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THE STRUCTURE AND STRATIGRAPHY OF GRAVINA AND REVILLAGIGEDO ISLANDS, ALASKA

BY

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THE STRUCTURE AND STRATIGRAPHY OF GRAVINA AND REVILLAGIGEDO ISLANDS, ALASKA.

By Theodore Chapin.

INTRODUCTION.

SCOPE OF PAPER.

This paper is intended to supplement a report by Philip S. Smith[1] on the same region. The finding on Gravina Island of Triassic fossils, which previously had been reported from but one other locality in southeastern Alaska, made his paper of particular interest. Since the publication of Smith's report the writer has had the opportunity to make further studies and to gather additional data on the structure and stratigraphy of the rocks of Gravina Island and adjacent regions. The discovery of fossils of Jurassic or Cretaceous age has made possible some changes in the geologic mapping and furnished the basis for the interpretations which are here presented, not as final conclusions but as a reasonable working hypothesis for future field work. The structure and stratigraphy of the rocks of Gravina Island are more clearly understood by a consideration of their relation to a larger area including a part of Revillagigedo Island (fig. 10).

This paper is a preliminary report on an area in the southern part of the Ketchikan district. A more complete report on the whole district, including a description of the mineral resources, is now in preparation. The accompanying geologic sketch map (fig. 11) is drawn from the field notes of P. S. Smith and the writer.

[1] Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 97-105, 1915.

LOCATION.

The area under discussion is included within the Ketchikan district, which lies in the southern part of southeastern Alaska, the panhandle

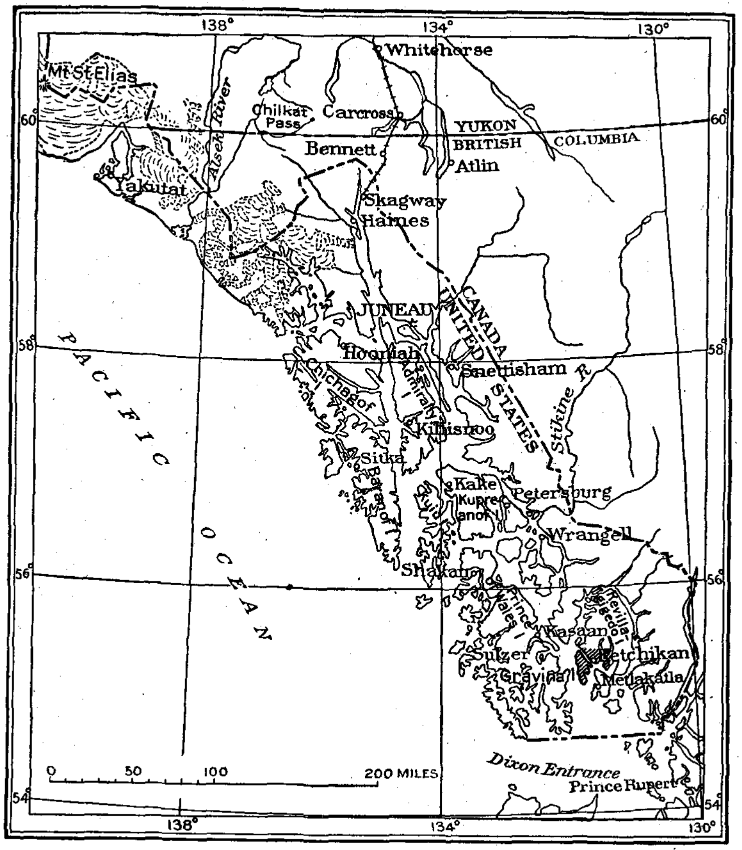


Figure 10.—Map of southeastern Alaska showing position of Gravina and Revillagigedo islands.

strip of Alaska extending along the seaboard from Mount Fairweather to Dixon Entrance. Southeastern Alaska is composed of a mainland area and a fringe of islands known as Alexander Archipelago. The Ketchikan district lies wholly within the Pacific Mountain system, a geographic province which, as defined by

Brooks,[1] includes a broad zone of ranges forming a concave belt parallel to the southern coast of Alaska.

SURFACE FEATURES.

PHYSIOGRAPHIC PROVINCES.

Physiographically the Ketchikan district falls naturally into three main provinces. One comprises essentially the mainland area and adjacent islands. It includes the Coast Range and may be denominated the Coast Range or mainland province. The eastern or Prince of Wales Province comprises Prince of Wales Island and the islands to the west. Between these two mountainous areas lies an intermontane lowland province including Clarence Strait, Revillagigedo Channel, and Behm Canal and low-lying areas along their shores.

The dominating feature of the mainland province is the Coast Range, a high mountain mass with elevations of 7,000 to 8,000 feet. Brooks [2] describes it as follows:

> The Coast Range extends from near the boundary of Washington northward through British Columbia into southeastern Alaska, where it lies partly in Alaska and partly in Canadian territory. Following the coast line for nearly 900 miles it passes inland behind the St. Elias Range near the head of Lynn Canal. Thence it can be traced northward, decreasing in altitude and gradually losing definition until it finally merges with the interior plateau near Lake Kluane, in longitude 130° 30′. This range has no well-defined crest line but is rather a complex of irregular mountain masses occupying a coastal strip between the Pacific Ocean and the Central Plateau region.

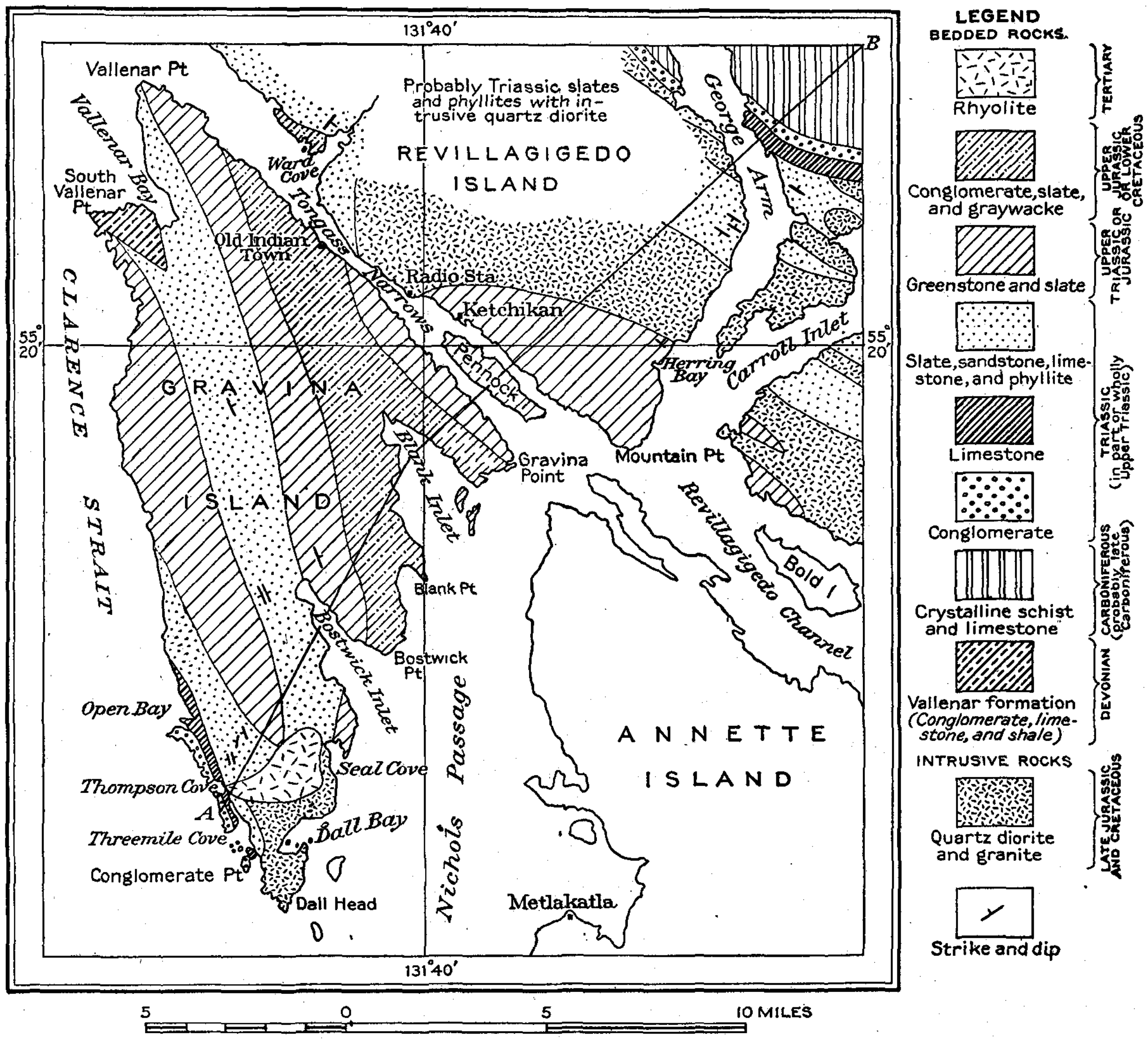


FIGURE 11.—Geologic sketch map of Gravina Island and a part of Revillagigedo Island, Alaska.

The Prince of Wales physiographic province is dominated by a complex group of short,

[1] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 14, 1902.

[2] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 28, 1906.

rugged ranges reaching elevations of about 4,000 feet. In the northern part of the Alexander Archipelago these are not sharply differentiated from the Coast Range and were regarded by Brooks as a southeastern extension of the St. Elias Range.[1] In the Ketchikan district, however, as has been pointed out, the Prince of Wales mountainous region is quite distinct from the Coast Range, from which it is separated by the lowland province. It is correlated with the Vancouver Range, named by Dawson [2] and consisting of "an irregular mountain system which in its submerged parts constitutes Vancouver Island and the Queen Charlotte Islands."

The lowland province as here defined comprises the submarine area covered by the waters of Clarence Strait, Revillagigedo Channel, and Nichols Passage, and the bordering lowlands. This lowland is evidently a submerged portion of the Pacific coast downfold,[3] a series of basins forming a more or less continuous depression extending from the Gulf of California to British Columbia and Alaska. This lowland province would thus be correlated with Puget Sound and with the lowlands covered by the sound separating Queen Charlotte and Vancouver islands in British Columbia from the mainland. The area under discussion lies within and along the border of this lowland province, an area covered largely by Mesozoic sediments which apparently occupy an overturned synclinal fold.

GRAVINA ISLAND.

Gravina Island lies between Clarence Strait and Revillagigedo Channel and is separated from Revillagigedo Island by Tongass Narrows, a narrow, shallow channel a quarter of a mile to 2 miles wide and in places less than 100 feet deep. The island is roughly triangular. It has rather straight shore lines on two coasts, but the southeast coast is very irregular in shape, being broken by two deep bays, Blank and Bostwick inlets, and by minor indentations. The longest dimension of the island is 21 miles, and its maximum width is 9 miles. It has an area of about 100 square miles.

Gravina Island lies along the border line between the Coast Range and lowland provinces. Two low ranges of hills, the California Range and Dall Ridge, extend across the entire island from northwest to southeast. Dall Ridge reaches a maximum elevation of about 2,000 feet, and California Range of over 2,500 feet. Between these two ranges of hills, extending from Vallenar Bay to Bostwick Inlet, is a low depression only a few feet above sea level. Another depression extends from Blank Inlet to a point opposite Ward Cove. It lies between California Range and a low range that borders Tongass Narrows from Gravina Point northward for about 4 miles.

A striking parallelism exists between the ranges of hills, the intervening valleys, and the large bays—Vallenar, Bostwick, and Blank inlets. All have a dominant northwesterly direction, approximately parallel to the structure of the bedrock, which has evidently been the controlling factor in the topographic development.

REVILLAGIGEDO ISLAND.

Revillagigedo Island, with the exception of a fringe of lowland along Tongass Narrows, belongs to the mainland province. It is a large island of 1,120 square miles separated from the mainland by Behm Canal, a semicircular fiord that borders the northern part of the island. The interior of the island is high and rugged, its peaks reaching elevations of 4,000 feet. Three long fiords—Thorne Arm, Carroll Inlet, and George Inlet—break the southern coast into irregular-shaped peninsulas.

SUMMARY OF FORMATIONS AND STRUCTURE.

The rocks of Gravina Island and that portion of Revillagigedo Island included in this discussion are essentially Mesozoic formations that rest unconformably upon Carboniferous and Devonian rocks (fig. 11). The Mesozoic formations include three distinct terranes, all of which are fossiliferous. The lower and upper terranes, which are dominantly sedimentary, are respectively Triassic and either Upper Jurassic or Lower Cretaceous. The terrane of intermediate stratigraphic position, composed of volcanic rocks and intercalated sediments, contains fossils of Upper Jurassic or Lower Cretaceous age but may include also Triassic rocks. Tertiary lava flows occur on

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 29, 1906.

[2] Dawson, G. M., Roy. Soc. Canada Proc. and Trans., vol. 8, sec. 4, p. 4, 1890.

[3] Willis, Bailey, U. S. Geol. Survey Geol. Atlas, Tacoma folio (No. 54), p. 1, 1899.

the southern part of Gravina Island but are not widely distributed. The most recent formations are marine glacial deposits that lie above the present high tide.

The intrusive rocks of the Ketchikan region comprise for the most part the dioritic and granitic rocks of the Coast Range. They are not, however, confined to the Coast Range but occur in large bodies on the islands. The age of these intrusives is regarded as late Jurassic and Cretaceous.

The following table shows the correlation of the Mesozoic formations of Gravina Island with those of Graham and Vancouver islands as described by Canadian geologists:

Correlation table of Mesozoic formations of Gravina, Graham, and Vancouver islands.

Age.	Gravina Island.	Graham Island.[a]		Vancouver Island.[b]	
		Formation.	Lithologic character.	Formation.	Lithologic character.
Upper Cretaceous.		Queen Charlotte series.	Fossiliferous shales and conglomerates, with coal.	Nanaimo series.	Conglomerates, sandstones, and shales, with coal.
Lower Cretaceous.	Conglomerate, sandstone, and graywacke.				
Upper Jurassic.	Quartz diorite, etc.	Batholithic intrusives, etc.	Quartz diorite, etc.	Batholithic and dike intrusives.	Granodiorites, quartz diorites, etc.
Middle Jurassic.	Volcanic flows and tuffs with intercalated sediments. Volcanic breccias.	Yakoun formation.	Agglomerates, tuffs, and flows.	Sicker series (Jurassic or Triassic).	Andesitic flows and tuffs; schistose, slaty, tuffaceous, and quartzose sediments.
Lower Jurassic.		Maude formation.	Dark-colored, fine-grained, thinly laminated fossiliferous argillites, grading upward into tuffs and agglomerates. Possibly detrital conglomerates at base.	Sutton formation, Vancouver volcanics.	Crystalline limestones, metamorphic andesites, and pyroclastic rocks.
Upper Triassic.	Conglomerate, limestone, sandstone, and slate.				

a Mackenzie, J. D., Canada Geol. Survey Mem. 88, 1916.

b Clapp, C. H., Canada Geol. Survey Mem. 13, 1912.

Across the area including Gravina Island and the southern part of Revillagigedo Island the beds present a dominant northwest strike and, except locally, dip northeast, giving the appearance of simple monoclinal structure over a wide area. (See fig. 12.) These beds, however, are believed to represent overturned and truncated isoclinal folds and thus give the impression of a much greater thickness of sediments than really exists. The evidence for this conclusion lies in the following observed facts. On the southwest coast of Gravina Island Triassic conglomerate, limestone, and black slate are overlain by volcanic rocks and intercalated sediments of Triassic or Jurassic age, which, in turn, are overlain by the slate and graywacke of Blank Inlet, determined to be Jurassic or Cretaceous. Succeeding the Jurassic or Cretaceous sediments are volcanic rocks, with black slates and tuffs. Here the section is interrupted by a boss of granite, beyond which are black slates and phyllites, limestone, and schistose conglomerate. Beyond the conglomerate occur crystalline schists and massive semicrystalline limestone-bearing fossils regarded as certainly Paleozoic and probably Carboniferous. This anomalous position of the Paleozoic and Mesozoic rocks is probably due to an overturned position of one limb of the syncline.

From the slate and graywacke area of Blank Inlet the general sequence of rocks is the same toward the northeast as it is toward the southwest, and it is believed that the similar rocks are in fact the same beds exposed on two limbs of an overturned fold, the trough of which is exposed on Blank Inlet. The volcanic rocks on each side of the Blank Inlet area of slate and graywacke are similar and may be correlated, as there is little reason to doubt their identity. The slates and phyllites of Revillagigedo Island are much more schistose than the black slates and sandstones of Gravina Island, with which they are correlated, but this is evidently due to the contact metamorphism caused by the adjoining intrusive granite. The other sediments of Revillagigedo Island are also more metamorphosed than their supposed equivalents on Gravina Island. The limestone is crystalline and the conglomerate is schistose, but these differences in metamorphism are also easily accounted for, not alone by the small body of granite shown in the sketch but also by the immense batholith of the Coast Range.

Along this eastern limb of the syncline is a greatly disturbed belt which apparently continues the entire length of southeastern Alaska along the border of the intrusives of the Coast Range. In this disturbed belt the folding is much more close, and the beds are more tightly compressed and, if correctly interpreted, are in part overturned. The structural form is not a simple syncline and might more correctly be termed a synclinorium, for one prominent anticline and a number of minor folds occur, the details of which are brought out more fully in the discussion of the different formations.

DEVONIAN ROCKS.

VALLENAR FORMATION.

DISTRIBUTION AND CHARACTER.

The oldest rocks recognized by the writer are the Devonian beds exposed on the west coast of Vallenar Bay, on Gravina Island. They consist of conglomerate, limestone, calcareous shales, sandstone, and argillites. The conglomerate is composed of cobbles of schist, quartz, and limestone embedded in a schistose matrix. The conglomerate is in part interbedded with thin limestones, calcareous shales, argillites, and sandstones containing Devonian fossils.

STRUCTURE AND STRATIGRAPHY.

The structure and stratigraphic relations of the Devonian beds are not clear. The beds are closely folded and deformed, and the relations are obscured by movement along the contacts. From South Vallenar Point eastward the beds trend dominantly northwest and dip northeast at varying angles. From the present position of the beds the base of the formation appears to be the conglomerate, which apparently rests upon the Mesozoic volcanic beds of the west coast of the island. This anomalous condition indicates an overturned position of the beds.

On the west coast of Vallenar Bay, about a mile east of South Vallenar Point, is the crest of a very sharply folded anticline (Pl. VIII, *D*), which has involved the calcareous shales and argillites. It is believed that these are the lowest of the Devonian beds and that the limestones and conglomerates to the west are stratigraphically higher in the section and occupy the overturned limb of a steeply pitching anticline that is overturned toward the west. It may be that the schistose conglomerate containing an abundance of limestone cobbles is a member of the Mesozoic greenstone and intercalated sedimentary beds. The contact with the Mesozoic beds at the head of Vallenar Bay is covered by gravels. This anticline along which the Devonian beds are brought to the surface on Vallenar Bay is presumably the same fold that extends along Dall Ridge to Seal Cove and forms a minor fold in the broad synclinorium involving all the rocks between the west coast of Gravina Island and George Arm.

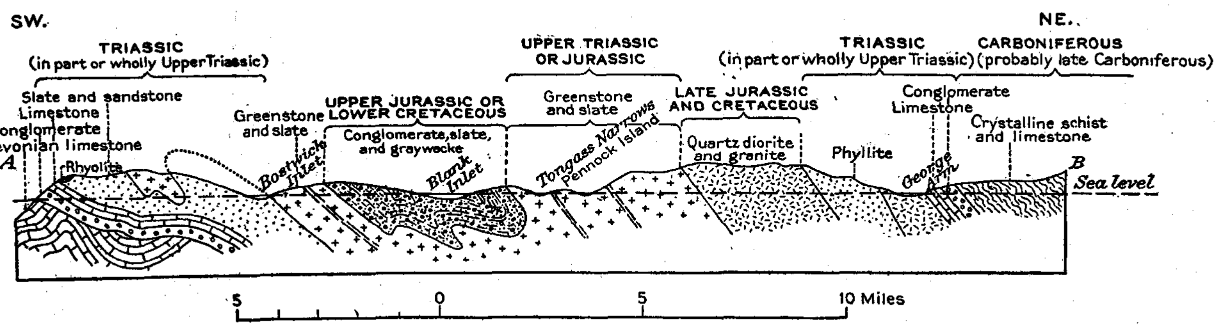


FIGURE 12.—Structure section across Gravina and Revillagigedo islands, Alaska.

AGE AND CORRELATION.

The Devonian rocks of Vallenar Bay were first described as the Vallenar "series" by Brooks,[1] who states:

> The Vallenar series [is] so named from its type exposures on Vallenar Bay, at the northern end of Gravina Island. The series is composed essentially of limestones and calcareous schists with some black slates.

Fossils were collected at this locality by Brooks in 1901 and determined by Charles Schuchert as Devonian. More collections were made in 1905 and 1906 by the Wrights and E. M. Kindle [2] who report:

> *One mile west of Vallenar Bay, Gravina Island.*—The material from this locality, while generally insufficient for specific determination, is much better than that obtained last year (1905) and leaves no doubt as to the Devonian age of the beds west of Vallenar Bay. Several specimens of *Atrypa reticularis* are present. This fixes the horizon as not later than Carboniferous, while the association of *Chonetes* cf. *manitobensis*, *Spirifer* sp., *Proetus* sp., and *Cyclonema* sp. indicate a horizon of Devonian age, probably middle Devonian.

Some poorly preserved material collected by the writer in 1915 was determined by T. W. Stanton as probably Devonian.

The beds of Vallenar Bay were correlated by Brooks with rocks on Long Island.[3] Middle Devonian rocks of similar character occur on Clover Bay, on the east coast, and Hunter Bay and Klakas Inlet, on the west coast of Prince of Wales Island and on Hotspur Island.

CARBONIFEROUS ROCKS.

BEDS INCLUDED.

The term "Ketchikan series" was applied by Brooks [4] to argillaceous and carbonaceous rocks with some limestone beds and finely foliated slates and phyllites that occur on Tongass Narrows, near Ketchikan, on Revillagigedo Island, and on Cleveland Peninsula. Brooks considered these rocks to be in part Carboniferous and in part Mesozoic and suggested that probably the limestones are Carboniferous and the slates are Triassic.

The Wrights [5] state:

> In view of the comparatively weak paleontologic and stratigraphic evidence bearing on the precise age of these argillites and crystalline schists, it is possible that their period of deposition extended even beyond the Carboniferous period into the Triassic, especially when the extensive development of Triassic strata to the south in British Columbia, as described by G. M. Dawson, is taken into consideration. The evidence thus far gathered, however, indicates Carboniferous age for the greater portion of these crystalline schists and argillites.

Brooks noted that the limestones overlie the argillites (slate and greenstone) and thus appear to be younger. This confusion was due to their overturned position, the older beds actually overlying the younger ones.

The assignment of the rocks mapped by Brooks as the "Ketchikan series" to both Carboniferous and Triassic is in harmony with the writer's interpretations. The part of Brooks's "Ketchikan series" that stratigraphically underlies the conglomerate and massive limestone which in this report are correlated with the Upper Triassic rocks of Gravina Island is here regarded as Carboniferous.

DISTRIBUTION AND CHARACTER.

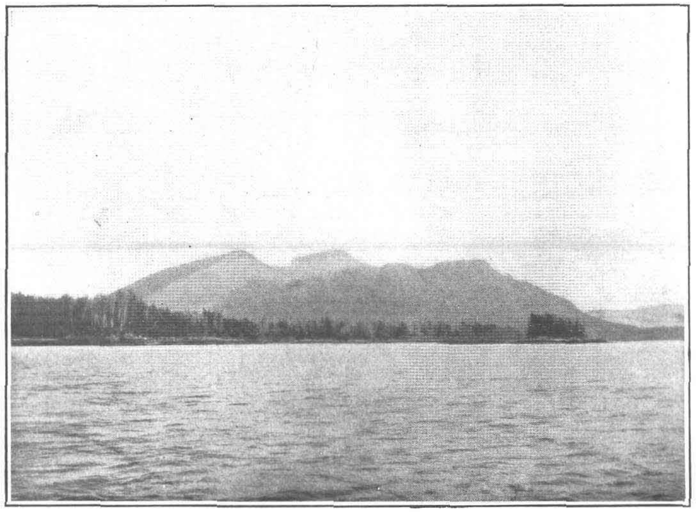
The rocks herein assigned to the Carboniferous are essentially crystalline schists and limestone. In areal distribution they occupy a broad belt along the border of the Coast Range, extending from the mouth of Portland Canal northwestward for an unknown distance. In the area under discussion they are restricted to a small area on Revillagigedo Island near the head of George Arm. The schists make up the greater part of the series. They are evidently the result of contact metamorphism induced by the intrusive rocks. An adequate description of them would require a detailed petrographic study of the rocks in the field and an intensive microscopic study, neither of which has been made by the writer. The limestone constitutes a relatively small part of the series. It occurs in beds 100 feet in maximum thickness intercalated with the crystalline schists. It is dominantly white and crystalline.

STRUCTURE AND STRATIGRAPHIC RELATIONS.

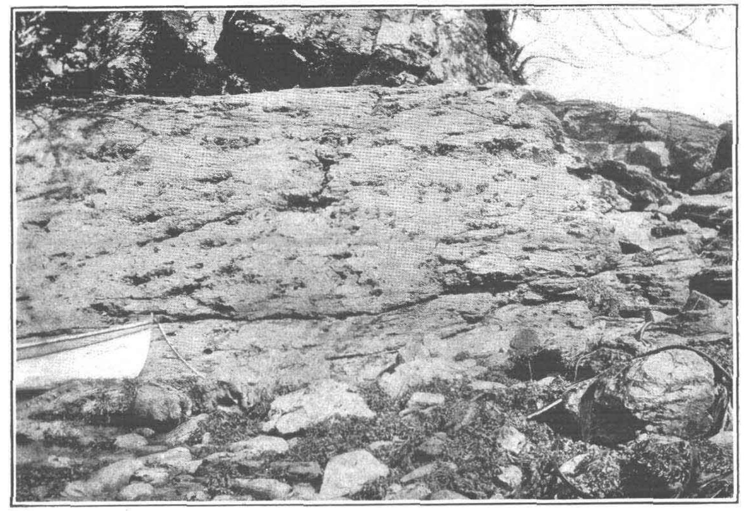
The Carboniferous rocks are closely folded and contorted. They occupy a greatly disturbed belt along the western border of the Coast Range and form the overturned limb of a synclinorium in which are involved all the formations east of Clarence Strait. The other limb of the syncline comes to the surface on the western coast of Gravina Island.

The base of the Carboniferous schists and limestones is not exposed. They apparently

[1] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 42, 1902.
[2] Wright, F. E., and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 50, 1908.
[3] Brooks, A. H., op. cit., p. 43.
[4] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 44, 1902.
[5] Wright, F. E. and C. W., op. cit., p. 56.

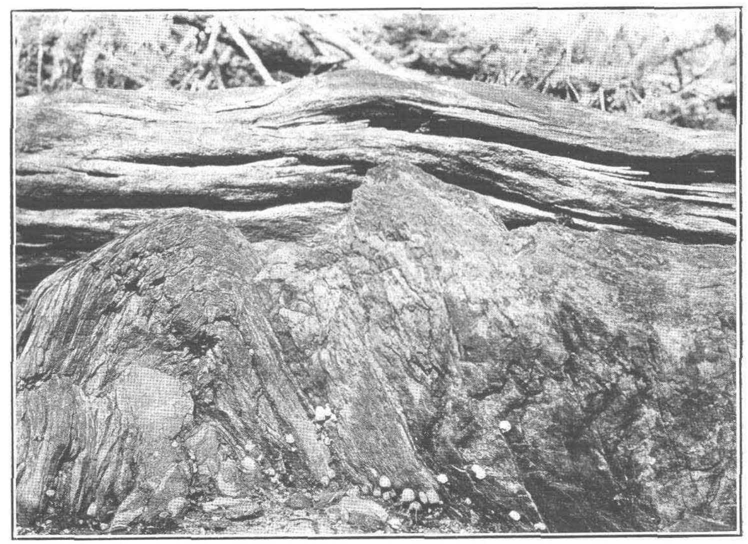


A. WAVE-CUT BENCH, DALL BAY, GRAVINA ISLAND, ALASKA.



B. CONGLOMERATE, BLANK INLET, GRAVINA ISLAND.

C. SLATE AND GRAYWACKE, BLANK INLET, GRAVINA ISLAND.



D. ANTICLINE ON VALLENAR BAY, GRAVINA ISLAND.

overlie conglomerate and limestone beds whose age is unknown but which are regarded as Upper Triassic. The strata at this locality, however, are believed to be overturned so that the normal sequence of the beds is reversed. (See fig. 12.)

AGE AND CORRELATION.

Fossils were collected from the limestone near Coon Island at the head of George Arm by Mr. Brooks, who states that the many crinoid stems suggest that at least the limestones belong to the upper Paleozoic. C. W. Wright also collected fossils from George Arm, on which E. M. Kindle reports as follows:[1]

No. 966. Point on southeast side of George Inlet 10 miles from its head, Revillagigedo Island.—The fossils from this point comprise only crinoid stems, which, however, are so abundant as to make up a large portion of the rock. Crinoid stems can not ordinarily be used for correlation. However, their great abundance here seems to justify a surmise that they very probably represent a Carboniferous horizon. Crinoids in such abundance as is shown by these specimens occur in very few places, if anywhere, outside of Carboniferous horizons. In the absence of other evidence the horizon represented may be referred tentatively to the Carboniferous.

Other collections made by P. S. Smith in 1913 contained nothing of determinative value but were considered as probably Paleozoic. No collections were made by the writer, but the crinoid-bearing beds were observed at a number of places.

There is little doubt of the Carboniferous age of at least one of the fossiliferous beds in this series of schists and limestones, but their exact age and stratigraphic position are much in doubt. Lithologically, except in amount of metamorphism, they resemble the slate and limestone of the Porcupine district. The slates and limestone beds of the Porcupine district are not fossiliferous, but from closely associated massive limestone beds fossils were collected which G. H. Girty first doubtfully referred to the lower Carboniferous but later determined as upper Carboniferous. Regarding a similar fauna from Admiralty Island, Girty[2] says:

The fauna from point at southeast entrance to Pybus Bay, Admiralty Island, which also seems to occur at point on divide between Chapin Bay and Herring Bay, Admiralty Island, is without doubt upper Carboniferous in age and probably can be designated Permo-Carboniferous. This fauna is known to be at but one other point in Alaska—Porcupine mining district—where some of the same species were obtained last year. This fauna also is entirely dissimilar from those of the Mississippi Valley and Appalachian region and finds nearer affinities in those of western United States and of eastern Europe (Russia).

These schists and limestones are therefore tentatively regarded as late Carboniferous. Their relation to the Devonian beds of Vallenar Bay is not evident, as the two are nowhere known to be in contact. If these schists and limestones are correctly correlated with the late Carboniferous it would appear that there is lacking in this region a very thick section of Carboniferous rocks which are widely developed on the west coast of Prince of Wales Island. These include Mississippian limestone and cherts, which are probably the equivalent of the Lisburne limestone, and Pennsylvanian limestones that include Moscovian and Gschelian faunas.

TRIASSIC ROCKS.

BEDS INCLUDED.

The term "Gravina series" was first applied by Brooks[3] to massive conglomerate overlain by black slates or shales occurring on the south end of Gravina Island. He included in his mapping of this "series" the somewhat similar massive conglomerates and associated black slates and arenaceous sediments of the west coast, Bostwick Inlet, and Blank Inlet and suggested its probable extension to other places. As a result of recent investigations, however, the sedimentary rocks of Gravina Island originally defined as the "Gravina series" are now known to include two sedimentary formations—one of Triassic age and one of Jurassic or Cretaceous age. These two sedimentary formations are associated with volcanic rocks of intermediate stratigraphic position. Brooks first regarded the "Gravina series" as Cretaceous and correlated it with the Queen Charlotte series of Vancouver and Queen Charlotte islands, but later he stated that its identity with the "Vancouver series" (Triassic) seemed equally probable.[4] His correlations with both Triassic and Cretaceous formations, made without any fossils, proved substantially correct.

[1] Wright, F. E. and C. W., op. cit., p. 55.
[2] U. S. Geol. Survey Bull. 287, p. 143, 1906.
[3] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 45, 1902.
[4] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 226, 1906

DISTRIBUTION AND CHARACTER.

The Upper Triassic rocks on Gravina Island comprise a gradationally conformable series of conglomerates, limestones, sandstones, and slates. They are most typically exposed on the southwest coast of the island, where they occupy a narrow belt that extends from a small cove opposite Dall Bay northwestward for about 7 miles. Unfossiliferous rocks, presumably of the same formation, to judge from lithologic similarity and structural relations, occupy a narrow belt that extends across George Arm and Carroll Inlet.

On Gravina Island the Upper Triassic rocks fall naturally into three main divisions—one composed essentially of conglomerate, one essentially of limestone, and one of interbedded black slate, sandstone, conglomerate, and limestone. These three conformable terranes are shown by fossils to be probably Upper Triassic. Overlying the Upper Triassic sediments, with apparent conformity, are volcanic agglomerates and intercalated sedimentary beds which are, at least in part, of Upper Jurassic or lower Cretaceous age and possibly in part of Upper Triassic age.

The exposed basal member of the series on Gravina Island is a coarse conglomerate that extends along the southwest coast of the island from Conglomerate Point northwestward to Open Bay and occupies three narrow strips whose continuity is broken by Fivemile Cove, Thompson Cove, and Threemile Cove. The conglomerate is a heavily bedded, massive rock. The boulders are essentially of angular coarse-grained granite resembling the granite of Annette Island, and the matrix is quartz-feldspar sand presumably derived from the same source as the boulders. Intercalated with the coarse conglomerate are thin beds of sandstone, which are composed of the same material as the matrix of the conglomerate, and gradational beds of grits. Thin beds of fossiliferous limestone and black slate with pronounced cleavage occur sparingly. The conglomerate and intercalated sandstone beds are strongly indurated and break with prominent fractures across the boulders.

On a small cove south of Threemile Cove[1] the conglomerate is finer grained toward the top and passes upward into grits, sandstone, and slate which are overlain by a large block of fossiliferous massive limestone. There has been some movement along this contact, so that the relations are confused, but the limestone is apparently above the conglomerate and sandstone. On Thompson Cove the conformable relations of the limestone to the conglomerate, sandstone, and slate are more evident, although here also there has been some faulting.

In the upper part of the conglomerate the beds are thinner and the material is much finer grained and contains more sandstone, slate, and thin beds of limestone, which are conformably overlain by the massive limestone.

The limestone varies in appearance from place to place. On Thompson Cove and Open Bay it is a soft gray fossiliferous rock, corals being especially abundant. On Threemile Cove it is more closely folded, is considerably silicified, and weathers out brick-red. The limestone here is less fossiliferous, and the fossils are poorly preserved. The greater amount of deformation of the limestones on Threemile Cove is probably the result of contact metamorphism induced by the intrusive rocks of Dall Head.

The massive limestone is conformably overlain by a great thickness of black slate with intercalated beds of conglomerate, sandstone, and limestone. These beds crop out along the coast of Gravina Island for a distance of about 3 miles north of the limestone area and extend to the high hills of Dall Ridge north of Dall Head. Similar rocks are exposed on Bostwick Inlet and Seal Cove and extend northwestward in a belt from 2 to 3 miles wide to Vallenar Bay and North Vallenar Point.

The dominant rocks of this series are black-clay slates having a pronounced cleavage. Intercalated with the slate are thin beds of quartz sandstone, quartzite, and conglomeratic sandstone. The limestone beds are not numerous but are usually fossiliferous. The interbedded limestone layers are about 20 to 30 feet in thickness but appear to be lenticular.

The black slate and associated sediments are closely folded, especially on Threemile Cove, where the beds are thrown into sharp contorted folds. The beds on Vallenar Bay are much more regular and show none of the close folding.

On Revillagigedo Island associated conglomerate, limestone, schistose slates, and phyllites are correlated with the sedimentary series of Gravina Island on the basis of similarity of

[1] Threemile Cove has appeared in the literature as "cove 3 miles north of Dall Head."

lithology and sequence and stratigraphic and structural relations. The beds are exposed on George Arm, Carroll Inlet, and Thorne Arm. The lithologic similarity of these rocks to the Triassic rocks of Gravina Island is marked, notwithstanding their more schistose nature, which is due to their proximity to the large masses of intrusive rocks. The conglomerate is very schistose, and the cobbles are mashed and deformed. The limestone is white and crystalline, and the slates are in part schistose and might more correctly be termed phyllites and schists. Similar slates, phyllites, and schists occur on the north end of Tongass Narrows.

These rocks show different degrees of metamorphism. The most extreme phases occur along the borders of the plutonic bodies of Revillagigedo Island, and the amount of metamorphism varies more or less directly with its nearness to the igneous rock. On Tongass Narrows the slates show little metamorphism except cleavage and the development of a little secondary mica. As the igneous rocks are approached the metamorphism becomes more noticeable. On Ward Cove the slates have a very pronounced schistosity and contain considerable secondary mica and hornblende. The most prominent type is a dark-gray rock with acicular hornblende crystals a centimeter in length, white mica, quartz, and colorless garnet in large euhedral crystals. Pyrite is locally abundant. Another type is a dark-green schist composed essentially of hornblende and quartz. Garnet is an abundant accessory. It occurs in euhedral crystals partly altered to calcite and quartz. Epidote, chlorite, and pyrite also occur.

No fossils have been found in these rocks, but on account of their stratigraphic position between the Carboniferous rocks of Revillagigedo Island and the supposedly Triassic or Jurassic volcanic rocks of Tongass Narrows and Gravina Island, they appear to occupy about the same horizon as the Triassic slates and sandstones of Gravina Island. The sequence of this series is also the same as the Triassic succession of sedimentary beds of Gravina Island—conglomerate, limestone, argillaceous and arenaceous sediments. From the present relation of the beds the sequence on the two islands appears to be reversed, but this is due to the overturned position of the section on Revillagigedo Island.

STRUCTURE.

The Triassic conglomerate, limestone, and black slate of the west coast of Gravina Island, although closely folded, maintain a general strike of about N. 70° W. The beds dip northeast and occupy one limb of the synclinorium, which dips beneath the volcanic rocks and comes to the surface in Bostwick Inlet and presumably also on Revillagigedo Island near the head of George Arm, where the beds are involved in the overturned limb of the synclinorium.

STRATIGRAPHIC RELATIONS.

The base of the Upper Triassic series of Gravina Island is not visible. The lowest part exposed occurs at Threemile and Thompson coves, where the actual base of the conglomerate is concealed by the water. At Vallenar Bay the Triassic rocks overlie Devonian sediments that come to the surface along the axis of an anticline. The contact is covered by the Quaternary deposits of Vallenar Bay. The presence of Devonian pebbles in the conglomerates of Threemile Cove indicates an underlying rock of that age, and on George Arm the supposedly Triassic rocks rest upon Carboniferous rocks. A marked unconformity at the base of the Upper Triassic rocks is thus evident.

On Gravina and Revillagigedo islands the Triassic rocks are in places conformably overlain by volcanic beds of Upper Triassic or Jurassic age and in places unconformably by slate and graywacke of Jurassic or Cretaceous age. The conglomerate and sandstone of Dall Head are invaded by dioritic rocks, presumably of Jurassic or Cretaceous age, and are unconformably overlain by Tertiary lavas.

ORIGIN.

The Upper Triassic rocks are the products of normal deposition and are evidently of marine origin, as shown by the fauna present in all the members. They are believed to represent an unbroken period of deposition, but the abrupt change from conglomerate to massive limestone and black slate with numerous intercalations of limestone, conglomerate, and sandstone indicates that the rocks were deposited under constantly changing conditions. The massive conglomerate was evidently a basal formation and was laid down in comparatively shallow water near the shore line and derived its material from the products of land waste. The organic nature of the limestone is clearly proved by the great abundance of organic remains, especially corals, which it contains. The schists and phyllites were originally slates and sandstones, probably of marine origin, but have been changed to their present condition by the contact influence of the intrusive rocks.

AGE AND CORRELATION.

The age of these rocks is shown by a large number of fossil collections, made from all members of the series, to be Triassic, probably Upper Triassic.

Fossils collected by G. C. Martin and K. M. Overbeck from the massive conglomerate at the exposed base of this series were determined by T. W. Stanton as follows:

8831 (G. C. M. No. 3). Gravina Island near 8830. Large limestone nodule in conglomerate. The whole nodule is a nautiloid with deeply lobed suture, possibly referable to *Cosmonautilus*. On the back is a *Rhynchonella* (?). Probably Triassic.

8833 (G. C. M. No. 5). Gravina Island, south arm of cove 3 miles north of Dall Head. Near zone of nodular masses of limestone in conglomerate. This lot appears to be Devonian.

Mr. Martin's opinion, with which the writer agrees, is that the Triassic conglomerate rests unconformably upon Devonian rocks, and the Devonian fossils from Threemile Cove were obtained either from boulders in the conglomerate or from unrecognized Devonian rocks occurring in complex structural relations with the Triassic beds. The beds on Threemile and Thompson coves are faulted and also closely folded and contorted, thus being thrown into complex structural relations. From the wording of the locality description given above it would appear quite possible that the fossils were collected from included masses of limestone in the conglomerate. In 1916 A. H. Brooks and the writer collected fossils from narrow bands of limestone definitely interbedded with the conglomerate. J. B. Reeside reports on these as follows:

9899 (16 ACh 136). Threemile Cove, Gravina Island. Echinoid spine, possibly of *Cidaris*. Age undetermined.

Fossils were first collected from Threemile Cove in 1906 by the Wrights.[1] The exact locality is uncertain, but the matrix of the fossiliferous rocks is described as calcareous schist, which is evidently the siliceous limestone. The fauna was regarded by G. H. Girty as coming from the uppermost part of the Carboniferous or from the Mesozoic. These beds were thus doubtfully referred to the Mesozoic for some years, but recent collections have shown them to be without much doubt Triassic and probably Upper Triassic.

Collections made by Martin and Overbeck from the limestone beds of Threemile Cove occurring beneath the black slate were determined by T. W. Stanton as follows:

8830 (G. C. M. No. 2). Gravina Island, south arm of "cove 3 miles north of Dall Head." Massive limestone outcrop near anchorage béhind wooded island.
- Undetermined corals of Mesozoic type, two or three genera represented.
- Ostrea? sp.
- Pseudomelania? sp., internal cast.
- Arcestes?? sp., fragment; may not even be an ammonite.

Probably Triassic.

8832 (G. C. M. No. 4). Gravina Island, near south foreland on arm of "cove 3 miles north of Dall Head," near contact with conglomerate.
- Undetermined coral fragment.
- Pentacrinus sp., segment of column.

Probably Triassic.

8834 (G. C. M. No. 6). Gravina Island, north arm of "cove 3 miles north of Dall Head." Massive limestone in reef west of cabin. Probably about 100 feet below 8704.
- Corals, probably several genera.
- Cassianella sp.
- Myophoria?? sp.
- Natica sp.
- Murchisonia? sp.

Triassic.

8835 (G. C. M. No. 7). Gravina Island, near 8834, from thin-bedded limestone interbedded with shale about 20 or 30 feet below 8834.
- Corals; several genera represented.
- Spiriferina? sp.
- Myophoria? sp.
- Natica sp.
- Turritella? sp.
- Pseudomelania? sp.
- Trachyceras? sp., small fragment.

Triassic.

The following collections made by the writer in 1915 from the limestone overlying the massive conglomerate were determined by Mr. Stanton:

9531 (15 ACh 111). West coast of Gravina Island. Cove $2\frac{1}{2}$ miles north of Dall Head.
- Echinoid spines.
- Undetermined corals.
- Ostrea? sp.
- Gryphaea? sp.
- Pecten sp.
- Natica? sp.
- Turritella? sp.

The fossils in this lot are poorly preserved and mostly fragmentary. They are apparently Mesozoic and may be Triassic.

[1] Wright, F. E. and C. W., op. cit., p. 52.

15 (ACh 121). Northeast shore of Thompson Cove, Gravina Island.

Corals, genus undetermined.
Pentacrinus sp.
Echinoid spine.
Ostrea? sp.
Solemya? sp.
Turritella? sp.
Spiriferina? sp.
Probably Triassic.

9534 (15 ACh 122). Northeast shore of Thompson Cove, Gravina Island.

This lot includes undetermined corals, Ostrea?, Turritella?, and undetermined gastropods. Probably Triassic.

9535 (15 ACh 123). North shore of Thompson Cove, Gravina Island.

Pecten? sp.
Gryphaea? sp.
Halobia sp.
Undetermined ammonite.
Triassic.

9536 (15 ACh 129). Fivemile Cove, Gravina Island. Limestone apparently overlying massive conglomerate.

Corals, several undetermined genera.
Bryozoa?
Pecten sp.
Purpurina?? sp.
Undetermined slender gastropod.
Probably Triassic.

9537 (15 ACh 130). Fivemile Cove, Gravina Island.

Corals, several genera.
Bryozoa?
Myophoria sp.
Purpurina?? sp.
Turbo? sp.
Triassic.

9538 (15 ACh 132). Fivemile Cove, Gravina Island, immediately north of 9537.

Gryphaea sp.
Probably Triassic.

Two lots of fossils collected by P. S. Smith from the black slate of Threemile Cove (8704) and also from Fivemile Cove (8705) were submitted to Mr. Stanton, who reported as follows:

The only fossil species recognized in these two lots is a *Halobia*, which is closely related to if not identical with *H. superba* Mojsisovics, an Upper Triassic species. The rocks from which these collections came are therefore referred to the Triassic.

The writer made the following collections in 1915 from the black slate and interbedded limestone and sandstone beds of Threemile Cove, Thompson Cove, and Dall Ridge. Stanton reports:

15 ACh 112. Threemile Cove, Gravina Island, 300 yards north of 15 ACh 111.

Spiriferina? sp.
Halobia? sp.
Probably Triassic.

9532 (15 ACh 113). Threemile Cove, Gravina Island, 300 yards southeast of north end of cove and about 700 yards north of 15 ACh 112. Fossils from black slate and limestone.

The black slate shows fragmentary specimens of *Halobia* cf. *H. superba* Mojsisovics, of Upper Triassic age, while the limestone shows imperfect specimens which seem to be referable to *Aucella* and hence is probably of Upper Jurassic age.

The limestone and black slate from which the fossils regarded as Upper Triassic and Upper Jurassic were obtained are apparently interbedded. This anomalous occurrence may be due to very closely infolded Jurassic rocks, but it appears more probable that the doubtful Jurassic forms are not correctly identified.

9533 (15 ACh 115). Thompson Cove, Gravina Island. Halobia slates in fault block.

Cidaris? sp., imprint of surface.
Halobia cf. H. superba Mojsisovics.
Triassic.

15 ACh 124. Dall Ridge, 1 miles north of Dall Head, Gravina Island.

Echinoid spines, etc.
Probably Triassic.

The following collection was identified by J. B. Reeside:

9900 (16 ACh 137). Threemile Cove, Gravina Island.

Cerithium? sp., fragment showing part of two whorls.
Isastraea cf. I. profunda Reuss.
Thamnastraea cf. T. rectilamellosa Winkl.
Spongiomorpha? sp.
Hydrozoan, undetermined.
Natica? sp.
These forms are apparently of the Upper Triassic coral fauna referred by J. P. Smith to the Noric.

The conglomerate sandstones near the crest of Dall Ridge contain Devonian fossils, but as these are fragmentary and occur in pebbles they indicate nothing more than the post-Devonian age of the rocks. Kirk reports:

15 ACh 126. Dall Ridge, 4 miles north of Dall Head.

Fragmental fossils apparently occurring as pebbles in conglomerate. At least one of the fossils is Devonian. It is a coral, probably *Alveolites*.

Black slates and sandstones exposed on the west coast of Bostwick Inlet are correlated, on structural grounds and lithologic similarity, with the upper part of the Triassic rocks on the west coast of the island, but fossils collected by different men have served to confuse the relations. The fossils listed below were collected in 1914 by Martin and Overbeck from the west shore of Bostwick Inlet and identified by T. W. Stanton:

8836 (G. C. M. No. 8). Gravina Island, Bostwick Inlet, west shore near entrance. From angular nodules in a brecciated (?) nodular limestone.

Terebratula sp.
Spiriferina? sp.
Pecten sp.
Plicatula? sp.
Cassianella sp.
Myophoria sp.
Myophoria or Trigonia sp.
Nacula sp.
Astarte? sp.
Arcestes? sp.

Triassic. This assemblage suggests the fauna of the lower part of the Modin formation in California, which was tentatively assigned to the Jurassic.

Near this same locality P. S. Smith[1] also collected fossils on which Girty reports as follows:

Three lots from Bostwick Inlet, Gravina Island, contain round crinoid stems (13AS170) and a single compressed pelecypod (13AS169), suggesting the genus *Posidonomya*. The third lot (13AS171) contains a pelecypod fauna interesting and varied but entirely new to me. As these fossils at best show only the shapes and some of them the sculpture, and as pelecypods of similar external appearance may belong to widely different genera, the identifications made here are offered with doubt. Though similar doubt tacitly surrounds many pelecypod identifications in faunal lists and elsewhere, I have expressed it in this case by the use of question marks because the age of the whole fauna is involved in such uncertainty. In lot 171 five types are represented more or less abundantly and by specimens more or less good. These are *Glossites?* cf. *G. lingualis*, *Schizodus?* cf. *S. appressus*, *Paracyclas?* cf. *P. ellipticus*, *Crenipecten?* cf. *C. crenulatus*, *Elymella?* cf. *E. nuculoides*. Besides these, however, there are a good many indeterminate forms, some of which suggest the genera *Leda*, *Chonetes??*, *Pseudomonotis??*, *Aviculipecten*, and *Nucula*. The age of the fauna is quite uncertain. You declined for the time being to admit it into the Triassic, and nothing resembling it has thus far been brought in from the Alaskan Carboniferous. The generic and specific resemblances suggested above might indicate a Devonian fauna, but neither has any Devonian fauna related to this been obtained from Alaska. The genus *Chonetes*, if definitely present, would at least limit the geologic age to the upper Paleozoic, but the specimen is so imperfect that even the identification as a brachiopod is doubtful.

Thus the age of this, the best fauna in the collection, must for the present remain undesignated. It would be highly rash to attempt any definite age determination or conclusion for the other lots, containing, as they do, for the most part, only crinoid stems (even that being doubtful in some cases), though they may tentatively be placed in the Paleozoic.

Regarding this report Smith suggests that this doubtfully determined fauna from Bostwick Inlet, which is unknown elsewhere in Alaska, may mark a Lower Triassic horizon, also unknown in Alaska. He states:

As Mr. Girty points out, this fauna is entirely unlike any other from Alaska. It therefore affords little aid in solving the stratigraphic position of the beds on Gravina Island. Certain significant deductions, however, suggest themselves. In general in southeastern Alaska the known Carboniferous rocks are limestones and not lithologically similar to the rocks of Gravina Island. The rocks here discussed are much less dynamically metamorphosed and are less intensely deformed than the known Devonian or Carboniferous rocks of the region. Their relation to the andesitic agglomerates and flows fits in better with an assumed Mesozoic age than with a Paleozoic age. The almost uninterrupted succession of beds from a basal (?) conglomerate to shales containing unquestioned Triassic fossils on the southwestern coast suggests that the doubtfully determined genera from that locality, provisionally assigned to the Carboniferous, justify the suggestion made by Mr. Girty at that time that they may mark a Triassic horizon. No Lower Triassic is known in Alaska. Is it not possible that this fauna from Bostwick Inlet, which is unknown elsewhere in Alaska, fits into this as yet unfilled gap?

Its reference to the Lower Triassic, however, seems improbable, for the fauna is in the upper part of the formation, above the position of the *Halobia*-bearing slates (determined as Upper Triassic) and immediately below the Upper Jurassic or Lower Cretaceous volcanic rocks. Its reference to the Upper Triassic or the Lower or Middle Jurassic would be more in keeping with the observed relations.

The term "Vancouver series" was first applied by Dawson [2] to the entire mass of volcanic materials and interbedded limestones, flaggy argillites, and quartzites that unconformably underlie the Cretaceous rocks of Vancouver Islands. At that time, on the evidence of intercalated fossiliferous beds, this series of rocks was regarded as largely Triassic, although the possibility of its including both Jurassic and Carboniferous rocks was recognized. The "Vancouver series" was later subdivided by Clapp,[3] who has shown that it is in part Jurassic and possibly also Carboniferous. The Triassic rocks of Gravina Island are probably the equivalent of parts of the "Vancouver series" of Vancouver and Queen Charlotte islands.

Triassic rocks are widespread throughout Alaska and occur at many places in southeastern Alaska. Fossils of Upper Triassic age

[1] Notes on the geology of Gravina Island, Alaska: Prof. Paper 95, p. 103, 1915.

[2] Dawson, G. M., Canada Geol. Survey Ann. Rept. 1886, p. 10B.

[3] Clapp, C. H., Southern Vancouver Island: Canada Geol. Survey Mem. 13, p. 37, 1912.

have been found on Admiralty, Kupreanof, and Screen islands.

Martin [1] states that the abundant corals in some of these Triassic rocks of Gravina Island suggest that they may represent the lower Noric coral fauna of Iliamna Lake. He considers that the Triassic limestones of southeastern Alaska, which in general are characterized by faunas containing *Halobia* cf. *H. superba* Mojsisovics, correspond at least approximately in position to the Chitistone limestone of the Copper River valley.

UPPER TRIASSIC OR JURASSIC ROCKS.

The rocks designated greenstone and slate on the map are made up of an interbedded series of altered tuffs, flows, and black slates, with some intrusives, occurring on Gravina and Revillagigedo islands. The greenstones and slates overlie the Upper Triassic rocks with apparent conformity. On the evidence of a few fossils found in the intercalated sediments and on structural grounds and analogy with rocks of known age these rocks are regarded as Upper Triassic or Jurassic.

DISTRIBUTION.

The greenstone and slate occupy three parallel belts on Gravina Island. One extends from South Vallenar Point to Seal Cove, another from the east shore of Bostwick Inlet to Vallenar Point, and the third along Tongass Narrows from Old Indian Town to Gravina Point. Northeast of Tongass Narrows similar rocks extend from Radio station to Herring Bay.

CHARACTER AND STRATIGRAPHIC RELATIONS.

The rocks consist essentially of volcanic breccias and tuffs with interbedded black slates and water-laid fine-grained tuffaceous sediments. Certain green schistose tuffs apparently interbedded with the more massive tuffs and breccias may be older infolded rocks, and some graywackes and slates may be younger infolded rocks.

The detailed sequence of the volcanic rocks of Gravina Island has not been worked out. In general they may be divided into two parts—a lower series of purely igneous material, mainly coarse pyroclastic rocks and breccias and an upper series of mixed water-laid tuffs and black slates and limestone, with porphyritic basic rocks of similar composition, evidently partly intrusive and partly explosive. No sharp line separates the two parts, which the writer has not differentiated on the geologic map. The black slates pass into green fissile tuffs, and these into more massive varieties, so that as a rule a sharp line of contact can not be drawn between them. By more detailed work the lower purely volcanic material might be separated from the upper mixed sedimentary and igneous material. The limestone bodies are too small to be shown on a map.

The base of the volcanic rocks is evidently the coarse breccia that overlies the Upper Triassic sediments of the west coast of Gravina Island. This breccia occupies the southern part of Dall Ridge and portions of California Ridge. It is a fine-grained green rock with large angular fragments set in a dense matrix of the same composition.

The breccia passes upward into finer-grained tuffs, in part at least water-laid material with which are intercalated black slates and thin beds of crystalline limestone. The black slates are typical clay slates having a well-developed cleavage, with bedding planes discernible in places. The slates are plainly conformable with the green tuffs.

The black slates and green bedded tuffs are best developed along the north shore of Tongass Narrows from Ketchikan to Mountain Point. The black slates are in places considerably metamorphosed and schistose and might more correctly be called phyllites. They are closely interbedded with and grade into fissile green tuffs, both of which are interbedded with more massive tuffs. The green tuffs are also schistose and in places completely recrystallized. The greater part of the town of Ketchikan stands on rocks of this character, and excavations for street building show both the blocky and fissile types. The most schistose types are completely recrystallized and consist of secondary quartz, feldspar, calcite, epidote, and chloritic material. The massive types consist essentially of secondary epidote, hornblende, chlorite, sericite, and calcite, with pyroxene and plagioclase feldspar crystals almost entirely replaced by secondary minerals.

[1] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 700, 1916.

The schistose green tuffs referred to by Brooks[1] as greenstone schist and by Smith[2] as the green schist near Ketchikan, were regarded by both as Paleozoic. According to the present interpretation of the structure of Gravina and Revillagigedo islands these tuffs stratigraphically overlie the massive igneous rocks carrying Jurassic fossils and occupy a position near the top of the formation. Their schistose nature is believed to be due to contact metamorphism induced by the intrusive masses of Revillagigedo Island, as indicated by the increase of schistosity toward the igneous rocks on the northeast.

The base of the greenstone and slate series is evidently the coarse breccia found along the west coast of Gravina Island. It overlies the Upper Triassic sediments with apparent conformity. As previously brought out, the breccia grades upward into a more dominantly sedimentary series of green tuffs and black slates which are unconformably overlain by conglomerate, slate, and graywacke of Upper Jurassic or lower Cretaceous age.

STRUCTURE.

On Gravina Island the volcanic rocks of Dall Ridge occupy the trough of an overturned syncline, and the other two areas—one extending from Vallenar Point to Bostwick Inlet and the other on Tongass Narrows—form the two limbs of another overturned syncline, the trough of which contains the Upper Jurassic or Lower Cretaceous sedimentary rocks of Blank Inlet. The volcanic rocks on the northeast shore of Tongass Narrows are also believed to be overturned and to overlie stratigraphically the phyllites of Ward Cove and George Arm and the Carboniferous schist to the northwest, which seem to overlie the volcanic rocks.

ORIGIN.

The volcanic breccias at the base of the series are evidently the product of volcanic explosions. The perfect stratification of much of this igneous material and the conformable intercalations of slate and limestone show that at least portions of it were deposited or collected in water. The pillow-like structure of some of the flows that occur with the fragmental rocks indicates that they also were submarine.

AGE AND CORRELATION.

The age determination of the greenstone and slates rests upon rather slender paleontologic foundation. The collections from Bostwick Inlet were submitted to Mr. Stanton, who reports as follows:

9528 (15 ACh 104). Bostwick Inlet, Gravina Island.
9529 (15 ACh 105). Bostwick Inlet, Gravina Island.
Aucella sp.
Probably Upper Jurassic; possibly Lower Cretaceous.
9530 (15 ACh 106). Bostwick Inlet, Gravina Island.
Pecten? sp.
Not sufficient for determining age but probably from same formation as 9528 and 9529.

These fossils were collected from the west coast of Bostwick Inlet about half a mile south of the localities from which the Triassic and doubtful collections were made. The fossils occur in sedimentary beds apparently interbedded with the volcanic breccias and overlying the Triassic sediments, but the relations are somewhat obscured by the gravel covering.

Some correlations with rocks of known age are suggested. The greenstone and slate series extends more or less continuously along the mainland and adjacent islands of southeastern Alaska. In the Juneau region the recent detailed work of Spencer and Eakin shows a section similar to that exposed along Tongass Narrows and adjacent islands, and Brooks, who has studied both sections, believes that the black slate and greenstones of Ketchikan should be correlated with the andesitic flows and black slates of Juneau, which carry Triassic fossils. The finding of Upper Triassic fossils by Spencer and Eakin[3] in the slate and greenstone series of Juneau suggests to the writer the possibility that the rocks of Tongass Narrows are of similar age. Smith[4] notes the similarity between the volcanic rocks of Gravina Island and the augite melaphyres of the region north of Juneau, referred by Knopf[5] to the Upper Jurassic or Lower Cretaceous, and it is not at all unlikely that the upper portion of the slate and greenstone series of the Ketchikan district may be the equivalent

[1] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 48, 1902.
[2] Smith, P. S., op cit., p. 100.
[3] U. S. Geol. Survey Thirty-eighth Ann. Rept., p. 90, 1917.
[4] Smith, P. S., op. cit., p. 164.
[5] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, p. 18, 1912.

of the volcanic rocks associated with the Berners formation. The slate and greenstone of the Ketchikan district may thus be correlated with both the Triassic and Jurassic rocks of the Juneau region.

Rocks of greater value for purposes of correlation occur on Vancouver and Queen Charlotte islands. The "Vancouver series," first defined by Dawson as Triassic, was later subdivided by Clapp[1] on the basis of distribution, lithology, and structure into the Nitinat formation, Vancouver volcanics, Sutton formation, Sicker series, and Metchosin volcanics. He uses the term "Vancouver group" in place of "Vancouver series" as used by Dawson. The Nitinat formation is made up of highly altered calcareous sediments and is regarded as Jurassic or Triassic (?). The Vancouver volcanics are composed largely of volcanic materials with interbedded sediments. On the evidence of fossils collected from the intercalated limestone beds of the Sutton formation the Vancouver volcanics are regarded by Clapp as lowermost Jurassic. The Jurassic age of these rocks, however, is not accepted by Martin,[2] who considers that the fossil evidence is not conclusive and that the Sutton limestone fauna may with equal confidence be called Upper Triassic. The Sicker series is made up of metamorphic, chiefly schistose sedimentary and volcanic rocks, with intrusive porphyrites. The stratigraphic relation of this "series" to the "Vancouver group" of which it forms a part is not certain, but it is believed to occur above the Vancouver volcanics.

On Graham Island, one of the Queen Charlotte group, the "Vancouver group" was subdivided by MacKenzie[3] into the Maude formation, referred to the Lower Jurassic and possibly in part to the Triassic, and the Yakoun formation, of Middle Jurassic age. The Maude formation is composed of a lower part, made up of banded slaty and flaggy argillites, in places carbonaceous, and an upper part of feldspathic sandstones. Partly crystalline bituminous massive limestones are provisionally classed with the Maude formation. Near the top of the formation, where it begins to grade into the overlying Yakoun formation, the sandstone contains igneous material. The Maude formation is regarded on fossil evidence as Upper Triassic and Lower Jurassic.

The conformably overlying Yakoun formation consists of water-laid agglomerates and tuffs, conglomerates, lavas, and possibly intrusives. Fossils contained in the intercalated sediments indicate a Jurassic age, suggesting correlation with the Tuxedni sandstone (Middle Jurassic).

The correlation of the lower part of the volcanic rocks of Gravina Island with the Vancouver volcanics and the upper part of the Maude formation is suggested. The upper part of the volcanic rocks of Gravina Island may be the equivalent, at least in part, of the Sicker series and the Yakoun formation. The age of the Gravina Island volcanic rocks is by no means certain. It is not at all unlikely that they contain both Triassic and Jurassic rocks and possibly some infolded Paleozoic rocks also.

UPPER JURASSIC OR LOWER CRETACEOUS ROCKS.

DISTRIBUTION AND CHARACTER.

A formation consisting essentially of interbedded conglomerate, graywacke, and black slate exposed along a wedge-shaped strip extending from Blank Inlet to the northeast coast of Gravina Island (see Pl. VIII, *B* and *C*) is determined on fossil evidence to be Upper Jurassic or Lower Cretaceous, and similar rocks just northwest of Ward Cove are correlated with this formation.

The conglomerate does not appear to be the basal member but occurs at intervals throughout the formation interbedded with the graywacke and slate. It is composed of rather fine grained pebbles with a few boulders as much as a foot in diameter. The matrix is essentially a graywacke but contains a considerable amount of igneous rock fragments. The pebbles and cobbles are mostly igneous and resemble the volcanic rocks of Gravina Island. Pebbles of dioritic rocks resembling the plutonic rocks of the Coast Range also occur. No members of this formation are known to be of igneous origin, although both matrix and cobbles of some of the conglomerates contain so great an amount of igneous material that they resemble agglomerates.

[1] Clapp, C. H., op cit., p. 37.
[2] Martin, G. C., op. cit., p. 709.
[3] MacKenzie, J. D., Geology of Graham Island, B. C.: Canada Geol. Survey Mem. 88, p. 39, 1916.

The conglomerate passes by increasing fineness and decrease of igneous material into typical-looking graywacke with angular slate fragments. Microscopic examination of the graywacke shows it to consist essentially of quartz and feldspar grains with angular fragments of slate and decomposed particles of dioritic rocks, hornblende, pyroxene, and epidote. Flakes of biotite may be secondary, but no marked schistosity has developed.

The slates are very fissile black clay slates and are closely interbedded with the graywacke members. The slates have a marked cleavage. (See Pl. VIII, *C*.)

STRATIGRAPHIC RELATIONS.

These Upper Jurassic or Lower Cretaceous beds overlie the volcanic rocks of Gravina Island described above and regarded as Triassic or Jurassic, but in most places the relations are rather obscure. On the northeast shore of Bostwick Inlet near the entrance the slates and graywacke overlie the eroded surface of the volcanic rocks with marked unconformity. On the northeast shore of Gravina Island conglomerates and graywacke overlie the volcanic rocks without apparent angular unconformity. The conglomerate and graywacke of Ward Cove are noticeably unconformable upon the black phyllite that has been correlated with the Upper Triassic rocks.

STRUCTURE.

The conglomerate, slate, and graywacke beds of Blank Inlet occupy the trough of an overturned syncline in which are also involved the volcanic rocks of Gravina Island, which actually overlie them on the east shore of Blank Inlet.

ORIGIN.

These Upper Jurassic or Lower Cretaceous conglomerates, graywackes, and slates are the products of normal deposition in a shallow sea. The constantly changing character of the deposits indicates corresponding changes of conditions during their deposition. The materials of the rocks were apparently derived in part from the volcanic rocks of Gravina Island near by and in part from the surrounding regions.

AGE AND CORRELATION.

The age determination of the slates and graywackes of Blank Inlet rests on a single fossil collection from which only one form was identified. Mr. Stanton reports:

9527 (15 ACh 99). Blank Inlet, 1½ miles north of Blank Point, Gravina Island.
Belemnites sp.
Jurassic or Lower Cretaceous.

Smith[1] correlated the conglomerates and other sediments on the west coast of Gravina Island with these somewhat similar ones on Blank Inlet. However, besides the fossil evidence which now shows that the two are distinct, there are very marked differences in the lithology. The conglomerates of Threemile Cove are composed essentially of a peculiar type of igneous rock that was not noted on Blank Inlet, where the conglomerates contain a great amount of greenstones and dioritic rocks similar to the intrusives of the Coast Range, types neither of which was observed in the conglomerate of the west coast. The sedimentary beds of both Bostwick Inlet and the west coast contain beds of siliceous sandstone and quartzite but no appreciable amount of graywacke. On Blank Inlet the reverse is true; the arenaceous beds are dominantly graywacke, and pure quartzose beds are lacking. Structural differences are also very apparent. The conglomerate of Blank Inlet is considerably sheared; the rocks of the west coast are massive. This might appear to indicate a greater age for the rocks of Blank Inlet but the greater amount of deformation is no doubt due to the difference in composition of the rocks, the soft agglomeratic material being much more easily affected than the granite. It is a noticeable fact that the few diorite boulders in the conglomerate of Blank Inlet have withstood the deformation.

The rocks of the Queen Charlotte series, with which these beds of conglomerate, slate, and graywacke on Gravina Island were at first correlated, are now determined as Upper Cretaceous[2] and are thus younger than any known rocks of Gravina Island. The conglomerate, slate, and graywacke of Blank Inlet are possibly the equivalent of the Berners formation of Eagle River, the conglomerate, graywacke, and slate of Admiralty Island and other places in southeastern Alaska, and the Valdez group of Prince William Sound.

[1] Smith, P. S., op. cit., p. 104.
[2] MacKenzie, J. D., op. cit., p. 65.

TERTIARY ROCKS.

The only rocks of Tertiary age within the area consist of rhyolite, which occurs on the peaks of Dall Head and extends from Thompson Cove nearly to Seal Cove. It is a light-gray dense rock composed essentially of quartz and feldspar. It overlies unconformably the granite and greenstones of Dall Head and has not shared in the mineralization of the underlying rocks. It was regarded by the Wrights and Smith as Tertiary.

QUATERNARY ROCKS.

GLACIAL DEPOSITS.

DISTRIBUTION AND CHARACTER.

The most recent sediments are the glacial deposits. Rocks of this character are not abundant but have been found at one place on Gravina Island. About half a mile northwest of the cabin at the head of Dall Bay is a small exposure of glacial material about 80 feet above sea level. The outcrop is concealed on all sides by vegetation. The exposed base contains about 2 feet of glacial till and blue clay and is overlain by stratified beds of glacial gravel about 5 or 6 feet thick. Fossils occur in both the blue clay and the stratified gravel.

AGE AND CORRELATION.

A small collection of fossils from the glacial deposits was submitted to W. H. Dall, who reports:

I have examined the material from Dall Bay, Gravina Island. The material is a "boulder clay" which disintegrates in water, and when it is strained off the fossils remain in a clean condition. Near the Treadwell mine opposite Juneau the same formation extends to an altitude of 200 feet. The species contained in Mr. Chapin's collection are as follows:

Cylichnella n. sp.
Bela violacea Mighels.
Colus sp., fragment.
Cardium (Cerastoderma) ciliatum Fabricius.
Axinopsis viridis Dall.
Macoma calcarea Gmelin.
Saxicava arctica Linné.
Mya intermedia Dall.
Balanus sp., fragment.

The assembly naturally indicates the colder climate associated with the period of glaciation.

These fossiliferous deposits occur about 80 feet above high tide, a position that indicates an uplift of the land since the glacial epoch. Corroborative proof of a recent uplift is found in the elevated wave-cut benches found in this vicinity. That part of Gravina Island south of Dall Head, the bold promontory that marks the south end of the highlands of the island, is a flat plain (Pl. VIII, *A*). This and similar features on Annette Island and at other places near by are regarded as wave-cut benches. Smaller features of the same character are low-lying, flat benches along the coast, some a few feet above high tide and others only partly above water. The higher benches are forested and dissected by erosion, but others near the water level are bare of vegetation and apparently have been only recently uplifted, and it is not at all unlikely that this emergence has continued to the present time. As the benches are developed only locally, however, it is probable that the uplift was of a differential character and that some parts of the region are sinking below sea level and others are rising, owing to the warping nature of the movement.

MARINE GRAVELS.

During the period in which the fossiliferous deposits of Dall Bay stood at sea level the low depression that connects Vallenar Bay and Bostwick Inlet was evidently in large part flooded if not wholly covered. It is thus safe to assume that the gravels that mantle the floor of this "through" valley are largely marine, although partly reworked by later stream action. The valley floor is covered by vegetation which hides the deposits.

INTRUSIVE ROCKS.

The intrusive rocks of Dall Head were not examined in detail by the writer. On the west coast of Gravina Island they are apparently dioritic in composition and along the contact with the sediments are gneissoid. This structure is regarded as purely cataclastic; the gneissoid effect is commonly noted in the diorites at other places in the Ketchikan district and is not regarded as evidence of an older gneiss. On the extreme southern point of Gravina Island, however, Smith noted gneisses which he regards as Paleozoic, intruded by igneous rocks. He states: [1]

At this place they consist of highly metamorphic gneisses and amphibolites which have been intruded by igneous rocks. Undoubtedly the older rocks have been metamorphosed locally by the younger intrusives, but apparently

[1] Smith, P. S., op. cit., p. 97.

they were considerably metamorphosed dynamically before they were intruded. No definite determination of the age of the gneisses and amphibolites has been made. Judged by their physical character they seem to be much older than any of the known late Paleozoic rocks. Although their aspect may be due in large measure to the contact effects produced in proximity to the large intrusive masses, the impression gained in the field, and not dispelled by later investigations in the office, is that those rocks are probably at least as old as the middle or earlier part of the Paleozoic era.

The relation of the old gneisses and amphibolites to the other sedimentary rocks of the region is indefinite, because they occupy only a small area at the extreme end of the island and are surrounded on all sides by sea or by a large area of younger igneous rock. No other rocks on Gravina Island are correlated with these rocks near Dall Head.

The great abundance of coarse angular blocks of granite occurring in the Upper Triassic conglomerate suggests a near-by land mass of this rock. The gneisses noted above may be a remnant of this old land mass, but if so the granite must be locally metamorphosed, for the cobbles of the conglomerate are massive and have suffered little metamorphism. As previously stated, the material of the conglomerate is lithologically similar to the granite of Annette Island and is supposedly from a stock of similar composition.

The intrusives of Dall Bay and Seal Cove are granites and associated pegmatites or alaskites. These are composed essentially of quartz and orthoclase with a subordinate amount of muscovite and secondary sericite. They range in texture from medium-grained holocrystalline rocks to fine-grained aphanitic and porphyritic phases. They are evidently the equivalent of similar rocks occurring at several places on Prince of Wales Island and other localities. Wherever the relations were observed the granite has been found to be later than the quartz diorite and associated intrusives of the Coast Range, and is probably Cretaceous. The granite and quartz diorite of Gravina Island have not been separated on the map.

The intrusive rocks of Revillagigedo Island are quartz diorites and associated types and are to be correlated with the intrusives of the Coast Range. They occur as batholithic masses cutting diagonally across the sedimentary formations. They are regarded as Middle or Upper Jurassic, as the conglomerates of Upper Jurassic or Cretaceous age contain many boulders of similar rock, which is lacking in the earlier conglomerates.

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