THE DEVELOPMENT OF A GNEISS ZONE
IN THE FLIN FLON
AREA.

By

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INTRODUCTION.

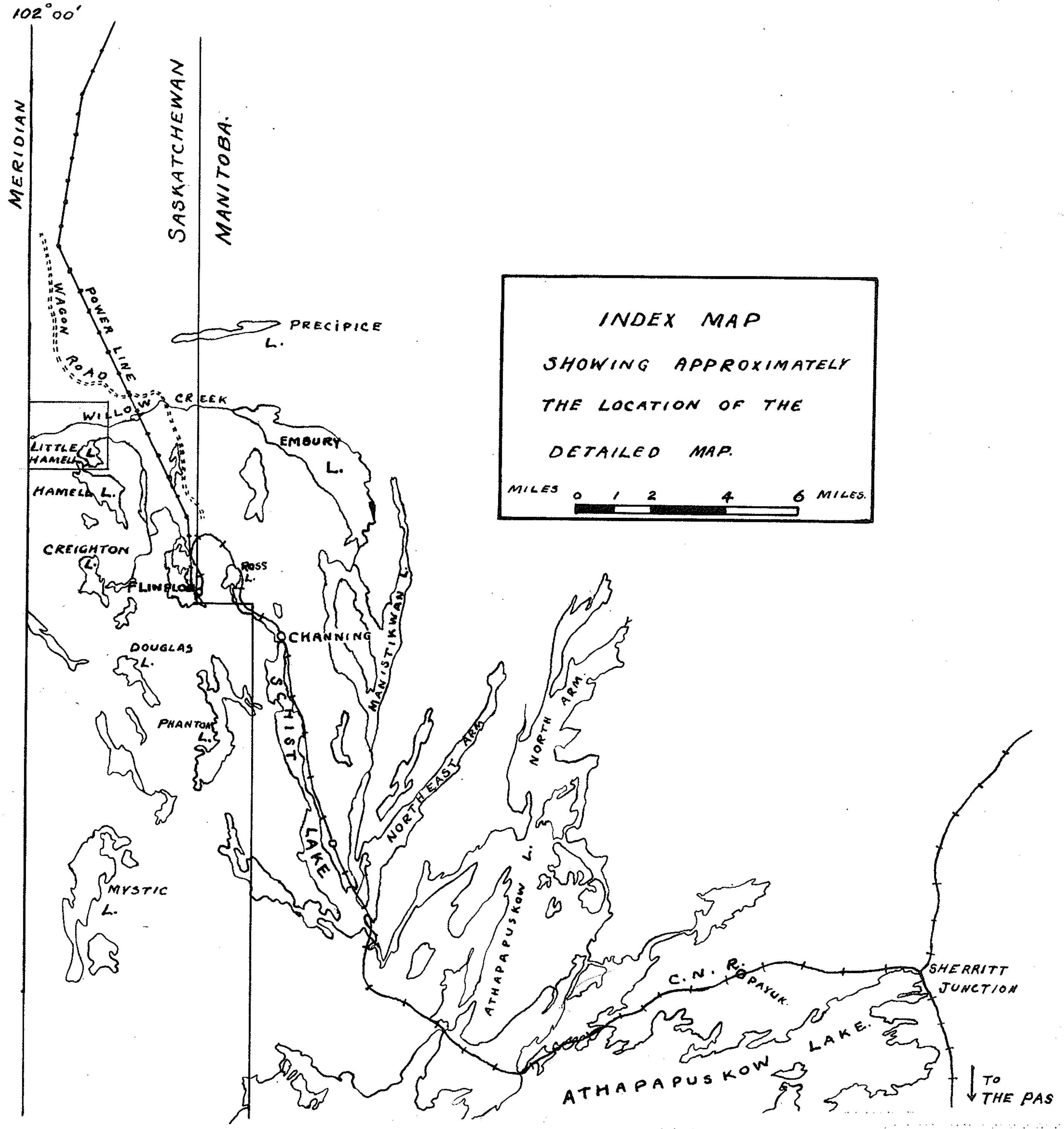
The Flin Flon Map area roughly occupies a rectangle of about two hundred square miles, with the mining town of Flin Flon occupying a central position. It is bounded on the West by the second meridian, which is marked by a monumented survey line, running due North and South.

The area discussed in the present paper is situated immediately east of the meridian, near the northwest corner of the Flin Flon Map area, along Willow Creek, as shown in the accompanying index map.

There are several routes by which the area may be reached. The route used while mapping the area, during the summer of 1935 was to start on foot from the northwest corner of the main body of Flin Flon lake, proceeding west to the valley occupied by Creighton Creek. This valley may be followed northward to Beaverdam lake, on which, about two thirds of the way up, is an old portage trail running west, across to Hamell Lake. From there, it is but a short distance by canoe to the north end of the lake, and through a small creek across to Little Hamell Lake. Camp was made at the head of the long narrow bay at the northeast corner of the lake. A portage trail leads in a northwesterly direction to a point on Willow Creek, which is about two thousand feet south of the main body of the Meridian gneiss. Access may be made to the area by taking the Hudson Bay Mining Company's electric railroad, known as the "flux line," where it crosses Willow Creek, and travelling westward following the creek. This creek is not readily navigable as it is, through out most of its length, overgrown with willows and in places is quite shallow.

The work in the field was carried out plotting the data directly on aerial photographs, taken at ten thousand feet. Flights were made east and west, with a good overlap both within and between flights. In the flight covering the area just north of Willow Creek, a gap was left from the Meridian east, for about twenty-five hundred feet. Here, the outcrops were sketched in by pace and compass traverses tying to the flight immediately south, and the flight to the north of the gap.

The topography is typical of the Pre-Cambrian in this part of the country with a relief rarely exceeding fifty feet. Willow creek follows a large, somewhat swampy valley which is probably of structural origin. Another area of swamp lies just north of the intrusive, paralleling the regional trend of the structure. The outcrops are somewhat scattered, and generally low lying, elongated in the direction of regional strike. Breaks in the outcrops may be caused by local structures, but in the main are due to changes in lithology. Discontinuities along the strike are often caused by a fingering out of the relatively hard silicified material. The outcrops in the sediments are more scattered than elsewhere, many of them being quite small. This is due largely to the incompetent nature of the sediment, which is more easily eroded. Larger, more closely grouped outcrops are found in the zones of hard silicified tuffs and gneiss.



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WAGON ROAD
POWER LINE
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GENERAL GEOLOGY.

The regional strike of this section is approximately East-West, with a fairly consistent north dip. Following the structure eastward, especially in the belt of Missi sediments, the strike takes a rather abrupt swing south, and along Beaverdam Lake the strike is north-south. The Missi sediments, which are here largely greywacke and conglomerate, with occasional tuff beds, especially near the top, rest upon the eroded surface of a complex of volcanic material and granite. Passing north, or upward in the sediments, tuffaceous material becomes more prominent, eventually grading through to rock that is entirely of volcanic origin. The well-bedded tuffs pass into a silicified which grades through to granitized tuff and gneiss. North of the gneiss, the same sequence as to the south is present, grading through to relatively unaltered tuffs and flows. The granodiorite porphyry is in contact with the volcanics in this section. Toward the northwest corner of the area, north of the gneiss are rhyolites and rhyolite breccia, but in the main, throughout the area, the tuffs represent a basic series which is very high in hornblende.

THE LOWER WILLOW CREEK FORMATION.

The Lower Willow Creek Formation occurs in a narrow band along Willow Creek. At the western limit of the map area it rests on upper Missi tuffs and tuffaceous sediments, whereas to the east it rests on sediments with a small tuffaceous content, not readily recognized in the field. The difference in character in the field seems to be due to a lateral change in the same stratigraphic horizons, but as there is an important break between the two formations, the rocks in the two localities may be of different ages. The Lower Willow Creek Formation in the west is made up largely of inter-bedded conglomerate with a tuffaceous matrix, and tuffs. At Willow Creek, the basal part is largely conglomerate with little or no readily apparent tuffaceous content. Higher, however, the tuffaceous content becomes more and more marked, and tuffs become more abundant; tuffs are more abundant throughout the western part of the area.

The tuffs, for the most part are finely bedded; they are dark gray, hard and brittle, dense to fine-grained. Some, especially in the upper part of the formation are green to brown, and somewhat softer, made up largely of actinolite. This difference is due in part to later alteration, an induration associated with the formation of gneiss. The softer tuffs are made up almost entirely of amphibole, which is mainly actinolite. The original feldspars have, almost without exception been altered to epidote and zoisite, by some hypothermal alteration earlier than the gneiss. Epidote and zoisite may in part be an original constituent of the tuff. The conglomerates with a sedimentary matrix are relatively soft, and as a rule are considerably sheared. In some places, as over the crests of sharp folds, the boulders are drawn out beyond recognition; here the rock is a gneiss. With a greater tuffaceous content, the conglomerate is much harder. Throughout the lateral extent of the formation, there are coarse conglomerates with boulders which were probably six inches in diameter before being drawn out into their present lenticular shape. There is much the same variety of materials constituting the boulders as occurs in the lower Missi.

This formation shows an unusual development of red garnets as compared both to the Missi below and the Upper Willow Creek Series above. South of Willow Creek, where the strata are involved in a series of sharp overturned folds, the conglomerate horizons, probably with a small tuffaceous content are exposed directly below a series of hard tuffs. The conglomerate has been highly metamorphosed into a garnet gneiss. In places, in the axes of folds, fifty percent or more of the rock is garnet; its original conglomeratic character is no longer apparent, and it resembles the garnet gneisses which are common in other parts of Manitoba and Saskatchewan. Down the limbs of the folds, the abundance of the garnets and the intensity of alteration decreases, so that within one hundred feet, the same horizons, where not badly deformed, show no readily apparent garnets. Garnets occur in the overlying tuffs, though not so numerous, and their abundance bears the same relationship to the folds as found in the conglomerate. Elsewhere garnets were noted, in the conglomerate, in the conglomerate with a tuffaceous matrix and in the tuffs. They are generally best developed along certain horizons--in places these are conglomerate beds or below or between tuffs, elsewhere they may be tuffs, which are not greatly different in appearance from the overlying and underlying beds. In places it was noted that lower conglomerates generally less tuffaceous carried fewer garnets than the higher ones. Garnets were also noted in tuffs overlying conglomerates in which none were found. The strata are all steeply dipping; in most places where garnets were found to be abundant, there is clear evidence of minor folds, but in a few, the strike and dip were uniform.

The evidence suggests that the development of these garnets was in direct proportion to the intensity of folding and was greatest in this formation because of the marked difference in tensile strength between the hard silicious tuffs and tuffaceous sediments, conglomerate, and other materials present. Strata readily sheared, such as the conglomerate with a soft, sedimentary matrix when enclosed between strong tuff or tuffaceous sediment beds, and intensely folded, apparently provided the most favorable place for the development of garnets.

Careful search disclosed may outcrips of the underlying Missi and a few of the overlying Upper Willow Creek tuffs with small scattered garnets, but in many cases none were found. In the Upper Willow Creek series, garnets were noted largely in the basal, more silicious tuffs. Higher in the series, small garnets were noted microscopically in sheared flows. No garnets were noted in any formation near the Meridian gneiss or the porphyritic granodiorite. Therefore they do not appear to be related to these. The only apparent controlling factors are the relative abundance of silica, the extent of deformation and of shearing or pressure due to differences in competence of the strata.

The Lower Willow Creek series varies from a tuffaceous sediment, near the base, to a rock composed of ninety-five percent or more actinolite. The tuffaceous sediments are composed chiefly of quartz and horneblende, with grains of feldspar varying from orthoclase to andesine. The majority of the tuffs in this zone carry a small percentage of sedimentary material. Feldspar and biotite are more abundant in the underlying formation, in the Missi series proper. The grains are mostly subangular to sub-rounded, with a somewhat elliptical shape, due in part to shearing. The tuffaceous constituents are largely ragged fragments of hornblende, and zoisite. These fragments are, in general larger than the accompanying sedimentary material. Higher in the series, the tuffaceous material becomes finer as well as that of the sediment. Where shearing has been intense, the hornblende has been reduced to talc; usually, upon such shearing, garnets were also formed. Tremolite also has been developed from the hornblende by shearing, and was noted where the garnets were quite abundant. Iron and alumina were probably used in the formation of garnet.

Higher in the series, the percentage of tuffaceous material increases markedly until there is little or no felsic mineral present, the rock originally being a hornblende crystal tuff. Where the tuff has not been silicified, the original hornblende has been altered to actinolite, by some later stage of alteration, while the residual bands of hornblende in the silicified zones have escaped this alteration. The actinolite rocks are both massive and schistose. In the massive type a banding is present that may represent original bedding. There is an alternation of coarse and fine fragments, not oriented, and show no evidence of shearing. Epidote and Zoisite are quite common in the tuffs and may in part be original, but also may represent original feldspar, which were altered to epidote and zoisite prior to the formation of the gneiss. In this series there has been some local silicification, which may or may not be, associated with the silicified zones to the north.

The Lower Willow Creek Formation is probably in the main between forty and seventy feet thick. Deformation and lateral variations make it impossible to determine to what extent the thickness changes, and to what extent parts now included in the Lower Willow Creek Formation correlate with the Upper Willow Creek or Missi series.

THE UPPER WILLOW CREEK SERIES.

The Upper Willow Creek Series occurs mainly north of Willow Creek. Its description is made difficult by complex structures in places, by extensive alteration due to the formation of the Meridian gneiss and to lateral variations in character.

From the Meridian nearly to Willow Creek, the part of the Meridian gneiss consists almost entirely of well-bedded tuffs. Rarely more massive beds which appear to be flows occur. The tuffs in the lower part of this series are mainly hard, dark-gray materials such as occur in the Lower Willow Creek series. Higher up, however there are more green tuffs, many of which are very soft. In places the lowest tuffs carry scattered pebbles and boulders. Above the basal part of the series there is a section which is rarely exposed, probably being more susceptible to erosion. These in part are known to be soft schists of chlorite and actinolite. In one outcrop, well to the west, there are light gray, dark gray, brown and black carbonate beds. Some contained small lenses of quartz believed to be quartz pebbles, and most, on weathering, left a quartz sand. It is thought to be likely that beds of limestone, and calcareous and dolomitic tuffs are continuous in this lower section of the series, at least toward the east. The strata here are rusty in places, decomposing readily and there may be some non-calcareous sedimentary beds especially toward the east. Some of the tuffs higher in the series carry small pebble-like lenses of quartz.

From just north of Willow Creek, near the third rapids east of the Meridian, going eastward the hard basal tuffs are succeeded by a gap of no exposures, traversed by a fault. Overlying, the same tuffs as found to the west continue, but are restricted to narrow bands between which are interbedded materials of a different character. These include carbonate beds similar to those found to the west, in about the same stratigraphic horizon, and a variety of materials ranging from true sediments such as occur in the upper part of the Missi, through various intermixtures to the tuffs. Many of these beds contain pebble-like lenses, and grains of quartz. The lenses are very abundant in places and sufficiently large to represent original boulders. The changes in character which become more pronounced toward the east because of interbedding, quite intimate in places, are clearly due to lateral variations along the same horizons: a decrease in tuffaceous content, and an increase in the products of complete weathering. In the upper part of the series mapped, in the east the tuffs continue, but toward the east flows are interbedded, and in the highest part of the series are the dominant rock. They are light to dark green, and grade from dense to moderately coarse dioritic texture.

The tuffs of this series are microscopically quite similar to those of the lower Willow Creek Series. In general they are fine, even textured rocks, quite high in hornblende. Near the base some horizons contain a small percentage of sedimentary material, but higher in the series, where there has been no alteration, the tuffs as well as the flows are dominantly hornblende or actinolite. Epidote and zoisite are quite common in part representing the alteration product of the original feldspars.

Alteration of the tuffs has been chiefly silicification, with minor quantities of orthoclase and acid oligoclase; the feldspar content becomes higher as the zone of gneiss is approached. Some horizons show a development of dark greenish tourmaline, usually in localities where there has been considerable shearing. The tourmaline occurs in both tuffs and flows. The occurrence of this tourmaline does not appear to bear any relation to the proximity of the intrusive granodiorite, and no tourmaline was noted in the main body of the gneiss. In one locality where tourmaline was notably abundant, red granitic stringers composed chiefly of quartz, microline and orthoclase were quite numerous.

In others, this relationship was not observed. Near the northern edge of the gneissic zone and within the silicified zone, rare tourmaline was noted in highly sheared massive volcanics, probably a flow, which had been somewhat granitized. Here, where the shearing was intense the rock was reduced to a talc schist, bearing a few scattered crystals of garnet and of rare tourmaline. Within two hundred feet west, along the strike, there is no silicification or granitization, little or no shearing, and no garnet or tourmaline. The rock here is almost entirely actinolite, with the original feldspars altered to epidote. The original rock appears to have been a basic flow. The tourmaline crystals in every case are aligned, parallel to the shearing, and are present in the form of long unbroken prisms. Tourmaline is enclosed by talc in one case. The feldspars, though drawn out to an augen shape are not badly altered. They are, as in other granitized zones, mainly orthoclase and oligoclase. Large fragments of magnetite are present in this rock, probably representing an original constituent of the flow. From this data it appears that shearing followed granitization, tourmaline being introduced at the same time as shearing. The formation of garnet was a result of the shearing of the granitized material. This type of shearing is quite local, where the beds are thrown into a series of minor folds.

Toward the northeast corner of the area occurs a small zone of rhyolite and rhyolite breccia. This rhyolite is a fine to medium grained rock carrying from fifteen to twenty percent green hornblende and brown biotite, the former being slightly in excess of biotite, The feldspars are orthoclase, albite, and some oligoclase. Epidote and zoisite occur in the rock and are probably alteration products. There has been some silicification.

Garnets occurring in the Upper Willow Creek Series are confined largely to the lower, more silicious tuffs which carry considerable sedimentary material. The original minerals of these tuffaceous sediments are chiefly green hornblende, quartz, and a variety of plagioclases varying from albite to andesine. Here, as elsewhere the garnets show a corrosion due to later, introduced quartz. Fracturing, subsequent to their formation may have, to a minor extent facilitated this replacement. Pyrite is present in most sections, usually quite minor in quantity, and shows a corrosion similar to that of the garnets, and a general rusty appearance. Pyrite is included by the garnet. Where hornblende is altered to tremolite, the iron and alumina were probably used in the formation of garnet.

Alteration in this series was chiefly silicification and granitization which will be discussed later in the paper. Elsewhere, the alteration is in the form of calcification; calcite stringers cutting through both the gneiss and silicified material, altering the feldspars, chloritizing the biotite, and usually causing a general pinkish coloration. Stringers of epidote are believed to be associated with this same type of alteration, which is quite late.

THE PORPHYRITIC GRANODIORITE.

The porphyritic granodiorite occurs north of Willow Creek along the western boundary of the map area. In a general way it presents a fairly uniform texture which is distinguished by phenocrypts of oligoclase feldspar. This porphyritic texture is noted everywhere, both in the main mass and associated dykes. This porphyritic texture exists right to the contact of the main mass which although never well exposed, appears to be sharp. The porphyritic character was noted everywhere, both in the main mass and the associated dykes. Even in the very narrow bands, phenocrysts were found to be present. The rock is, in the main light gray, locally it is dark, and elsewhere it is pink. In most places it shows some gneissosity and might be termed gneissic, while in others, there is practically no banding. Possibly in the centre of the mass, beyond the areas examined the banding might be absent. The banding does not appear to be related to the contacts. In the main, the rock does not appear to be greatly deformed, though the gneissosity seems to be the result of some deformation. Related sills and dykes, the former being by far the most abundant, are fairly numerous near the mass. They are drag folded and badly sheared in places. The sills and dykes range in size from tiny stringers up to dykes ten feet and more in width. Some of them have a porphyritic texture like that of the main mass. The phenocripts in some cases have not clear cut crystal boundaries, but appear to fade into matrix. This may in part be due to shearing. The abundance of phenocrysts varies, but in the typical porphyry, they stand out on the pink to brown weathering surface as small white knobs.

These sills and dykes sharply cut the Meridian gneiss and in the main appear to be younger. In other places however, the dykes appear to grade to the gneiss and appear to be closely related. The dykes of the latter type are in general more sheared and somewhat altered, and although they are quite similar to the other porphyry dykes in the vicinity they amy represent a somewhat earlier stage of intrusion.

Red and gray granitic sills and dykes, aplitic in character, cut the porphyry sills, and are most abundant near the main mass of the porphyritic granodiorite. They also occur within the main mass, near the contacts and are believed to be related to it. Feldspar porphyry dykes which occur widespread and fairly abundantly throughout the areas to the south are also believed to be related. The porphritic granodiorite cuts the Willow Creek Volcanics, including both tuffs and flows. Generally, nothing was noted which suggested that the porphyry, both main and mass, and some of the dykes and sills had any direct metamorphosing effect on the adjacent rocks.

In this section the main mass of the intrusive shows the porphyritic texture, which is not as outstanding as some of the related sills or dykes. The phenocrysts are of intermediate oligoclase, in a ground mass of medium to fine grained oligoclase and orthoclase, present in approximately equal amounts. Quartz composes from fifteen to twenty percent while ferromagnesians, either hornblende or biotite or both compose from ten to fifteen percent of the rock. Titanite, apatite and epidote are accessories. Idiomorphous crystals of titanite are characteristic of the main mass and sills of the later, relatively unaltered type. Abundant irregular fragments or grains of titanite were observed in all dykes and sills, and also in the gneiss, to a smaller extent. Apatite, in small rectangular crystals, is fairly abundant throughout the area, both in the intrusive, silicified tuffs and gneiss. Epidote occurs both in the dykes and main mass, quite frequently having grown around a nucleus of allanite. Allanite is found elsewhere, in the main intrusion of porphyritic granodiorite and related porphyry sills of both types, as idiomorphous yellowish brown zoned crystals.

The porphyritic dykes and sills of the area, related to the granodiorite porphyry, appear to fall into two groups. The first is a group of quite fresh rocks, little sheared, and very similar to the main mass, except that in the section examined, no hornblende was noted. Biotite is the chief mafic constituent. This group is characterized by large abundant phenocrysts similar to those of the main mass. The second group is one of a somewhat similar type, of a porphyritic character, but with fewer phenocrysts. The twinning in the phenocrysts of the first group is rather distinctive, with considerable pericline twinning, and have grown with repeated albite twinning in different directions. This was not noted in the second group. The ratio of feldspar to quartz is about the same. The femic mineral content is somewhat higher in the second type, which may in part be due to assimilated volcanic material. Biotite in this group makes up about twenty-percent of the rock. These dykes are generally quite dark in color and considerably sheared, which has rounded and reduced the clearness of outline of the phenocrysts. Titanite and allanite are present, the latter being occasionally in well formed crystals

Here, as in other porphyry, both main mass and sills, allanite forms a nucleus around which epidote has grown with fairly distinct crystal boundaries. In some cases allanite is zoned and in others zoning is absent. The feldspar phenocrysts in these rocks are characteristically corroded, and altered, epidote replacing the feldspar, accompanied by some silicification or replacement by quartz within the rock. In places fine pegmatitic stringers traverse the rock locally developing crystals of orthoclase with abundant quartz. Dykes of this second group appear to grade directly to the gneiss with no apparent sharp contact. The abundance of phenocrysts increases and toward the centre of the porphyry band it becomes more like a typical dyke rock. Near the contact the altered volcanics (gneiss) and porphyry are quite similar in compostion with odd scattered phenocrysts in the porphyry and relatively more epidote and biotite characterizing bands of altered volcanic material. Alteration here appears to have been effected by the injection of narrow bands of porphyry material into the tuffs and an almost complete alteration of the intervening bands of tuff.

The aplitic dykes and sills in the area are made up chiefly of microcline, quartz and orthoclase, in order of abundance. Minor constituents are chlorite, titanite, and apatite. These dykes are relatively fresh and unaltered with no evidence of extensive shearing. Reddening is due to the presence of iron oxide.

The evidence points to at least three stages of igneous activity associated with the main body of granodiorite porphyry. The earliest was probably the intrusion of the dykes directly connected with the formation of the gneiss, which was formed at this time. A late stage of alteration may have caused the alteration such as found in the earlier dykes. Following this, the main mass of the granodiorite porphyry along with the later sills was intruded into the volcanics north of the gneiss. This stage was accompanied by little or no metamorphic effect at the contact. The last stage was the injection of the aplitic dykes.

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THE MERIDIAN GNEISS AND BORDERING HIGHLY GRANITIZED AND SILICIFIED ZONES.

The Meridian gneiss and bordering highly altered zones occur within the Upper Willow Creek Series. The Meridian gneiss, over considerable areas is a uniform gray to pink material which on the weathered surface shows drawn out grains of quartz. The rock is finely banded in places, shown by an alternation of light and dark bands of mineral. In places as many as twenty-five bands to the inch may be counted. Within the borders of the gneiss are bands of material as occur in the bordering altered zones, and the gneiss, in places, occurs within these. Proceeding away from the gneiss, granitization becomes less pronounced and silicification is the main type of alteration. Here the rock is mainly pink weathering, but frequently is a very hard light gray rock. To the north there are dark coloured gneisses as well as silicified and granitized volcanics.

In approaching the Meridian gneiss from the south, the first notable change in the tuff series is, that instead of dark green and gray tuffs which are mainly soft, some of the beds are gray to faded green, hard and silicious. In the field this change might normally be attributed to a change in the original composition of the tuffs, but the characteristic is so closely related to the gneiss, and with fairly distinct lateral variations, that the reasonable conslusion is that the tuffs have been silicified.

Much more definite evidence is found in the presence of pink weathering material. For as much as five hundred feet from the highly altered zone, in both dark and light tuffs there are occasional beds, groups of beds or parts of beds which weather pink and are light gray to pink of the fresh surface. These are quite hard and appear to have been silicified. In places the changed appearance follows a single narrow bed for many feet, even if the strata have been intricately folded. Elsewhere it will follow an irregular bed on either side of a fracture crossing the bedding. In places the changed part is sharply set off from the other rock, mainly along the bedding planes, where the gradation takes place over long distances. The evidence of many localities indicates that the tuffs have been altered along the bedding, in and near the gneiss. Shearing may have, to some extent guided the solutions which caused the alterations. Isolated patches occur, not apparently related to fractures or structures.

Within the highly silicified and granitized bedding is as well preserved, as in the original tuffs and in places is accentuated. Locally there is a considerable development of epidote and quartz in irregular veinlets and masses. Within the southern silicified zone there are local bands and irregular masses of the gneiss which occupies the area to the north. This gneiss becomes more and more abundant northward until it is continuous. In all localities the clearly granitized volcanics appear to grade to this gneiss and at no place was a contact suggestive of sharp intrusive relationship observed.

Locally, highly granitized volcanics and gneiss appear to grade to sills of feldspar porphyry. These sills, as discussed earlier are probably of a much earlier stage than the main intrusive and accompanying sills and dykes which show sharp intrusive relations. Gradational contacts were noted within the gneiss or highly granitized material suggesting a relationship between the earlier type of sills and gneiss. This belief is supported by a study of the thin sections which show a distinct gradation through from feldspar porphyry to gneiss and finally granitized volcanics.

North of the gneiss, through to the relatively unaltered tuffs, much of the same relationships are found as to the south except that there is much less red weathering material and a greater variety of materials with dark, banded gneisses becoming more abundant. The differences may appear to be much greater than they actually are, because the red coloration may mask characteristics which would be readily apparent if it were absent. The reddening seems to be a late development, associated with quartz epidote and calcite stringers which is later than the gneiss and not an important feature of the alteration. Some of the beds north of the gneiss are merely silicified tuffs of pale green or gray color, a few of which are pink or red. With these are bands of coarse gneiss containing an abundance of dark hornblende bands of light colored gneiss of the common type, with various intermediate types between these and the silicified tuffs and relatively unaltered tuffs. There are also some very dark green bands of what appear to be ultra-basic material occurring in very irregular masses. They do not look quite like dykes, yet they appear to be later than the alteration.

Some masses of this type are lenticular as of boulders. Peculiarities of this zone may in part be due to a difference in original materials including the presence of dykes and of breccias.

A microscopic study of the gneiss and bordering highly granitized and silicified zones supports the belief that they have been produced by the injection of granitic stringers, with relative abundance of quartz to feldspar increasing away from the main gneiss zone. Every stage of the alteration from slightly silicified volcanics to highly granitized material and gneiss has been observed in thin section. The less intense phases are mainly silicification along the bedding planes, with a corrosion of the original material, which is largely hornblende. Occasional introduced feldspar occurs within these zones. In some places the silicification has been intense, the original rock having been almost totally replaced by fine uniform quartz. These zones carry some biotite which may be an alteration product of the original hornblende. Hornblende is partially altered to biotite along the edges of silicifed bands, while in the central part of the silicified band, biotite alone is present. The volcanic material, which is largely hornblende, between the silicic bands have been replaced, and has in general, a moth-eaten appearance. Epidote and zoisite remain unchanged in the silicified bands. Occasional titanite grains are present in the silicic material.

Approaching the gneiss, granitization becomes more important. Here, the granitic materials are introduced as a type of lit-par-lit injection, cutting across the beds in places, and replacing the intervening bands of volcanic material, with the formation of biotite as described above. The feldspars are mainly orthoclase and acid to intermediate oligoclase, with the quartz form fine to medium grained bands. Titanite is occasionally present, though not nearly so abundant as in the porphyritic granodiorite. Apatite is quite abundant both in the silicified, granitized and gneissic material. Locally quartz comes into the gneiss at a late stage in the form of veinlets, or irregular lenses.

Calcite is quite common in the rocks of this vicinity, cutting the gneiss in small veinlets, frequently following fractures across the banding. In places calcite replaces the feldspar, and in almost all cases chloritization of the biotite accompanies the veinlets. Where calcite is absent, little or no chlorite was observed.

Within the central area of the gneiss, the rock in the main has a uniform appearance. There is little or no suggestion of bedding or banding due to the different textures and compositions as in most gneisses. There is, however a definite trend to the gneiss due to the orientation of the quartz and other grains. In some cases streaks of the original material aid in bringing out this regional trend, which is found to be parallel to the bedding in the adjacent silicified and granitized tuffs.

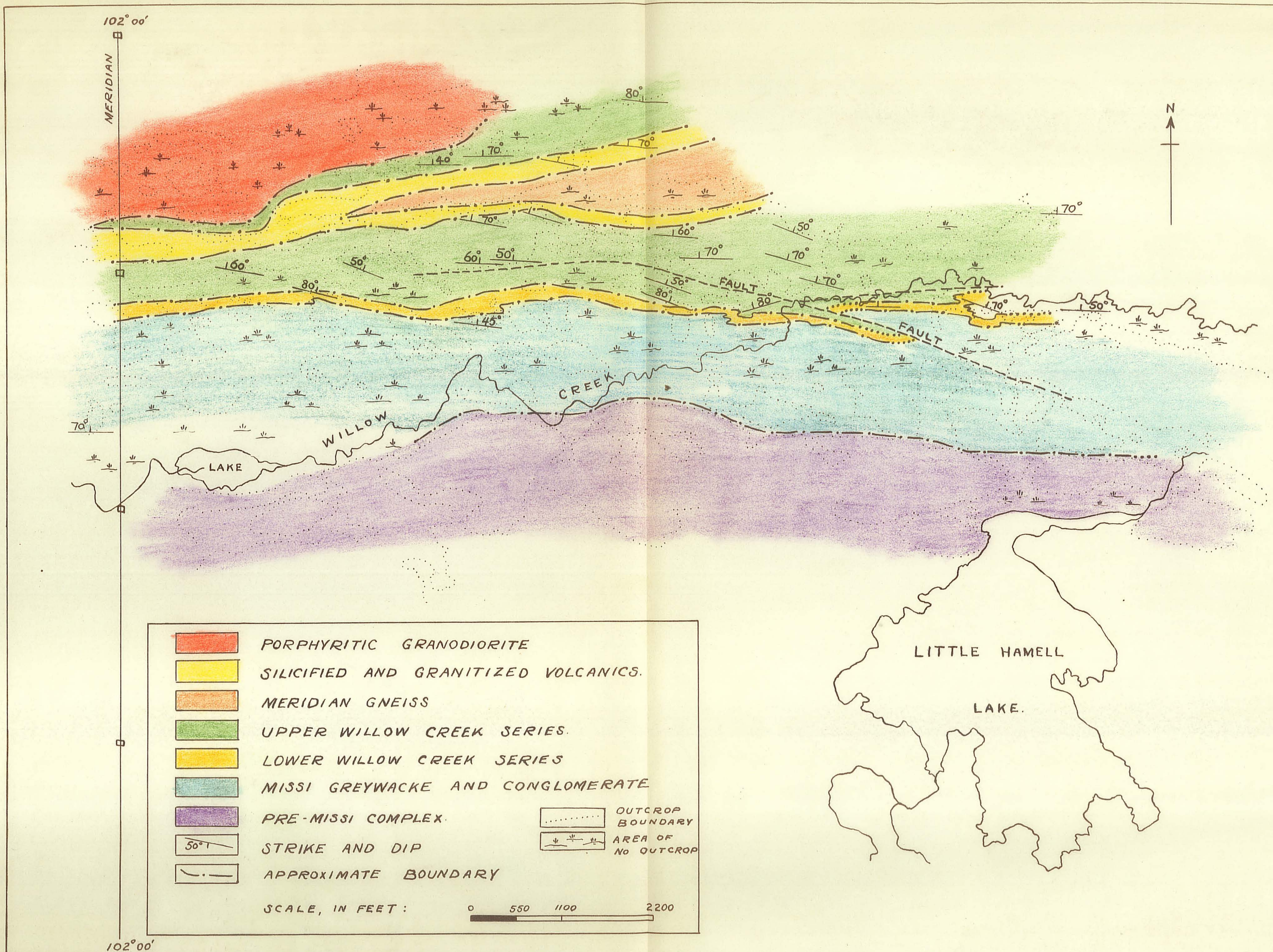
CONCLUSION.

The highly silicified and granitized tuff zones and the gneiss appear to be within the Willow Creek Series. Along the strike in many places, relatively unaltered hornblende tuffs grade through the various stages of alteration to the silicious gneiss. In a general way the strikes of the bedding parallel the southern boundary of the altered zone, and of the gneiss.

To the north, all the strikes are similarly parallel, but in both cases the trend of the bedding is oblique to the boundaries. As previously noted, other than for minor overturned folds which are abundant in places, the series appears to be mainly right side up and to represent a continuous succession. Where the Willow Creek tuffs are complexly folded, there is no evidence of much greater alteration, gneissosity or schistosity than elsewhere. Some of the dark gneisses to the north may, in part owe their gneissic appearance to shearing, with some silicification or granitization. In general no evidence was noted which would suggest that the gneiss was of an intrusive origin. It is believed therefore that the Meridian gneiss and bordering zones of altered tuff are the result of silicification and granitization of the Willow Creek tuffs.

The remarkable similarity in mineral content of the porphyritic granodiorite and the gneiss indicates a relationship between the two. The gneiss probably represents an early phase of the intrusion with the zone of tuffs providing the most ready channels for the granitic solutions. The granodiorite porphyry was not guided in a similar manner, but passed upward into the relatively unaltered volcanic material.

The age of the development of the gneiss is clearly post Willow Creek and pre-porphyritic Granodiorite. It has not been determined whether the gneiss is later that the main deformation of the Willow Creek Series, but this is believed to be the case, since there seems to be no clear cut evidence of the gneiss body haveing influenced the structure. The shearing and drag-folding of later dykes within the gneiss area however indicate clearly that some later deformation took place.



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MERIDIAN
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FAULT
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CREEK
WILLOW
LAKE
LITTLE HAMELL
LAKE.
PORPHYRITIC GRANODIORITE
SILICIFIED AND GRANITIZED VOLCANICS.
MERIDIAN GNEISS
UPPER WILLOW CREEK SERIES.
LOWER WILLOW CREEK SERIES
MISSI GREYWACKE AND CONGLOMERATE
PRE-MISSI COMPLEX.
STRIKE AND DIP
APPROXIMATE BOUNDARY
OUTCROP BOUNDARY
AREA OF NO OUTCROP
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