Art. XV.—*The Devonian Orcas Group of Washington;* by Roy D. McLellan.

The majority of the formations exposed on the San Juan Islands of the State of Washington belong to one more or less conformable series, here called the San Juan series, which is composed of highly metamorphosed sedimentary and volcanic rocks of Paleozoic age.

The lower portion of the series consists largely of cherty quartzite with intercalated limestone beds. Because it is well exposed on Orcas Island, it is here named the *Orcas group.*

The upper portion of the series, which will be referred to as the *Leech River group,*[1] since it no doubt includes Clapp's Leech River "formation,"[2] is composed of black argillites, schists, tuffaceous graywackes, slates, and volcanics. It also includes occasional thin limestone beds containing the Pennsylvanian foraminifer *Fusulina,* and the argillites have scattered thin seams of semi-anthracite. Most of the sediments of the upper part of the series were derived from the underlying Orcas group.

Distribution.—The Orcas group is the oldest one exposed on Orcas and San Juan Islands, and the outcrops are all included within a belt 22 miles long and 10 miles wide. The underlying strata are covered by the waters of the straits, and on the southeast the group is cut off by a fault that appears to cross the whole San Juan area.

Lithology.—The Orcas group was laid down by normal processes of marine sedimentation, i. e., periodic conditions produced thin strata of fine-grained sand alternating with strata of mud. It is composed of highly metamorphosed and contorted sediments with some interbedded volcanic rocks, the outstanding lithological component being a light bluish-gray chert. The chert is so badly fractured, and the joint planes so intricately recemented by white quartz, that it is impossible to obtain a thin section that will not show several quartz veinlets within its area. The veinlets are usually normal

[1] G. M. Dawson, Report on a Reconnaissance of Leech River and Vicinity: Geol. Survey Canada, Report of Progress 1876-77, 95-102, 1878.

[2] C. H. Clapp, Southern Vancouver Island: Ibid., Memoir 13, 35-38, 1912.

to the bedding plane, and in places are so abundant that the rock passes into a cherty quartzite.

The chert strata range from half an inch to 3 inches in thickness, but usually they are less than 2 inches thick. Each band of chert is separated from the next by layers of argillite. The thickness of the argillite bands is generally slightly less than that of the chert layers, and they vary in color from light brownish-gray to dark brown. By differential erosion, especially along the coast, the argillite layers have been completely removed, while the cherty layers stand out in relief, and present a surface and structure resembling that of shredded wheat. The argillite has a tendency to pass into the chert, although in places it is highly schistose.

In addition to the quartz veinlets, thin sections of the chert show numerous small round "spots" filled with quartz, and these are occasionally present in the interbedded argillites. The size of the "spots" is approximately that of the radiolarians seen in the cherts of the Franciscan formation of California, and since radiolarian cherts have also been found in northern California[3] in formations of similar age and lithology, it is assumed that the quartz-filled "spots" were originally radiolarian tests that have since recrystallized. A careful examination of selected samples of the chert has, however, failed to reveal radiolarians.

The origin of such chert deposits has been discussed at length by E. F. Davis[4] and by E. Sampson.[5]

Interbedded with the cherty quartzite are numerous lens-shaped beds of limestone. These are not confined to any one horizon, but occur scattered throughout the whole group. The limestone is always recrystallized and recemented with calcite, the texture is usually coarse, and the color is generally bluish gray, with white veinlets of calcite. In the vicinity of igneous dikes, the limestone is silicified, and irregular masses of flint are found. Tremolite and wollastonite are present near the contact of some dikes. Still other limestones contain a consider-

[3] J. S. Diller, Mineral Resources of South-Western Oregon: U. S. Geol. Survey, Bull. 546, 15-16, 1914.

[4] E. F. Davis, The Radiolarian Cherts of the Franciscan Group: Univ. Calif. Publ., Bull. Dept. Geol., vol. 11, 353-408, 1918.

[5] E. Sampson, The Ferruginous Chert Formations of Notre Dame Bay, Newfoundland: Jour. Geology, 31, 571-598, 1923.

able quantity of carbonaceous matter, and in such cases the limestone is black in color, and the joint planes are often covered with glistening films of graphite.

The volcanic rocks included in the Orcas group consist chiefly of fine-grained altered basalts and basic andesites, at the present time so greatly altered that several thin sections are frequently necessary to prove the original nature of the rock. The basalts are often amygdaloidal, and contain calcite and serpentine in the amygdules. In all of the volcanic rocks, the feldspars have been altered to kaolin, and later silicified.

It is possible that the conglomerate exposed along the shore, near the foot of Orcas Knob, represents the base of the Orcas group. The coarse greenish sandstone that forms its matrix greatly predominates over the enclosed bowlders which consist chiefly of altered andesite, quartzite and granite. Its thickness is at least 35 feet. The conglomerate is overlain by 25 feet to 50 feet of thin alternating beds of argillite and quartzite; this is followed by a fairly persistent limestone bed about 30 feet thick, which contains Devonian fossils, the rocks here being less metamorphosed than those in the surrounding areas. In general, the Orcas group is more cherty in its upper portion.

Thickness.—No accurate measurement of the thickness of the Orcas group is possible. Assuming that the strata do not repeat themselves, a rough estimate of the thickness of the group, as exposed on San Juan Island, shows not less than 10,000 feet. How much of this is Devonian, and how much is Mississippian, is not yet determined.

Structural Relations.—The rocks of the Orcas group are folded into a broad open syncline, with an east-west axis, and plunging to the eastward. The northern arm of the syncline is exposed on Orcas Island, and its general trend is in a north-east and south-west direction. The beds dip to the south-east with an average angle of 35 to 40 degrees, although the angle of dip ranges from zero to 90 degrees. The same general trend and dip are seen in the exposures on Shaw Island.

In the south-west part of San Juan Island, in the vicinity of Mount Dallas, the general strike of the chert group is about N. 50° W., and the dip is towards the north-east. On the north-east side of the island, the

strike is nearly east and west, or slightly to the northwest, with a steep dip to the southward. If the shoreline is followed around the north end of San Juan Island, the chert group is seen to strike more or less parallel to the shore, and dips toward the center of the island.

The Orcas group is cut off on the south-east by the Kanaka fault. This passes through False Bay, on San Juan Island, and extends in a north-easterly direction, following the Upright Channel between Shaw and Lopez Islands, and crossing Orcas Island near the villages of Olga and Doe Bay. The depth of the channel drops to more than 100 fathoms just outside of False Bay and Kanaka Bay, in the fault zone. The fault is a composite one, with more vertical than horizontal motion. No Orcas group rocks have been observed on the south-east, or down-throw side, of the fault.

The rocks of the group have been subjected to prolonged regional metamorphism, and in addition, have been cut and locally metamorphosed by igneous dikes of several periods of igneous activity. Near the contacts of the dikes, the sedimentary rocks are often schistose. In regions where there has been intense pressure and accompanying movement, the chert strata are often shattered, while the argillite has flowed so as to completely enclose the chert fragments. On Orcas Island, considerable areas may be found in which the cherty quartzites are free from igneous intrusions, but elsewhere the cherts are cut by a network of both concordant and discordant igneous rocks. These dikes have been interpreted as feeders to flow rocks, the latter having been completely removed by erosion.

Although, in detail, the rocks of the Orcas group are complexly folded, faulted, and contorted, their general trend is reasonably constant, and the broad structural features are relatively simple.

Age and Correlation.—In the Orcas Lime Quarry, near the foot of Orcas Knob, Sections 30 and 31, T 37 N, R 2 W, Willamette base-line and meridian, the writer discovered some brachiopods on the weathered surface of the limestone ledge as it outcrops along the face of the cliff. These fossils occur only to a depth of one inch, and beneath this level, the limestone is entirely recrystallized and shows no trace of fossil remains.

Apparently this fossil-bearing block has been preserved in some unknown manner, while all other portions of the limestone have been completely recrystallized.

These brachiopods have been examined by Dr. Charles Schuchert, who determines them to be a variety of *Atrypa reticularis* Linnæus. He says, in a letter to the writer: "All of them are *Atrypa reticularis,* one of the commonest of all Paleozoic forms. This species ranges throughout the Silurian and Devonian, but your specimens look to me like the Euro-Asiatic variety seen in the late Middle and Upper Devonian throughout the west, from the Pacific to Iowa. The spirals show in a number of specimens, and these prove that their apexes turn to the center of the dorsal shells. Very few genera do this, so that there is no doubt that you have *Atrypa reticularis,* and, I think, a late Devonian form."

The Orcas group is to be correlated with the lower part of the Cache Creek series of British Columbia. The Cache Creek series was first described by Dawson,[6] who found in it the Pennsylvanian fossil *Fusulina.* He also found fossils in the lower formations, however, that ranged back into the Devonian, and he remarks that "The lower portions of the Cache Creek formation may be older than the Carboniferous period."

In the Bridge River District, west of Lillooet, British Columbia, McCann[7] describes the Bridge River series, which he considers to be of Pennsylvanian-Permian age, but his description applies equally well to the rocks of the Orcas group.

The Orcas group may also be partly equivalent to the Hozomeen series[8] that occurs in the Skagit and Hozomeen Ranges, near the forty-ninth parallel.[9]

The limestone ledges exposed on Orcas Island, to the north of Mount Woolard, in Sec. 2, T 36 N, R 2 W, Willamette base-line and meridian, are structurally near

[6] G. M. Dawson, Report on Area of the Kamloops Sheet, British Columbia: Geol. Survey Canada, Ann. Rept., new ser., 7, 39B-49B, 1896.

[7] W. S. McCann, Geology and Mineral Deposits of the Bridge River Map-Area, British Columbia: Ibid., Memoir 130, 23-26, 1922.

[8] G. O. Smith and F. C. Calkins, A Geological Reconnaissance Across the Cascade Range Near the Forty-ninth Parallel: U. S. Geol. Survey, Bull. 235, 22-23, 1904.

[9] R. A. Daly, Geology of the Forty-ninth Parallel: Geol. Survey Canada, Memoir 38, vol. I, 500-508, 1912.

the top of the chert group. These limestones contain the Carboniferous coral *Lithostrotion*.

The argillites and graywackes of the Leech River group in this area contain fragments of the "spotted" chert, and also include *Fusulina*-bearing limestones, hence it is probable that the *Lithostrotion*-bearing limestones are of Mississippian age.

The Orcas group, therefore, had its beginning in the Middle or Upper Devonian, and the deposition of its sediments continued on into the Lower Carboniferous.

University of Washington, Seattle.