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PAPER 50-37

STRATIGRAPHY OF THE WEST COAST OF VANCOUVER ISLAND BETWEEN KYUQUOT SOUND AND ESPERANZA INLET, BRITISH COLUMBIA

(REPORT, MAP AND FIGURE)

BY

J. A. Jeletzky

OTTAWA
1950

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Preliminary map-West Coast of Vancouver Island between Kyuquot Sound and Esperanza Inlet, British Columbia ..... In envelope

Figure 1. Correlation table of the Mesozoic rocks of the area mapped ..... In envelope

STRATIGRAPHY OF THE WEST COAST OF VANCOUVER ISLAND BETWEEN KYUQUOT SOUND AND ESPERANZA INLET, BRITISH COLUMBIA

INTRODUCTION

The field season of 1949 was spent in the study of the stratigraphy of the marine and volcanic Mesozoic succession along a part of the west coast of Vancouver Island and adjacent islands and reefs. The area studied lies between McLean Cove, on the south shore of Kyuquot Sound, and a point on the northern shore of Esperanza Inlet, opposite the western point of Catala Island. It was hoped that the study might establish a type section and succession of Upper Jurassic and Lowermost Cretaceous fossil faunas that would serve as a standard for strata of these ages throughout the Canadian Cordillera. The results obtained so far are encouraging.

The structural complexity of the area, the relatively small size of the tectonic units, and extensive and rigid zonal collecting from all fossiliferous members necessitated a detailed study of the area. Most of it was mapped on a scale of about 1 inch to 2,000 feet, but some especially complicated parts were mapped on about 1 inch to 1,500 feet, and some at about 1 inch to 1,250 feet. An enlarged copy of Admiralty Chart No. 3682 was the base for the map accompanying this report.

Work in the field was facilitated by the able assistance of P. M. Nolan and D. H. McDonald. Dr. J. W. Hoadley, of the Geological Survey of Canada, gave much valuable advice and help.

GENERAL CHARACTER OF THE AREA

The area mapped is entirely within a narrow coastal plain lying between the steep slopes of a mountain range on the east and the Pacific Ocean. This strip of coastal plain nowhere in the area mapped exceeds 2 miles in breadth and most of it is 1 mile to 1½ miles wide

or less. On the southern shore of Kyuquot Sound, about $\frac{1}{2}$ mile east of McLean Cove, and on the northern shore of Esperanza Inlet, about $\frac{1}{3}$ mile west of the western end of Catala Island, this coastal plain pinches out where the steep slopes of the mountains rise immediately above the narrow wave-worn shelf.

Much of the coastal plain lies 100 to 120 feet above sea-level and is, for the most part, almost featureless and flat, but is interrupted here and there by gently rounded hills, none of which exceeds 500 feet in elevation and most of which are not more than 200 to 250 feet high.

An irregular and broken line of islands extends along the shore, the farthest lying 2 to $2\frac{1}{2}$ miles from the mainland. It seems probable these islands also represent fragments of the coastal plain not yet destroyed by powerful marine erosion because of the relative durability of the rocks composing them.

All the land areas above the high-tide mark or that reached by waves during winter gales, including all the hills and slopes of the mountains landward of the coastal plain, are densely wooded. Along the shores of Kapoose Creek, however, are patches of grassy, partly swampy land just above the high-tide mark.

The shoreline, in contrast with the surface of the coastal plain, shows everywhere a great diversity of relief, due, apparently, to powerful marine erosion. More than 50 per cent of it is formed of bedrock, with occasional insignificant patches of sandy or pebbly beach. In this type of shoreline, a wave-worn, rocky shelf is commonly bordered by steep to precipitous rocky bluffs crowned by dense forest. The contact between shelf and bluff commonly coincides with that between the Upper Triassic sedimentary strata and the overlying volcanic rocks, and the same abrupt change in relief applies to the contact between the Lower Shale member and the overlying Sandstone member of the Upper Jurassic series between Kapoose and Brecciated Points.

Such rocky shores are, however, interrupted for considerable distances by long, and relatively broad, sandy or pebbly beaches immediately bordered by dense forest. Along these beaches only minor patches of bedrock are exposed, forming isolated rocks or bluffs surrounded by beach or forest.

Several larger rocky points break the shoreline and project far into the sea. These points consist for the most part of bare rock, surrounded by flat, rocky shelves or beaches, and covered on top, above the reach of the waves, by dense forest and underbrush.

The islands, islets, and numerous reefs are mostly quite bare. Only a few of the largest islets and islands, such as Clark and Grassy Islands, are densely covered by high grass and underbrush in the parts beyond the reach of the highest tides and the waves of winter gales.

Except for some of the more rugged parts, travel is relatively easy along shore. Between Rugged Point and Jurassic Point it is also possible to use an open boat with an outboard motor, except during strong winds or storms. Travel inland, however, is very difficult, as the underbrush is extremely dense, fallen trees are everywhere abundant, and passable trails are all but lacking. Furthermore, outcrops are very scarce. Consequently, the survey was largely confined to the seashore, islands, islets, and numerous reefs.

The area is uninhabited. However, a group of cabins near the mouth of Kapoose Creek and a single partly dilapidated cabin 400 to 500 feet north from Mushroom Point present mute evidence of unsuccessful attempts at settlement. The nearest settlements are Kyuquot on Walter Island, Chamiss Bay logging camp in the bay of the same name within Kyuquot Sound, and Queens Cove in Eliza Inlet. The writer's party camped nearly all season at the mouth of Kapoose Creek, where two, fairly well-preserved cabins on its right shore, 700 to 800 feet upstream from its mouth, offered welcome shelter. This creek was found to be nearly always navigable for an 18-foot boat at high tide

for a period of 2½ to 3 hours, and offered a camping place perfectly sheltered from any gale. The broad, open bay at its mouth affords suitable anchorage for any fishing boat during fair weather or even during a breeze. The 18-foot boat was also anchored there when tides were not suitable for reaching the campsite.

Porritt Creek also seems to offer a good, sheltered campsite, but not as satisfactory as the one on Kapoose Creek.

During the entire field season, from June to mid-September, the weather was generally fair and mild. However, the generally damp air made life in tents somewhat unconfortable, especially due to the tendency for all equipment, personal belongings, food, and the tents themselves to become mouldy. Two or three prolonged spells of bad weather during June and July, accompanied by gales and heavy rains, forced the party to stay in the camp for a period totalling 2 to 3 weeks.

Big game is fairly common and quite bold in this area. Deer and black bears were often seen around the camp and even visited it on several occasions. Especially in late August and early September, while camping at Yellow Bluff, hardly a day passed when members of the party did not see one or more black bear on the shore collecting sea food. On two occasions tracks of a cougar were seen, and one visited the camp one night. Mink and racoon appear to abound in the area and, according to the information of old-timers from Kyuquot, trapping was good during the previous winter.

A few trout and steelhead were seen in Kapoose Creek, and some cod were caught by trolling in the sea, but, on the whole, fish were scarce in both sea and stream. However, local fishermen along the coast considered it a poor season.

PREVIOUS GEOLOGICAL WORK

The first geological work done in the area mapped, so far as is known to the writer, was that by Haycock (1906)[1] and Webster (1906)

[1] Dates in parentheses are those of references listed at end of this report.

who investigated the northern shore of Esperanza Inlet between Eliza Inlet and Tatchu Point. Dolmage (1921) spent part of one field season mapping in the area, and Bancroft (1940) revised the geological structure and succession along the northern shore of Esperanza Inlet between Eliza Inlet and Tatchu Point. Due acknowledgment of their results will be made elsewhere in this report.

STRATIGRAPHY

INTRODUCTION

The following preliminary account of the stratigraphy and structure was based on one season's field work. As yet the conclusions reached are necessarily limited, and the descriptions of rock types are based on megascopic examinations only.

TABLE OF SEDIMENTARY AND VOLCANIC ROCKS

AGE		LITHOLOGY AND THICKNESS	LITHOLOGICAL DIVISIONS AND THICKNESS	PALAEONTOLOGICAL ZONES
TERTIARY	OLIGOCENE OR (?) MIOCENE	Sandstone, shale, coarse and fine grit and conglomerate; all marine; 900-1,100 feet, top not exposed	SANDSTONE-SILTSTONE MEMBER: 700-750 feet, top not exposed	Portunites alaskensis Rathbun; plant remains and marine shells
			SANDSTONE-CONGLOMERATE MEMBER: 200-300 feet	Only a few poorly preserved marine shells

MAJOR UNCONFORMITY

LOWER CRETACEOUS	LOWER NEOCOMIAN		SANDSTONE-SHELL LIMESTONE MEMBER: 250-350 feet, top not exposed	Aucella crassicolis Keyserling; Aucella crassa Pavlow; Aucella solida Lahusen Polyptychites sp. indet.
		Sandstone, siltstone, shale impure limestone; some grit and conglomerate; all marine; 650-850 feet; top not exposed	SHALE-SILTSTONE MEMBER: 150-200 feet SANDSTONE MEMBER: 250-280 feet	Aucella ex gr. keyserlingi d'Orbigny, A. ex gr. lahuseni Pavlow, A. ex gr. volgensis Lahusen, Lytoceras ex gr. saturnale Anderson, etc.
			SANDSTONE-LIMESTONE MEMBER: 15-25 feet or more	Aucella okensis Pavlow (=A. cascadensis Crickmay) and relatives
	EROSIONAL DISCONFORMITY			
	PORTLANDIAN	DIVISION B	UPPER SHALE MEMBER: 130-150 feet	Aucella ex gr. rugosa Fischer
		Shale; impure limestone; minor siltstone and sandstone; all marine; 450-550 feet, base not exposed	SANDSTONE-SILTSTONE MEMBER: 25-35 feet	Aucella ex gr. russiensis Pavlow and relatives Phylloceras ex gr. subplicatius Burghardt
			LOWER SHALE MEMBER: 300-350 feet, base not exposed	
	GAP IN SUCCESSION			
UPPER JURASSIC	CALLOVIAN TO KIMMERIDGIAN	DIVISION A	UPPER SHALE MEMBER: 230-250 feet or more, top not exposed	Aucella ex gr. kirghisensis Sokolow, A. bronni Rouillier, A. ex gr. spitiensis Holdhaus, Phylloceras ex gr. glennense Anderson
		Shale and sandstone; siltstone, greywacke, grit, conglomerate; some breccia and agglomerate (mixed sedimentary and volcanic rocks); 700-1,800 feet, top not exposed	SANDSTONE MEMBER: ±200-250 feet	Aucella bronni Rouillier var. leguminosa Stoliczka, A. bronni Rouillier; in lower 80-100 feet Cardioceras ex gr. lillooetense Reeside

UPPER JURASSIC	CALLOVIAN TO DIVISION A		LOWER SHALE MEMBER: 350-300 feet or more	?
			SANDSTONE-LIMESTONE MEMBER: 30 or 40 feet to 800 or 1,000 feet; facies variable	Cadoceras doroschini (Eichwald) and variants
		UNCONFORMITY		
LOWER AND (?) MIDDLE JURASSIC	JURASSIC	Acidic to basic volcanic tuff, crystal tuff, volcanic breccia, acidic to basic lava flows; 2,500 to 3,000 feet or possibly more -----?----------?--------		Unfossiliferous
	UPPER TRIAS. OR JURASSIC	Waterlain pyroclastic rocks, tuffaceous sediments, minor shale, limestone, shale and conglomerate; 500 to 1,000 feet or possibly more -----?----------?--------		A few poorly preserved plant remains
		EROSIONAL DISCONFORMITY (POSSIBLY UNCONFORMITY)		
UPPER TRIASSIC	NORIAN AND POSSIBLY (?) RHAETIAN	Mostly thin, alternating beds of dark shale and grey limestone, dark shale, siltstone, sandstone, greywacke, impure limestone, massive limestone, grit, conglomerate sedimentary breccia, tuffaceous rocks; 900 feet or more; top and bottom nowhere well exposed	LIMESTONE MEMBER: 39-54 feet, or more	Hannaoceras? sp. ind.
			ARENACEOUS MEMBER: 500-550 feet	Myophoria cf. cairnesi McLearn
			THINLY BEDDED MEMBER: 200-300 feet, base not exposed	Monotis subcircularis Gabb

UPPER TRIASSIC SEDIMENTARY ROCKS

A succession of predominantly marine strata, which, in its lower part at least, is known to be Upper Triassic in age, is best exposed along an anticline, with a general trend of north 20 to 40 degrees west, between Brecciated and Mushroom Points. Although neither the

bottom nor the top of this succession was exactly defined, not less than 900 to 1,000 feet of sediments of this age are exposed in the eastern limb of this anticline, in what may be considered as the typical section.

Thinly Bedded Member

The lower 200 to 300 feet of the Upper Triassic assemblage consists of thin, alternating beds of dark grey to black shale, calcareous shale, impure limestone, massive limestone, calcareous sandstone, and quartzitic sandstone, and is referred to in this report as the Thinly Bedded member. In the lowest beds, well exposed on Kapoose Rocks, limestone and calcareous shale predominate and some beds are 5 to 10 feet thick.

In the type section of this member, only small, indeterminate ammonoids were found, but elsewhere it is more fossiliferous. On Kapoose Rocks, the upper, more thinly bedded part contains the following fossils of Upper Triassic time, probably late Norian Age, as determined by F.H. McLearn: Lingula sp. indet.; tubes of wood borers; Monotis cf. subcircularis Gabb; Dictyoconites sp. indet.; Gladiscites? sp. indet. On Amos Island, near Kyuquot outside the area mapped, Monotis subcircularis of Upper Triassic (late Norian Age) was identified by F.H. McLearn. This fauna is mostly confined to dark grey to black shales in about the middle of the member.

Arenaceous Member

In the upper 100 to 150 feet of the Thinly Bedded member the amount of arenaceous sediments increases at the expense of shale and limestone to where the latter become nearly completely replaced by fragmental sandy limestone, calcareous sandstone, quartzitic(?) sandstone, and grit. A bed of fine conglomerate, about 2 to 3 inches thick, accompanied by several thin beds of coarse grit interbedded with light-coloured calcareous sandstone with dispersed pebbles, is

accepted as the lower limit of the Arenaceous member.

Some 500 to 550 feet of mainly arenaceous rocks overlie this conglomerate, and, together with it, are here referred to as the Arenaceous member. They consist of thick beds of dark grey to brownish sandstone interbedded with siltstones, sandy shales, fine to coarse greywacke, some agglomerate, and numerous beds or rows of impure limestone concretions. From a bed of coarse tuffaceous greywacke, with associated sandstones, some 20 to 36 feet above the base of the Arenaceous member, the following Upper Triassic fossils were obtained and subsequently identified by F.H. McLearn: Myophoria cf. cairnesi McLearn, Macrodon (Catella) sp., (cf. tyaughtonae McLearn), Pecten sp., Leda? sp., and an ostreid.

In the upper 300 to 350 feet of the Arenaceous member, dark grey or brownish sandstones, siltstones, and sandy shales with numerous thin beds or rows of concretions of impure limestone are more widespread than in lower beds.

Limestone Member

The next succeeding Upper Triassic member consists predominantly of limestone, conformably overlies the Arenaceous member, and may be referred to as the Limestone member. At the base is a layer, 12 to 13 feet thick, of fragmental, impure limestone, with thin beds or lenses of calcareous siltstone and sandy shale. In places this layer is formed almost entirely of fragments of shells, corals, etc. The following fossils were identified by F.H. McLearn in the collection made by the writer: Myophoria sp., Pecten sp. 1, Pecten sp. 2, Pecten (Entolium) sp., Pleuromya? sp., ostreid, and indeterminate pelecypods. His comment on the age of this fauna is that "although a positive dating is not possible, a Triassic age is probable".

Overlying the basal layer are strata of similar, impure, clayey or sandy limestone, with layers and lenses of fragmental shell-limestone 15 to 17 feet thick. These have yielded the following fossils, determined by F.H. McLearn: Pecten sp., an ostreid?, 'Terebratula' sp., and Zygites? (a gastropod). The age is possibly Triassic.

The visible top of the Limestone member is represented by a bed of massive, grey to dark grey limestone about 12 to 14 feet thick, with nests and lenses of light brown, fragmental limestone. This limestone shows strong differential weathering. Many fossils are scattered in nests on the weathered surface, but cannot be extracted from the fresh rock. The following were identified by F.H. McLearn from a collection made by the writer in this bed: Terebratula sp., Pseudoscalites sp. (a gastropod), Loxonema? sp. (a gastropod), Cardium cf. martini Bottger, Orthoceras? sp., Hannaoceras? sp., and worm tubes. Again the age is possibly Triassic.

Halfway between the southeastern side of Mushroom Point and the mouth of Porritt Creek, greenish grey, heavily metamorphosed volcanic rocks disconformably overlap the deeply eroded and uneven surface of the Thinly Bedded member on the east limb of the same Upper Triassic anticline. In black shale, some 20 to 30 feet below the contact, poorly preserved, small ammonoids were found and are regarded by F.H. McLearn as small, immature specimens of a trachyceratid?, probably Triassic in age. These ammonoids are probably conspecific with the indeterminate ammonoids previously referred to as occurring in the shale of the Thinly-Bedded member between Brecciated and Mushroom Points. The contact of Upper Triassic sediments with volcanic rocks is practically duplicated by that on the west side of Amos Island near Kyuquot where Monotis subcircularis occurs in shales immediately below the contact. Arenaceous and limestone members are apparently

eroded in these sections prior to the eruption of the Jurassic volcanic rocks. This overlapping of different members of the Upper Triassic assemblage by Jurassic volcanic rocks suggest that their contact may be not only disconformable but structurally unconformable. Although there seems to be no doubt of the erosional disconformity, the writer hesitates to assert positively that there is an unconformity; the contacts seen are so complicated by folding and faulting that no positive statement is warranted.

Age

Although the entire assemblage described above is undoubtedly not older than Upper Triassic, only the age of its lowest, Thinly Bedded member can be accurately determined in terms of international standard stages. This member contains Monotis subcircularis Gabb, which is considered to be characteristic of a zone at the top of the Norian Stage, the second latest in Upper Triassic time.

None of the beds overlying the Thinly Bedded member has yielded any fossils whose age could be precisely determined, although, according to F. H. McLearn, their fauna shows definite Upper Triassic affinities throughout. As they do not contain Monotis subcircularis and directly overlie the member containing it, they must be considered younger. It is, however, uncertain whether these younger members represent a younger Norian zone not yet recorded on this continent, or represent the next younger, Rhaetian Stage, which comprises the youngest Triassic rocks, and to date has been recorded only in the State of Nevada.

In the opinion of the writer, the considerable thickness of sedimentary rocks above the zone with Monotis subcircularis definitely favours the presence of rocks of Rhaetian Age in the area under consideration. Even the possibility that lowermost Jurassic rocks may be represented below the succeeding volcanic assemblage cannot be categorically denied, especially as sedimentary rocks of this age

were discovered by Crickmay (1929-30, p. 59) in the vicinity of Parson Bay on the east side of Vancouver Island, where they lie with apparent conformity on shales containing Monotis subcircularis.

UPPER TRIASSIC OR JURASSIC PYROCLASTIC AND TUFFACEOUS ROCKS

A succession of waterlain pyroclastic rocks and tuffaceous beds, including some volcanic tuff and lava, is of uncertain age with respect to other assemblages in the map-area.

The best exposures of these rocks are on the southeast and northwest sides of Mushroom Point, where they are in rather disturbed and obscure contact with Upper Triassic sedimentary strata. Along the northwest side of Mushroom Point, the beds of conglomerate and grit, with limestone pebbles and fragments, tentatively accepted as marking the contact with the Upper Triassic beds, are overlain by dark green to dark grey lava flows, of which only 20 to 30 feet are exposed. Both sedimentary and volcanic rocks are disturbed and strongly faulted, and are intruded by dykes of light-coloured felsitic to porphyritic rocks. Farther southwest, beyond a covered interval of about 200 feet, are some 55 to 60 feet of conglomerate and breccia. The lower beds consist mainly of poorly rounded pebbles, but angular fragments become increasingly prevalent in the higher beds. In the upper 30 to 35 feet, the breccia is largely composed of volcanic fragments, whereas in the lower horizons fragments and pebbles of limestone predominate. The matrix is in part tuffaceous and is rather limy, and a few, thin, arenaceous or calcareous sedimentary beds, in part at least waterlain, are interbedded with conglomerate and breccia. This succession is conformably overlain by 100 to 120 feet of bluish green, amygdaloidal or porphyritic lava followed by about 150 feet of lilac-red to green-grey tuff including some beds of volcanic breccia. This series is in turn overlain by 40 to 50 feet of light grey to

slightly reddish, fine-grained tuff and lithologically similar, felsitic lavas, which resemble the tuffs and lavas of the islands named 'Volcanic Islets', to be discussed later in this report. On the extreme northwesterly end of Mushroom Point, the highest of the beds described above is overlain by some 100 feet or more of distinctly bedded, waterlain pyroclastic rocks. These form an irregular, dome-like structure that plunges beneath the sea. At the most southerly exposure, the beds strike north 10 to 20 degrees west and dip westerly at 60 degrees, whereas at the most northerly point they strike south 25 to 35 degrees east and dip 20 to 25 degrees northeast. Apart from local disturbances, the whole succession seems to strike north 10 to 30 degrees west, and dip westerly at from 50 degrees to vertically, but the dip of individual beds may be completely reversed within a short distance along strike.

The same succession is exposed on the southeastern side of Mushroom Point, where the pyroclastic rocks, tuffaceous sediments, and peculiar limestone breccia are in fault contact with Upper Triassic sedimentary strata. The pyroclastic and tuffaceous rocks of this section are very strongly faulted and disturbed. They strike north 20 to 30 degrees west; dips range from 60 degrees to vertical, but may change direction from westerly to easterly across or along strike.

A similar succession of pyroclastic rocks and tuffaceous sedimentary strata, exposed on Volcanic Islets, is believed to represent the part of the succession immediately overlying the succession of Mushroom Point already described.

The following succession of strata is exposed on the most southerly Volcanic Islet (in ascending order):

Feet

(1) Dark, greenish grey, aphanitic, somewhat calcareous, massive rock; probably calcareous, volcanic tuff; base not exposed 60-75

(2) Greenish grey, thick-bedded, fine-grained, tuffaceous rock, containing spherical, calcareous, and chloritic inclusions up to 2 or 3 inches in diameter; some beds with coarse to fine, angular fragments; probably volcanic tuff 25-30

(3) Light grey to reddish grey, distinctly bedded rock. Some beds are definitely waterlain pyroclastic rocks; others are probably felsitic lava 10-12

(4) Light-coloured, grey to reddish grey, bedded pyroclastic rocks, interbedded with thin layers of coaly shale and calcareous tuffaceous rock or tuffaceous limestone; a few lenses or thin beds of dark grey volcanic(?) rocks. The layers of coaly shale contain a few small lenses of low-grade coal, 2 to 3 inches thick, carrying poorly preserved plant remains; these were examined by W. A. Bell, who reports: "Equisitites sp. A single node with leaves resembling those of E. pellati Saporta from the Jurassic of France". Nests and lenses of coaly shale, plant remains, and pieces of charred wood also occur quite commonly in the pyroclastic rocks themselves 15-17

Feet

(5) Tuffaceous rocks similar to those in the above beds but without the persistent coaly layers. In these beds coaly shales occur in small lenses arranged in disorderly rows. Most of these rocks appear to be waterlain pyroclastic rocks; top concealed beneath the sea on the west side of the islet 60-70

On the eastern part of another, larger, and more northerly islet of the group the same succession of beds is exposed. On the northwest part of this islet they are apparently overlain by 100 feet or more of thick-bedded, greenish grey to reddish green, speckled tuff, fine-grained tuff, and light grey to reddish grey, felsitic lava(?). Volcanic and interbedded sedimentary rocks exposed on the third Volcanic Islet farther west, are probably part of this succession.

The waterlain pyroclastic and volcanic rocks exposed on these three islets probably have an aggregate thickness of 350 to 450 feet or more; they are strikingly similar lithologically to the light-coloured tuffs and lavas exposed on the northwest side of Mushroom Point.

Nipple Rocks shows the same succession of pyroclastic rocks and tuffaceous beds as Volcanic Islets, whereas the nameless rocks between the two and those between Volcanic Islets and Entrance Rocks expose dark grey amygdaloidal lavas and volcanic tuffs, which are believed to be part of the same assemblage. The only other known outcrop of tuffaceous beds referable to this assemblage is that of a small reef about one-third mile north 50 degrees east of McQuarry Islets.

Age and Contact Relations

Owing to the lack of well-exposed sections and established palaeontological or lithological horizon markers, the writer was unable to reach any definite conclusion as to the age of the assemblage here discussed. Contacts with the Upper Triassic sedimentary strata on both sides of Mushroom Point are obscured by faults and other structural irregularities, so that it was impossible to infer the proper place of the assemblage in the stratigraphic succession of the area mapped. Lithologically, the limestone breccia, pyroclastic rocks, and lavas exposed at the above sections and elsewhere in the area mapped closely resemble certain strata of the Upper Triassic assemblage of Zeballos map-area, and so may be correlative with them and may lie below the Thinly Bedded member of the known Upper Triassic strata. On the other hand, the rather indefinite evidence of plants collected on the most southerly Volcanic Islet favours their Jurassic age. They may, consequently, represent only a different facies of the Jurassic volcanic rocks, whose description follows, yet the writer has mapped them separately on the basis of the total lithological dissimilarity of both volcanic assemblages. Both assemblages, too, remain separate in their geographical distribution throughout the area mapped.

JURASSIC VOLCANIC ROCKS

A thick succession, consisting of various lavas, volcanic tuffs, and breccias, overlies the Upper Triassic sedimentary assemblage in the area mapped, and will be referred to henceforth in this report as the Jurassic volcanic rocks. Neither the entire thickness of the assemblage nor its contacts with the underlying and overlying sedimentary rocks was observed in a single section, and the contacts, in the few places observable, were partly obscured by faults or irregular local folds. This lack of well-exposed, complete sections

and of any established palaeontological or lithological horizon markers prevented the writer from subdividing these rocks or from indicating more than a tentative succession. However, it should be noted that, in spite of the extreme lithological diversity of the volcanic rocks and their rapid variation along strike within short distances, such subdivision is by no means impossible.

As the succession in these Jurassic volcanic rocks is imperfectly understood, and as some of the members closely resemble the volcanic rocks in the underlying Upper Triassic assemblage, the mapping must be regarded as subject to revision.

The oldest rocks of the Jurassic volcanic assemblage are best exposed south of Mushroom Point and outside of the area mapped, on Amos Island near Kyuquot. In both places Upper Triassic sedimentary strata are disconformably overlain by 100 feet or more of highly altered, light to dark grey, volcanic rocks. Around the mouth of Porritt Creek, the latter rocks are overlain conformably by several hundred feet of coarse volcanic breccia. A fault block of entirely similar volcanic breccia is wedged between Upper Triassic and Upper Jurassic sedimentary assemblages north of Brecciated Point. At the mouth of Porritt Creek and farther south along the shore, this volcanic breccia is overlain by a thick succession of volcanic rocks represented mainly by dark green to dark grey, medium to basic, porphyritic and amygdaloidal lavas. The top of this succession was not observed, but the rocks outcrop along the shores of Porritt Creek for 250 to 300 yards upstream from its mouth.

The upper part of the Jurassic volcanic assemblage is represented by somewhat different volcanic types, which are best exposed at Rugged Point and inside McLean Cove. Rugged Point is composed entirely of these volcanic types, and at the southeast base

of Rugged Point and on the west side of McLean Cove they dip beneath the strata of Division A of the Upper Jurassic group.

The succession on Rugged Point is typical of this part of the Jurassic volcanic assemblage. It consists, apparently exclusively, of various volcanic tuffs, volcanic breccias, and medium to acidic lava flows. Acidic(?), brick-red to dark reddish, crystal tuffs and similarly coloured porphyritic lavas, with phenocrysts of alkaline feldspar, abound in most beds and form nearly the whole of the middle part of the section. The uppermost few hundred feet of the succession, however, consists mostly of dark grey to greenish grey tuffs and highly amygdaloidal, probably andesitic, lava flows. Yet even in this part the more acidic crystal tuffs and porphyritic lavas are common locally. The lowest beds are represented by more basic, dark grey to greenish grey, volcanic tuffs and some volcanic breccia interbedded with dark amygdaloidal or porphyritic lavas somewhat similar to those of the lower part of the Jurassic assemblage already described. The base of these rocks is not exposed on Rugged Point.

The visible thickness of the Jurassic volcanic assemblage at Rugged Point may be estimated as 1,500 to 2,000 feet. A more exact measurement is not possible as the whole succession, which generally strikes north 20 to 40 degrees east and dips 30 to 40 degrees southeast, is rather strongly faulted and dips and strikes vary locally.

Age

The age of the Jurassic volcanic rocks can only be inferred from their relations to better dated overlying and underlying strata. The fact that in some exposed sections a considerable thickness of sedimentary rocks lies between the zone of *Monotis subcircularis* Gabb and the base of the Jurassic volcanic rocks makes it very improbable that the latter are also of Upper Triassic age. It has already been pointed out that strata above the zone of *Monotis subcircularis* may well

be of Rhaetian Age, and, if so, that the overlying volcanic assemblage, under present consideration, could hardly be of Triassic age. Furthermore, these volcanic rocks overlie the youngest sedimentary members of the Upper Triassic Series disconformably, or possibly even with a structural unconformity, in consequence of which there is even less possibility of them being of Upper Triassic age.

The Jurassic volcanic rocks are overlain unconformably by marine deposits of Callovian Age (earliest Upper Jurassic). It would, therefore, seem most probable that they were formed at some Lower or (?) Middle Jurassic time.

UPPER JURASSIC SEDIMENTARY ROCKS

In several parts of the map-area, a thick succession of fossiliferous sedimentary rocks is exposed. According to the fossils, these rocks are all of Upper Jurassic age, and it has been found convenient to subdivide them into two major parts, designated Divisions A and B respectively.

Division A

The strata of Division A overlie unconformably the older assemblages of the area mapped, and are best exposed between the southeast base of Rugged Point and the northeast base of Brecciated Point. Within this area they occupy most of the shore, and seem to extend inland for some distance. The following description of the upper three members of this division is based exclusively on their exposures in this limited area. The lowest member, however, is unsatisfactorily represented here, and its description is based on better exposures on Kapoose Rocks, Jurassic Point, and inside McLean Cove.

Sandstone-Limestone Member

The lowermost member of Division A, referred to in this report as the Sandstone-Limestone member, presents a great diversity of facies and thickness in the various sections within the area mapped. Sections differ so much from one another in their lithology and thickness that only the resemblance of certain beds and the fossil content prove that these differences are due to changes in facies and not to difference in age. Two principal facies groups have been recognized, but some sections do not conform exactly to either of these.

One principal facies group was observed on Kapoose Rocks and on the northeast side of McLean Cove, where it is characterized by an insignificant thickness of basal conglomerate overlain by calcareous sandstone, siltstone, and greywacke. No limestone was observed.

On Kapoose Rocks, several feet of coarse, basal conglomerate is overlain by 5 to 10 feet of finely interbedded coarse grit, fine pebble-conglomerate, and coarse sand, which grade upward into 25 to 35 feet of fine-grained greywacke, dark grey sandstone, and siltstone. The siltstone, in turn, seems to grade upward into the dark grey shale of the succeeding Lower Shale member, although this could only be observed at the base of Brecciated Point. At Kapoose Rocks, just above the basal conglomerate of Division A, a rich fauna was collected that included Cadoceras doroschini (Eichwald) and its variants, Phylloceras sp., Trigonia sp. indet., Cylindroteuthis sp. indet., etc. The same fauna is represented throughout the member and also seems to occur in the lowermost beds of the overlying Lower Shale member.

The section on the northeast side of McLean Cove presents essentially the same succession as that on Kapoose Rocks. Here, however, the basal conglomerate is only a few inches thick. It is

composed of small pebbles and grades into coarse grit. The overlying, thinly interbedded conglomerate, grit, and calcareous sandstone do not exceed 25 to 30 feet in thickness and grade upward into dark grey shale and siltstone. A Cadoceras doroschini (Eichwald) fauna was also collected in this locality in calcareous sandstone and grit some 20 to 25 feet above the basal conglomerate.

On the southwest end of McLean Cove, at the southeast base of Rugged Point, and immediately south of the mouth of Tatchu Creek at Jurassic Point, a thick succession of beds is exposed that is totally distinct lithologically from the beds already described. However, as it carries for the most part the same fauna, it must be considered as representing the other principal facies of the Sandstone-Limestone member of Division A.

The succession at Jurassic Point is the most complete, except for the lowermost beds, which are not exposed; it will be described in some detail. The basal beds and the actual contact are masked by beach deposits, but it seems probable that the beds are similar to those on the southwest side of McLean Cove.

The lowermost beds visible outcrop on the right side of the mouth of Tatchu Creek and consist of 60 to 75 feet of finely interbedded impure limestone, calcareous sandstone, coarse and fine grit, and fine conglomerates. Most of these beds show pronounced crossbedding. The matrix and most of the grains and pebbles are calcareous. The coarser beds appear to prevail in the lowermost 20 feet of the section and nearly disappear in its upper part. An abundant fauna occurs in many beds. It includes inocerami close to, or identical with I. obliquiformis McLearn, which forms the bulk of the fossils, and belemnoids of the genus Cylindroteuthis, abundant in some beds. The only fragment of an ammonoid encountered a few feet above the bottom of the section does not admit of exact determination, although possibly

it belongs to Cadoceras ex gr. doroschini (Eichwald). About 50 to 60 feet above the base of the section Cadoceras doroschini (Eichwald) abounds in two beds of calcareous sandstone.

These beds grade upwards into about 100 feet of dark grey to nearly black siltstone, fine-grained greywacke, and shale, interbedded with lenses or rows of concretions of dark calcareous shale or impure limestone; at least one thick bed of coarse conglomerate was observed. Here, also, the matrix is rather calcareous in many beds, some of which might be called impure sandy limestone. Cadoceras doroschini (Eichwald) abounds in the lower 30 to 40 feet below the bed of coarse conglomerate. Above the latter, beyond a narrow disturbed belt apparently representing a fault striking about north 80 degrees west, two or three beds of a siltstone zone about 60 to 70 feet thick, with limy concretions in the upper 50 feet, yielded a totally different fauna, which includes Oppelia ex gr. subradiata Sowerby, s. lato, one or more species of perisphinctoid ammonoids and juvenile ammonoids of the genus Macrocephalites ? s. lato. Also present are Phylloceras spp., belemnoids of the genera Cylindroteuthis and Pachyteuthis, and some gastropods and pelecypods as yet undetermined. The plants were determined by W. A. Bell as cf. Sagenopteris goeppertiana Ward(? non Zigno) and Nillsonia sp. of the group Nillsonia orientalis Heer.

The strata described above grade upward to the south into 140 to 150 feet of similar, but more lightly coloured, nearly unfossiliferous siltstones, sandstones, and impure limestones, including some coarse sandstone and grit. The top of this succession is marked by a conglomerate bed 1 foot to 1½ feet thick, composed nearly entirely of fairly well-rounded volcanic pebbles.

Above this conglomerate bed the general character of the sedimentary beds remains unchanged for about 400 to 450 feet across the strike, but finer siltstones and sandy or calcareous, light grey to brownish shale predominate. About 50 feet above the conglomerate, a dark grey to

nearly black, somewhat resistant bed of limy siltstone or shale, with abundant calcareous concretions, proved to be fairly fossiliferous. Cadoceras doroschini (Eichwald) and its variants, and Phylloceras ex gr. columbianum Crickmay predominate. Brachiopods, gastropods, and pelecypods are represented, but have not yet been determined. Belemnoids are rare and poorly preserved. At no other bed were fossils found.

On the southern side of Jurassic Point, the beds described above grade upward into rather sandy limestone or limy siltstone interfingered with calcareous sand. Here, again, is a fairly abundant fauna, consisting mainly of inocerami close to or identical with Inoceramus obliquiformis McLearn. Belemnoids close to Pachyteuthis densus Meek and Hayden were observed, and are very abundant in certain beds. No ammonoids were collected.

These limy beds grade upward somewhat abruptly into 30 or 40 feet of calcareous sandstone and grit carrying scattered pebbles and lenses of gravel, with a 4- to 8-foot bed of coarse conglomerate in the middle. The conglomerate is composed of rounded pebbles of lava, and is interstratified with several beds of coarse grit, coarse sandstone, and fine conglomerate. Fossils collected in the sandstones above the main conglomerate bed include: Cadoceras doroschini (Eichwald), Phylloceras sp. indet., and 'Rhynchonella' sp. indet.

This zone of coarse, arenaceous beds grades upward into another siltstone-shale succession, the visible thickness of which is 200 to 250 feet or more. In its lower part, calcareous sand, grit beds, and sandy limestone still appear interbedded with siltstone and shales, but in the upper part siltstone and dark coloured shale predominate. They include, however, numerous rows of variously shaped concretions of limestone and thin beds of impure limestone and a few 1- to 3-inch beds of greenish grey sandstone.

About 100 feet above the main conglomerate of the underlying section, a bed of impure clayey limestone is replete with Cadoceras doroschini (Eichwald) and its variants and some Phylloceras sp. indet. and belemnoids. The same fauna was also encountered in fine-grained sandstone and limy siltstone several feet above and below this bed. About 50 to 60 feet higher in the succession, a thin bed of limestone was encountered that carried abundant but poorly preserved pelecypods (Inoceramus ?). The intermediate beds and the upper part of the siltstone-shale zone have not yielded any fossils. The top is concealed beneath the sea.

All the beds above the main conglomerate are exposed along the southern side of Jurassic Point where they form a broad semi-circle plunging westerly toward the sea. This trend is especially apparent in the beds of the arenaceous zone, and is repeated in all the younger beds of the section and probably in the older beds as well. On the southern side of Jurassic Point, all the beds exposed are so broken by a dense network of faults that they form in places a veritable tectonic breccia. The main conglomerate bed, for example, is shattered into dozens of blocks 10 to 100 feet square with relative displacements of 10 to 150 feet.

At the southeast base of Rugged Point, near the northern end of the area mapped, only about 150 to 200 feet of impure limestone, calcareous sandstone, and grit, with a considerable amount of coarse conglomerate in the lower part, are exposed. These beds strike north 20 to 25 degrees east, dip 40 to 45 degrees southeast, and so lie between the Jurassic volcanic rocks, which dip beneath them, and those of younger members of Division A, which are exposed about ¼ mile farther south. The uppermost beds of impure limestone have yielded numerous inocerami close to or identical with Inoceramus obliquiformis McLearn, brachiopods, belemnoids, pelecypods, and plants. The last

were determined as cf. Sagenopteris goeppertiana Ward (? non Zigno) by W.A. Bell, who reports on the plant lots from Jurassic and Rugged Points: "The above lots are considered to be of the same age. The plant remains are all fragmentary, but there is no question that the species designated cf. Sagenopteris goeppertiana is the same as one represented by complete leaves in the upper part of the Yakoun formation (early Upper Jurassic) of Skidegate Inlet, Queen Charlotte Island" (McLearn, 1949, p. 17). There seems, therefore, no question as to the correlation between the sedimentary beds exposed at Rugged Point and those at Jurassic Point.

On the southwest shore of McLean Cove a very similar succession of beds is exposed. Although palaeontological evidence is not conclusive, these beds are tentatively accepted as equivalent to, and of the same facies as, the sections of the Sandstone-Limestone member discussed above. The section at McLean Cove is especially interesting as it is the only one in which the contact between this facies and the underlying Jurassic volcanic rocks is exposed. At the base of a small point at the entrance to McLean Cove, the coarse-grained crystal tuff, with a reddish tinge and containing irregular inclusions and lenses of coarse, dark greenish tuff, is overlain by a conglomerate composed of pebbles and boulders 1 foot to 1½ feet in diameter, mostly poorly rounded, of volcanic rocks that appear to be derived locally. This conglomerate rests on an uneven, eroded surface of the underlying volcanic rocks, apparently with a sharp angular unconformity. Only the lowermost 5 to 10 feet of the conglomerate is coarse and poorly sorted in this outcrop, but on the northwest side of the point and farther west along the shore 50 to 75 feet of similar conglomerate can be seen, and neither top nor bottom is exposed.

Above the coarse conglomerate is 60 to 80 feet of much finer, better rounded and sorted conglomerate, in which few pebbles exceed 5 inches in diameter. Overlying this are 20 to 30 feet of thinly

interbedded coarser conglomerate, fine-grained conglomerate, and grit. These, in turn, grade upward into 150 to 175 feet of mixed volcanic-sedimentary breccia, with only a few rounded pebbles. This succession is conformably overlain by about 150 feet of distinctly crossbedded, calcareous sandstone or impure, fragmentary (clastic) limestone interfingered with thin beds of grit or fine conglomerate that is so similar to the lowermost beds of the Jurassic Point succession and that at Rugged Point that the writer considers it possible to correlate them, despite the fact that this zone at McLean Cove has only yielded a few indeterminable brachipods (? '*Rhynchonella*'), and *Pecten* cf. *lens* Sowerby, which are not diagnostic. All the calcareous beds of this zone are poorly sorted, and sand grains and even small pebbles occur even in fine-grained calcareous sandstone or impure limestone.

A coarse conglomerate bed, 5 to 6 feet thick, overlies the calcareous zone with a sharp, uneven contact, suggestive of erosional disconformity. The conglomerate, in turn, grades upward into about 350 feet of volcanic breccia or coarse tuff, which shows little sign of reworking by water. Overlying this is grit and sandstone, 40 to 50 feet of which can be measured, although the top is not exposed.

Lower Shale Member

The Sandstone-Limestone member of Division A is overlain conformably by about 250 to 300 feet of dark grey shale and containing many rows of shale or limestone concretions and fine beds of dark grey, impure limestone. This is designated the Lower Shale member, and only a few not diagnostic pelecypods and ammonoids were found in it. At the northeast base of Brecciated Point, the shale and siltstone beds assumed to represent the base of the member yielded a few imperfect ammonoids, which seem to belong to one of the varieties

of Cadoceras doroschini (Eichwald) and to Phylloceras sp. indet., as well as a few pelecypods, brackish water gastropods, and plant remains. None of these is considered diagnostic.

Sandstone Member

The Lower Shale member grades imperceptibly and rather gradually upwards into greenish grey sandstone and finely grained greywacke referred to as the Sandstone member. Although the top and bottom of this member were nowhere seen in one section, its thickness is believed to be about 200 to 250 feet.

In the lowermost beds of the Sandstone member, an abundant fauna, including Cardioceras ex gr. lillooetense Reeside, Phylloceras spp., Lytoceras sp. ind., Cylindroteuthis sp. indet., Aucella bronni Rouillier, Aucella bronni Rouillier var. leguminosa Stoliczka, Pleuromya vancouveronsis Whiteaves, Pecten spp., and other forms not as yet determined, makes its first appearance. So far as could be ascertained, Cardioceras ex gr. lillooetense Reeside is strictly confined to the lower part of the succession and was never found more than 100 feet above its base. All other forms persist to the top, and, with the possible exception of Aucella bronni Rouillier var. leguminosa Stoliczka, continue into the overlying Upper Shale member. In general, aucellas appear to be scarce in the lower part of the member carrying Cardioceras ex gr. lillooetense Reeside, but are locally abundant in its upper part. Some indeterminable plants were found in the upper part. The fossils are distributed very irregularly, and seem to be mostly confined to calcareous nests or concretions, or to individual thin beds within the member. Some parts are nearly barren of fossils.

The uppermost beds of the Sandstone member show a considerable increase of pelitic particles and should more properly be referred to as siltstone than fine-grained sandstone. They are transitional to the shale of the Upper Shale member and are exceedingly rich in rows of

variously shaped limestone concretions that contain abundant and excellently preserved fossils. This fauna seems to be rather close to that from the overlying Upper Shale member. In addition to Aucella bronni Rouillier and other pelecypods mentioned above, large Phylloceras ex. gr. glennense Anderson, Aucella ex gr. kirghisensis Sokolow, and large Lytoceras sp. indet., characteristic of the Upper Shale member, make their first appearance. This transitional zone grades upward into dark grey shale, with few if any limestone concretions and some thin beds of greenish grey sandstone that form the basal beds of the Upper Shale member.

Upper Shale Member

The name 'Upper Shale member' has been applied to a succession of dark grey shale beds, with numerous thin beds or rows of concretions of dark grey, yellow weathering, impure, possibly dolomitic limestone. It includes, however, some siltstone beds, and a few persistent beds, 1 inch to 5 inches thick, of greenish grey sandstone, barren of fossils.

In contrast with the Lower Shale member, this succession is everywhere fossiliferous, although fossils are rarely abundant even in limestone concretions and beds. The dominant and rather characteristic feature of this member is the common occurrence of the large, ornamented Phylloceras ex gr. glennense Anderson, Phylloceras spp. indet., and large Lytoceras sp. indet. (?. ex aff. liebigi Oppel). It is believed that no less than five or six species of these 'Mediterranean' ammonoids are represented in these shaly beds; they were the only type of ammonoid found. The species of Aucella also appear to have changed. Aucella bronni Rouillier var. leguminosa Stoliczka, abundant in the underlying Sandstone member, was not observed here, and Aucella bronni Rouillier is common. Aucella kirghisensis Sokolow, or a form rather close to this species, and an Aucella identical with or fairly close to

the Himalayan Aucella spitiensis Holdhaus seem to be characteristic of the Upper Shale member. The latter form was not even observed in the transitional beds. Further observations are, however, needed before a decision can be reached on the regional importance of these faunal changes.

The visible thickness of the Upper Shale member is estimated at about 230 to 250 feet. Its top was, however, nowhere seen. The member represents the top of Division A of the Upper Jurassic Series as here defined.

Contact Relations

The presence of an erosional disconformity between the Jurassic volcanic rocks and the lowermost beds of Division A of the Upper Jurassic Series is quite apparent in the sections studied. Furthermore, on Kapoose Rocks off the mouth of Kapoose Creek, the sandstones of the lower member of this division rest directly on the Thinly Bedded member of the Upper Triassic assemblage containing Monotis cf. subcircularis Gabb, whereas in McLean Cove, at Rugged Point, and at Jurassic Point they overlie the Jurassic volcanic rocks. This suggests that considerable deformation and subsequent erosion of the older rocks must have taken place prior to the invasion of the early Upper Jurassic sea. A conservative estimate of the thickness of strata removed at Kapoose Rocks by this pre-Upper Jurassic erosion is 2,000 or 3,000 feet; it may have been much more. It is uncertain, however, whether this regional unconformity is in the nature of an angular discordance, such as would accompany mountain building. At Kapoose Rocks, the discordance, if such it be, does not appear to exceed 5 or 10 degrees. At McLean Cove, on the other hand, the beds are much disturbed and faulted, and comparison between the dips and strikes of the older volcanic and younger sedimentary formations near the contact suggests a strong angular discordance.

Age

On Kapoose Rocks and at McLean Cove, Cadoceras doroschini (Eichwald) was obtained from beds overlying, but near the top of, the basal conglomerate. At Jurassic Point, this ammonite was first found about 50 feet above the lowest exposure of the member, which exposure is itself somewhat above the basal conglomerate. A narrow zone some 150 feet above the bottom of the section here carries quite a different ammonoid fauna, including Oppelia ex gr. subradiata Sow. s. lato, macrocephaloid ammonoids, and "Perisphinctes" sp. indet. The middle and upper parts of the section again carry Cadoceras doroschini (Eichwald).

The Cadoceras doroschini (Eichwald) fauna observed at Jurassic Point and elsewhere in the area is believed to be of mid-Callovian Age. This correlation is based mainly on the fact that, in Alaska, Cadoceras ex gr. doroschini (Eichwald) occurs well up in the Upper Jurassic, Shelikof formation, with a zone of Seymourites immediately below it and another zone, with Miccocephalites, at the base of the formation, all of which faunas are considered Callovian and younger than its lowermost zone with Macrocephalites macrocephalus Schlotheim (See Kellum, 1945, pp. 203-208). The plant evidence supports this view, as W. A. Bell correlates the lower beds of the member exposed at Rugged and Jurassic Points with the upper Yakoun formation of Queen Charlotte Islands, which is Callovian and carried Seymourites.

The age of the second fauna above mentioned is uncertain. Oppelia ex gr. subradiata Sowerby is generally considered an index fossil of younger Middle Jurassic rocks (from Upper Bajocian to Upper Bathonian); it is not known to occur even in the oldest Upper Jurassic rocks (lowermost Callovian zone with Macrocephalites macrocephalus Schlotheim). The rest of the ammonoids of this fauna are not considered diagnostic at this stage of our research. On the

contrary, the occurrence of this Oppelia fauna between two zones carrying Cadoceras doroschini (Eichwald) and the evidence of plants collected with it favour its early Upper Jurassic age (Lower Callovian). However, the occurrence of a probable fault at the base of the Oppelia Zone striking roughly parallel with the strike of the beds may account for the presence of Middle Jurassic rocks between the two zones of undoubted Callovian rocks. Additional study of the fauna concerned is needed, however, before a decision as to its Middle Jurassic age can be reached. For this reason the writer has not shown the presence of the Middle Jurassic rocks on his map and for the time being treats the rocks of the Sandstone-Limestone member throughout the area mapped as of Callovian age.

The age of the Lower Shale member is uncertain, although the occurrence of Cadoceras-like ammonoids in its lowermost beds suggests that it may be Callovian, at least in part.

The lowermost part of the overlying Sandstone member contains Cardioceras ex gr. lillooetense Reeside and Aucella ex gr. bronni of Oxfordian Age. The same age seems true of the upper part of the Sandstone member, which does not contain Cardioceras but carries the same Aucella bronni (Rouiller) and A. bronni var. leguminosa. However, these Aucella species may range upward into Lower Kimmeridgian and the boundary between the two stages cannot be placed definitely at present. The passage beds to the Upper Shale member contain ribbed Phylloceras ex gr. glennense Anderson, which, in California, characterizes the Knoxville series of very late Jurassic, Portlandian Age. Although not conclusive, this evidence favours a Kimmeridgian rather than Oxfordian Age for these passage beds. The same is true for the Upper Shale member itself, where Phylloceras ex gr. glennense Anderson is associated with Aucella ex gr. bronni more advanced than that in the Oxfordian members of this group. Aucella ex gr. kirghisensis Sokolow, in particular, appears to be more suggestive of a Kimmeridgian than Oxfordian Age for this member. An early Kimmeridgian Age seems more

likely than late Kimmeridgian, as, in the latter, Aucella ex gr. mosquensis (Buch) should be present, but it was not observed even in the youngest beds of the Upper Shale member. However, the upper age limit of this member cannot be definitely decided as yet except that it cannot be younger than the upper part of the Kimmeridgian Stage.

Structure

The largest area of strata of Division A lies between Rugged Point and Brecciated Point. It appears to represent a basin-like body whose northern extremity is probably at McLean Cove but whose southern and eastern limits have not been established. Strata within this basin are gently folded, with a general strike of north 20 to 40 degrees west and dips of 20 to 40 degrees, and are mostly much less faulted than those at Jurassic Point or the older rocks of the map-area.

The occurrence at Jurassic Point is believed to represent the eastern end of a similar basin-like structure mainly concealed beneath the sea.

An isolated outcrop of the Sandstone member at Eastern Entrance Rocks cannot be connected with either of the basins described above and may represent part of a third, basin-like structure concealed beneath the sea. The rocks exposed are steeply folded and strongly faulted.

Division B

On the northern part of Grassy Island, on McQuarry Islets, and on a few small reefs adjoining Grassy Island to the north, is exposed a succession of marine Upper Jurassic beds that are undoubtedly younger than any part of Division A. This succession is referred to as Division B.

Division B consists essentially of 450 to 550 feet of light-coloured, grey to bluish grey shale, with numerous thin beds or rows of concretions of grey, impure limestone or calcareous shale. It is divisible into three members: a Lower Shale member, 300 to 350 feet thick; a Sandstone-Siltstone member 25 to 35 feet thick, composed of siltstone and very sandy shale with 10 to 15 feet of sandstone in the middle part; and an Upper Shale member 130 to 150 foot thick.

The lower part of Division B, up to an horizon some 90 to 100 feet below the base of the Sandstone-Siltstone member, is characterized by the presence of Phylloceras apparently identical with, or rather closely related to Phylloceras reticulatum Burghard and to P. subplicatium Burghardt, and by occasional belemnoids of the genus Cylindroteuthis. In the higher beds of the division, no determinable ammonoids were found except near the contact with Lower Cretaceous strata.

Aucellas are common throughout the succession, and are rather numerous in certain beds. It seems probable that several Aucella zones will be distinguishable with further study, as no less than half a dozen species and several varieties seem to be represented. At present, however, only two zones can be distinguished with certainty. The lower zone, embracing all of Division B to within 40 or 50 feet of the contact with Lower Cretaceous rocks, is characterized by a host of small, thick, and more or less strongly curved forms of the group of Aucella mosquensis Keyserling and Lahusen non Buch, which Pavlow (1907, pp. 50-54) has split into several species and designated as a branch of Aucella russiensis Pavlow. This rather complex taxonomic problem cannot be discussed here, and the collective name Aucella ex gr. russiensis Pavlow will be used conditionally in this report. However, the forms described by Anderson (1945, pp. 964-968) as Aucella stantoni Pavlow, Aucella andersoni Pavlow, Aucella russiensis Pavlow, etc., appear to be characteristic of this Zone.

In the uppermost 40 to 50 feet of Division B, another Aucella fauna appears, which consists of large, thick, curved, and thick-shelled forms, some apparently identical with Aucella rugosa (Fischer) and some a new but related form. Although the older group of Aucella russiensis Pavlow appears to be completely replaced by Aucella ex gr. rugosa Fischer in these uppermost beds it seems probable that the latter are descendants of the former group; the subject, however, requires further study. In the uppermost 20 to 25 feet of the succession a few poorly preserved ammonoids were collected. So far it is only possible to say that a Phylloceras sp. indet., one oppelioid form, and one perisphinctoid form are represented among them. Belemnoids of the genus Cylindroteuthis occur throughout the succession, but most specimens are fragmentary and indeterminable.

Age

It is certain that all of Division B is younger than the youngest member of Division A. All members of the group of Aucella russiensis Pavlow represent a different and distinctly younger stock as compared with Aucella ex gr. bronni Rouillier, which was found only in the upper part of Division A. So far, not a single Aucella form common to both divisions has been found. All forms of A. russiensis collected in Division B are identical with, or closely related to, the aucellas of the Knoxville Series of California or to those of so-called Volgian Stages of central and northern Russia, Siberia, and the Arctic. As these beds are considered to be the undoubted equivalents of the Portlandian Stage (in the broad sense of Arkell, 1946) of Northwestern Europe, this may also be accepted as the age of Division B.

The extent of the gap between the youngest beds of the Upper Shale member of Division A and the oldest beds of Division B is not exactly known. For one thing, it is not yet possible to decide whether the Upper Shale member includes Upper Kimmeridgian strata, and, for another, the stratigraphic position of the lowermost

beds of Division B is still uncertain. The stratigraphic gap between the two seems, however, to be substantial. Beds containing Aucella ex gr. mosquensis (Buch) non Keyserling non Lahusen, which correspond approximately with Upper Kimmeridgian and lowermost Portlandian, should normally occur between Divisions A and B. They have not been found in the area mapped, but the writer has seen Aucella ex gr. mosquensis (Buch) in collections made in Tyaughton Creek Valley, British Columbia, from beds younger than those with Cardioceras spp. and Aucella ex gr. bronni Rouillier that correspond with Division A of the present area.

The aucellas of the group A. rugosa Fischer, which characterize a narrow zone at the top of Division B, are also index fossils of the Volgian Stages (Portlandian), and are not known anywhere to ascend into the lowermost Cretaceous.

Although present information seems to indicate that even the oldest beds of Division B are Portlandian, the exact position of the base of the division within this stage cannot be definitely determined. Apparently, not even the upper part of Division B includes any Lower Cretaceous beds, as the Aucella fauna at the top is still essentially Portlandian in character. Moreover, the character of the Aucella fauna changes abruptly at the erosional disconformity at the top of the division, where Aucella ex gr. rugosa Fischer disappears completely to be replaced by quite a different Aucella fauna of Lower Cretaceous affinities. The amount of Portlandian missing below this disconformity cannot yet be determined because of the lack of index ammonoids and the uncertainity as to the stratigraphic range of Aucella ex gr. rugosa Fischer within the Portlandian Stage.

Nothing definite is known of the structural relations between Division A and Division B, as nowhere do they occur in close proximity. However, the close agreement of strike and dip of the

Sandstone member of Division A on Eastern Entrance Rocks with those of the rocks of Division B on the western part of Grassy Island suggests a general accordance.

JURASSIC AND CRETACEOUS FELSITIC TO PORPHYRITIC INTRUSIONS

The Upper Triassic sedimentary assemblage, the Upper Triassic or Jurassic waterlain pyroclastic rocks and tuffaceous sediments, and the Jurassic volcanic rocks are nearly everywhere intruded by dykes and sill-like bodies of light-coloured and apparently acidic igneous rocks of felsitic or porphyritic texture. In many places these rocks are mineralized with pyrite, and weather reddish or tawny. Few of the bodies exceed 20 to 30 feet in thickness, but at Brecciated Point an irregular sill-like body, 200 to 400 feet thick, of light-coloured felsitic rock intrudes the Thinly Bedded member of the Upper Triassic assemblage, and was observed along strike for more than 2,500 feet. This body is the only one large enough to show on the map.

Some of the above dykes and sills are definitely intrusive into Jurassic volcanic rocks, and the latter were nowhere observed to overlap the intrusions unconformably. Only a very few small, but lithologically similar dykes have been observed intruding Upper Jurassic and Lower Cretaceous rocks, and none was seen intruding Tertiary rocks. A Jurassic or Cretaceous Age is, therefore, suggested for these intrusive bodies, but it is possible that some may be older than the Jurassic volcanic rocks.

The age relations between these felsitic to porphyritic intrusions and the Upper Jurassic or Cretaceous granitic intrusive bodies remain obscure, but it seems possible that they each represent different phases of the same magmatic invasion.

UPPER JURASSIC OR CRETACEOUS GRANITIC INTRUSIONS

Granitic intrusions were observed at only two places in the area, both in the vicinity of Tatchu Point. One locality is on the northwest side of Sandstone Point, where several irregular bodies, 50 to 100 feet square, of light-coloured aplitic or pegmatitic rock intrude the Jurassic volcanic rocks at their contact with Tertiary sandstone, the latter overlapping unconformably both volcanic and intrusive rocks.

Another, larger area of these intrusions is exposed on the west side of the broad open bay lying between Yellow Bluff and Tatchu Point. The most easterly occurrence is that of isolated blocks of coarse-grained granodiorite in the breccia of a large fault zone, to the west of which the Jurassic volcanic rocks are intruded by irregular, minor bodies of light-coloured aplite, pegmatite, or granodiorite. Farther west, the relative amount of intrusive rocks increases to where they predominate, and the volcanic rocks are represented by large masses, blocks, and fragments engulfed and partly digested by the intrusive rocks. Both volcanic and intrusive rocks are strongly sheared, broken, and jointed, and carry a network of associated veins and stringers of calcite.

The entire complex is overlain unconformably by Tertiary rocks whose basal conglomerate is largely composed of pebbles and boulders of granodiorite and volcanic rocks. Nowhere in the vicinity of Tatchu Point do granitic rocks appear unmixed with less than 40 to 50 per cent of altered volcanic fragments, blocks, and masses, the whole cut by irregular bodies of light-coloured aplite- and pegmatite-like rocks.

The age of the granitic intrusions is known only within wide limits. They cut volcanic rocks believed to be Lower or (?) Middle Jurassic in age, and are overlain unconformably by Tertiary strata. Their relation to Upper Jurassic and Lower Cretaceous rocks

is not known. Therefore, all that may be said is that they are Upper Jurassic or Cretaceous.

LOWER CRETACEOUS SEDIMENTARY ROCKS

Lower Cretaceous sedimentary rocks occupy the southern parts of Grassy Island and of McQuarry Islets, where they directly overlie Division B of the Upper Jurassic Series, all of Clark Island to the east of Grassy Island, and nearly all of the numerous rocks and reefs around it. They were referred to as the One Tree formation by Bancroft (1937, p. 4), from the original name, now discontinued, for Clark Island.

The lower part of the Lower Cretaceous succession is best exposed on the southern part of Grassy Island, and the higher beds at other localities. Lithological and faunal correlations can, however, be made with some certainty, and a satisfactory succession has been established.

Sandstone-Limestone Member

Across the centre of Grassy Island the typical light-coloured, grey to bluish grey shale of the Upper Jurassic, Division B is overlain disconformably by greenish grey calcareous sandstone and rather sandy, fragmental limestone interbedded with layers and lenses of calcareous grit and conglomerate referred to here as the Sandstone-Limestone member of the Lower Cretaceous Series.

The lithological distinction between the Lower Cretaceous and Jurassic strata is very marked, and the upper surface of the latter is uneven. Immediately below the contact, the shale is coloured red or tawny and penetrated by numerous burrows of marine animals for a depth of 1 inch to 2 inches or more. Just above the contact, especially in hollows in the surface of the shale, irregular fragments or rounded pebbles of shale occur in the younger rocks. Locally

these form a pronounced basal conglomerate, which may be as much as 6 to 10 feet thick on the western part of the island. In other places, especially to the east, pebbles occur only sporadically, and the basal conglomerate is reduced to a thin bed of calcareous grit with, here and there, a few dispersed pebbles, or is missing; in such places the disconformity may only be apparent on close scrutiny.

The calcareous sandstone beds above the contact are 12 to 15 feet thick in places, but tend to pinch out towards the west where the basal conglomerate is thickest. A local, erosional disconformity occurs at the top of the calcareous sandstone, and is marked by another conglomerate up to 12 feet thick. Both conglomerates are thickest to the west and merge on the extreme western part of the island to form a single conglomerate bed 15 to 20 feet thick interfingered with minor lenses and beds of sandstone. In the eastern part of the island, the upper conglomerate was not observed and appears to have pinched out. Above these beds lie some 4 to 6 feet of thin-bedded, green-grey, calcareous sandstone and fragmental, impure limestone that are included in the Sandstone-Limestone member of the Lower Cretaceous Series.

Large, thick-shelled, and more or less flat aucellas of the group A. okensis Pavlow (invalid synomym A. cascadensis Crickmay), which first appear at the base of the Sandstone-Limestone member, abound in all beds described above and are accompanied by Acroteuthis sp. indet., indeterminate ammonoids, and numerous Dentalium sp. indet. This is undoubtedly a Lower Cretaceous fauna.

Sandstone Member

The Sandstone-Limestone member of the Lower Cretaceous Series is overlain conformably by 250 to 280 feet of sedimentary rocks composed principally of thick-bedded, green-grey sandstone, with minor amounts of impure, fragmental, clastic limestone, coarse

sandstone, and calcareous grit, which may be referred to as the Sandstone member.

The lower part of this member consists of 20 to 25 feet of thick-bedded, green-grey sandstone containing few fossils, overlain by 4 to 6 feet of impure, fragmental limestone carrying abundant aucellas. These consist of small to medium-sized aucellas that may be referred to as Aucella ex gr. terebratuloides Lahusen, A. ex gr. volgensis Lahusen, A. ex gr. lahuseni Pavlow, and A. ex gr. keyserlingi d'Orbigny. Only a few shells, doubtfully referable to Aucella ex gr. okensis Pavlow (small variant?), were collected in this bed.

The remaining 230 to 250 feet of the member consist of beds rich in aucellas alternating with beds poor or even barren of fossils. The fauna of this part consists almost exclusively of aucellas that seem to belong to the forms mentioned above. The top of the Sandstone member is exposed in a bluff at the south end of the main body of Grassy Island. It consists of 20 to 30 feet of siltstone and sandstone, with abundant irregular calcareous or sandstone concretions. These beds contain a rich fauna including, in addition to the Aucella species already mentioned, some ammonoids belonging to Lytoceras ex gr. saturnale Anderson and Phylloceras ex gr. ononense Stanton.

Shale-Siltstone and Sandstone-Shell Limestone Members

The higher members of the Lower Cretaceous Series occur in the rocky fringe of Grassy Island immediately south of its main area, but are much better exposed on Clark Island and on the large islet about halfway between the northern extremities of Grassy and Clark Islands. On the east side of Clark Island and on the north side of the islet mentioned, beds approximately equivalent to the highest beds of the Sandstone member and carrying the same Aucella and ammonoid

fauna are overlain by 400 to 550 feet of sediments featuring a certain cyclic alternation. Grit and fine conglomerate, restricted to beds from several inches to 2 feet thick, occur at intervals of 10 to 30 or 50 feet. Between them are beds of sandstone 4 to 5 feet thick, replete with shells, or shell-limestone with a calcareous sandy matrix, which are in most places succeeded by, or interbedded with, coarse sandstone or grit beds, with few or no fossils. These beds, in turn, are overlain by 5- to 10-foot beds of siltstone, fine-grained calcareous sandstone, or sandy shales, with fewer aucellas, but carrying other pelecypods, gastropods, brachiopods, and ammonoids. These may be succeeded by beds of grey or bluish grey shale, with few fossils. The succession is then repeated. Such a cyclical repetition of similar sediments is not everywhere strictly maintained, and considerable deviations from the above order occur here and there. There is also a definite tendency toward a decrease upward in the amount of shale and siltstone, with corresponding increase in sandstone, shell-limestone, and grit. It is, accordingly, possible to subdivide the succession into a Shale-Siltstone member below, about 150 to 200 feet thick, and a Sandstone-Shell Limestone member above, about 250 to 350 feet thick, although no sharp boundary can be drawn between them.

The Shale-Siltstone member is characterized by an Aucella fauna consisting of Aucella ex gr. lahuseni Pavlow, an Aucella similar to A. volgensis Lahusen, and other Aucella forms not as yet well understood. This fauna has probably developed from the Aucella fauna of the underlying Sandstone member; both zones have been combined for the purpose of this report.

Near the top of the Shale-Siltstone member, the above Aucella fauna is gradually replaced by another fauna including Aucella inflata Toula, A. crassa Pavlow, A. crassicolis Keyserling, and other forms. Some 50 to 60 feet above the bottom of the Sandstone-Shell

Limestone member, ammonoids of the genus Polyptychites occur in a bed of shale or siltstone about 10 to 12 feet thick. These ammonoids are associated with Aucella solida Toula, A. ex gr. crassicolis Keyserling, etc. This fauna, which may be called the Aucella crassicolis fauna, continues to the top of the Sandstone-Shell Limestone member. All sections studied so far end with the same resistant beds of impure shell limestone and calcareous sandstone replete with Aucella ex gr. crassicolis Keyserling. These beds are the youngest Mesozoic rocks yet recorded in the map-area.

Age and Lower Contact Relations

It is clear from the foregoing discussion that the boundary between the Jurassic and Cretaceous Systems in the area mapped coincides with the erosional disconformity between the shales of Division B of the Upper Jurassic Series and the overlying Sandstone-Limestone member of the Lower Cretaceous succession. This boundary is especially well marked by the sudden and complete change in the Aucella fauna at this disconformity. Below it only Upper Jurassic aucellas were observed and above it only Lower Cretaceous aucellas. The local, erosional disconformity within the Sandstone-Limestone member is, apparently, of no stratigraphic importance, as the same Aucella fauna occurs both above and below it.

Of the three Aucella zones distinguished in the Lower Cretaceous rocks of the map-area, the lower one, embracing the Sandstone Limestone member, is characterized by the predominance of aucellas of the group of Aucella okensis Pavlow, and particularly by the presence of the species itself. These species are considered to be characteristic of a zone at the very bottom of the boreal Lower Cretaceous (Riasan beds) that corresponds to the so-called Infravalanginian (Berriasian) Stage (or Substage) of Western Europe. This zone has not been positively identified in California or elsewhere in the United States. In Canada, it is known only in the Harrison

Lake area, where Crickmay (1930a, p. 487; 1930b, p. 47) has described a typical Aucella okensis Pavlow from his Peninsula formation as a new species, Aucella cascadensis Crickmay.

The succeeding palaeontological Zone, with Aucella ex gr. keyserlingi d'Orbigny, A. ex gr. terebratuloides Lahusen, Lytoceras ex gr. saturnale Anderson, and Phylloceras ex gr. ononense Anderson, bears such a strong faunal resemblance to the lower part of the Paskenta group of California (See Anderson, 1938) that the writer considers it possible to correlate it with the latter. In British Columbia, it corresponds probably with the upper part of the Peninsula formation of the Harrison Lake area, as some Aucella species of Crickmay (1930b) are very closely related to, or identical with, forms above mentioned. In terms of European standard stages, this zone corresponds approximately with the Lower Valanginian (Arctic and Russian zones of Tollia stenomphala Pavlow and of Polyptychites keyserlingi Neumayr) of the boreal province, where Aucella keyserlingi d'Orbigny and its relatives reach their maximum development.

The upper zone, with Aucella solida Toula, A. crassa Pavlow, A. crassicolis Keyserling, and related forms, corresponds approximately with some of the higher beds of the lower part of the Paskenta group of California, which Anderson (1938) has grouped together with its lower beds into one general Aucella fauna. In British Columbia, the lower part of the Brokenback Hill formation of the Harrison Lake area (Crickmay, 1930a) appears to be equivalent to this zone and, in terms of European standard stages, it corresponds with some part of the Upper Valanginian. The lower part of the zone of Polyptychites polyptychus Keyserling, where all the Aucella forms mentioned above reach their maximum development, may be tentatively suggested as its equivalent. This correlation is supported by the presence of Polyptychites sp. indet. in its lower beds. This Aucella fauna has

already been recognized at a great many localities along the Pacific coast of North America from Alaska to California.

As Infravalanginian and Valanginian Stages (or Substages) together represent the lower part of the Neocomian Stage, all the Lower Cretaceous rocks of the map-area may be referred to as Lower Neocomian rocks.

No beds referable to the upper part of the Paskenta group of California or to the upper part of the Brokenback Hill formation of Crickmay (1930a, 1930b) with Yaadia lewisagassizi Crickmay and Aucella teutoburgensis Weerth are known to be represented in the area mapped, and the Lower Cretaceous succession there apparently ends with beds of Lower Neocomian (Valanginian) Age.

TERTIARY ROCKS

A thick succession of sandstone, sandy shale, siltstone, dark shale, grit, and conglomerate occupies most of the shore near Tatchu Point and reappears on Tatchu Rocks off the mouth of Tatchu Creek and at the northern end of Jurassic Point.

At Tatchu Point, 900 to 1,100 feet of strata have been measured between the base of the assemblage and where they disappear beneath the sea. They probably extend inland for ½ to 1 mile, but are not exposed.

The Tertiary rocks have a general persistent strike of north 30 to 55 degrees west, and dip from 20 to 35 degrees southwest. Folds and faults are of minor consequence, and only a few fault zones contain vein matter of hydrothermal origin, all of which is in contrast with older assemblages.

Sandstone-Conglomerate Member

A coarse conglomerate, consisting of volcanic and granitic pebbles and boulders up to 5 to 10 feet in diameter, outcrop wherever

the base of the Tertiary assemblage is exposed. This basal conglomerate overlies the uneven and deeply eroded surface of the Jurassic volcanic rocks or of granitic rocks except on the east side of Tatchu Rocks where they apparently overlie rocks whose age has not been definitely established. The conglomerate varies in thickness from a few inches to 10 or 15 feet.

Above the basal conglomerate lies a succession of thin-bedded conglomerate, grit, and coarse- to medium-grained sandstone. Individual beds may be lenticular and vary considerably in thickness and extent. They are composed of rather poorly sorted material, and small- to medium-sized pebbles are commonly dispersed throughout the sandstone. Most of the grains of the sandstone are imperfectly rounded to angular. To the south of Tatchu Point, these rocks reach a thickness of 50 to 60 feet, but on the northwestern side of Sandstone Point they are all but missing.

The above strata are in turn overlain by some 200 to 250 feet of sandstone, which also varies greatly in grain size, is rather poorly sorted, and includes a few thin beds of grit or fine conglomerate. Coarse grains and small pebbles are dispersed in fair quantity in many beds, and most of the sand grains are imperfectly rounded to angular. These sandstones are in general moderately to strongly calcareous, and contain numerous small and large nests and lenses of calcareous sandstone or impure limestone that weather out to produce a honeycombed surface. Peculiar structures that rather resemble worm trails or burrows abound in many beds, and are probably fossilized burrows of Dentalium. The grain-size decreases markedly in the upper beds, and the upper 100 feet or so of beds consist mainly of medium-grained sandstone, with fine-grained sandstone and siltstone appearing in the uppermost beds.

Fossils occur sporadically in many beds, but are nowhere abundant. They are definitely marine, but include only a few species. Ostrea sp. indet., and ? Epitonium cf. condoni Dall have been identified by Ralph Stewart of the United States Geological Survey from collections made by the writer, mainly from one zone some 30 to 50 feet above the base of the Sandstone-Conglomerate member.

Sandstone-Siltstone Member

The Sandstone-Conglomerate member is overlain by 700 to 750 feet of sandstone, fine-grained sandstone, siltstone, sandy shale, and grey laminated shale that constitute what will be referred to as the Sandstone-Siltstone member. The transition between the two members is gradual, light-coloured, coarse- to medium-grained sandstone of the lower member passing imperceptibly upward into grey to dark grey siltstone, sandy shale, and dark grey, laminated shale. In the upper member, rather numerous, variously shaped concretions of dark sandstone and siltstone are distributed irregularly or in rows.

Many beds in the lower 350 to 400 feet of the Sandstone-Siltstone member are fossiliferous; well-preserved crabs, all of one species, Portunites alaskensis Rathbun, being characteristic. In addition, the following were identified by Ralph Stewart: Bruclarkia cf. acuminata Anderson and Martin, Epitonium cf. condoni Dall, Priscofusus cf. hannibali Clark and Arnold, Siphonalia? sp. indet. (internal mould), Dentalium sp. indet., brachiopods, and bryozoans. In addition, shark teeth, Platanus and Laurus-like leaves, and much fossil wood bored by wood borers were collected. This fauna is mostly confined to the concretions but also occurs in the rocks surrounding them.

In the upper part of the succession just described, siltstone and sandy shale become predominant; they are interbedded with a fair number of beds of dark grey shale. On the other hand, sandstone becomes

rare. Off Tatchu Point, still higher beds of the member may be seen at low tide, among which dark grey, laminated shale predominates almost to the exclusion of all other types. In these beds, loaf-like concretions consisting of grey sandstone or siltstone 5 to 12 feet in diameter occur, but no fossils were found. The top of this series was not seen, but 350 feet of beds were measured.

Age

These Tertiary rocks were first described by Webster (1906, p. 74A) from the extremity of Tatchu Point; at that time he correlated them tentatively with the Tertiary rocks of St. Juan Point.

Dr. Ralph Stewart, of the United States Geological Survey, to whom the molluscs collected were submitted for identification, comments as follows: "This shipment consists of four collections containing 8 species and about 50 specimens from Tatchu Point, West Coast of Vancouver Island. The 3 species identified specifically have been reported from the Sooke formation, and correlation with that formation is suggested. The age of the Sooke formation has been considered Miocene, and Upper Oligocene or Lower Miocene.

"The Sooke fauna seems better referred to the Miocene because it is much more closely related to the Recent fauna than to the Eocene fauna."

The fossil crabs that abound about midway of the assemblage are all specimens of Portunites alaskensis Rathbun. This species occurs in Oligocene beds in numerous localities along the Pacific coast of North America from Alaska to Oregon (Rathbun, 1926, pp. 74-75). No representative of the genus Portunites is known to be older than the Eocene nor younger than Oligocene, and the species above mentioned is known only from the Oligocene. Although this suggests an Oligocene age for the strata at Tatchu Point, the molluscan fauna favours Miocene rather than Oligocene. Accordingly, for the purpose of this report, the age is considered to be Oligocene or (?) Miocene.

The Tertiary rocks of Tatchu Point are lithologically similar to, and probably contemporary with, the Escalante formation of Nootka Island, Estevan Point, and southern Vancouver Island, which Bancroft (1940) considered to be Oligocene in age.

CORRELATION OF THE MESOZOIC ROCKS

The succession of Mesozoic rocks discovered in the area studied is much more complete and, lithologically, rather dissimilar to any previously described from other parts of Vancouver Island. Its correlation with the Vancouver group is based largely on the occurrence of Monotis subcircularis Gabb in the lower sedimentary part of the Bonanza group in Zeballos, Nimpkish, and Quatsino map-area (Dolmage, 1921, pp. 14-15; Gunning, 1930, p. 105; 1932, p. 23; 1933, p. 34; Bancroft, 1937, p. 6). As this index fossil also characterizes a narrow zone in the Thinly Bedded member of the Upper Triassic assemblage in the area mapped, the correlation of the two can be considered as established (See Figure 1, correlation table). The overlying Jurassic volcanic rocks thus appear to be the equivalent of the younger volcanic part of the Bonanza group. Thus, it appears that only the upper part of the Vancouver group, the Bonanza group, outcrops in the area mapped.

The reasons for believing that the Jurassic volcanic rocks are Lower or(?) Middle Jurassic in age have already been given, and the opinion of Gunning (1930, p. 105), and others, that the upper part of the Vancouver group is in part Jurassic, appears to be well founded.

The exact position of the Triassic-Jurassic boundary cannot be determined exactly from present information. It probably roughly coincides with the contact between the sedimentary and volcanic parts of the Bonanza group. Crickmay, however, makes the generalization that the Jurassic period of volcanic activity along the Pacific slope commenced in Middle Jurassic time and that the earlier part of the period is represented by sedimentary rocks (Crickmay, 1931, pp. 26-29). His

discovery of Lower Jurassic sedimentary rocks at Parsons Bay on Vancouver Island (1929-30) lends colour to this suggestion. It, therefore, would appear more probable that the boundary between the systems lies within the sedimentary part of the Bonanza group above the zone of Monotis subcircularis rather than within its volcanic part.

Neither of the Upper Jurassic divisions of the present area has any known equivalents elsewhere on Vancouver Island. The similarity of their faunas to those of the Upper Jurassic formations of southern and central British Columbia suggests that they are remnants of a much larger body of these rocks, largely removed by erosion, rather than that they are local sedimentary facies of rocks that elsewhere are mainly of volcanic origin.

The Lower Cretaceous and Upper Jurassic rocks of the present area nearly bridge the erosional gap between the early Upper Jurassic Yakoun and late Lower Cretaceous Haida formations described by McLearn (1949) from Queen Charlotte Islands. It seems probable that the lowermost beds of Division A of the Upper Jurassic Series are slightly younger than the uppermost beds of the Yakoun formation. This is suggested by the fact that Cadoceras doroschini (Eichwald), which occurs near the base of Division A, in Alaska occurs immediately above the zone with Seymourites (Kellum, 1945, p. 208), which is found in the upper Yakoun formation.

In the Harrison Lake area, the youngest Jurassic formation known is equivalent to Division A of the Upper Jurassic rocks. The Upper Jurassic, Division B of the area mapped is represented by the erosional gap between Crickmay's Agassiz Prairie formation and his Lower Cretaceous Peninsula formation. The presence of Aucella ex gr. mosquensis (Buch) seen by the writer in collections from Tyaughton Creek Valley suggests, however, that more complete sections of Upper Jurassic rocks are present locally in central British Columbia.

The situation in Alaska is very similar to that in British Columbia, as the youngest Upper Jurassic formation so far studied, the Naknek formation, carries a Cardioceras fauna in its lower part and an Oxfordian Aucella fauna (A. ex gr. bronni Rouillier) in its upper part. Younger Upper Jurassic rocks are undoubtedly present locally although they have not yet been studied in detail.

In California, Upper Jurassic rocks equivalent to Division B are thick, highly fossiliferous, not too greatly deformed, and relatively well studied. The Upper Jurassic rocks of Division A, on the other hand, although apparently represented, have been so little studied by local stratigraphers that as yet no correlation can be attempted.

Dawson (1887, pp. 13-15, 80, 83-99) and Dolmage (1921, pp. 16-17) described Lower Cretaceous rocks from several points along the west coast of Vancouver Island and in Quatsino Sound. Unfortunately, the stratigraphic and palaeontological information on these Lower Cretaceous localities is too scanty to admit of an exact correlation with the Lower Cretaceous beds of the present area. It appears, however, that the Lower Cretaceous succession in some of these localities is more complete in its upper part than that described in this report, as even Aptian and Albian rocks may occur in places (Dawson, 1887, pp. 80, 83-99).

The close similarity between the Upper Jurassic and Lower Cretaceous faunas of the area under consideration and those of Alaska, Greenland, Siberia, and Middle Russia, on the one hand and California, Mexico, and even the Australasian province on the other, is rather remarkable, and definitely suggests a free marine connection between all these regions during most or all of this time. This in turn suggests that the relative scarcity of known Upper Jurassic and Lower Cretaceous marine deposits throughout northwestern

and western Canada may be due to their subsequent destruction or to our still very imperfect knowledge of this spaceous region.

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