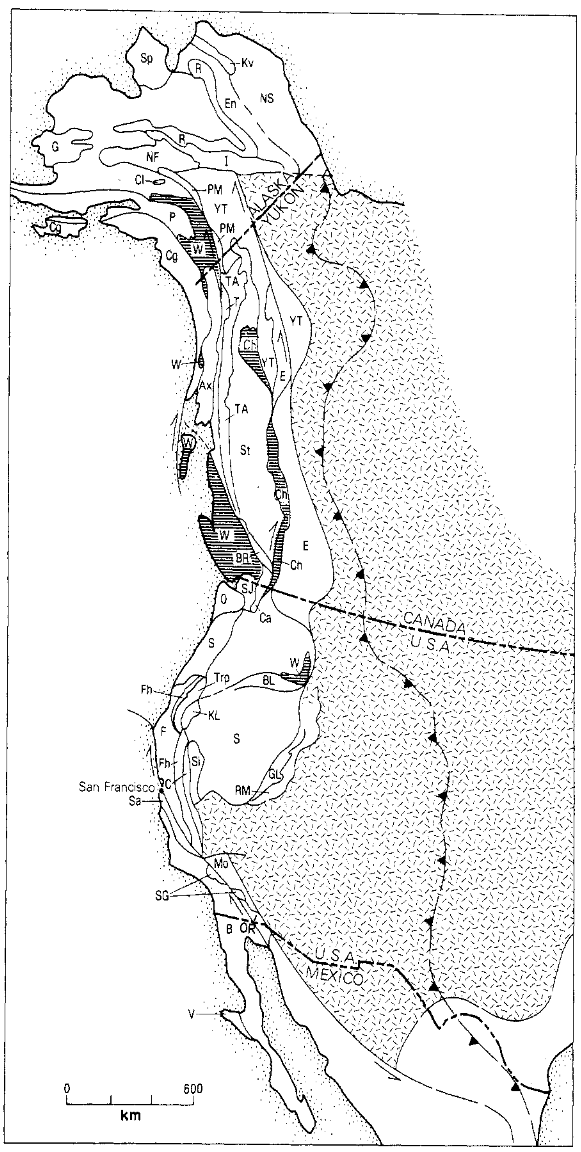
Several features stand out in particular (*64*): (i) The Andes are made up of several tectonically and stratigraphically distinct geological assemblages, possibly allochthonous terranes, which have been welded together over a wide range of geological time (*65*). (ii) Many Paleozoic and early Mesozoic structures run obliquely to the overall north-south structural trend of the Andes, including regions with deformation that penetrated into continental basement rocks of late Paleozoic age. (iii) Deep crustal fractures provide sharp boundaries between sections of the Andes. Some of these sections differ from one another in their geological history and rock types. In the northern Andes, these sections are characterized by rocks with oceanic affinities, whereas from Peru south, rocks have mostly continental affinities. (iv) Prominent and extensive continental basement rocks are exposed along the western coast from Tierra del Fuego to Peru, with ages ranging from 1.8 billion to 300 million years. These basement rocks have been greatly deformed in Paleozoic and Precambrian times, but only mildly since. (v) Many investigators suggest that continental sources to the west of the Andes fed voluminous late Paleozoic and early Mesozoic conglomerates and sandstones now found in the Andean chain (*66, 67*). Arc terranes incorporated from the west have also been invoked by geophysicists (*68*) to explain the presence of old continental basement off the Peru coast.

We believe that these general observations, while lacking in detail, open the possibility that allochthonous terranes have played a major role in the Andean orogenic belt. It is possible that the concept of Andean-type orogeny (orogeny produced by subduction of oceanic crust beneath a continent) is invalid. In other words, it may well be that only one type of process is responsible for orogenic deformation, namely, collision. To test this hypothesis, key areas in the Andes must be studied to determine whether major allochthonous terranes are embedded in the Andean belt.

Conclusion

The role of allochthonous terranes in continental accretion and mountain building is becoming apparent. Some of these terranes were probably oceanic plateaus at one time during their past. Many of the hundred or so plateaus in today's oceans are fated to be incorporated at active continental margins, as many must have been in the past. The immediate effects of the accretion of plateaus include the control of volcanic activity and deep seismicity, trapping of oceanic crust, and shifting of subduction zones.

More lasting effects of the accretion of plateaus are the growth of continental crust and deformation in orogenic belts. We suggest that all orogenic belts, even



Principal terranes

Alaska

NS North Slope
Kv Kagvik
En Endicott
R Ruby
Sp Seaward Peninsula
I Innoko
NF Nixon Fork
PM Pingston and McKinley
YT Yukon-Tanana
Cl Chulitna
P Peninsular
W Wrangellia
Cg Chugach and Prince William
TA Tracy Arm
T Taku
Ax Alexander
G Goodnews

Canada

Ch Cache Creek
St Stikine
BR Bridge River
E Eastern assemblages

Washington, Oregon, and California

Ca Northern Cascades
SJ San Juan
O Olympic
S Siletzia
BL Blue Mountains
Trp Western Triassic and Paleozoic of Klamath Mountains
KL Klamath Mountains
Fh Foothills belt
F Franciscan and Great Valley
C Calaveras
Si Northern Sierra
SG San Gabriel
Mo Mohave
Sa Salinia
Or Orocopia

Nevada

S Sonomia
RM Roberts Mountains
GL Golconda

Mexico

B Baja
V Vizcaino

Fig. 7. Map showing the distribution of principal tectonostratigraphic terranes in North America (*1*). The extent of the craton is shown by pattern. The barbed line marks the eastern limit of cordilleran Mesozoic-Cenozoic deformation. Possible examples of oceanic plateaus are shown by horizontal lines.

those classified as the subduction type, may in fact be the result of collisions—collisions not with major continents but with oceanic plateaus, whose origins include extinct arcs, submerged continental fragments, clusters of seamounts, and hot spot traces.

The link between allochthonous terranes on land and migrating plateaus in the oceans provides a new way to relate land geology to the marine-derived concept of plate tectonics. Instead of envisioning vast oceans in the past underlain by simple ocean floor, we must think in terms of a more complex oceanic geology in which many plateaus with different origins were embedded in ancient oceanic plates, just as they are today.

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