GEOLOGY OF THE CENTRAL PART OF THE MOUNT VERNON QUADRANGLE

by

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GEOLOGY OF THE CENTRAL PART OF THE MOUNT VERNON QUADRANGLE

INTRODUCTION

Location of Area.- The area covered by this report is located in the Mount Vernon quadrangle. It extends from Skagit County southward into Snohomish County, and is about six miles due east of the town of Mount Vernon and about eighty miles north of Seattle. It may be reached from Seattle by the Northern Pacific Railway. Also there are three main highways running into the area, one going north from Arlington through Bryant and Pilchuck, a part of the Pacific Coast Military Highway; another good road running east from Conway into McMurray which is in the southern part of the area; a third county highway also running east from Mount Vernon connecting with one going south from Sedro Woolley, joining with the Military Highway which runs diagonally across the area. Passing from north to south this road goes through Big Lake, Montborne, Ehrlich, and McMurray, all small villages on the area. The roads are in good shape but are not paved.

Size of Area.- The area covered by this report contains Sec. 17-20, 29-32 of T. 34 N., R. 6 E; Sec. 13-16, 21-28, 33-36 of T. 34 N., R. 5 E; Sec. 5-8, 17-20, 29-32 of T. 33 N.,

R. 5 E; also Sec. 5 and 6 of T. 32 N., R. 6 E., and Sec. 1-4 of T. 32 N., R. 5 E. The area is in the shape of a rectangle, being 6 x 11 miles and making an area of 66 square miles.

PURPOSE OF INVESTIGATION

The purpose of the investigation is to study the stratigraphy and structure of the region involved, to find its relations to the San Juan Island group to the west and to the Cascades on the east, to classify and identify by means of petrography the varieties of rocks involved, to determine the direction and kinds ^ forces involved which produced the present conditions, and to determine the ages of the formations as nearly as possible.

Method of Investigation.- The investigation as conducted by the author consisted of going over the ground as carefully as possible, noting outcrops, their areal extent, noting lithology and relations between formations in the field, taking strike and dip where possible and definitely locating the outcrops on the map by means of compass bearings upon certain physiographic features as noted in the field and which are shown on the quadrangle map of the area. The time spent in the field has amounted to about six weeks, three weeks during the first of the year, a week during the latter part of March, and several three and four day periods between the first of the year and the middle of June.

PHYSICAL CONDITIONS

Relief and Elevations.- Within the area is found an "island mountain mass" rising out of a comparatively flat plain on all sides. To the east and separated by the mountain mass is a much higher mass whose elevations immediately jump up to 4,500 feet in less than a mile. These mountains make the extreme western flank of the main Cascade range. The island mountain mass is separated from the main mass by a very low valley. The elevation of the plain to the west is as a rule under fifty feet. The elevation of the valley separating the island mountain mass from the main mass to the east is between 100 to 250 feet, while the island mountain mass reaches an elevation of 1,800 feet. Cultus Mountain, on the extreme eastern border of the area, attains an elevation of 1,200 feet, and a mile farther east it rises to over 4,000 feet.

Topography.- The ruggedness of the topography may be realized by referring to the map and also to the photographs accompanying the report. The topography is directly influenced by the earth-making movements which have affected the sedimentary and metamorphic members involved. In the main these forces have been from the southwest and from the northeast. They probably have been in the form of a tensional force. As a result the sediments are standing in all cases at a high angle, and the metamorphics are brought to stand up as nobs and remnants which may best be called "huerfanos."* (See Plate I,

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* Lahee, Frederick H. Field Geology, p. 335. 1923

Fig. 2, Plate II, Fig. 1, 2.) As a result the sediments are exposed as long ridges, the harder members standing up above the softer ones, and the whole having a general strike of northeast and southwest. This may best be seen by reference to the map where the long ridges are shown to stand out with marked relief. The hill immediately to the southwest of McMurray has what seems to be a sharp escarpment on the northeast flank and a gentle slope to the southwest, thus producing a very marked structure similar to a fault block, which is visible for great distances, appearing as a cuesta. (See Plate VII, Fig. 1) The ridge to the southwest of Devils Lake is probably a similar block fault but of a much higher angle and is the highest ridge in the area. To the north of Lake Ten and also to the northwest of Big Lake are several metamorphic nobs or huerfanos which stand up in marked relief and are completely surrounded by sedimentary deposits. (See Plate I, Fig. 2; Plate II, Fig. 1, 2)

Drainage.- The drainage follows a northwest-southeast general trend and is a consequent stream pattern which has probably reached early maturity in development. It is to be noted in the island mountain mass that the streams all run parallel to the strike of the strata except in a very few cases. The lakes in the area are a result of glaciation and are due to differential gouging of the strata and also to the damming up of a preglacial valley by outwash deposits.

Plate I

Fig. 1 - This view shows the relation of topography to structure. The high hill on the right is massive sandstone dipping to the right. Next comes a shale member which easily erodes out,and a much smaller sandstone stratum is shown by the low ridge running from the middle of the picture to the right.

Fig. 2 - This shows one of the huesfanos lying about two miles to the north of the town of Big Lake. It is characterized by the long train left on the leeward side of the nob as the glacier overroad the country.

Plate I.

Fig. I.

Fig. II.

Plate II

Fig. 1 - This view shows a huerfano about three miles southeast of Mount Vernon. The gentle slope on the leeward side may be noted here.

Fig. 2 - This shows another type of huerfano which is not as well developed as the others.

Plate II.

Fig. I.

Fig. II.

The streams are all of the intermittent type except those draining Lake McMurray and Big Lake. There are very few springs in the area and the water soon disappears after a rain. This has been greatly accentuated by the logging off of the land, and as a result the mountains in the area are very dry in summer and very little water can be found that is fit to drink.

Vegetation and Culture.- All the land contained within the area has been logged off except one little patch, located to the west of Big Lake, that is being held for high prices. About twelve or fifteen years ago the area contained some of the state's finest cedar and fir, and where the land has not been burned off there is a good second growth coming up. This, however, is choked in many cases by the dense underbrush which rapidly springs up after the timber is gone. In some cases, notably around Devils Lake, the land was burned off several years ago, and there is not a single green thing alive there today. All the soil has been burned, and the acid igneous rocks which underlie it do not furnish fertile soil. (See Plate III, Fig. 1, 2; Plate IV, Fig. 1,2; Plate V, Fig. 1, 2) Over the rest of the hilly part of the area there are a great many wind-falls, blackberries, and salmon berry bushes, making it exceedingly difficult to traverse during the summer. The valleys are for the most part under cultivation or are in the process of being cleared. Practically all the good tillable land in the area has been marked on the map as

PLATE III

Fig. 1 - View looking east from Devils Lake shows, in the middle of the picture, one of the metamorphic nobs noted on the map by Devils Lake. The hill on the ~~right~~ left is dacite, those on the right are sedimentaries, and the hill in the far distance is sedimentaries and dacites.

Fig. 2 - This is another view of the same area only it is taken from the far hill in Fig. 1 and is looking westward. Shows the dacite on the right, metamorphic nobs in the center, and sedimentaries on the left. The hill in the distance is of massive sandstone with a shaly member in the center which has eroded out, leaving the sharp gash in the hillside.

Plate III.

Fig. I.

Fig. II.

Plate IV

Fig. 1 - This view shows the results of fire and poor soil found upon the dacite. The trees were never more than two or possibly three feet in diameter while those nearby are over seven and eight feet in diameter.

Fig. 2 - This another view showing the same result as found in Fig. 1.

Plate IV.

Fig. I.

Fig. II.

Plate V

Fig. 1 - This view was taken from the southern end of Big Lake looking toward the southwest and shows the type of topography. The high hill in the center is composed of dacite and sandstone.

Fig. 2 - This view was taken from the opposite direction of Fig. 1. It shows the surface character of the dacite on the high hill noted in Fig. 1.

Plate V.

Fig. I.

Fig. II.

glacial till or outwash, which only applies to the valleys and a very little distance on either side. Outside of the immediate vicinity of the small streams the soil is too stony, and the water passes through the soil too quickly to permit of any very extensive farming. This is shown by the very poor crops that are obtained from the side hills and none at all from the hills themselves. The only farming land that will yield favorable crops at all is in Walker Valley, due east of Montborne. In traveling through the hills, the old logging roads were followed as much as possible, but it is surprising how fast they become overgrown after a few years and thereby lose their usefulness as a means of getting about. There is one logging concern located at Ehrlich, which has been getting out telephone poles from the burnt-off area by Devils Lake, but it is not now operating. Berry culture is by far the most profitable occupation.

Exposures.- The exposures may best be noted by referring to the map of the areal geology found at the end of the report. It is to be noted that the amount of glacial drift and outwash is surprisingly small, being confined solely to the valleys, and there it is to be found only in small amounts. The sedimentary deposits south of Devils Lake and southwest of Lake McMurray are very well exposed, in many places the bare rock outcrops, and in others there is but a slight veneer of soil over the deposits. The metamorphic sedimentary and igneous rocks surrounding Lake Ten are also very well exposed in most places, but their presence has to be inferred in a few instances. The rocks directly east of Devils Lake and forming the nobs which stand up so markedly are of igneous origin and are dacites. They are very well exposed, have practically no soil upon them, and are interbedded with massive white sandstones. There are also several nobs of metamorphic rocks seen to the north, which stand up well from the surrounding territory. (See Plate I, Fig. 2) One is about a mile due east of Mount Vernon, and the other is about two miles north of Big Lake. These have been referred to previously as huerfanos. In the region due west of Devils Lake and occupying the highest ridge in the island mountain mass and running westward from the lake for the full length of the ridge there is to be found a good example of a gossan-like outcrop composed of limonite, hematite, and quartz.

To the east of Lake McMurray there is a complicated mass of sedimentaries and metamorphics whose relations are very difficult to work out because of the glacial material. To the north, between the town of Montborne and Walker Valley, there is a series of low hills having a sharp scarp, similar to a fault scarp, on the west side amounting to over two hundred feet. Outcrops are well exposed, are composed of igneous rocks, and are of basaltic composition. Some differentiation is shown in the flows. Farther south along the above mentioned ridge and due east from the southern end of Big Lake is found an outcrop of dacite containing quartz phenocrysts as well as some sandstone that also contains these phenocrysts in association with the dacite, thus showing the age of the igneous material. In Walker Valley there are several exposures of sedimentary origin, but there is quite a covering of soil in most cases. To the northeast of Walker Valley and at the foot of Cultus Mountain are exposed various forms of serpentines and other metamorphosed materials.

GEOLOGIC CONDITIONS

Regional.- The structure in the area covered is very complicated and in most cases is impossible to work out in detail. In fact the region has been folded, faulted, and eroded so many times that its ultimate solution will, in most cases, probably never be obtained. Furthermore there have been many periods of igneous activity in the region which have further cut up the already folded and faulted sediments in such a manner that great complexity has evolved. The whole region is underlain by a highly metamorphosed complex of sedimentaries and igneous intrusives and extrusives. This basement complex is overlaid by arkosic sedimentaries which are in the main very coarse. These sediments are separated by a very marked unconformity from the underlying metamorphics, and are in the main very massive and have intercolated with them a few igneous intrusives and extrusives which have only been found so far in the area mapped and not outside of it. This whole series has been highly faulted and folded. The materials which are unconformable upon this series are glacial till, outwash, and some small delta deposits. The most recent formation in the region is the delta deposit of the Skagit River, which covers a large area and is in the main composed of sands and silts.

Local.- Structurally the area mapped is intimately associated with the San Juan Island complex and its outlying phases. In fact the only separation between this area and the San Juan Island area is the Skagit River delta which has filled in the embayments between the former islands and thus extended the main land farther to the west into the Sound. At the present time few of these islands are to be seen extending above the delta deposits and are quite scattered about so that all field evidence would seem to show that the former embayments did exist much farther to the eastward. The only direct reference covering this area is the one worked out by McLellan,* who has done a very commendable

*McLellan, Roy Davison. University of Washington Thesis, Geology of the San Juan Islands, 1926.

piece of work upon the subject, and many references to it will be made hereafter. Upon an examination of the topography of the country (See map at end of report), it will be noted that the type of structure is very intimately reflected in the relief. The old metamorphics stand up as nobs and hills high above the surrounding country and form part of the highest ridge in the island mountain mass. They are all highly altered greenstones and serpentines with a few remnants of their former material still present. Probably they are a part of the Paleozoics deposited during Carboniferous time, which have been intruded by pyroxenites of Triassic age, or at least they are the same lithologically as have been noted on the San Juan Islands and which have been definitely correlated as Triassic. Some dacites were also found. The present outline of this mass is very irregular and was so during the submergence which allowed the deposition of the present sedimentaries. There is a marked unconformity between the two. The early sedimentaries are all coarse grained and light colored and quite arkosic, all indicative of a near-shore brackish water phase. There are also many fossil leaves found, such as those of the fan palms which appear to be identical with those of the Chuckanut formation.

Near the top of this formation there are found some igneous intrusions, notably at Devils Lake. These are a porphyritic dacite, which occur as surface flows and sills. They are also to be noted as the first outcrop north of Ehrlich and due east of the south end of Big Lake. To the north of this outcrop, there is a larger one of basalt which has differentiated in part and probably has a fault scarp on the southwest face. The upper members of the sedimentaries contain a less and less amount of quartz as one goes up the stratigraphic column, and a great preponderance of ash comes in near the top. This series may correlate with a part of White's Puget Group.* Unconformably upon these sedimentaries

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*White, C. A. On the Puget Group of Washington: American Journal of Science, 3d Series, V. 36, pp.443-450, 1888 lie the remains of the last glacial epoch. Its areal extent is very small as compared to that of the general Puget Sound region as it occupies only the valleys and has built a few small deltas east of Ehrlich. The lakes found in the area are a result of this glacial action. The youngest deposit found in the area is that of the Skagit River delta and is confined to the northwest portion of the map area. The glacial deposits appear to be only those of the Vashon Epoch, as none of the Admiralty have been found, and because the area of the Vashon till is very small, it is doubtful if any of the Admiralty period remains.

SEDIMENTARY PETROGRAPHY

Method Used.- Due to the rapidity of erosion and the covering up of the various outcrops as well as the complexity of the faulting, it is extremely difficult to work out the structural relations. As a result the problem has been attacked by means of sedimentary petrography, which, in conjunction with the scanty field evidence, will, I think, bring out some very interesting facts, which, by the field evidence alone, it has been impossible to work out. Some of the prescribed methods of treating the samples obtained in the field have been varied somewhat, and I shall endeavor to outline them here. Every precaution was taken to eliminate as far as possible the sources of error which might be encountered. The method which I have used consisted of the following steps:

As all of the sediments were consolidated it was necessary to crush up each sample by means of a mortar and pestel. This done, about 150 grams were obtained in each case. This amount was sifted through a 35-mesh sieve, using the Tyler Standard Screen Scale nested sieves. I then weighed out 50 grams in every case using the ordinary apothacary scales. After noting the color, each sample was put in a 600 cc. pyrex beaker, and about 300 cc. of commercial hydrochoric acid, commonly known as muriatic acid, was added. As the acid was added, I noted the effect upon the sediment, that is, whether it efforvesced or not, which would indicate the presence of a carbonate, probably in the form of calcite; also whether there was evolved any hydrogen sulphide, which would indicate the presence of ferrus sulphide. After noting these various changes in the sediments themselves, the material was digested over a hot plate, using both gas and electric hot plates, for a period of about half an hour. This was found to be sufficient for cleaning the grains of any cementing material which might adhere and was of very great assistance in the microscopical work which was to follow. It may also be noted that boiling the sediments for this short period has practically no solvent action upon the grains themselves, and as a result there is no loss to speak of in the acid treatment. After this period of digestion the sediments were washed for a period of about two hours. This was done to get rid of all remaining acid and also to eliminate all of the very fine clay that is held in colloidal suspension in water. The sediments were then dried over a radiator and hot plate, care being used to prevent the sediments from becoming too warm and causing a dehydration of some of the minerals and thus spoiling them for microscopical determination. After they were totally dry the color was again noted, and in all cases a great change from the first color was observed. They were then weighed and the loss figured in percentages. After this the sediments were screened, using the same Tyler Standard Screens. All the sediments that passed 100 mesh and remained upon 200 mesh were saved, and the remainder was thrown out. On the average, this gave me from five to ten grams. The size through 100 and on 200 was found to be the most satisfactory for microscopical determination, the larger sizes being too big for satisfactory results, and the sizes that pass 200 mesh being altogether too small for accurate determination. The amount that passed 100 and remained on 200 was separated by bromoform.

The bromoform was distilled to bring it up to a specific gravity of about 2.87 which was found to be satisfactory for the separations required. This bromoform was then poured into a separatory funnel and the sized sediments added later. The whole was then shaken up and allowed to settle. This method was repeated several times until about all of the heavy crop had settled to the bottom. The stop cock was then turned, allowing the heavy crop to pass out along with some of the bromoform. This was caught upon a filter paper and washed with benzol. The washings were saved as the bromoform could be recovered from it by distillation, thus preventing a considerable loss. Then the light crop which was floating upon the bromoform in the separatory funnel was drained out and washed by benzol in the same manner as was the heavy crop. These two filter papers were then dried with their respective crops. They were next put in 3 dram glass bottles, numbered, corked, and filed away.

In the mounting of these fragments Canada balsam was used with an index of refraction of about 1.54, approximately that of quartz. Bausch & Lomb glass slides, 26 x 45 mm., were used with a square cover glass. In making these permanent mounts, considerable practice is required so that the minimum of air bubbles is retained in the slide. In mounting the detrital sediments, the end of a dissecting knife was used, which was very narrow, and as a result I was able to obtain about the same amount of material in each case. Care was also used in pressing the cover glass down upon the melted Canada balsam so that a minimum of the grains would flow out with the balsam. These slides were then allowed to cool, and the excess Canada balsam was removed by a knife. The slides were washed with xylene, care being taken that it did not dissolve under the cover glass. The slides were then labled and were ready for determination.

Some of the grains were impossible of identification by this means as they had their optical properties hidden. For this reason they were immersed in various oils of known index of refraction. This was done by taking some of the heavy crop, when possible, putting it upon a slide, adding a drop of the oil, covering it with a cover glass, and getting its index by means of the Becke method. The oils used were prepared by A. C. Hawkins of Ward's Natural Science Establishment, Rochester, N. Y., and they range in index from 1.440 to 1.740. A few of the rarer minerals were not identified in the slides because of a lack of time, but those that are known are of sufficient range and importance to be used in the following proofs which I shall endeavor to bring out.

Location of Samples.- The following samples were not chosen at random but were taken with a definite purpose in view. The location of the samples is as follows:

No. 1 was taken about 200 feet north of Glen Allen along the road to the north. Glen Allen is situated at the end of the road which runs along the west side of Big Lake south from the town of Big Lake. The sample has a strike of N. 5° W., and a dip of 32° to the west. It is a light gray, massive sandstone, containing much carbonaceous material and fairly coarse.

No. 26a was taken about a mile southwest of Glen Allen on the south side of an old shingle-butt dam, located on the stream which feeds Glen Allen. The sample has a strike of N. 55° W. and a dip of 47° to the south. The sample is a very coarse sandstone and conglomerate containing carbonaceous material and is of a light brown color.

Nos. 42 and 42a were taken about a thousand feet west and south of the south end of Big Lake, about 800 feet above the lake, from an old log shoot which is easy to find. It is a coarse and fine grained sandstone containing many fossil leaves and carbonacrous material. It is finely limonated dark gray in color. The sample has a strike of N. 25° E. and a dip of 20° to the southeast.

No. 143 was taken just north of the high ridge immediately to the south of the point where samples 42 and 42a were taken, between the two sills of porphyritic dacite, immediately to the south and above the point just mentioned. It is a coarse and fine bedded sandstone, containing carbonaceous material. Strike and dip were impossible to obtain but seems to be to the south. Its color was a light brown.

No. 92 was taken about 35 feet above the north end of Devils Lake. The coarse sandstone is of a light brown color and too well weathered to give its strike and dip. It is massive, and just to the north of it there are sediments which have a dip of 4° to the south and a strike of N. 85° W. and are located about 300 feet north of the sample.

No. 142 was taken from the second high ridge to the south and a little east of sample No. 143. The two samples are separated by about half a mile. The sandstone is very coarse and massive, containing no strike or dip, but immediately to the east along the logging road that runs to Devils Lake from Ehrlich and about 1,000 feet east of No. 142, the strike was found to be N. 37° E. with a dip of 66° to the northwest. The sandstone is white with pinkish spots of iron oxide.

No. 9 BF. This sample was taken about a mile due north of the western end of Lake Sixteen on an old logging road on the north bank of the stream at the foot of the highest ridge to the south of Lake Ten where there is an old railroad bridge crossing the stream. The strike is E. and W., dip 31° to the south. It is a fine grained sandstone of brown color.

No. 8BF was taken about two miles northwest from Lake Sixteen and is the extreme western limit of the ridge running parallel with the highest ridge south of Lake Ten. It has a dip of about 15° to the south and an E. and W. strike. The sample is very conglomeritic in part, is of a light gray color, and contains some carbonaceous material.

No. 74 was taken from the highest place upon the ridge immediately to the north of Lake Sixteen, about due north of that lake. It has an east and west strike and a dip of about 36° to the south. It is a massive conglomerate, dark brown in color.

No. 72. This sample was taken from the massive conglomerate on the next high nob along the ridge from which No. 74 was taken. Strike is E. and W., dip is 31° to the south. It is a dark brown color and contains boulders up to six inches in diameter.

No. 71 was taken from the east end of Lake Sixteen where the stream enters. The sample contains brackish water pelecypods and fossil leaves and has a rich brown color. Strike is N. 70° W. with a dip of 19° to the southwest. It is a well banded fine grained sandstone.

No. 7BF. This sample was taken from the bottom of a well that is being put down at the foot of the hill southwest of McMurray at a depth of about 50 feet. The sample is a gray conglomeritic sandstone.

No. 1BF was chosen from the face of the hill in a little draw located in a line with No. 7BF, running due west. It is about 200 feet stratigraphically above No. 7BF. Strike Northwest, dip to the southwest. It is a massive gray colored sandstone.

No. 2BF. This sample was chosen farther up the same draw and is the same as No. 1BF only about 100 feet stratigraphically above it. It is a little finer grained sandstone.

No. 69 is a massive dark greenish brown coarse sandstone, taken along the road that runs from McMurray to Conway, located where the second road branches off and goes to the south. Strike N. 65° W., dip 30° to the south.

No. 6BF. This sample was taken on about the 750-foot level of the hill southwest of McMurray and on the section line running south of Lake McMurray. It is a very coarse conglomeritic sandstone of a greenish brown color containing bits of lignite and has the same strike and dip as No. 2BF.

No. 5BF. This sample was chosen on the 1,000-foot level of the above mentioned hill. It has the same texture and color as No. 6BF and was taken about where the 1,000-foot contour line crosses the county line between Skagit and Snohomish counties south of Lake McMurray. Strike and dip are the same as for No. 2BF.

No. 150 was also taken at about the same elevation as No. 5BF. It is a coarse greenish sandstone and was taken from a little shaft that was started in an endeavor to find gold. It is about 1,000 feet north of the above station. Same strike and dip as mentioned for No. 2BF.

No. 3BF was taken from the summit of the hill south of McMurray. It has the same strike and dip, and the same lithologic character as that of No. 5BF.

No. 4BF. This sample was taken to the southwest of No. 3BF and is a brown sandstone, fine grained and not well bedded, having the same strike and dip as No. 3BF.

No. 401. This is from a fossil locality described and located by the author. It is a highly fossiliferous sandstone of a dark gray-greenncolor, located about 1,000 feet north of Pilchuck along the Northern Pacific Railway. The dip of the strata is to the southwest with a strike approximately northwest and southeast.

These samples have been taken up in about the order of relative age, starting with the oldest and working toward the youngest. This order has been deviated from somewhat in describing those from the probable block fault hill to the southwest of McMurray. In this case I have enumerated the samples in stratigraphic sequence and have not taken into consideration those occurring on the high ridge north of Lake Sixteen, which are probably of the same age as those upon the summit of the above mentioned block fault hill.

Discussion of Chart No. 1.- There are several things to be noted in the Mechanical and Physical Analysis Chart No. 1 that are of importance as follows:

It will be noted that there is a marked correlation between the percentage in weight lost and the stratigraphic horizon from which the samples were taken. This is notably shown in Nos. 150, 3BF, 4BF, and 401. The first three were taken all within a half mile and cover a stratigraphic range of about 300 feet. While No. 401 was taken fully four miles to the south, it is still in the same horizon and shows the same amount of material lost by acid and washing. This fact is also brought out by No. 72 and 74 which are of the same strata but are separated by about a mile along the ridge. This fact is of course reflected in the types of gases evolved by the action of the muriatic acid. Another fact that is brought out is that the cementing, in almost all cases, has been of ferruginous nature with some fine clay mixed in. In only a few cases does the cementing material seem to be a carbonate, probably in the form of calcite, as this mineral has been found filling the joint planes and is in many of the fault planes found on the area. The change in color is

Chart No. 1

MECHANICAL AND PHYSICAL ANALYSIS

Sample number	Color before acid treatment	Color after acid treatment	Loss in weight %	Gases evolved
1	Light gray	White	20.	Great amount of CO_2 & H_2S
26a	Buff	White	17	None
42a	Light gray	Light gray	43.2	Great amount of H_2S & CO_2
42	Dark gray	Dark reddish gray	35.6	Great amount of H_2S & CO_2
143	Light brown	Light gray	39.2	None
92	Brown	Light reddish gray	25	Trace of H_2S
142	Pink	Light gray	13.6	Trace of CO_2
9BF	Brown	White	17.6	None
8BF	Light pink	Cream	15.4	None
74	Brown	Light gray	19.9	Trace of H_2S
72	Brown	Light gray	19.1	None
71	Gray brown	Dark gray	41.4	Little H_2S and CO_2
7BF	Dark gray	Gray	10	Trace of CO_2
1BF	Reddish brown	White	12.8	None
2BF	Gray brown	Gray	16	None
69	Brown	White	20	None
6BF	Red brown	Cream	22.4	Trace of CO_2

Chart No. 1 (Cont.)

Sample number	Color before acid treatment	Color after acid treatment	Loss in weight %	Gases evolved
5BF	Golden brown	Light gray	13.4	None
150	Dark gray	Dark gray	26.7	None
3BF	Reddish brown	White	27.8	None
4BF	Yellow brown	White	27.4	None
401	Dark gray	Light gray	35	Great amount of CO_2

notable in most cases too as this is accompanied by a large percentage of lost material which shows approximately the amount of ferruginous material which went to make up the cementing material. The presence of the hydrogen sulphide gas can only be inferred as due to ferrous sulphide which is undoubtedly present due to the reduction of the iron oxides by the free sulphur derived from the carbonaceous material of the plant remains which are so abundant in the area. The odor of hydrogen sulphide and the presence of free sulphur was noted in the field around certain shaley outcrops which were rich in plant and invertebrate remains. These facts give a little help in showing the laws of continuity which can be brought out by the mechanical analysis alone, which is as nothing when compared to the analysis of the heavy residues.

Discussion of Charts 2 and 3.- Before working with the Mineral Determination Sheets Nos. 2 and 3, and describing the story which they tell, I wish to state that these samples were worked over at random, that is they were not assembled stratigraphically as they now are, and as a result the individual slides were worked on not knowing definitely what position they occupied stratigraphically. Of course, as soon as a particular suite of minerals was seen, I would know about where it occurred. This was done in order to avoid knowing beforehand for what to look.

Before going ahead I wish to show the accurate correlation which can be brought out by samples chosen from the same horizon and yet widely separated horizontally. Between Nos. 150 and 401 was the greatest horizontal distance, from four to five miles, yet when the heavy mineral suite is compared, there is found a remarkable similarity throughout. The greatest difference is found to be in the light crop and in the ash content. Another close check may be had in looking at the mineral suites of Nos. 74 and 72 on sheets 2 and 3. Here the greatest distance is about one mile apart, yet the only notable difference is to be found in the amounts of anatase in the two cases, the rest of the minerals agreeing fairly well. Again to show the marked vertical variation I have chosen Nos. 42 and 42a which are stratigraphically separated by not over one hundred feet. When the mineral suites are compared on sheet No. 2, it will be noted that they differ markedly and approach similarity only in muscovite and magnetite. There is also a similar difference to be noted in 9BF and 8BF found on sheet No. 2. The stratigraphic difference here is within two hundred feet, yet the two samples are found to agree only in a few cases and then there is but a slight agreement.

Again where the deposition has been rapid and the source of the material the same, there will be a marked similarity between points that are separated by large distances stratigraphically. This can be shown by comparing Nos. 6BF and 5BF which are separated by fully 500 feet stratigraphically. In these a marked similarity will be noted in most cases, as will be found on sheet No. 3. Many more cases proving the wonderful continuity of the same mineral suites in the heavy and light crops may be shown, but these will be sufficient for the present purpose.

In working out the details of the sequence of deposition and in identifying the minerals, works of Milner, Holmes, Larsen, and Mortimore were used.*

---

*Milner, Henry B. An Introduction to Sedimentary Petrography.

Holmes, Arthur. Petrographic Methods and Calculations, 1921

Larsen, Esper S. The Microscopic Determination of the Non-opaque Minerals. Bull. 679, 1921, U.S. Geological Survey.

Mortimore, M. E. and Trowbridge, A. C. Correlation of Oil Sands by Sedimentary Analysis. Economic Geology, Vol. XX, No. V, pp.409-423, August, 1925.

It will be noted first of all that the samples treated were found to be arkosic, indicated by the presence of feldspars. This indicates a very rapid mechanical erosion rather than a chemical change. Furthermore the material was not transported very far after disintegration. In studying the types of quartz grains it was noted that those with irregular inclusions were subangular and that those with regular inclusions were decidedly angular. The following information was taken from Dr. Machie,* and I quote him as follows:

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*Machie, Dr. W. Transactions of the Edinburgh Geological Society, Vol. VII, p. 148, 1896.

Inclusions in Quartz Grains

N-- Inclusions absent, or so minute as to escape observation. R - "Regular" inclusions. These consist of minerals such as micas, rutile, zircon, apatite, and black iron ores.	Especially characteristic of quartz from schists and metamorphic gneises.
I - "Irregular" inclusions. These consist of fluid lacunae with or without gas-bubbles, often arranged in streams. A - Acicular inclusions. These consist of fine dark lines (which may be rutile) and colorless needles, sometimes in tufts which are probably silimanite.	Especially characteristic of quartz from granite, quartz-diorite, and related rocks including quartz veins.

From the above table it will be clearly understood as to just what is meant by "Regular" and "Irregular" inclusions. As I have stated before, in the six samples on sheet No. 2, those grains of quartz with "Irregular" inclusions were subangular, and those with the "Regular" inclusions were decidedly angular. In working out the types of minerals found in the earlier sediments, it will be found that erosion was taking place from an area of metamorphic rocks which were not far removed, a condition comparable to that which is found at present in the San Juan Islands. If the sediments which are being deposited there at the present time were analyzed, they would undoubtedly show the same suite of minerals as found above. Of course there will be some adulteration due to the glacial material which is scattered over the country. It will further be noted that the topography must have been very rough and erosion well along in maturity as a few pieces of schorl are found which is a high temperature mineral. This would indicate that erosion was well down into the heart of the mountains. Furthermore the presence of the "irregular" grains of quartz and their subangularity indicates a source far removed and that it was an area of igneous rocks. As a result it is probable that a river was supplying material to this area of deposition, probably like the Skagit is at the present time. This river was probably a long one as there is very little to indicate the presence of any other mineral commonly associated with igneous rocks. Another explanation for the occurrence of this type of quartz grain is that in some cases the metamorphic rocks surrounding and making up the islands of this region are composed of highly altered igneous rocks, and some of the quartz may have been derived from them as the plagioclases probably were. However, in looking at these igneous materials petrographically, it will be noted that they are in the main peridotites and pyroxenites and a few very basic igneous flows of a basaltic nature. All are highly altered and none contain quartz. Therefore the hypothesis of a river feeding the area will not be stretching the imagination too far in accounting for the origin of these quartz grains. Also their subangularity would require a greater distance of transportation than could be found if derived in situ. Facts upon this point are brought out by reference to Mackie.*

*Mackie, William. Laws That Govern the Rounding of Particles of Sand. Edinburgh Geological Society, No. 7, 1893-1908. Read 29th of April, 1897.

This general condition of deposition kept on for quite a long period of time. It was a near-shore phase as indicated by the carbonaceous material and plant leaves found as well as the coarsemess of the grains. The sandstones are all more or less light colored.

The exact thickness of the sediments is hard to determine, but it is probably well over 1500 feet. This condition continues throughout sheet No. 2. However, toward the end of sheet No. 2, starting with No. 9BF, a marked change is felt. The region is no longer fed entirely by metamorphic material. In the near vicinity the land has been uplifted as shown by the increasing coarseness of the material as one goes up the stratigraphic column, the color of the sediments changing markedly to a reddish brown. There is a sudden increase in the amount of hornblende probably due to the erosion of new lava flows of a basic nature. This is shown by a study of the thin sections of some of the pebbles in the conglomerates which are basaltic in nature. There is still some metamorphic material being contributed to the area as will be shown by looking for that type of mineral in sheet No. 3, as for example, anatase. The most remarkable feature that has come to affect the area is the presence of a large number of explosive types of volcanoes. This is shown by the gradual increase of ash that is found in the light crop of residues. This activity increases as one goes up the scale stratigraphically, and only slightly dies out at the very top of the series. This material contributes enormously to the amount

Chart No. 2

MINERAL DETERMINATION SHEET

Convention - "Flood" . . . . . 9 - 90% or better
Very Abundant . 8 - 66-89%
Abundant . . . 7 - 51-65%
Very Common . . 6 - 36-50%
Common . . . . 5 - 15-35%
Scarce . . . . 4 - 11-14%
Very Scarce . . 3 - 6-10%
Rare . . . . . 2 - 3-5%
Very rare . . . 1 - 1-2%

Heavy Crop -	1	26a	42a	42	143	92	142	9BF	8BF	74
Anatase	5	1	2		1	1			1	1
Chloride						1				1
Epidote	4		1			3	4	4	1	3
Garnet	6	4				7	6	4	1	2
Hornblende	1	1	1			3	1			8
Ilmenite	5	3	5	3	5	4	5	5	1	5
Magnetite	2	1	5	4	2	1	4	1		7
Muscovite	5	4	9	9	9	4	1	4	4	3
Rutile	2	2	1		4	4	1	3	3	
Tourmaline	2		2		1	1				
Uwarowit	1		1							
Zircon	4	4	4	1		5	3	4	5	1
Light crop:-										
Ash								6	7	6
Plagioclase	2	5	7	3	2	3	3	4	5	6
Quartz	6	5	7	4	5	6	5	3	4	5

Chart No. 3

MINERAL DETERMINATION SHEET

Convention - "Flood" . . . . 9 - 90% or better
Very abundant . 8 - 66-89%
Abundant . . . 7 - 51-65%
Very common . . 6 - 36-50%
Common . . . . 5 - 15-35%
Scarce . . . . 4 - 11-14%
Very scarce . . 3 - 6-10%
Rare . . . . . 2 - 3-5%
Very rare . . . 1 - 1-2%

Heavy Crop -	72	71	7BF	1BF	2BF	69	6BF	3BF	150	3BF	4BF	401
Anatase	4					22			1	1	1	1
Chloride			4	4	4	2	6	1	4	2	1	6
Epidote		1	3	4	3	5	4	2	3	1	2	4
Garnet	3	2	3	3	2	1	3	1	4	1		5
Hornblende	7	1	7	8	8	8	7	7	7	7	8	8
Ilmenite	5	6	3	1	4	4	2	5	4	5	5	4
Magnetite	6	1	2	2	2	1	2	3	2	1	2	2
Muscovite	5	4	2	4	1	1	2	3	1	1	3	1
Rutile			1	1	2		1	2			1	
Tourmaline		1										
Zircon	1	1	2	2	2		2	1	2			2
Light Crop -												
Ash	8	7	7	6	6	9	9	8	9	9	9	7
Plagioclase	3	1	5	5	5	3	2	5	3	4	4	1
Quartz	4	6	3	5	4	4	3	3	4	2	3	6

of sediments deposited and is probably of a basic nature for the following reason: When washed after the acid treatment it is snow white, but if some of it is heated it will turn a deep red due to a dehydration of the iron compounds in the ash. This change cannot be recognized in the field as there is no remnant left of these volcanic cones, and in the hand analysis of the samples it can not be determined except by examination of the larger boulders that may be found in the conglomerates. These facts bring out very well the powers of sedimentary petrography in noting changes that might otherwise escape observation.

Results of Determinations.- There are two things that I shall now endeavor to prove by means of sedimentary petrography: First, the dacites found directly to the east of Devils Lake are sills rather than extrusive flows.

We will first take the outcrop of dacite which is due east of the southern end of Big Lake and north of Ehrlich. The following features are to be noted: It is porphyritic, containing phenocrysts composed almost entirely of quartz with some sanidine. By thin section analysis of the dacite, it will be noted that these phenocrysts show remarkable resorption cavities. (See Plate VI, Fig. 1, 2) The cause of these cavities is explained by the fact that they were formed at depth and as they were shot upward the relief of pressure caused an increase in fluidity and a consequent resorption of the quartz and sanidine phenocrysts. Furthermore it is to be noted that the material, when it came up, was not very gassy as there are practically no gas inclusions in the quartz phenocrysts or alteration of the feldspar phenocrysts which are very rare. In the field there is no evidence of metamorphism or of contact phases. One thing noted was that the sandstone associated with the dacite contains bits of dacite as well as phenocrysts of quartz that show the same resorption cavities as are found in the dacite. (See Plate VI, Fig. 3, 4) Here I have shown microphotographs of the phenocrysts in the dacite as well as phenocrysts from the sandstone. This proves beyond a doubt that the sandstone was derived in situ from the breaking down of the dacite and furthermore that the shore line was not far away because some of the boulders measure a foot or more in diameter. There is also a great amount of volcanic tuff and ash mixed in with the material as well as a few pieces of greenstone which shows that the matamorphics were nearby. The specimens may be viewed in the collection and are numbered from 123 to 127 inclusive. The large amount of ash present also indicates that a great amount of volcanic activity was going on at the time of their extrusion. The sediments also show that the age of the igneous flow was the same as that of the sediments and that it was intercalated with them and not of a previous generation because older sediments are found which also contain ash but no resorbed phenocrysts of quartz. This material will show that the dacite was extruded near the shore line during the period of extreme volcanic activity.

Plate VI

Fig. 1 - This is a microphotograph of a resorbed phenocryst of quartz found in Sample No. 37. It is a dacite and is magnified 34 times.

Fig. 2 - This is another view of a different type of quartz phenocryst from the same sample and is magnified 60 times.

Fig. 3 and Fig. 4 - Two views of quartz phenocrysts taken from sample No. 125. It is a very coarse grained sandstone. Magnification, 34 times.

Plate VI.

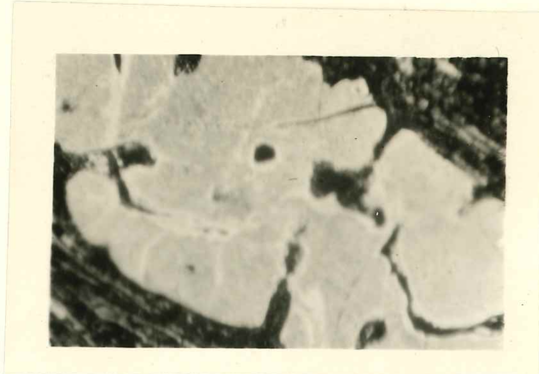


Fig. I.

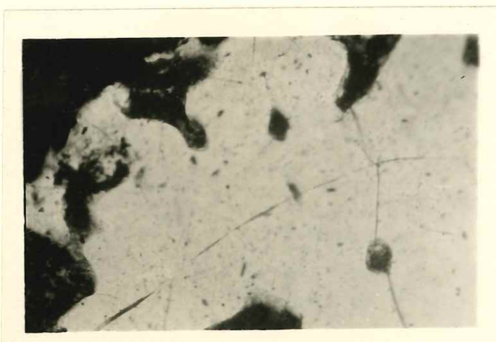


Fig. II.

Fig. IV.

Fig. III.

In going over to those flows of dacite which are west of the above outcrop and east of Devils Lake the following features will be noted. They contain the same identical resorbed phenocrysts of quartz and were very dry when forced up as shown by the absence of gas inclusions in the phenocrysts of quartz and by the fact that there has been no reaction with the phenocrysts of feldspar except resorption. In the field a glassy phase was noticed at the base or top, it was impossible to tell which, but no contacts could be found either at the top or at the bottom. It will also be noticed that it is dipping at a high angle, 85° to the north, the same as the sediments in conjunction with the material. The contacts both above and below apparently weather out very fast, and a few blow-holes were noted in the flow seen in picture (Plate V, Fig. 2), which were highly compressed and drawn out by flowage. As a result of the petrographic analysis there is every indication pointing to the fact that this igneous material is the same as that previously described on the other side of Big Lake, and there can be but little doubt that both bodies came from the same igneous magma which has differentiated below the surface.

In referring to the Mineral Determination Sheet No. 2, the exact location of the following samples should be noted: Nos. 42a, 42, 143, 142, and 92. The following things will be noted in the heavy and light crops: First, that the material which went to make up this mass of sediments was derived solely from metamorphic sources with some slight variations as mentioned before; second, that there is no ash in the light crop; third, that there are no resorbed phenocrysts of quartz found in the thin sections of these sediments, and fourth, that these sediments were near-shore deposits, being coarse grained and containing fossil leaves and carbonaceous material.

In going back to the flows themselves, the following conditions will be discussed: First, if they were extruded on the surface beneath the water, the question will immediately be asked concerning the absence of ash. The Devils Lake Flows are not over two miles from the flows described before as being east of the south end of Big Lake. When the latter flows occurred there was a great deal of volcanic ash being thrown up as is shown by the character of the sediments, and if the flows around Devils Lake were on the surface at the same time there would necessarily have been a great deal of ash deposited with them as this ash is found scattered over all of the upper members of the sedimentary series covering the area. Therefore it seems reasonable to suppose that the flows by Devils Lake were sheltered by something other than water.

Secondly, if the flows came out upon the surface, their decomposition should have contributed something to the sediments above them because, as I have mentioned before, the water was shallow and near shore, but the sediments associated with them show no trace of being adulterated by any such decomposition products. The above two reasons are sufficient to prove that the only way in which these dacite flows could have been formed there and not have left a trace in the surrounding sediments is by being intruded as sills. This hypothesis would account very nicely for their present condition and the fact that they left no trace in the surrounding sediments.

Sedond, I shall try to prove that the mountain to the southwest of McMurray is a block fault mountain with the fault line running along the valley to the west of McMurray and also around that town and down the valley to the southeast. A picture of this mountain will be seen in Plate VII, Fig. 1. This view was taken about seven miles to the southeast and shows a distance along the dip slope of the cuesta of about three miles. Every indication in the field would seem to show a fault block, several points being noted. First, there are a great many faults in the area, some of which have a displacement which is greater in the horizontal component than in the verticle; second, there seems to be no flexure in the block itself. It has a gentle and continuous dip of 15° to the southwest, with no changes noted over the whole block excepting on the two ends where it gradually dies out; third, to the north there appears to be a recurrence of the same beds, that is, they appear the same lithologically. Their dip, however, is different as it is about 35° to the southwest. No curving was noted as would be expected in folding. Fourth, to the northeast there is a

Plate VII

Fig. 1 - This is a view of the block fault hill in discussion. About three miles are exposed upon the dip slope.

Plate VII.

Fig. I.

smaller hill with a dip of 28° to the southwest, and it too has approximately the same lithologic composition in its makeup. About one mile to the north of McMurray there is a small anticline which is the only flexure found in the whole area, its axis running at an angle to the escarpment. It will further be noted that there are some 1,000 feet of sedimentaries exposed on the vertical in this escarpment.

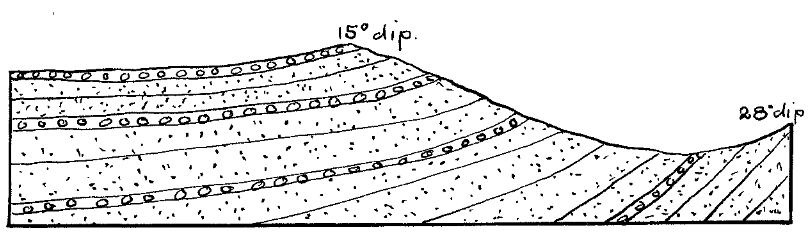
In endeavoring to prove that this is a fault block, reference must be made again to the Mineral Determination Sheets Nos. 2 and 3, and particularly to No. 3. The location of samples 69 and 4BF will be compared first, then No. 69 will be compared with No. 1BF. Their location on the map is of importance as 4BF is the youngest exposed upon the block fault hill, and No. 69 is the youngest exposed on the hill to the north. Also No. 1BF is the very oldest rock that could be obtained from the block fault hill. No. 7BF was not used because it was taken from a well that is being drilled without casing, and there is too much contamination with other material. It however could be used as it brings up the difference which I wish to show, but I consider 1BF to be better.

In comparing No. 4BF with No. 69, it will be noted that there is a marked similarity except for the amounts of epidote, which difference, in view of the fact that these samples are three miles apart horizontally, is not surprising, and their correlation is very good. Then in comparing No. 69

with No. 1BF, though these samples are closer together by about a mile, yet their difference is out of all proportion to the horizontal difference, and can only be explained by a marked difference stratigraphically. In comparing Nos. 4BF, 3BF, and 5BF, representing a stratigraphic difference of about 800 feet, it will be noted that there is much less difference in the suites of these samples than there is between No. 1BF and No. 69, showing that there must be quite a difference stratigraphically or else there must have been a marked variation in the source of the material. In these particular types of sediments a marked variation has not been noted in the residues, but rather a gradual one so that the members at the top of the block fault mountain and at the bottom are markedly different. There is no great variation between one sample and the next lower one. The difference would usually be expected by the difference in the stratigraphic relations.

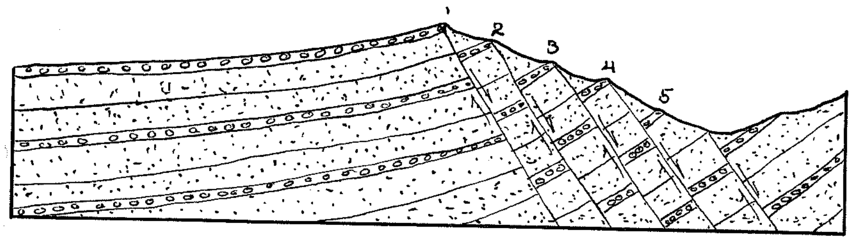
There are several hypotheses that might account for the formation of the hill referred to above, and I shall describe them as follows:

The first one will be that of a folded mass as shown in the following sketch.



This drawing will indicate a possible mode of origin, which, however, is highly improbable for three reasons. First, it would necessitate a repetition in the origin of the material making up the sediments in order to account for the similarity of the light and heavy crops found to exist. Sedond, there is no such folding observable in the field as I have stated before. There was only the one little flexure that has been observed, all the other changes of dip being very marked and sudden. Third, if the above hypothesis were true an erosion of over 1,000 feet would be required over the area immediately to the north of this hill because this type of sediments are not picked up again anywhere north of Devils Lake. This erosion becomes more phenomenal when it is taken into consideration that there are high mountains within three miles immediately to the east. Furthermore, the streams that are active in the area have removed practically no material since the period of glaciation as they are of an intermittent character. The Skagit River, twelve miles to the north, and the only powerful river in the region, would have had to flow up hill in order to come into contact with this area which is some 250 feet above the river at the base of the hill in question. Also this erosion must have removed fully 2,500 feet of sediments north of Devils Lake due to the addition of the underlying beds. It would seem peculiar if this erosion did go on that it should have stopped where it did and have left the sharp escarpment noted on the northeast slope of the hill. Therefore, I think the above hypothesis is untenable.

The second hypothesis is as follows:



In this we have a series of faults with about 800 feet between fault planes. This hypothesis is untenable for the simple reason that it would give a repetition of beds which would easily show up in the analysis of the light and heavy crops. A marked similarity would have been noted down the face of the hill at 1, 2, 3, 4, and 5. This was not shown, but rather a gradual change from top to bottom. With the above facts in view, the hypothesis of a block fault will stand justification without a reasonable doubt, even though the fault plane is hidden in the allevium of the two valleys and may never be found.

IGNEOUS ROCK PETROGRAPHY

Only a few characteristic samples will be noted to serve for identification. Microphotographs showing structure of the dacite may be seen on Plate VIII, Fig. 1-4, Plate IX, Fig. 1-2.

Dacites.- In describing the dacites the following representative samples were chosen:

Sample 37 from the top of the dacite nob above Devils Lake and east of it about 400 feet, is a light greenish

ish white rock, showing many phenocrysts and flattened blow holes which have been filled with a clayey substance. Its petrographic analysis is as follows: Resorbed phenocrysts of quartz free of inclusions and similarly resorbed phenocrysts of plagioclase composed of oligoclase and albite. They are of the first generation only and occupy about 15 per cent of the volume. There are also a few very small crystals of femics, probably augite, and several remnants of larger ones as shown by the magnetite and chlorite remains, which occupy about two per cent of the mass. The groundmass is microcrystalline and isotropic in part, giving a vitrophyric texture. There are many small blow holes which, in some cases, are lined with zeolites and then secondary quartz, which will occupy about 10 per cent. The groundmass takes up the rest of the volume of 63 per cent.

Sample 95 was taken from the very small sill about a quarter of a mile due north of Devils Lake. It is very well weathered and stained by iron oxides to a pink color with many veins of a greenish material, probably chlorite. It shows good flow structure and is porphyritic. Petrographic analysis shows that the rock contains resorbed phenocrysts of quartz, orthoclase, probably as sanadine, and first generation plagioclase, probably oligoclase, which make up about 30 per cent of the volume, the remaining being glass which shows good flow structure. There are a few blow holes which contain a radiating mineral, probably a zeolite, as well as several patches of some former femic that had

Plate VIII

Fig. 1 - This shows the type of flowage seen in the dacites. Taken from sample No. 32. Magnification 18 times.

Figs. 2, 3, and 4 - These are all different views of sample No. 40, showing a variety of flow structures. Magnification 18 times.

Plate VIII.

Fig. I.

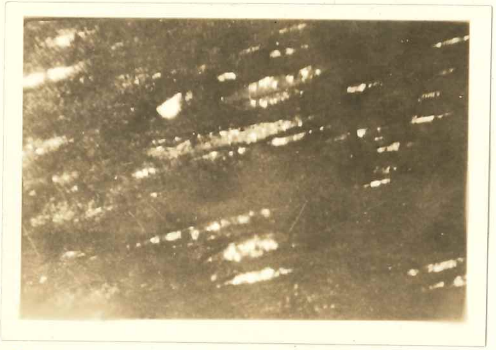


Fig. II.

Fig. III.

Fig. IV.

Plate IX

Fig. 1 - This shows the type of zonary phenocryst found in sample No. 99. It runs from oligoclase to albite. Magnification 34 times.

Fig. 2 - This shows a type of structure resembling a spherulitic texture. However, the crystals are really one and extinguish as such, and do not show the black cross. Taken from sample No. 90. Magnification 18 times.

Plate IX.

Fig. I.

Fig. II.

been completely altered. The rock is highly stained in places by hematite and limonite has filtered in. There are also several small phenocrysts of quartz and albite that are probably of a second generation while the groundmass is microcrystalline in part, and secondary quartz has filled some of the smaller cavities.

Sample No. 99 was taken about halfway between sample No. 37 and Devils Lake. It is a flow breccia with a light green color, and is porphyritic. Its petrographic examination shows that it contains resorbed phenocrysts of quartz, orthoclase, and zonary plagioclase, ranging from oligoclase to albite. There also seem to be two generations of plagioclase as one large one has completely gone over to kaoline-like material. These phenocrysts total about 15 per cent of the mass. There are several remnants of femics shown by chloritic masses as well as a few zeolitic masses. The groundmass is highly fragmental and some of the pieces picked up in flowage contain many small crystals of plagioclase. The glass is all isotropic. (See Plate IX, Fig. 1)

Basalts.- In describing the basalts found upon the area the following two samples were chosen as being representative as well as showing a marked differentiation. (See Plate X, Fig. 1-5)

Sample No. 122 was taken about a quarter of a mile southeast of the highest hill immediately to the east of the lower end of Big Lake. In the field it is impossible to determine the exact attitude of the flow as no contacts were seen, but it was probably on the surface. Megascopically it is a fine textured dense black rock weathering to a brown. A few phenocrysts are observable which are plagioclase. There are no vesicles observable in the specimen. (See microphotograph, Plate X, Fig. 5) Petrographically the rock is composed of small euhedral plagioclase phenocrysts which are probably bytownite, some of which show glass inclusions, and are of the same generation. They run about 40 per cent. There are also some well formed crystals of augite making about 20 per cent of the mass. Scattered about in the glass are a few small, well developed grains of magnetite which will run about 4 per cent. The remainder of the material is a glass and makes up about 36 per cent of the total mass. The texture is vitrophyric.

Sample No. 119 was taken about 300 feet to the north of the high nob mentioned in the location of the above sample. Megascopically it is a dense, finely crystalline mass, light gray in color and weathered to a light brown. No vesicles are observable in it, but there are one or two small phenocrysts to be seen. (See Plate XI, Fig. 3, 4) The petrographic analysis shows that there is about 41 per cent of euhedral phenocrysts of plagioclase, some of which are of a former generation and show glass inclusions, and are zonary between bytownite and basic labradorite. The glassy groundmass is clouded by femics and contains some well formed crystals of magnetite amounting to about 4 per cent, while the glass makes up about 55 per cent of the mass. The texture is

Plate X

Figs. 1 to 5.- Here is shown the differentiation found in the basalt flow running from top to bottom. Fig. 1 has a phenocryst of the first generation. The gradual decrease in the amount of glass is very well shown. The pictures were taken from the following samples in order: Nos. 114, 117, 120, 121, and 122. All are magnified 34 times.

Plate X.

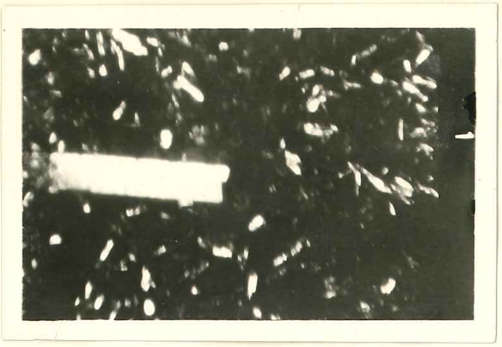


Fig. I.

Fig. II.

Fig. III.

Fig. IV.

Fig. V.

Plate XI

Fig. 1 - Taken from sample No. 116 which is a basalt and shows a type of blow hole that has subsequently been filled by a mineral like quartz, the identification of which is not positive. Magnification 34 times.

Fig. 2 - Shows two generations of plagioclase in sample No. 118, a basalt. Magnification 34 times.

Fig. 3 and Fig. 4 - Shows the type of ground mass in the basalt and also the type of plagioclase phenocrysts found representing the first generation. Its mottled appearance is due to glass inclusions. Taken from sample No. 119. Magnification 34 times.

Plate XI.

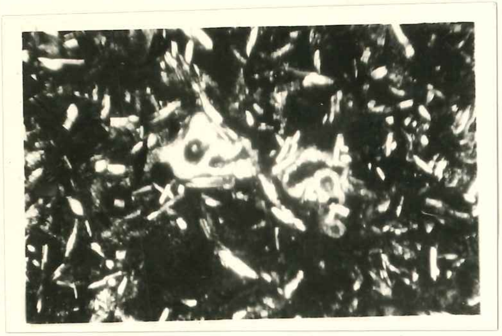


Fig. I.

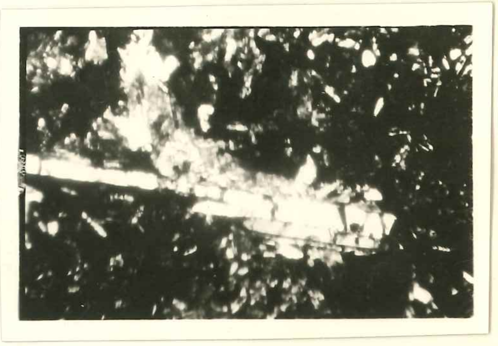


Fig. II.

Fig. III.

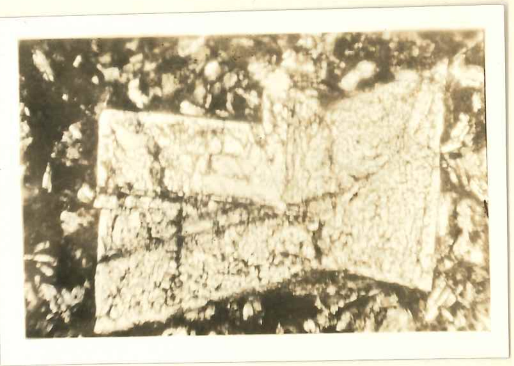


Fig. IV.

vitrophyric. As a whole the phenocrysts are not so well formed as they are in the first sample. There are also some small amygdules that are filled with a substance that appears like quartz. Its occurrence in a basalt is rather strange.

Gossanlike Outcrop.- The next series of samples is from the oxidized outcrop which appears like a gossan and may be found due west of Devils Lake and south of Lake Ten. (See Plate XII, Fig. 1-3) In the field the outcrop appears to have an east and west strike and extends for about three miles. The color varies from a brick red to a bright ochre. On closer observation the quartz veins stand out from the iron oxide mass, all the iron having been leached out from the quartz, giving it a bleached and sintery appearance as if it had been burned.

Sample No. 85 was taken from the highest point in the island mountain mass, being due south of Lake Ten. As shown in the hand specimen, it is green and yellow in part with quartz veins running through it. It is weathered to the deep red and sintery appearance mentioned above, and is very dense and hard. Note the microphotographs. (Plate XII, Fig. 1-3) Petrographically little can be determined except that the rock has been highly altered, having been shot through in many directions by small veins containing sedondary quartz. Some of the cavities have been lined by a radiating fibrous structure inside of which has grown many well developed crystals, probably of a carbonate, secondary

Plate XII

Fig. 1 - Taken from sample No. 85, showing the type of cavity filling found in the gossen.

Fig. 2 - Taken from the same sample, showing the way the limonite and hematite have filled in the veins.

Fig. 3 - Also from sample No. 3, showing the type of black cross found in the zeolitic material surrounding one of the cavities. All are magnified 18 times.

Plate XII.

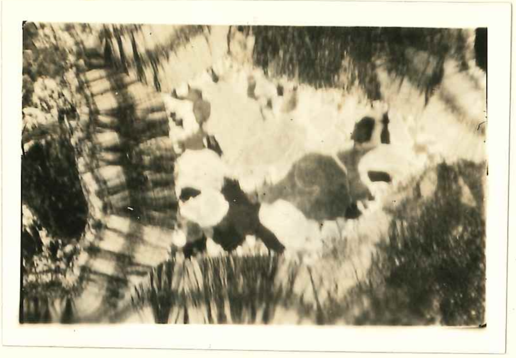


Fig. I.

Fig. II.

Fig. III.

quartz taking up all the vacant space. A chemical analysis would be required to identify all the minerals present.

Sample No. 82a was taken from the western end of the ledge immediately above Devils Lake. The color is a salmon red inside and a very deep red on the outside where it is weathered. There are quartz veins running all through it, which are crystalline. Otherwise the rock is very dense. Petrographically it is the same as sample No. 85, only there is a greater stain of hematite through the mass.

Metamorphics.- The metamorphic rocks are very complex and their exact nature can only be inferred in many cases. A few representative samples were chosen and worked out. (Note the illustrations, Plate XIII, Figs. 1, 2) As far as noted, the metamorphic rocks found upon the area are altered igneous rocks either intrusive or extrusive in mode of origin. However some of the samples collected from the mountains immediately to the east of the area show that the rocks were derived from a shale which has been highly metamorphosed so that all previous textures are totally wanting.

Sample No. 136 was taken about a quarter of a mile northwest of Lake Ten. Megascopically it is a light greenish gray rock, slightly porphyritic. Some of the phenocrysts appear to be plagioclase crystals, but they are so very small that it is impossible to identify them by a hand lens. A few holes are to be noted, but they are probably phenocrysts that have weathered out. The whole mass is weathered to a reddish brown color. Petrographically it contains two generations of plagioclase phenocrysts. The first generation is quite badly altered to sericite and magnetite, some of which has segregated in the flowage lines, and there is also a carbonate present. No zonary phenocrysts were observed, and the whole amounts to about 40 per cent of the mass. All of the femics present have been altered to chlorite and uralite and some hematite, making a total of about 10 per cent. Magnetite is dusted through the mass to the extent of about 4 per cent. A little orthoclase was noted and amounted to about 5 per cent. The plagioclase phenocrysts were oligoclase and albite, and about 5 per cent of quartz is present, while the groundmass is holocrystalline and makes up about 41 per cent.

Sample No. 138, also characteristic, was taken from a place about one mile west of Lake Ten. Megascopically it is a black rock containing phenocrysts of bastite. The whole is weathered to a brown color. (Note illustration, Plate XIII, Fig. 1) This slide shows a remarkable sample of metamorphism. The rock originally contained a great amount of augite which has passed in the most cases into serpentine with veins of chlorite running through it. Some of it, however, has been altered to bastite. The augite stands up all through the rock in little knots, remnants of once large phenocrysts of augite, which have been highly fractured, the cleavages still being observable. The serpentine has all but replaced the very centers of the original augite crystal, while in some cases they have been altered to bastite and

Plate XIII

Fig. 1 - Taken from sample No. 138, showing the alteration of a large phenocryst of augite to bastite and then into serpentine in the veins. Magnified 34 times.

Fig. 2 - This shows the two generations of plagioclase phenocrysts in sample No. 136. All have been highly altered by metamorphism. Magnification 34 times.

Plate XIII.

Fig. I.

Fig. II.

serpentine. The other femics are indicated by the presence of spots of chlorite. The sample is a remarkable example of metamorphism. These metamorphics probably stand out as the most prominent feature of the topography and form all the peculiar types of steep sided hills called huerfanos.

SEDIMENTARY ROCK PETROGRAPHY

Two samples of the sedimentary slides will be chosen as representative of the two types of sediments found upon the area.

Sample No. 1 was taken about 200 feet north of Glen Allen and may be located near the end of the road which runs down the western side of Big Lake. Megascopically it is a coarse grained, light gray sandstone. The sample was taken from a slickensided surface which shows on two of its sides. In certain parts it contains carbonaceous material in large amounts as well as muscovite. Petrographically there is about 60 per cent of quartz, very angular grains, some of them showing a very marked fracturing probably due to the shearing of the fault plane. About 20 per cent of the rest of the fragments are plagioclase and orthoclase, with about 10 per cent muscovite, while the remaining material is the cementing agent and is mostly a carbonate, with some clay.

Sample No. 72 was taken from the second high ridge south of Lake Ten, located definitely under the samples of sedimentary petrography. Megascopically it is an extremely coarse conglomerate of a deep brown color, containing many fragments of a basic nature and some bits of volcanic ash. Petrographically the sample is very arkosic, containing many fragments of pebbles of a basic and acidic nature, all quite altered. The cementing agent is limonite and a carbonate. There are also many fragments of metamorphics mixed in as indicated by the presence of large pieces of the greenstone associated with secondary silica. Topographically the rock stands out as prominent ridges which in some cases may be followed for several miles.

HISTORICAL GEOLOGY

Due to the fact that the fossil remains are very scarce and those that have been found are of a new type of species not described before, and also due to the fact that very little work has been done on the area in the way of a paleontological report, it is difficult to correlate the exact ages of the sediments in most cases. The specimens which were collected, I was unable to identify, and the fossil leaves have been sent to Ralph W. Chaney, University of California. No reply has been received as to the age of the flora for Dr. Chaney will be in the field all summer. The invertebrate fauna were sent to Ralph B. Stewart, Philadelphia Academy of Sciences. Likewise no reply has been received as to what these forms are. However from collateral reading and from McLellan's report, to which reference has been made, the following history has been worked out:

Paleozoic Era.-

Permian Period.- Probably the very last stages of the Paleozoic are represented for immediately outside of the area there are great thicknesses of argillites and serpentines, all of which have been highly indurated by quartz, both in the form of veins and also in the form of secondary silica. These sediments are the oldest found near the area and were probably deposited upon an epicontinental sea. They may correlate with the Leech River group. At the close of the Paleozoic there was a marked uplift and extensive erosion took place.

Mesozoic Era.- During the early Mesozoic there were extensive outpourings of igneous material and also extensive amounts were found as intrusives. This is shown by the dacites and pyroxenites that were found. These were brought up probably as a phase of the Jurassic batholithic mass of granodiorite which was accompanied by intensive folding and faulting in Vancouver Island. After this there was a very long period of erosion which removed the roof from vast areas of the batholith. In the map-area the topography of the old metamorphics was extremely rough, and where the later sediments come in contact with it, they seem to have been deposited over a country that was very extensively dissected, and an extremely marked unconformity is observable.

Cenozoic Era.-

Eocene Period.- There has been much discussion about these younger sediments that were deposited in the embayments that came in from the northwest and from the west. They undoubtedly are of a near-shore brackish water phase which is shown by the plant remains. Furthermore they were of a tropical nature as shown by the palm leaves and by the types of gastropods that have been discovered. This formation was probably laid down at the same time as the Chuckanut formation for the fossil leaves are of the same types in both cases, and the sediments undoubtedly are of a marine brackish-water phase as shown by the fossil gastropods and pelecypods. In referring to the Chuckanut formation, the former belief was that it was a fresh water deposit of Eocene age. In regard to this matter reference is made to the work done by Newberry* who compared the fossil leaves taken

*Newberry, J. S. Description of the Fossil Plants Collected by George Bibbs, Geologist to the United States Boundary Commission under A. Campbell: Journal of the Boston Society of Natural History, Vol. 7, pp. 506-525, 1863.

from the Upper Cretaceous rocks to the south of Point Doughty on Orcas Island with those from the Chuckanut formation and decided that they were identical and of Upper Cretaceous age.

Recent work has been done by Knowlton on these two areas, and he has placed the rock formations in the vicinity of Bellingham Bay in the Lower Eocene. He believes that they are different from those found on Orcas Island. McLellan, however, has found marine Upper Cretaceous fauna interbedded with the strata found on Orcas Island. Both forms are very different from those found around the vicinity of Seattle in the Eocene.

Immediately after the lower beds were deposited, there was either an uplift of the land nearby or else a sudden uplift of the sea bottom although the continuity of deposition was not broken for no unconformities were noted in the field. At any rate the sediments become markedly coarser and very conglomeratic in some cases. Much ash was mixed in during this time, and the younger igneous flows and sills came into existence, which were both dacites and basalts. These volcanic series may probably be correlated with the Metchosen volcanics of Upper Eocene age. The sediments containing these volcanics are probably about 2,000 feet thick, 1,000 feet of which are exposed on the face of the fault scarp wouthwest of McMurray. This mass of sediments was probably laid down on a topography very similar to that of the present time, having many high metamorphic knobs sticking up through the sediments and even up above sea level as the islands of the San Juan group are doing now. At the close of the Eocene the whole region was uplifted above the sea and perhaps slightly folded and faulted.

Oligocene Period.- No sediments from this period are found, and the area must therefore have been above sea level.

Miocene Period.- While the Cascades were being formed the region was greatly uplifted and faulted, and the evidence brought out in this paper would indicate block faulting had occurred in several instances rather than folding.

Pliocene Period.- During this period the mass was greatly eroded and dissected into the present rough topography.

Quaternary.-

Pleistocene Period.- Evidences of glaciation are extremely abundant in the area, and in various places the dacite still shows slickened surfaces, notably on the east shore of Devils Lake. However it did not greatly affect most of the topography, and there is no evidence found in the area that would indicate that more than one glacial advance had occurred. However, as the ice retreated, the valley in which Big Lake and Lake McMurray are situated contained a temporary lake with the drainage to the southeast of the present Lake McMurray. Several small deltas were noted as being formed at the mouths of the small streams entering the southeast side of this temporary lake near Ehrlich, their tops coinciding with the 250-foot contour. Also a very nice gravel deposit is found on the flats due west of Big Lake. When the glacier retreated beyond the huerfanos to the north of Big Lake, the natural drainage of the temperary lake was resumed to the north and out by Mount Vernon, leaving the two lower depressions occupied by water to form the two present lakes.

Recent Period.- Nothing of note has happened since the last glacial advance except the formation of the Skagit

River Delta.

ECONOMIC CONSIDERATIONS

The economic values of the area have been principally in timber, wonderful stands of which have been cut off leaving a very ragged countryside. At present there are no economic resources found.

There has been some coal prospecting, notably immediately above McMurray in the face of the hill to the southwest, but the seam is only about two and one-half to three feet thick and of a very poor quality. Several other prospects are to be found over the area, but nothing of importance. One mine, notably the Blumond Coal Mine, was started by local capital. A shaft was sunk to considerable depth and several drifts were sent into a small seam, but the area has been so badly faulted and the coal is so poor that operation was stopped. The tipple still remains.

There is a small clay pit about two miles north of Big Lake in which some clay has been removed for brick making, but nothing is being done there at present.

Agriculture is the only thing that may be attempted at present, and that is on a very poor basis as has been explained before.

One vein of iron pyrite was found, which was assayed, but no values were shown beyond a small trace. Also a sample of the gossen-like outcrop was assayed with the same result.

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AREAL GEOLOGY
R.4E.
R.5E.
T.34 N.
T.33 N.
T.32 N.
48°
Nookachamps Creek
East Fork
BM 147
Big Lake BM 95
Big Lake
Montborne
Walker
Valley
Lake Ten
Davis Lake
Ehrlich
Lake Sixteen
Lake Mc Murray
McMurray
BM247
BM259
BM354
LEGEND
SEDIMENTARY ROCKS
Recent
SKAGIT RIVER DELTA DEPOSITS
Sand, clay, silt and alleuvium
UNCONFORMITY
Pleistocene
VASHON TILL
Glacial till, outwash and delta deposits
Quaternary.
UNCONFORMITY
Eocene?
PUGET FORMATION?
Arkosic, coarse and fine grained sandstones and conglomerates light colored to reddish brown and greenish, with admixtures of tuffaceous material in the upper members.
Tertiary?
UNCONFORMITY
Mesozoic
METAMORPHIC SERIES
Composed of greenstone and highly altered igneous intrusives and sedimentary material.
Pre-Tertiary
EXTRUSIVE IGNEOUS ROCKS
Eocene?
Dacites and basalts with differentiations porphyritic.
Tertiary?
Scale 1/31250
1/2
1 Mile
Contour interval 50 feet.
Datum is mean sea level.
TRUE NORTH
MAGNETIC NORTH
24°
Approximate mean declination 1909.