GEOLOGY OF VEDDER MOUNTAIN, NEAR CHILLIWACK, B.C.

by

WILLIAM JOHN McMILLAN

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Department of GEOLOGY

The University of British Columbia,
Vancouver 8, Canada.

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ABSTRACT

Vedder Mountain can be divided into three units: the eastern sediments, the crystalline rocks and the western sediments. Both eastern and western sediments are essentially unmetamorphosed whereas the crystalline rocks include both medium grade metamorphic rocks and saussuritized dioritic intrusive rocks. The crystalline rocks are bounded by steep southeast dipping faults.

White mica-amphibole and garnetiferous white mica-amphibole schists and gneisses, amphibolite, epidote amphibolite and garnet-sphene-white mica schists comprise the metamorphic rocks. The mineral assemblages are typical of the almandite-amphibolite facies of Turner and Verhoogen(1960).

Foliated diorites intrude(?) the metamorphic rocks. Basic contact zones, lighter colored diorite dikes, amphibole-feldspar pegmatites and small quartz diorite bodies are thought to represent various phases of differentiation of a parent magma. Pervasive saussuritization characterizes these rocks.

In structural succession, the eastern sediments are comprised of chert, granitic and volcanic pebble and cobble conglomerates with plagioclase volcanic arenite interbeds; plagioclase volcanic arenite with conglomerate interbeds near the base of the unit and argillite interbeds near the top; and micro-volcanic arenite with interbeds of plagioclase volcanic arenite, argillite, chert and siliceous argillite with scattered, impure limestone pods.

In structural succession, the western sediments consist of argillite; micro-volcanic arenite; chert lenticule arenite and volcanic chert arenite breccia which contain a band of impure, cherty limestone; argillite; and chert. Vulcanism produced dacite porphyries which structurally underlie the sediments.

The crystalline rocks comprise a tabular body believed to have been emplaced by faulting. Small, ellipsoidal serpentinite bodies lie along the southeast bounding fault of the crystalline slice.

During emplacement of the crystalline slice, it appears that the sediments were pushed aside in what has been referred to as phase I deformation. Folding in the argillaceous units was "similar" in nature but in the more competent units it was "concentric." The eastern sediments comprise a synform with near horizontal northeast trending fold axis and steep southeast dipping axial plane. The western sediments comprise a steep, southeast dipping homocline.

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Section I - INTRODUCTION

The objectives of this investigation were to determine the relationships between the sediments which comprise the eastern part of Vedder Mountain, the metamorphic and granitic rocks which comprise the western flank of the mountain and the small area of sediments west of the crystalline rocks. Furthermore, an attempt to determine the structural geology of the sediments was to be made in order to ascertain their stratigraphy.

A. Location and Access

Vedder Mountain is a northeast trending ridge, which lies on the western flank of the Skagit Range of the Cascade Mountains. It occurs at latitude 49° 00' and longitude 122° 08' and is essentially isolated, being bounded by Cultus Valley to the southeast and Sumas Prairie to the northwest. The peak of the mountain is roughly eight miles S30°W of Chilliwack, British Columbia.

Access around the base of Vedder Mountain is excellent by means of paved roads. On the mountain itself, a recently repaired dirt-base road near altitude 2,000 feet almost circumscribes the mountain. Branches from this road give extensive access, albeit many are overgrown and not drivable. Away from these roads, numerous burned, fallen snags combined with heavy second growth make travelling difficult and dangerous.

From Vancouver, via the Port Mann Freeway, Vedder Crossing or

Yarrow can be reached in less than two hours. Consequently, it was possible to make trips to the map-area, traverse and return to Vancouver again during the day.

B. Physiography, Topography and Climate.

Vedder Mountain is elongated in a northeast-southwest direction. It varies from about a mile to nearly three miles in width and is roughly twelve miles long. Four miles of its length extend into the United States. Near Vedder Peak, which has altitude 3,029 feet, the mountain is almost symmetrical in cross section. Normally, however, the outline is somewhat skewed, with steeper northwest slopes. The mountain is bounded to the northwest by Sumas Prairie which has average altitude near 50 feet above sea level. To the southeast, it is bounded by Cultus Lake and its valley. Cultus Valley has average altitude near 500 feet and lake level is 135 feet above sea level.

The climate of the Vedder Mountain area is characteristically mild and moist. Mean average rainfall is 62 inches, most of which falls from October to February. Temperature variations from 5 degrees F. to 100 degrees F. have been recorded but the extremes are rare.

No major creek valleys are seen along the northwest flank of the mountain. Along the southeast flank Hatchery, Ascaphus and an unnamed creek 4,500 feet southwest of Lindell Beach occupy the only deeply incised valleys. Traverses in the creek valleys in the map-area are unrewarding because bedrock exposure is poor.

C. Acknowledgements.

Field work for this thesis was carried out during May, 1964, for two weeks in September 1964, and on weekend trips until November, 1964. Costs of the work were defrayed by grants from the President's Research Fund and the Department of Geology, University of British Columbia.

Thanks are extended to Dr. J.V. Ross, who suggested the problem, helped arrange financing of the field work, visited the author in the field, supervised and critically reviewed the work. Useful discussions with J. Monger, who worked east of Cultus Valley, Dr. K.C. McTaggart, Dr. W.R. Danner, Dr. R.M. Thompson and Dr. W.H. Mathews are also gratefully acknowledged. Dr. J.E. Armstrong of the Geological Survey of Canada kindly loaned the author field maps, field notes and thin sections from field work carried out in 1953 on Vedder Mountain.

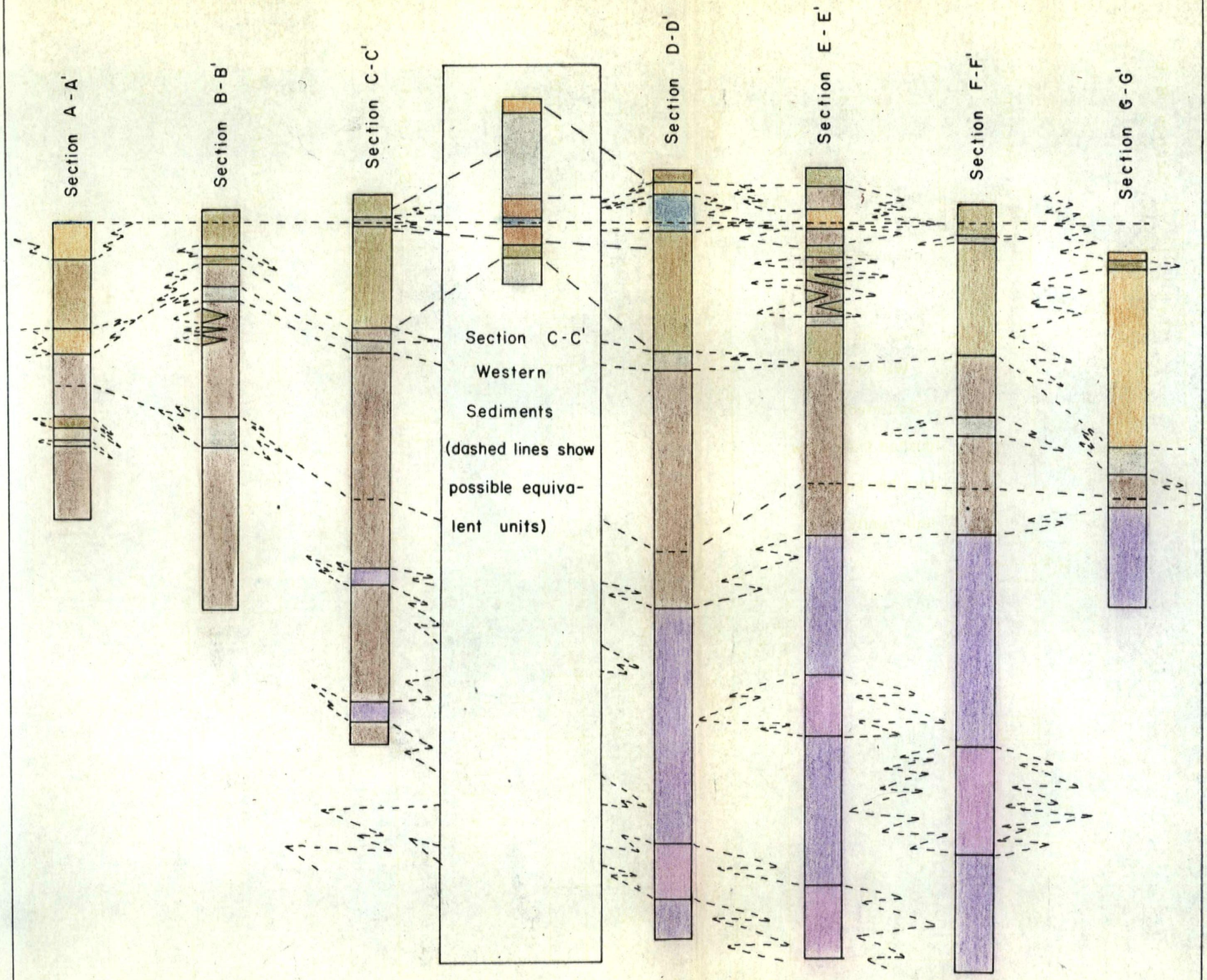
D. Previous Geological Work.

R.A. Daly mapped Vedder Mountain in 1912 as part of his 49th parallel project. He suggested that the sedimentary rocks were members of the Carboniferous or later Chilliwack Series. He grouped the crystalline rocks and called them the Vedder Greenstone. In his opinion, the Greenstone was an altered igneous sill intruding the sediments. Textural differences within the Greenstone were attributed to shearing.

C.H. Crickmay (1930) assigned the sediments to the Slollicum Series of Late Triassic age. He thought the crystalline rocks were altered volcanic rocks conformably underlying the sediments. His map omits the sediments west of the crystalline rocks.

Correlation Chart for Vedder Mountain Sedimentary Rocks

Figure 2



For Location of Sections See Figure I.

For Legend See Figure I.

Scale 1" = 1000'

J.E. Armstrong (1956) on the basis of field work carried out in 1953, suggested that the crystalline rocks were bounded by steep-dipping faults.

D.N. Hillhouse (1956) mapped the eastern side of Vedder Mountain on a reconnaisance scale.

W.S. Moen (1959), working in the Van Zandt Quadrangle, mapped the southern part of Vedder Mountain in Washington State. He correlated the extension of the eastern sediments with the Chilliwack Group. On the basis of pre-Devonian granitic rocks found by Danner (1957) in the San Juan Islands, Moen suggested that the crystalline rocks are upthrust slices of pre-Devonian basement rocks.

Section II - STRATIGRAPHY

The thickness of sediments exposed along the southeast side of Vedder Mountain, hereafter referred to as the eastern sediments, ranges from 2,400 to 6,350 feet. Neither the top nor the bottom of the section was exposed.

Conglomerate with interbedded plagioclase volcanic arenite is the lowest unit exposed. Going upward in the section, plagioclase volcanic arenite becomes increasingly abundant. Finally, conglomerate disappears and plagioclase volcanic arenite with argillite interbeds predominates. The conglomerate-bearing unit has a maximum exposed thickness of 3,500 feet west of Cultus Lake and lenses out about three miles southwest of the lake.

The unit which is predominantly plagioclase volcanic arenite is

only 275 feet thick at the north end of Cultus Lake but rapidly thickens to the southwest and is at least 3,350 feet near the southwest end of the lake. Argillite is more abundant in the upper portions of this unit and forms the upper boundary of it in sections D-D' and G-G'. Occasional thin lenses of micro-volcanic arenite occur in sections A-A' and B-B'.

Throughout much of the area, micro-volcanic arenite overlies the arenite unit. At the north tip of Cultus Lake, however, chert is the overlying rock. Fifteen hundred feet of chert crop out but only one thin interbed of micro-volcanic arenite occurs, that being one hundred feet below the top of the chert. Elsewhere in the map-area, chert occurs as interbeds ranging from a few to three hundred feet in thickness in the micro-volcanic arenite. Near Vedder Peak, three hundred feet of silicious argillite with limestone pods crop out within this unit. Similar limestone-bearing argillite crops out at the crest of the mountain near the International Boundary. In this locality, the argillite is less than fifty feet thick. West of Vedder Peak, plagioclase volcanic arenite interbeds are also prominent. The top of the predominantly micro-volcanic arenite unit is not exposed but it has a maximum thickness of at least 1,450 feet.

The sediments west of the crystalline rocks, hereafter referred to as the western sediments, have a maximum exposed thickness of fifteen hundred feet (Figure 2). Neither the top nor the bottom of section is exposed.

Quartz plagioclase porphyry is the oldest exposed unit of the western sediments. It crops out in a railway cut at the southwest edge of the outcrop area of the sediments where it is 100 feet thick. Overlying

the porphyry is argillite which ranges from 0 to 250 feet in thickness. Micro-volcanic arenite with scattered, thin layers of chert succeeds the argillite. It reaches a thickness of 150 feet in the central portion of the sediments but pinches out to the northeast and southwest.

A striking unit unlike any of the eastern sediments overlies the micro-volcanic arenite. It consists of radiolarian chert lenticule arenite and volcanic radiolarian chert arenite breccia which contain a thin, discontinuous impure cherty limestone horizon. This unit is continuous over the outcrop area of the western sediments and attains a maximum thickness of 400 feet. The calcareous unit varies up to 50 feet in thickness. Despite the distinctive features of this unit, it is suggested that the limestone from it is equivalent to the limestone pods within the silicious argillite of the eastern sediments (Figure 2).

A thick, continuous argillite band overlies the limestone-bearing unit. It is massive to thinly bedded and has a maximum thickness of 700 feet. The uppermost exposed unit of the western sediments is argillaceous ribbon chert. It crops out alongside the highway near the west central edge of the sediments where it is 100+ feet thick.

Near the way station of Sinclair and in a small area further northeast, diabasic to porphyritic volcanic rocks crop out. The diabasic rocks are not in contact with the porphyries so their relationship with them remains uncertain. Similarly, the dacitic porphyritic volcanic rocks are separated from the western sediments so no direct correlation can be made. However, since some of the Sinclair porphyries are identical to the porphyry which underlies the western sediments it seems probably that they correlate in part with it. Furthermore, since the Sinclair porphyries are

much thicker, some are probably older than the western sediments porphyry.

Amphibolites, epidote-amphibole schists and gneisses, amphibole and epidote-amphibole mica schists and granitic rocks underlie much of the western flank of Vedder Mountain. For easy reference, these have been designated crystalline rocks.

The epidote-amphibole schists and gneisses have mineral assemblages which are typical for basic and pelitic rocks from the Almandine-Amphibole Facies of Turner and Verhoogen (1960). These medium grade metamorphic rocks predominate northeast of Sinclair.

Southwest of Sinclair, the metamorphic rocks have been extensively invaded by granitic rocks. Foliated diorite in which feldspar has been completely saussuritized is the predominant granitic rock. Where shearing has been of little importance, original crystal shapes are pseudomorphed. Where shearing has been important, original crystal shapes have been destroyed. Cataclastically foliated quartz diorites illustrate the latter case. Near intrusive-metamorphic contacts dark-colored dioritic rocks and pegmatitic plagioclase-amphibole rocks crop out.

Along the eastern contact of the crystalline rocks, several ellipsoidal bodies of serpentinized peridotite crop out.

A. Eastern Sediments.

The following discussion is intended to give a fairly detailed picture of the various rock types which comprise the eastern sediments. They are covered as near as possible to the order in which they were deposited.

a. Conglomerates.

Conglomerates interbedded with volcanic arenites comprise the east flank of Vedder Mountain from the shore of Cultus Lake adjoining the water-manship Training Area to two miles southwest of Lindell Beach. West of Hook Point on Cultus Lake conglomerate outcrops are found up to an altitude of 1,700 feet above sea level; northeast and southwest they crop out at lower altitude as the conglomerate bearing unit thins laterally.

Detailed mapping within the conglomerate-arenite unit has not been carried out. From available data, however, it can be stated that conglomerate beds range from a few to several hundred feet in thickness. The conglomerates were massive and all attitudes recorded are conglomerate-arenite contact zones. Where contacts are exposed, undulations suggest that the arenite was eroded prior to or during deposition of the conglomerate. Whether these readings represent foreset beds or regional beds is not certain. However, thin arenite beds continuous over 50 feet with no thickening or thinning weigh against the likelihood of the unit being cross bedded.

The matrix of the conglomerates is very similar to the arenites with which they are interbedded. Ignoring the pebbles, the matrix would be classified as an immature plagioclase volcanic arenite using Folk's (1961) classification. Grains within the conglomerate matrix are angular but not quite so angular as those from the arenites (Plate 1).

Pebbles and cobbles from the conglomerate are characteristically well-rounded. Cobbles often display high sphericity as well. In general, as the diameter of the pebbles to cobbles from the conglomerate increased

so also did the roundness and sphericity.

Chert, granitic and volcanic pebbles and cobbles are present. Most of the chert is pale green but occasional jasper pebbles occur. Granitic rocks range from hornblende granodiorite in which feldspar has been extensively saussuritized to micromyrmekitic granite which contains clear, often embayed high temperature quartz and unaltered albitic oligoclase, An_{24}, phenocrysts. The volcanic rocks are quite variable. For instance, one well-rounded cobble consisted of equant fragments of volcanic quartz and angular devitrified volcanic glass fragments in a pale green glass matrix; another was derived from ophitic lava. Porphyries often with quartz and/or albite phenocrysts are the commonest volcanic rocks.

Relative abundance of the various rocks which comprise the pebbles and cobbles varies from place to place but the present study was not detailed enough to outline zones of distribution. Granitic pebbles seem to be most abundant toward the base of the exposed section yet even this is not certain on the basis of present information. In the conglomerates as a whole, rocks of volcanic origin are commonest, those derived from chert next and those derived from granitic rocks least common.

These conglomerates display an antipathetic relationship in which mature and immature components coexist. The simplest explanation of this relationship is that the conglomerates were deposited from turbidity currents. Visible evidence to support this hypothesis is lacking yet a reasonable alternative explanation is difficult to envision.

b. Plagioclase Volcanic Arenite.

Plagioclase volcanic arenites are prominent along the east side of

Vedder Mountain. These are interbedded with and overlie the conglomerates. They are commonly dark brown on a weathered face but yellow-brown with a greasy luster on a fresh face. Composition varies widely but plagioclase, quartz, volcanic fragments and lesser argillite fragments predominate. The matrix contains clay material. Occasionally, rounded augite grains were seen but they were never prominent. Except where elongated black argillite fragments gave the rock a fabric (Plate 2), bedding was seldom visible in the arenites.

Quartz from these rocks appears to be predominantly of volcanic origin. Erosive or corrosive agents have roughened grain boundaries yet clearly many grains were formerly idiomorphic. Most grains are very clear, inclusions are rare and straight extinction is the rule. These features fit volcanic quartz from Krynine's "Genetic Classification of Quartz Types" (Folks (1961) p. 69).

Much of the feldspar present has been saussuritized, although some grains are fresh. Sharp edges have been eroded from the grains but they are still angular. Albite ranges from An_0 to An_5 and comprises the only feldspar grains identified in the arenites.

Rock fragments of volcanic origin are more prominent than those of sedimentary origin. Epidotized diabase, quartz and albite porphyries and devitrified, sometimes vesicular, volcanic glass are typical of the volcanic rock fragments. Soft black argillite fragments and occasional chert fragments are the only sedimentary fragments which have been identified.

Angular fragments, presence of easily destroyed minerals and abundance of clayey material in the matrix show that these arenites are

immature. Using Folk's (1961) classification, the rocks would be called immature plagioclase volcanic arenites.

Veinlets of quartz or carbonate and prehnite are common cutting the arenites. Prehnite from these veinlets is often clouded with inclusions in thin sections. It occurs as stubby, often radially arranged crystals which are usually roughly perpendicular to the walls of the veinlets.

c. Argillite and Phyllite.

Argillite occurs as interbeds in the arenites and forms an extensive band of outcrops from altitude 1,500 feet on Ascaphus Creek to the northwest tip of Cultus Lake.

Within the arenite, argillite bands usually appeared massive. Occasionally, however, differential weathering or color banding could be seen. These bands varied from several to roughly two hundred feet in thickness. Bedding was more commonly seen in the thicker units.

At the north end of Cultus Lake, phyllite is prominent. It is soft, usually black on a fresh face and often slightly rusty on a weathered face. Although difficult to see in the field, thin banding is readily observed on most specimens when they are cut with a diamond saw. Commonly, this banding consists of very fine grained brown and much finer black bands with 1/16 to 1/4 inch spacing.

Within the argillites and phyllites are interbeds of immature, micaceous arkose. Although they reach thicknesses of 20 feet occasionally, most of these arkose bands are only a few inches thick. The thin bands commonly pinch out very quickly but in part this pinching is of tectonic

origin. Most of the grains in the arkose bands fall in the fine sand size-range (Folks (1961), p. 24). The bands weather brown and are dark gray-brown fresh. Except for aligned white mica flakes, they are massive.

At the base of the hill half a mile northwest of the Watermanship Training Area, sheared, talcose, phyllitic-looking sediments are exposed. Pinching and swelling of bands and differential movement between bands obscure detailed textural data but banding has not yet been destroyed. The rock consists of alternating argillite and volcanic arenite layers. The arenite is the same composition as that from the arenite unit to the south-west.

Alternating finer and coarser beds, evidence of small amounts of erosion at interfaces and what appear to be slump convolutions suggest that this argillite unit may be a turbidite.

d. Chert.

Chert is a prominent constituent of the eastern sediments and crops out along the crest of the Mountain from northeast of Vedder Peak almost to the International Boundary. Massive, ribbon and nodular chert, as well as some jasper, are present.

Massive chert is most prominent along the crest of the Mountain near the International Boundary. It weathers white to red-brown and is pale to dark gray on a fresh face. Intense brecciation with introduction of quartz along the fractures characterizes this massive chert. In thin section, it is seen to be microcrystalline, consisting of tiny, sutured quartz grains. Argillaceous material is prominent and clouds the quartz so that the section looks dark brown under low power in plane light. A

reticulate network of veinlets of clean, sutured quartz crystals cuts the chert. These veinlets range from 0.05 inches to less than 0.01 inches in thickness. Some of the fractures in which the quartz veinlets occur are incompletely filled. These have poorly developed quartz crystals lining their walls.

Ribbon chert is common west of Vedder Peak near the contact with the crystalline rocks. Much of this chert is gray or gray-green and weathers white to red-brown. Occasionally, the ribbons are jasper rather than chert. Where they are well-formed, the ribbons average two inches in thickness and are continuous over tens of feet. Although the chert is somewhat argillaceous, no interlayered argillite zones are present.

Along the mountain crest southwest of Vedder Peak, dark gray to black gray-green to brown-green color banded chert crops out. Intense brecciation and disruption of the banding is present; thus the nature and continuity of the banding is not known (Plate 3). Tension gashes, often lined with quartz crystals, are prominent features of these rocks.

Adjoining the road northwest of the Watermanship Training Area near the northwest tip of Cultus Lake, nodules of dark to nearly white chert occur in a foliated matrix of black argillaceous material (Plate 4). In some areas, the rock consists of ribbons of chert separated by thin layers of argillite. Since the nodular chert is physically similar and crops out nearby, it was concluded that the two rock types are the same but that the nodular rock has been disrupted by deformation.

e. Silicious Argillite with Limestone Pods.

Limestone pods enclosed by siliceous argillite crop out at

altitude 2,500 feet due south of Vedder Peak. Pods occur over a strike length of 2,500 feet and are sporadically distributed. This argillite is very similar to that which separated chert ribbons near the Watermanship Training Area. It is a dark gray cherty argillite with thin undulose black argillite stringers, which comprise about ten percent of the rock. These stringers have served as locii of slipping, consequently, they are foliated with many well-developed slickensided faces. They display widely variable orientation and have not been useful as bedding indicators.

Pods of limestone from two to five feet long and one to three feet wide predominate but one pod with dimensions of 50 feet by 30 feet was found. Uneven nodules of black chert comprise about 25% of the limestone pods. The limy portion of the pods consists of medium to coarse grained carbonate. It is pale gray on a weathered face but darker when freshly broken. When a fragment of the limy portion of a pod was immersed in dilute hydrochloric acid, a vigorous reaction ensued. However, insoluble residue quickly clouded the acid. The pods are cherty, impure crystalline limestone.

Limestone pods enclosed by siliceous argillite also crop out near the crest of Vedder Mountain 2,000 feet north of the International Border. These rocks are indistinguishable from the ones near Vedder Peak and are thought to be equivalents.

f. Micro-volcanic Arenite.

Micro-volcanic arenite, which is cliff forming, is prominent near the crest of Vedder Mountain, especially near the peak. The rock is typically massive, dark brown weathering and dark gray-green to brown when fresh. Bedding was not seen in the field but in thin section, mineral

fragments are often seen to be aligned. Brecciation of this arenite is common and fractures are partially or wholly filled with quartz, prehnite and occasionally carbonate.

Angular quartz, feldspar and rock fragments lie in a dense, dark brown, often foliated groundmass (Plate 5). Deformation is indicated by broken, offset twins in feldspar fragments. Fresh to strongly sericitized plagioclase grains ranging up to oligoclase, An_{30}, comprise the feldspar seen in these rocks. Quartz occurs both as volcanic-type and as sutured grain aggregates which are presumably of metamorphic origin. Rock fragments are predominantly of volcanic origin.

The groundmass is dense, dark brown and isotropic. Alteration combined with small grain size render its original nature uncertain.

The rock is an immature volcanic arenite. Whether it had its origin in a turbidity current, was formed by pyroclastic action or by some other mechanism is not certain.

B. Western Sediments.

The western sediments occupy an arcuate area which begins one mile northeast and ends about two miles northeast of Kidd while extending up to altitude 500 feet on the flank of Vedder Mountain. They comprise an overturned monocline and will be discussed in the order in which they were deposited.

a. Quartz Plagioclase Porphyry.

Quartz plagioclase porphyry is believed to be the oldest rock in the western sedimentary block. Quartz occurs as rounded crystals which are milky in hand specimen and comprise roughly 15% of the rock.

Plagioclase crystals are saussuritized and comprise roughly 10% of the rock. The groundmass is pale green and consists of microcrystalline quartz and feldspar.

This porphyry crops out 4,000 feet northeast of Kidd in a railway cut. In this cut, the porphyry is in contact with foliated quartz diorite of the crystalline rocks. Quartz phenocrysts show pronounced undulatory extinction and many feldspar phenocrysts are broken or bent. However, a thin section from a porphyry specimen six feet from the vertical diorite-porphyry contact was easily recognizable despite cataclasis. At the contact, both rocks are cataclasites.

b. Argillite.

Argillite is a prominent constituent of the western sediments. Except in railway and occasional stream cuts, however, it is very poorly exposed. Even in good exposures, it appears massive at first glance but careful scrutiny often reveals subtle color banding on the weathered face. Phyllitic foliation has been developed in places but overall, these rocks are less sheared than the argillites which crop out near the northwest tip of Cultus Lake.

In several localities, differential movement along joint faces has resulted in a stepped appearance on the outcrops (Plate 6). At times, friction during slippage has resulted in bending of lamellae to form small scale folds. Neither step-joints nor folds of this nature were observed in the eastern sediments.

c. Micro-volcanic Arenite.

Rocks which are almost identical in macro- and microscopic detail

to the micro-volcanic arenites which crop out near Vedder Peak are seen in a highway cut at altitude 250 feet, 8,000 feet northeast of Kidd. As with the eastern exposures, these rocks are commonly massive. In one small area, however, beds crop out which range from two inches to two feet in thickness with gross width about 10 feet. As with the eastern arenites, the origin of these rocks is uncertain.

d. Radiolarian Chert Lenticule Arenite.

Radiolarian chert lenticule arenite crops out in a railway cut northeast of the quartz plagioclase porphyry which was previously described and in a railway cut 9,700 feet northeast of Kidd. In both localities, it is in contact with volcanic arenite breccia but the nature of the contact is uncertain.

Large to small elongated angular to saucer-shaped black fragments and generally smaller elongated angular white to pale green fragments lie in a dark brown generally sand-sized matrix. The fragments are well aligned. In dimensions, the black fragments range up to 2.75 by 0.6 inches but average 0.6 by 0.2 inches; the others range up to 0.8 by 0.25 inches but average 0.4 by 0.15 inches. Fragments comprise 35% of the rock, of which 20% are black.

The black fragments were found to be argillaceous chert which contain up to 40% rounded (Plate 7) and occasional cigar-shaped radiolaria (Plate 8). White fairly clean chert fragments also contain a few radiolaria. Volcanic fragments are pale green and consist of devitrified volcanic glass in which thereare sometimes numerous microlites of feldspar. Well developed systems of cracks cut these fragments but they are planar

and not perlitic.

The matrix of this arenite consists of well-aligned sericitized feldspar, lawsonite and volcanic quartz fragments in an argillaceous groundmass. The quartz fragments are from former idiomorphic crystals. Lawsonite occurs as groups of radially arranged, fibrous crystals, which are pseudomorphous after subhedral feldspar crystals (Plate 9). Usually replacement is complete but occasional feldspar remnants are seen. In plane light, lawsonite is seen as dense, dark brown masses. Under crossed nicols, interference colors range up to first order red. Crystal fibers are length fast. Identification was based on x-ray powder data. Whether the lawsonite formed in place or whether replacement occurred prior to erosion of the source rocks is not certain.

e. Volcanic Radiolarian Chert Arenite Breccia.

Volcanic arenite breccia crops out north of the radiolarian chert lenticule arenite outcrops in the railway cuts and in a creek valley at altitude 400 feet, 1,000 feet due south of the micro-volcanic arenite outcrop along the highway.

This distinctive rock often has an overall greenish tint due to abundant green fragments and a greenish groundmass. Angular fragments predominate although rounded corners are not uncommon. Most fragments are relatively equant and range from 0.5 inches across down to microscopic size. Most, however, are between 0.2 and 0.3 inches across. Fragments comprise roughly 80% of the rock. Occasional fragments occur which have length to width ratios up to 7:1, yet no alignment has occurred (Plate 10). In thin section, a subtle foliation within the matrix can be seen but

elongated fragments do not conform to it.

Most of the fragments comprising the breccia are of volcanic origin although white or black chert and black argillite fragments occur. Within the chert fragments in the breccia, as in those of the lenticule arenite, scarce to abundant radiolaria are seen. Fragments of volcanic quartz, some of which are idiomorphic, are scattered throughout the matrix. A wide variety of rock types comprise the volcanic fragments. For instance, pale green slightly devitrified glass, gray volcanic glass with dark green amygdules, feldspar porphyry with a dark green microcrystalline groundmass, gray-brown microcrystalline volcanic rock and quartz porphyry with a white groundmass all occurred in one hand specimen.

The groundmass of the breccia is extremely fine and somewhat altered. Nothing to suggest its original nature was seen.

The jumbled arrangement of the fragments, presence of fragments which could not withstand long transport in a stream, paucity of matrix and preponderence of fragments of volcanic origin suggest that the rock was deposited quickly under turbulent conditions. Whether it is of pyroclastic, turbidity current or mixed origin remains uncertain.

f. Limestone.

Limestone interbedded with argillite occurs as interbeds in the lenticule arenite-volcanic arenite breccia unit. It crops out a few feet south of the arenites in the railway cut 9,700 feet northeast of Kidd. In the creek valley 1,000 feet south of the micro-volcanic outcrops, limestone is the westermost outcrop.

On a weathered surface, the limestone is dark gray; on a freshly

broken surface, dark gray-brown. It reacts vigorously with dilute hydrochloric acid releasing a large insoluble residue content. In plane light, a thin section of this rock is dark brown. Under polarized light, sutured carbonate crystals cut by a reticulate network of carbonate veinlets are seen. The rock consists essentially of medium to coarse grained calcite crystals which enclose much argillaceous material. Rounded zones in the limestone which consist of calcite with a core of quartz or argillaceous material are thought to be remnants of crinoid columnals. Chert nodules which are irregular in outline range up to three inches in long dimension and comprise 30 to 40% of the rock.

The distribution of the limestone remains somewhat uncertain because it was seen in only two outcrops. Its relation, if any, to the eastern limestone pods is not known. Evidence for age determination is lacking because no positive fossil identification was possible.

g. Ribbon Chert.

Six thousand feet northeast of Kidd, overlooking the highway is a low bluff composed of ribbon chert. It is white weathering but pale gray when freshly broken. Ribbons in this chert are continuous over tens of feet and slightly crenulated. No inter-ribbon argillaceous material is present although the chert itself is slightly argillaceous. Overburden surrounds the bluff.

C. Volcanic Rocks.

Intercalated volcanic and granitic rocks crop out from 4,000 feet northeast to 1,000 feet southwest of Sinclair. Volcanic rocks predominate and the granitic ones are thought to be imbricate slices associated with

the fault which bounds the crystalline rocks on the west. (Figure 3, Section E-E').

a. Altered Diabase.

Adjoining the highway 4,000 feet northeast of Sinclair, massive-looking olive green rock with numerous nearly black, lustrous, serpentine-coated slip surfaces crops out. The rock is very fine grained.

The green color of the rock results from extensive saussuritization of the abundant feldspar laths. Augite, which has been partially altered to serpentine alone cleavages, occurs as subhedral laths. Although rendered uncertain by alteration, the rock appears to have a sub-ophitic texture.

As well as replacing augite, serpentine forms thin coats on slip faces. Also cutting the rock are veinlets of stubby, radiating prehnite crystals. Occasional carbonate crystals are intergrown with this prehnite. In places, these veinlets comprise as much as 15% of the rock.

A thousand feet southward along the highway, rock is exposed which is almost indistinguishable from the diabase in hand specimen. In thin section, however, this rock is seen to be fragmental. Altered diabase, augite crystal, volcanic quartz crystal, dark brown devitrified volcanic glass and feldspar porphyry fragments lie in a dense, altered groundmass. No shards were found but the nature and diversity of fragments suggests that the rock is a tuff.

b. Volcanic Porphyries.

Porphyritic volcanic rocks crop out intermittantly along the

British Columbia Electric Railway tracks from 2,500 feet northeast to 1,000 feet southwest of Sinclair. Exposures of brecciated to mylonitized granitic rocks also crop out within this predominantly volcanic area.

The porphyries have been subjected to variable cataclasis. Tension cracks partially or wholly quartz-filled are prominent. The groundmass of the porphyries varies from pale to dark gray or green and contains white to pale gray phenocrysts. Quartz, which occurs as clean, embayed crystals and/or plagioclase laths with composition near An_{25} comprise the phenocrysts. Phenocrysts occupy 10 to 40% by volume of the rocks. The groundmass, where it is not obscured by cataclasis and alteration, consists of a mosaic of tiny, sutured quartz and oligoclase crystals. K-Feldspar was not found and the rocks would be called oligoclase bearing dacite porphyries.

Even in the porphyries least affected by cataclasis phenocrysts are bent and broken (Plate 11). In the more strongly affected rocks, the matrix is extremely fine grained and phenocrysts are reduced to scattered crystal fragments. Mylonite zones are common and appear as dense, isotropic, foliated zones with scattered, tiny crystal fragments.

Prehnite occurs both as veinlets comprised of stubby prisms and as scattered grains in mylonitized areas. It is widespread and occasionally comprises 5% of the rock.

Some of these porphyries are similar to that which underlies the western sediments. No basis other than physical and mineralogical similarity exists but if these porphyries correlate in part with the porphyry from the western sediments, some of them are very probably older.

More extensive exposure is the basis of this suggestion.

D. Crystalline Rocks.

As used here, crystalline rocks refers to amphibolites, epidote - amphibole schists and gneisses, amphibole and epidote - amphibole mica schists and granitic rocks. These rocks form a northeast trending unit which is roughly a mile wide and comprises much of the western flank of Vedder Mountain.

a. Metamorphic Rocks.

The non-granitic components of the crystalline rocks have mineral assemblages which are typical of the regional metamorphic Almandine-Amphibolite Facies of Turner and Verhoogen (1960). According to these authors, coexisting epidote and plagioclase in the range An_{25} to An_{45} indicate conditions of high load pressure. Further, they suggest that the mineral assemblages formed between 550 and 700 degrees Centigrade and 4,000 to 8,000 bars water pressure. Typical minerals from the Vedder Mountain metamorphic rocks include: hornblende, actinolite, white mica, almandite, epidote and oligoclase with accessory sphene and pyrite. By comparing mineral assemblages and textures, it seems clear that the amphibole schists and gneisses, garnet amphibole schists, mica amphibole and garnetiferous mica amphibole schists which crop out on Vedder Mountain were formed under conditions of fairly high temperature and pressure, presumably at considerable depth within the crust.

i. Hornblendite.

Hornblendite is relatively rare on Vedder Mountain. It was found

in one locality
only [redacted], about half a mile northeast of Vedder Mountain Station in a railway cut. Hornblende, which is pleochroic in browns and green, occurs as medium grained subhedral laths with irregular borders. No pronounced fabric was present, although they were poorly aligned. Sphene is accessory. Hornblende has been bleached and/or iron stained along a series of cracks which cross the rock.

ii. Amphibolite.

Amphibolite is not prominent among the metamorphic rocks. Only one locality has been verified by thin section work, that being a small quarry alongside the highway 1/4 mile northeast of the railway crossing northeast of Yarrow. From hand specimen study, it is suggested that amphibolite also occurs interlayered with the schists and epidote amphibolites which are well exposed in road cuts around the north end of the Mountain.

Hornblende, which is the predominant amphibole comprises 50 to 80% of the rock. Feldspar is oligoclase near An_{30}. Foliation, as defined by segregation of light and dark minerals and parallelism of the elongated amphibole laths, varies from weak to very strong. Where foliation is well developed, the texture of the rocks is gneissic. Quartz in the rocks usually occurs in thin stringers parallel to the foliation.

iii. Epidote Amphibolite.

Most prominent by far among these metamorphic rocks are epidote amphibolites. Outcrops of these rocks are well exposed in many road cuts around the north end of the Mountain. These medium grained rocks are usually fairly well banded. Hornblende or actinolite occur as stubby laths which, combined with mineral segregation, outline the foliation. In these rocks, amphiboles seldom exceed 50% and usually range from 35 to 45%.

Epidote, usually clinozoisite with minor amounts of zoisite, occurs as equant to slightly elongated, usually somewhat rounded grains. Often these grains are in subparallel alignment. Epidote comprises 10 to 30% of the rock. Oligoclase, usually An_{25} to An_{35}, occurs as interstitial, equant, somewhat sutured grains. Twins are rare. Rounded equant quartz grains occur interstitially with the oligoclase grains. Quartz varies from less than 5% up to a 1:1 ratio with the feldspar. Sphene occurs both as elongated prisms with rounded corners and as stubby prisms with rounded corners. Cross sections are equant to roughly diamond-shaped. Sphene comprises up to 3% of the rock. Pyrite cubes are rare accessories (Plate 12).

Along the Cultus Lake highway several hundred feet northeast of the turnoff to the Watermanship Training Area, a rock which was mapped as pseudo-serpentinized greenstone crops out. Just out of the map area, a similar rock is exposed in a quarry a few hundred feet northeast of the bridge across the Vedder River near Vedder Crossing. Mineralogically, however, the rock was found to be an epidote amphibolite. Serpentine, which appeared prominent in the field was found only as thin layers on joint surfaces in thin section. Foliation was not apparent in hand specimen but pronounced mineral alignment was visible in thin section. The outcrops of this rock are adjacent to the eastern bounding fault of the crystalline rocks which further clouded positive identification of the rock. Clearly, however, this pseudo-serpentinized lava is actually a medium grade metamorphic rock.

iv. Foliated Garnet White Mica Hornblende Quartz Feldspar Rock.

Although not abundant, foliated garnetiferous amphibole-rich rocks are widespread throughout the metamorphic rocks. The most accessible exposure of these rocks is 200 feet east of the railway crossing northeast of Yarrow. Several other good exposures occur along the road around the north nose of Vedder Mountain at altitude 500 feet.

The rock is usually banded with thin, white discontinuous, slightly undulatory stringers in a dark green medium grained matrix. Garnets, ranging from 1/8 to 3/8 inches diameter, comprise 10 to 20% of the rock. The foliation bends around the garnet crystals (Plate 13). Even in hand specimen, brecciation of the garnet crystals is apparent. White mica plates lie in the plane of foliation. Mica comprises roughly 10% of the rock.

Hornblende, which is pleochroic from green to brown, forms aligned, ragged laths. The isotropic garnet is near almandite in composition. Crystal edges are rounded with numerous embayments and quartz, feldspar and epidote occur abundantly within crystal boundaries. White mica cross sections are elongated and taper out gently at both ends. Quartz and plagioclase, most of which is albite, An_5 to An_{10}, are interstitial. Crystals of these minerals tend to be elongated parallel to the foliation. Elongated prisms of sphene with rounded corners and scattered anhedral medium grained pyrite crystals are accessory. Often, the pyrite has been partially altered to hematite.

v. Garnet Sphene Schist.

Porphyroblasts of pale red-brown garnet ranging up to 3/8 inches in diameter and sphene which is very nearly the same color but occurs as

porphyroblasts which are commonly 1/8 inch in diameter lie in a crinkled, foliated irregularly banded green matrix. This matrix consists of a framework of elongated, sutured quartz grains with interstitial albite, An_{10-15}, and irregular discontinuous layers consisting of bent, contorted white mica plates. Much of the quartz displays undulatory extinction.

The almandite crystals are intimately brecciated, have embayed edges and often contain quartz crystals. Quartz, mica and feldspar fill the embayments. Sphene usually occurs as roughly diamond-shaped crystals. They are often ragged and in places have been broken with fragments spread out along the foliation (Plate 14). Most of these crystals are brecciated and white mica occupied the cracks in one. What appear to be polysynthetic twins are prominent in some of the sphene crystals. Also present in the rock are pale green, faintly pleochroic chlorite and a few ragged epidote crystals.

An average mode for this rock is as follows;

Almandite Garnet	18%
Sphene	13%
White Mica	32%
Feldspar	10%
Quartz	25%
Chlorite	< 2%
Epidote	Trace

b. Granitic Rocks.

Granitic rocks within the crystalline slice predominate southeast of Sinclair. These rocks are thought to be magmatic in origin. Dykes of

light colored dioritic rock cutting darker dioritic rock have been seen (Plate 15). Border phase pegmatitic zones are thought to represent late stage fluids derived from the magma during crystallization. A melanocratic border phase separates the granitic rocks from the metamorphics and inferred contacts suggest intrusive relationships with the metamorphic rocks.

i. Foliated Quartz Diorite.

Foliated quartz diorite occurs in minor amounts within the diorites which are the predominant granitic rocks. These quartz-rich bodies are of very limited extent and their textures vary radically over short distances. For instance, in a highway cut just north of the micro-volcanic arenite outcrops which are within the western sediments, fine grained quartz diorite and quartz diorite gneiss with prominent stringers of quartz occur within a few feet of one another. The gneiss in this instance appears to be of cataclastic origin. Contacts were not exposed in the outcrop so relationships between the two rock types could not be determined.

Many of the quartz diorites are gneissic and in these rocks, quartz is very prominent. It occurs in discontinuous stringers with maximum width 1/10 inches which comprise up to 40% of the rock. Grayish white quartz which occurs as large, elongated, sutured grains comprises the stringers. Most of these grains exhibit pronounced undulatory extinction (Plate 16). Stringers of pale green chlorite which are subparallel to the quartz stringers comprise roughly 15% of the rock. The matrix contains a mixture of albite, zoisite and sericite. Prior to alteration, the matrix was medium grained plagioclase.

Where rocks of this group are poorly foliated, the mineralogy is

roughly the same but the stringers are thinner and not well aligned. In all instances, however, quartz is very prominent.

The relationship of these quartz diorites to the diorites is uncertain. Their locallized nature and high quartz content suggest that they may be late stage magmatic intrusions cutting the diorites. Their gneissic textures may be a function of their positions, since they commonly occur near the fault which bounds the crystalline slice. Mylonitized zones are common and perhaps cataclasis associated with emplacement resulted in mobilization and recrystallization of the quartz.

ii. Diorites.

Most of the crystalline rocks which comprise the southwest flank of Vedder Mountain are foliated diorites. Prior to ubiquitous, intense saussuritization, these rocks consisted essentially of hornblende and plagioclase, in the ratio of 2:3. Sericite, albite and zoisite now form pseudomorphs after the plagioclase. Hornblende has withstood alteration fairly well although it has been bleached and chloritized for short distances out from fractures. The diorites are uniformly medium grained and commonly show mineral alignment. This alignment is solely of the elongated hornblende lathes. Pyrite, partially altered to hematite, is a common accessory mineral (Plate 17).

Composition, color index, grain size and texture of these rocks tally with these features as described for typical diorites in Williams, Turner and Gilbert (1955, p. 106). Consequently, the name diorite has been assigned to these rocks despite destruction of the plagioclase.

Numerous quartz-albite and prehnite veinlets cut the diorites.

Both quartz and albite in these veinlets occur as tiny sutured grains which can be distinguished only by relief. Prehnite prisms vary from stubby to elongated. They are clear in thin section and often display so-called bow tie structure. Most of these prisms are roughly at right angles to the veinlet walls (Plate 18). In one hand specimen, white, vitreous prehnite filled a 1/4 inch veinlet and occurred as interlocking prisms with cockscomb texture. A second hand specimen had an open tension crack, the walls of which were covered by a felted mass of tiny, transparent, colorless prehnite needles.

iii. Mixed Rocks and Pegmatites.

Near the contacts with the medium grade metamorphic rocks, mixed rocks crop out which are characterized by the same alteration and minerals as the diorites but with much higher color index than the diorites. Typical color indices for this rock range between 60 and 70 (Plate 19). They are also slightly finer grained than typical diorites. Foliation is usually well defined in these rocks, perhaps in part as a result of their higher hornblende content and hence higher color indexes. Since these rocks occur near contacts, it seems reasonable to suggest that they represent the basic border phase of the diorite intrusion. Poor outcrop renders the extent and detailed distribution of this "border phase" uncertain.

Pegmatites, consisting of albite, again with superposed saussurite alteration, and clots of hornblende or actinolite crop out in the same general area as the mixed rocks. These are thought to be derived from late stage fluids derived from crystallization of the diorite. Contact relations

of these pegmatites were not determined during the field work and have been inferred.

The granitic rocks have been interpreted as being of magmatic origin. Misch, (personal communication with Armstrong), however, suggests that they are of metamorphic origin. His interpretation is based on thin section analysis of samples taken by Armstrong and a field trip to Vedder Mountain. Several features are left unanswered if the crystalline rocks of Vedder Mountain are all of metamorphic origin. Among these are the dikes, the mixed rocks and pegmatites and the fact that foliation in the granitic rocks is not related to that from the obvious medium grade metamorphic rocks.

c. Diorite Cutting the Eastern Sediments.

Four hundred feet east of Vedder Peak, a narrow, steeply dipping northeast trending body of diorite cuts the eastern sediments (Figure 1). Its outcrop pattern suggests that it parallels bedding in the sediments. The diorite superficially appears altered and sheared. In thin section, intense alteration is seen to have destroyed plagioclase in the rock, as is typical of the diorites. Unlike the other diorite specimens, zoisite in this specimen has reached such a size that it can be easily distinguished under low power. Clots of hornblende crystals contain individual crystals which have been partially chloritized and closely broken. Fragments of these crystals were subsequently drawn out by differential movement. Many of the hornblende crystals poikilitically enclose rounded quartz and feldspar grains which are spread out along cleavage directions and appear in part to replace the host.

A network of mylonite zones into which prehnite has been introduced comprise up to 30% of the rock. Prehnite in these zones is equant and very fine grained. A further 15% of the rock consists of quartz-prehnite veinlets in which prehnite occurs as elongated to blocky prisms arranged roughly at right angles to the walls of the veinlets. These veinlets cross-cut the mylonite zones and probably represent tension gash fillings. No chilled zone was seen at the borders of the diorite body and the adjoining sediments are massive, unaltered and not mylonitized. The data presented suggests that the diorite was emplaced in the solid state along a fault; presumably it is a slice separated from the crystalline rocks to the west.

d. Epidote Amphibolite Cutting the Western Sediments.

Epidote amphibolite of unknown extent crops out within the western sediments in a railway cut about 800 feet northeast of the ribbon chert outcrop. In hand specimen, foliation is obscure; in thin section, it is seen to be well developed. Numerous polished, slickensided faces cross the rock. Hornblende, clinozoisite, oligoclase, quartz and some white mica comprise the rock.

Thin crush and comminute zones along which quartz, plagioclase and carbonate bearing veinlets have been introduced are common.

The rock is of metamorphic origin and would be classified as an epidote amphibolite. Despite the relatively small amount of cataclasis observed, it is suggested that the rock was emplaced along a fracture and was derived from the crystalline rocks to the east (Section C-C', Figure 3).

e. Serpentinite.

Small, poorly exposed serpentine bodies crop out intermittently along the fault which bounds the crystalline slice on the east. Five serpentinite bodies were located during the field work but none was well enough exposed to be mapped in detail.

Numerous highly polished, often striated joint faces characterize the serpentine outcrops. These faces are often pale green but the serpentinite is dark green to black on a freshly broken face. Serpentine in these serpentinite bodies is commonly fine grained; remnant pyroxene crystals on the other hand range from very fine to coarse grained.

In polarized light a thin section from the serpentinite shows a mesh-like, subrectangular network of bladed antigorite crystals. Openings in the mesh are filled by massive antigorite (Plate 20). Tiny needles of a pale green, high relief mineral are common and project into the massive antigorite at right angles to be bladed antigorite walls (Plate 21). Pyroxene remnants are predominantly augite, although enstatite with clinopyroxene intergrowths occurred in one specimen. Most of these grains are rounded and many have been serpentinized for short distances out from the cleavage traces. During serpentinization, excess iron from the olivine was expelled from the serpentine crystals and tended to gather along what appear to be former olivine crystal boundaries. If this interpretation is correct, olivine in the rock was sub - to euhedral.

These serpentinite bodies, which are thought to be ellipsoidal, crop out along the eastern bounding fault of the crystalline body and were presumably brought up along the fault from great depth, possibly the

earth's mantle.

Section III - STRUCTURE.

Vedder Mountain contains well consolidated eugeosynclinal sediments which were folded and sheared during emplacement of a slice of crystalline rocks in the solid state. This slice, which trends northeast, is bounded by steep southeast dipping faults.

On the eastern flank of the mountain, the sediments were deformed into a synform. The average axis of this fold plunges less than one degree toward the northeast (Figure 3, Section E-E'). Its axial plane trends northeast and dips 75 degrees southeast. Along the western edge of the mountain, the sediments form an overturned(?), southeast dipping monocline (Figure 3, Section C-C').

A second period of deformation affected both the sediments and the crystalline rocks. Warping of the limbs of the synform resulted in places and is best displayed near the southwest end of the map-area near the crest of the mountain. The western sediments appear to occupy a fold embayment in the crystalline rocks formed during this second period of deformation. The overturned(?) monocline was folded about a steep southeast plunging axis. Axial planes of folds formed during the second deformation trend near 130 degrees and are vertical. The plunge of the fold axis was controlled by the dip of the bed being folded.

Within the crystalline slice, only mesoscopic folds were seen and were confined to the medium grade metamorphic rocks. Crinkles are common

in the foliation of these rock types. In the pseudoserpentinized lava especially, small scale faults at right angles to the foliation offset it as much as 1/4 inch. Openings formed during movement have subsequently been filled with what are now horsetail carbonate stringers. Folding and crinkling of the foliation took place under fairly high grade metamorphic conditions and was similar in nature. In the field, thickening at fold crests support this conclusion (Plate 22). In thin section, bending, rather than breaking of the crystals comprising crinkles support this conclusion. In one case, actinolite crystals were bent [illegible] to outline a microscopic S-shaped fold without breaking (Plate 23). The absence of stress twins in plagioclase also indicate folding under fairly high grade metamorphic conditions.

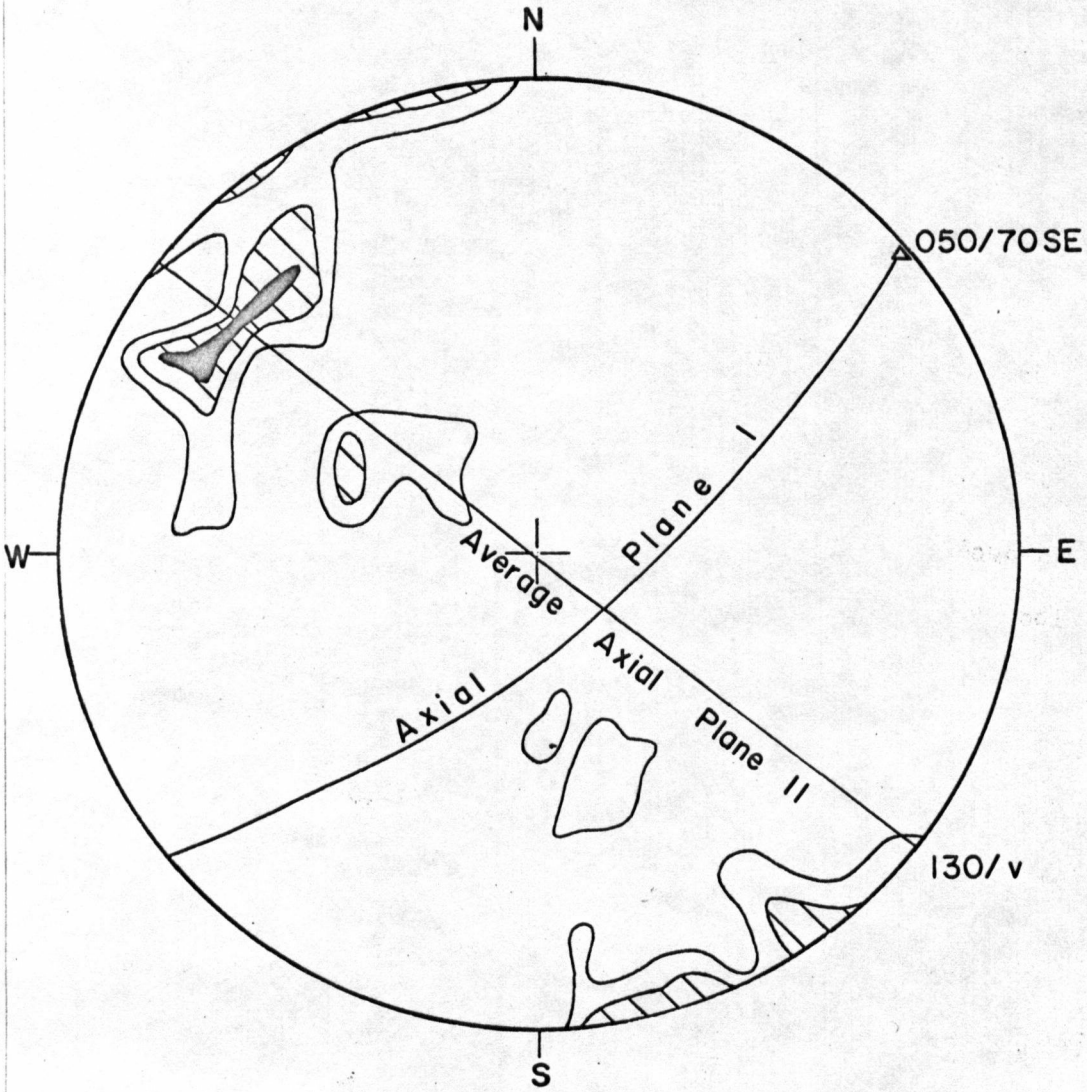
A. Faults Bounding the Crystalline Slice.

On the basis of field and laboratory work, it is suggested that the crystalline rocks are bounded by steep southeast dipping faults. Early workers thought that they comprised an altered sill or altered volcanic rocks but the most recent work done by the Geological Survey of Canada favors bounding faults (Armstrong, 1956).

Adjacent to the crystalline rocks are sediments which are essentially unmetamorphosed. If the crystalline rocks were an altered sill, one would expect to find thermal metamorphic effects. The trace of the eastern boundary of the crystalline rocks, when stratum contoured, indicates a 75° southeast dip for it. Bedding and foliation measurements (Figure 1) strike into the boundary, suggesting that an unconformity exists. From the cross sections (Figure 3), it is evident that a fault best explains this uncon-

Figure 4

Poles to Bedding - Eastern and Western Sediments



2 - 3%

3 - 4%

> 4%

formity. Serpentinite bodies along this contact also suggest that a fault of considerable magnitude exists.

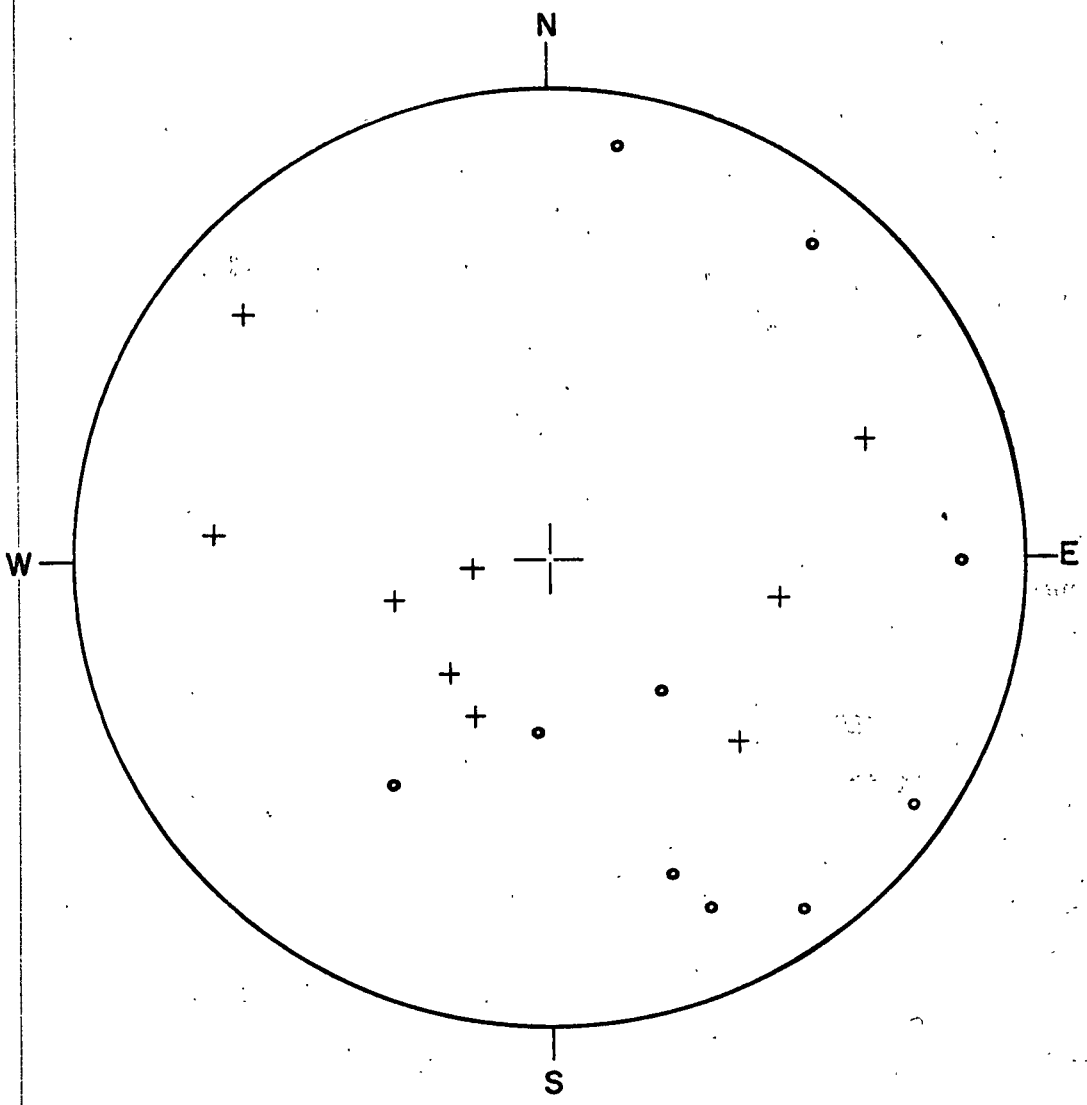
The western boundary of the crystalline rocks also crosscuts foliation and to a lesser extent bedding planes. Imbricate slices of dioritic and volcanic rocks with numerous mylonite zones (Plate 24) in each crop out near Sinclair (Figure 3, Section E-E'). In the railway cut in which the contact between the western sediments and the diorites is exposed, both sediments (Plate 25) and crystalline rocks (Plate 26) have been sheared and are now cataclasites. There are no thermal metamorphic effects at the contact. Consequently, it seems reasonable to suggest that the western contact is also a fault. Non-coring diamond drill holes in Sumas Valley showed that Tertiary bedrock is as much as 1,100 feet below the valley floor (Armstrong, 1959). It is probable that movement along the western bounding fault activated during the late Pliocene(?) orogeny (Moen, 1962) down-dropped these Tertiary sediments.

B. Phase I Folding.

The axial trace of the synform which comprises much of the eastern side of Vedder Mountain, crops out just east of the crest of the mountain and parallels the trace of the fault which forms the eastern boundary of the crystalline slice. The average fold axis plunges less than 1 degree toward the northeast. The axial plane strikes N50°E and dips 75° SE, except where disrupted by later deformation. Fold limbs are almost planar with steep dips but the hinge zone is rounded. Where the fold is little influenced by later deformation, the apical angle varies between

Figure 5

Minor Folds from the Sedimentary Rocks



Fold Axes

Poles to Axial Planes

50 and 70 degrees.

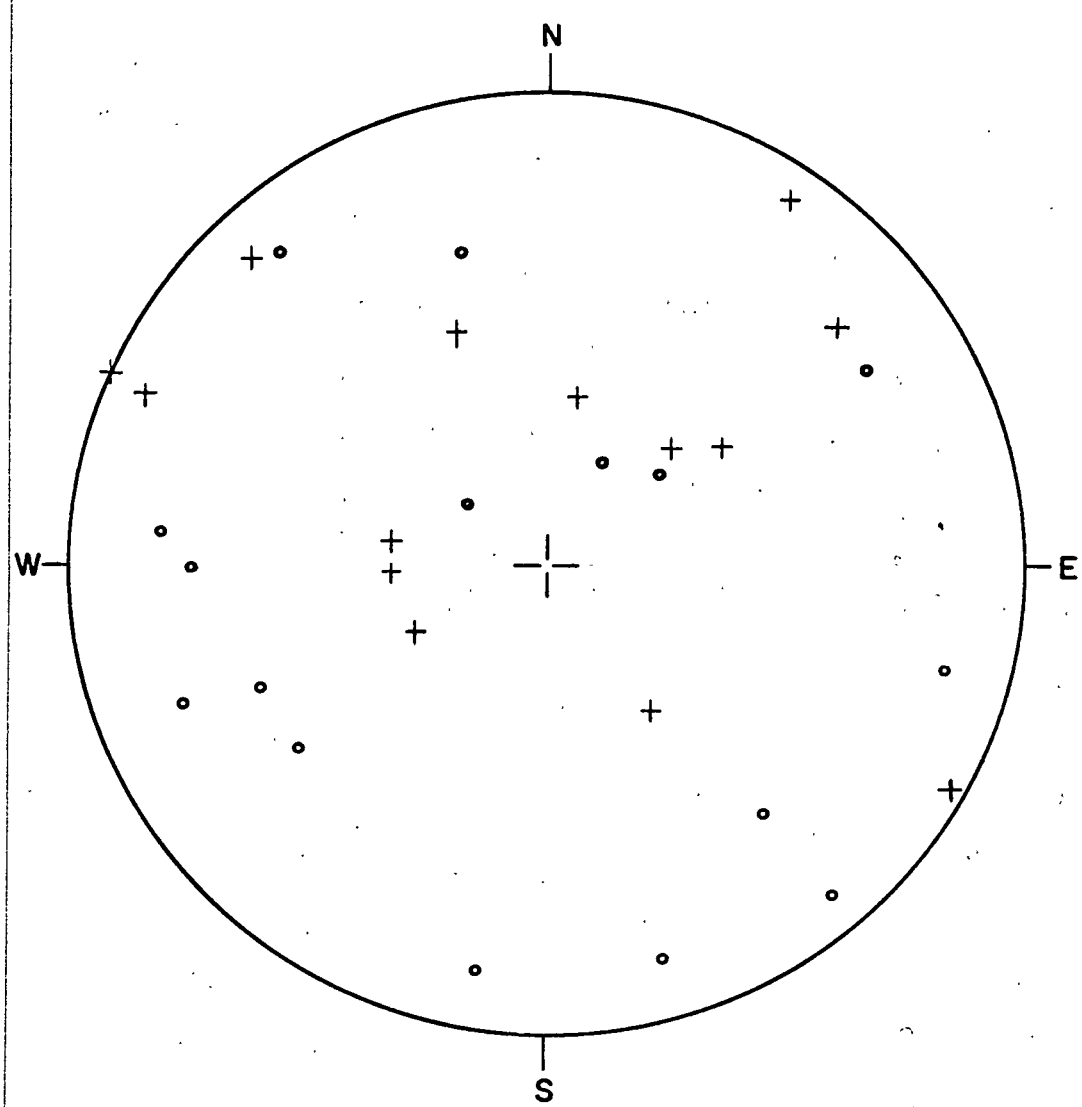
Near the International Border (Figure 3, Sections A-A', B-B') the limbs of the major synform are almost parallel with the eastern limb overturned. The contact with the crystalline rocks swings southward near the Border and this swing may have led to a concentration of force which in turn led to the overturned nature of the fold.

In the argillaceous rocks at the north tip of Cultus Lake, minor folds are similar in nature. However, since minor folds were developed only in the argillaceous zones they shed no light on the style of folding in the more competent rocks. Several features, when taken together, suggest that the competent beds were concentrically folded. First, they are unmetamorphosed. Second, cleavage is at best poorly developed. Third, no optical alignment of quartz grains or other evidence of strong shearing were seen. Fourth and less decisive are concentrations of poles to joints which seem to represent a-c and a conjugate set of shear joints related to the first period of deformation. If these joints are in fact related to the early deformation, then the folding must have been concentric. Less decisive still are concentrations of striae which nearly coincide with the intersection of these shear joints. If these concentrations are associated with shear joints formed during phase I folding, the folding must have been concentric.

Interpretation of the major synform as a syncline is based primarily on the hypothesis that the sediments were pushed aside and folded during emplacement of the crystalline slice. Tops from one cross bedded outcrop support this interpretation but data are insufficient to prove it.

Figure 6

Minor Folds from the Metamorphic Rocks



Fold Axes

Poles to Axial Planes

On the basis of this hypothesis, it is suggested that the western sediments are overturned. Following emplacement of the crystalline slice, the western sediments are thought to have comprised a steep, southeast dipping homocline which was subsequently folded during phase II deformation. Tops determinations from the western sediments could not be used to test the structural interpretation. Minor folds with tightly oppressed limbs are present within the sediments and because outcrop is poor, they cannot be traced. Consequently, the locations of the tops determinations with respect to the limbs of the minor folds could not be determined. Without this knowledge, the significance of the tops determinations was rendered uncertain.

a. Minor Folds.

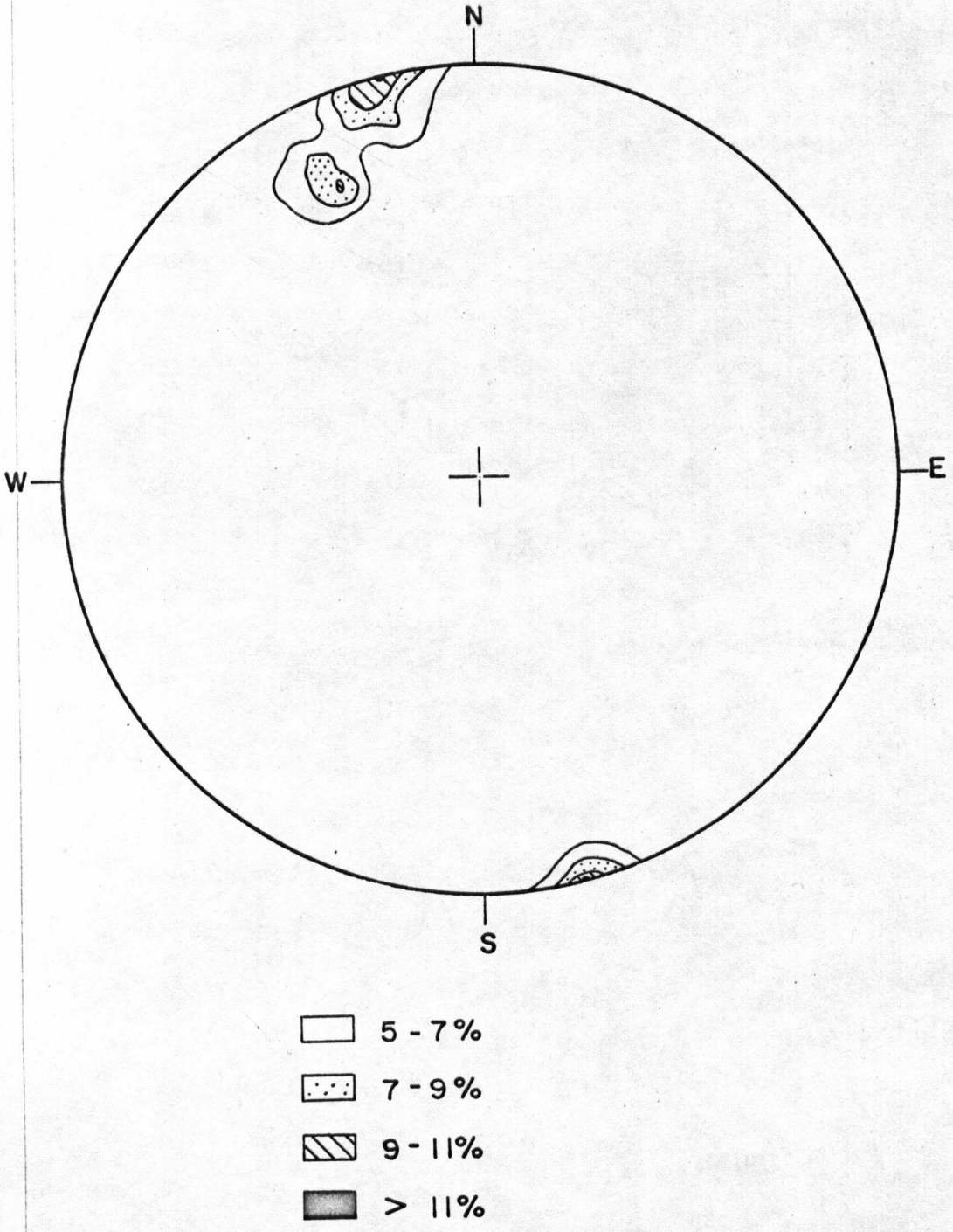
In total, only 26 minor folds were seen during the field work; of these 16 were from the metamorphic rocks and the rest from the argillaceous sediments. Axes plotted from the metamorphic rocks tended to lie in the southeast quadrant of the projection, although several lay in the northeast quadrant (Figure 6). Spread for these points was considerable. Although they might possibly represent a conjugate set of folds associated with shear joints, insufficient data is available to define the significance of these minor folds. Axes from the sediments show slightly different but equally diverse spread. Whether they represent a conjugate set of folds cannot be determined from present data (Figure 5).

C. Phase II Folding.

When plotted on a lower hemisphere equal area projection, poles to

Figure 7

Poles to Cleavage Planes



bedding clearly show spreading as a result of the second period of deformation (Figure 4). From field work, it is evident that the axial planes for phase II folds trend from 090 to 140 and are vertical. It is thought that axes for these folds vary in accordance with the dip of the bed being folded. In support of this idea is the extreme variation in trend of minor fold axes measured (Figures 5 and 6).

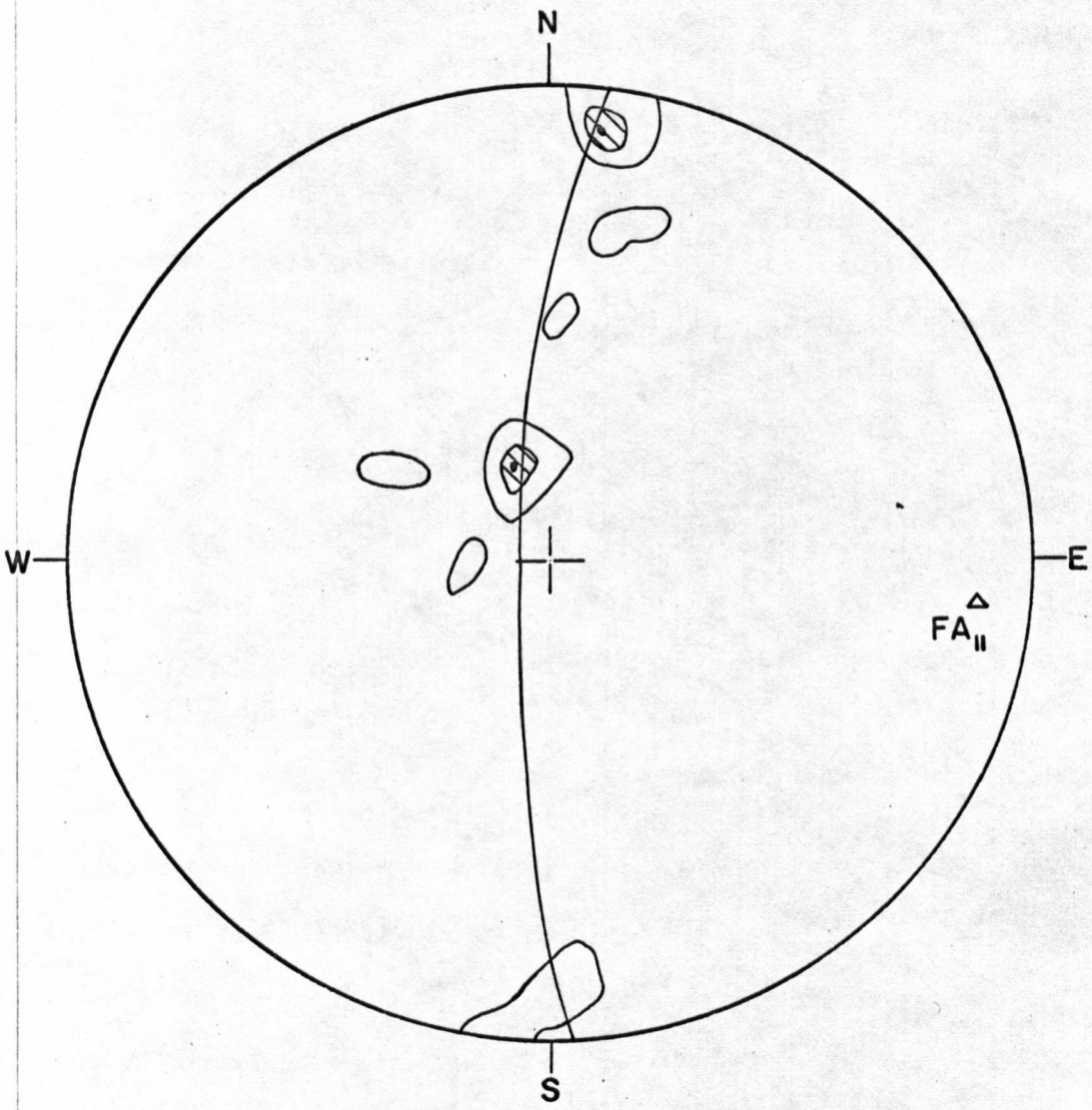
Near the International Border (Figure 1), it appears that the limbs of the overturned syncline were refolded during phase II deformation. From Figure 12, considerable scatter of poles to bedding is evident. From the geologic map, axial plane 140°/vertical and fold axis $140^{\circ}/60^{\circ}$ are indicated for the phase II folds. With three notable exceptions, poles to beds fall roughly on a conic surface with fold axis II as inferred from field work as its axis. The exceptions are poles to beds with southeast trend and steep northeast dips. The reliability of these readings is doubtful because the banding which they represent was observed in intensely brecciated dark colored chert in which banding is often disrupted. If one accepts that the poles to bedding are conically distributed about fold axis II, then the apical angle of the phase II fold can be estimated by measuring the extent of the spread of the poles to bedding. This spread indicated that the southwestern limbs of the syncline were moved 46° and the northeastern limbs 24° (Figure 12). Because these angles represent the movement of these beds from the planar condition, the apical angle of the fold is 180° - their sum. That is, the apical angle is 110°.

a. Foliation from the Granitic Rocks.

It was possible to measure foliation planes at only 32 outcrops

Figure 8

Poles to Foliation in Granitic Rocks



6 - 8%

8 - 10%

> 10%

within the granitic rocks of the crystalline slice. When poles to these planes were plotted (Figure 8), the resulting concentrations were found to lie roughly along a great circle whose pole trends $097^{\circ}/08^{\circ}$.

From this distribution, it is concluded that foliation in the granitic rocks prior to phase II folding was planar. During phase II deformation, poles to foliation would then be spread out to their present positions. If, as has been postulated, the granitic rocks are of magmatic origin, the foliation would likely be a result of flow within the magma. Such flow would likely result in a simple planar pattern and is consistent with the interpretation of Figure 8.

b. Foliation from the Metamorphic Rocks.

Foliation is well developed in the metamorphic rocks but exposure is limited so only 50 foliation planes were measured during the field work. Poles to these planes are very nearly conic in distribution with axis $120^{\circ}/88^{\circ}$ (Figure 9). Consequently, it would appear that the metamorphic rocks were refolded during phase II deformation about a near-vertical axis.

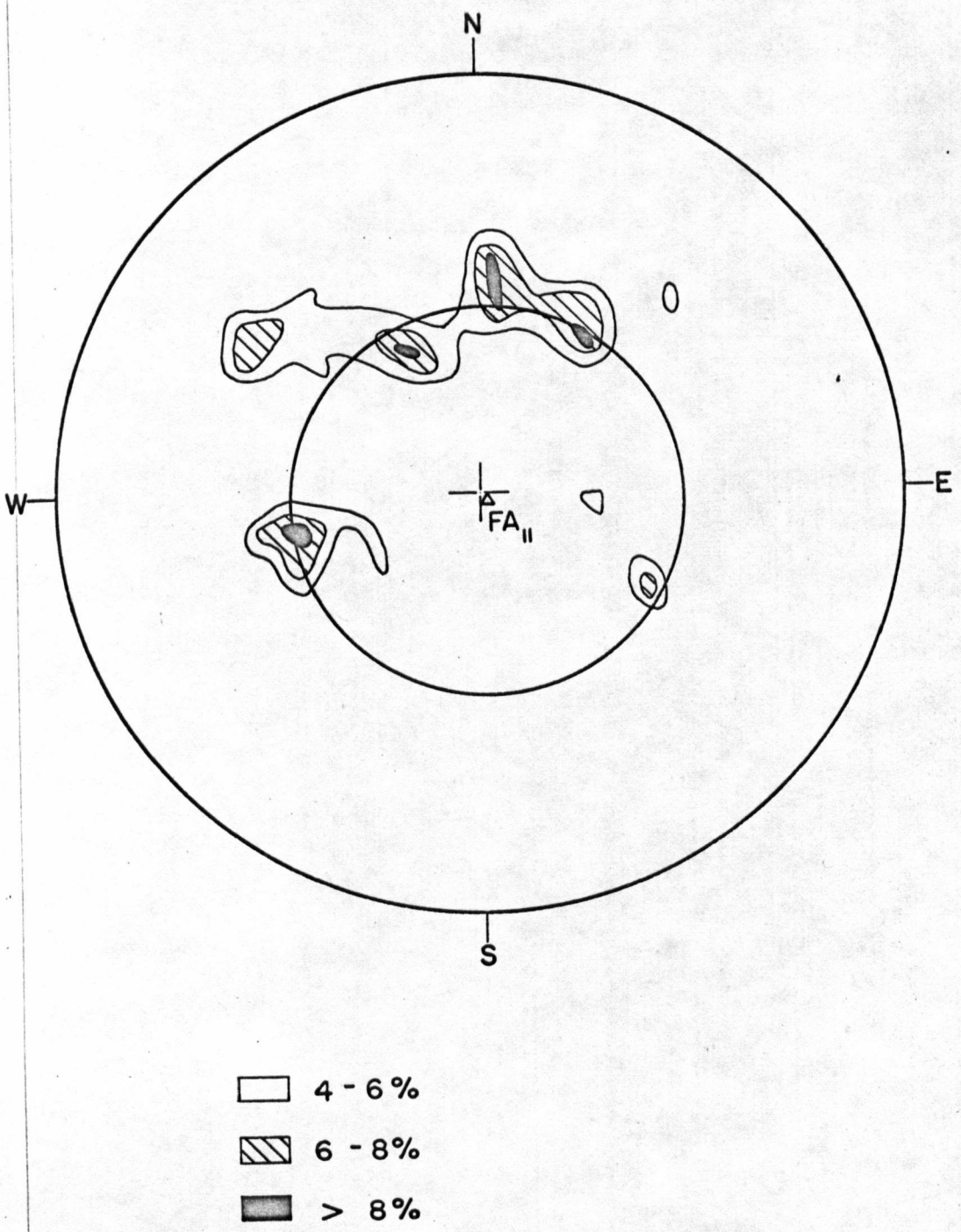
Distribution of the foliation prior to phase II deformation remains uncertain. As previously mentioned, minor folds from the metamorphic rocks indicate that they have undergone synkinematic recrystallization. However, distribution of these folds suggest nothing of the attitudes or extent of any large scale folds which may have been present. Since evidence suggesting high temperature and/or pressures after emplacement of the crystalline slice is lacking, it seems probable that the minor folds formed prior to this event.

c. Deformation of the Crystalline Rocks.

Both axial planes and fold axes of folds developed during phase II

Figure 9

Poles to Foliation in Metamorphic Rocks



deformation are different for the metamorphic and granitic rocks. If, as has been postulated, phase II fold axes have been controlled by the attitude of the plane being folded, granitic foliation trended N7°E/08°SE prior to phase II deformation. Similar reasoning suggests that the majority of the metamorphic foliation planes were steeply dipping to nearly vertical prior to phase II deformation. Variations in the attitude of the axial planes and the trend and plunge of fold axes from the metamorphic and granitic rocks are thought to have resulted from differences in attitude of the foliation planes prior to phase II folding.

C. Joints from the Sedimentary Rocks.

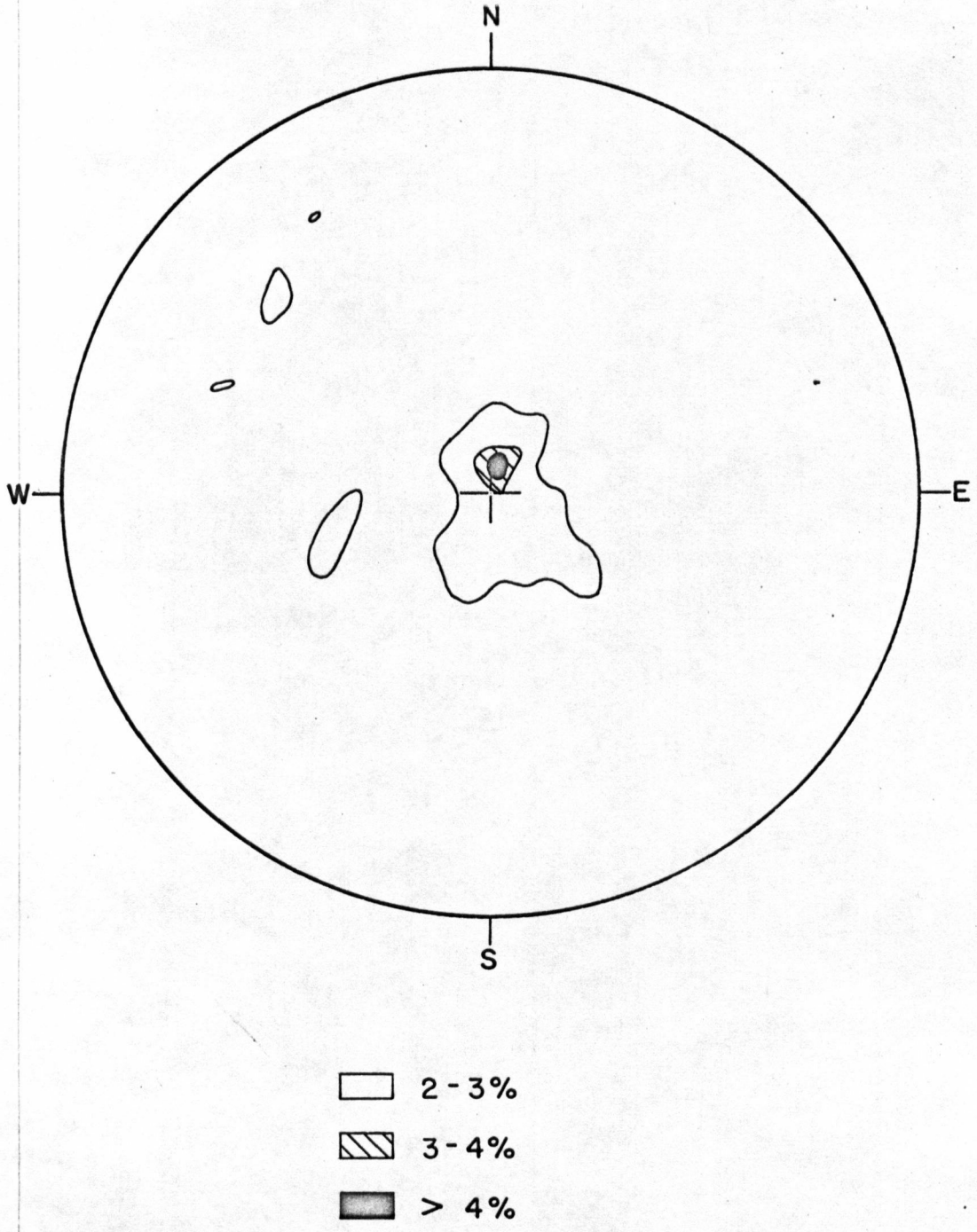
Joints as used here refers to fractures in the rock which are more than 1/8 inch apart. In the field, only well developed joints up to a maximum of four per outcrop were measured. Using this approach, it was hoped to avoid biased results. Poles to the 357 joints measured concentrated near the periphery of the projection, indicating that steeply dipping joints predominate (Figure 11). Joints with flat to intermediate dip are not well developed in the map-area.

a. Phase I Joints.

In Figure 11, concentrations of poles near 285° and 350° lie 36° and 30° respectively away from the pole to the axial plane of the major syncline. These concentrations may represent a conjugate set of shear joints formed during the first period of deformation. In support of this conclusion are offset joints in argillite of the western sediments along the railway tracks near the southern contact with the crystalline rocks.

Figure 10

Striae on Joint Faces



(Plate 6). Poles to these offset joints lie within the maxima near 285°. Strong concentrations of poles near 230° and 050° lie on the axial plane of the syncline and are steep dipping. These are thought to represent a-c joints formed during phase I folding.

b. Phase II Joints.

A weak cluster of points near 260° may represent shear joints formed during phase II folding. The angle between this cluster and the pole to the average axial plane II is 40°. No field evidence was found in support of this conclusion. Clusters at 130° and 310° probably represent $a\text{-}c_{II}$ joints since they lie along the average axial plane. High concentrations of poles spread from 210° to 230° and from 015° to 040°. These are thought to represent $a\text{-}b_{II}$ joints. The spread may be a result of earlier $a\text{-}c_{I}$ joints which would act as zones of weakness and cause the later joints to migrate from their theoretical location. Variations in the trend of the axial planes of the phase II folds might also cause this spread.

c. Concentrations of Poles of Joints with Uncertain Significance.

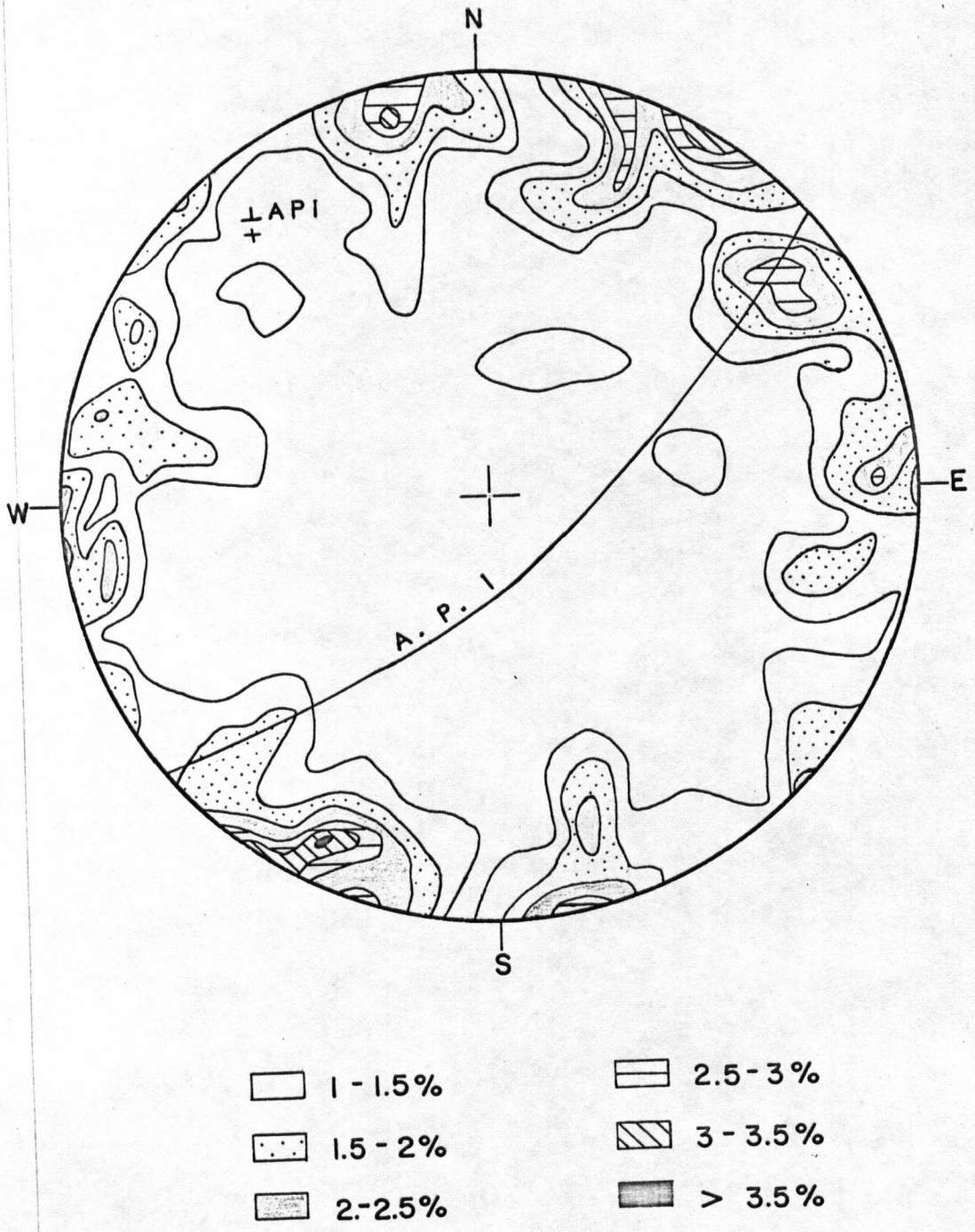
Concentrations of poles near 090° and 100° do not appear to be related to either period of deformation. Their significance is uncertain.

d. Cleavage.

Arbitrarily, if fractures in the rock were less than 1/8 inch apart they were called cleavage. During the field work, only 46 cleavage measurements were made. When plotted, poles to these planes formed concentrations near 350° (Figure 7). The two maxima appear to lie along a great circle whose pole plunges 28° toward 077°.

Figure 11

Poles to Joints in Sedimentary Rocks



If the planes measured represented axial plane cleavage formed during phase I deformation, their poles would concentrate at a point which would be the pole to axial plane I prior to phase II deformation. That is the cleavage would initially be parallel to the axial plane. During phase II deformation, the poles to cleavage would then be expected to be rotated about fold axis II. Consequently, they should lie along a great circle whose pole is this fold axis. However, no evidence to suggest a fold axis trending $077^{\circ}/28^{\circ}$ was found during the field or subsequent laboratory work.

On Figure 12, concentrations of poles to joints which are thought to represent a conjugate set of shear joints formed during phase I deformation occur at 350°. These concentrations are very close to those for poles to cleavage planes. Consequently, it is concluded that the planes which were mapped as cleavage were in fact closely spaced shear joints associated with phase I folding.

e. Slickensides on Joint Faces.

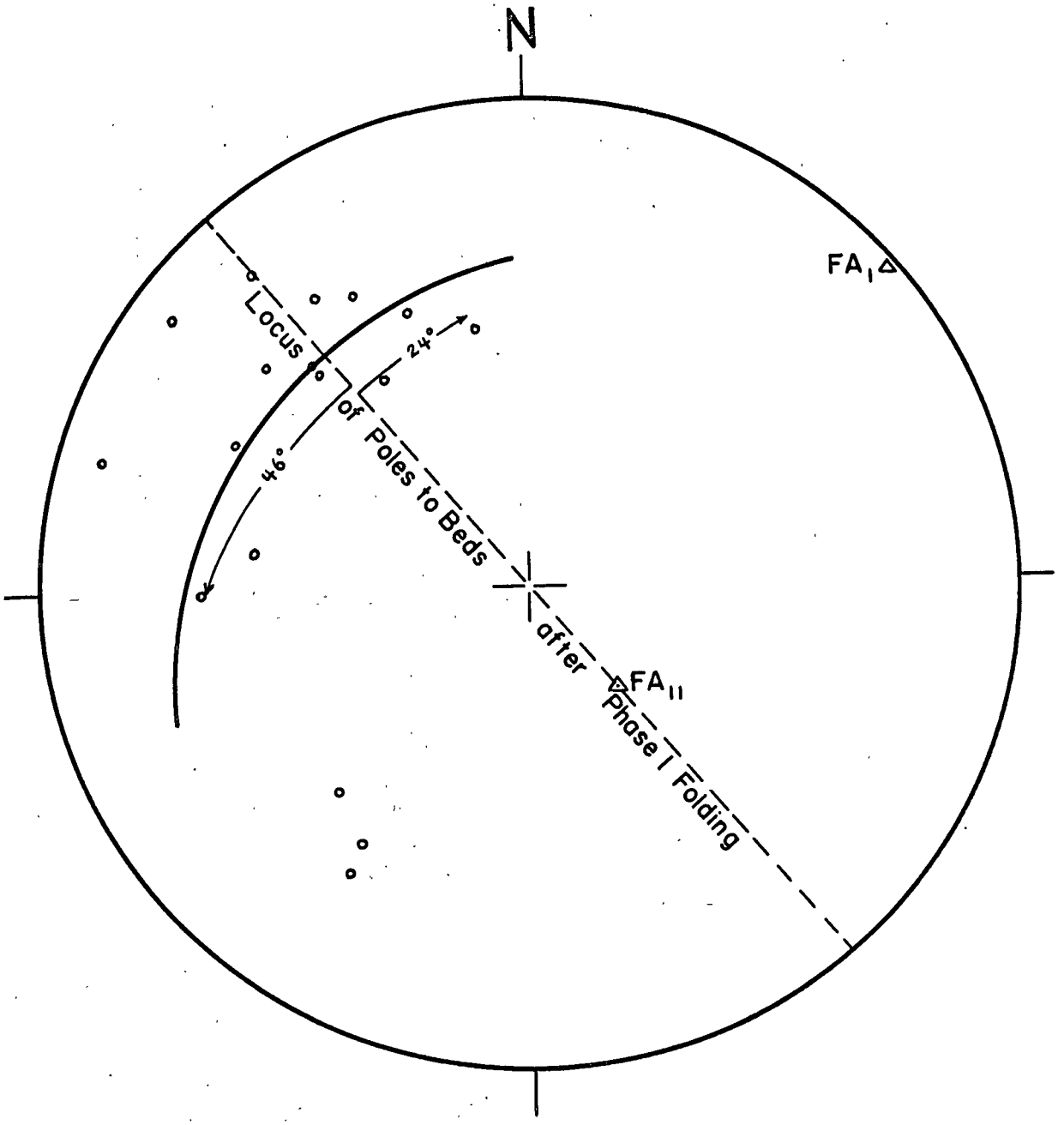
Striae from 219 slip faces were plotted to give Figure 10. A pronounced, somewhat skew concentration of points was found near the center of the projection. A second, less pronounced, concentration occurs in the northwest quadrant near the edge of the projection.

The steeply dipping striae probably formed during phase I deformation. Within the sediments, bedding plane slippage in the units which folded concentrically would account for part of the concentration. Within the crystalline rocks, small scale faults and slips parallel to the bounding faults would account for the remainder of the concentration.

Since phase II folding was concentric in nature, slippage between

Figure 12

Poles to Bedding from the Eastern Sediments near the International Boundary



beds would occur during deformation. Since this slippage would occur at right angles to the fold axis, it would give rise to predominantly northwest trending striae with shallow dips for the steeply southeast plunging fold axes. From these considerations it seems reasonable to correlate the concentrations of striae in the northwest quadrant with phase II deformation.

Section IV - DISCUSSION OF THE AGE RELATIONSHIPS OF VEDDER MOUNTAIN ROCK UNITS.

A. Eastern and Western Sediments - Other Workers.

Daly (1912) relegated both eastern and western sediments to the Chilliwack group which he suggested was of Carboniferous age.

Crickmay (1930) showed only the eastern sediments on his geological map. He placed them in the Slollicum Series of Upper Triassic age.

Misch (1955, personal communication with Armstrong) felt that the volcanic rocks which crop out near Sinclair could be correlated with the Nooksackvolcanics of northern Washington, which are of Jurassic age. Later in the communication he suggested that the eastern sediments also correlated with the Nooksack Group.

Hillhouse (1956) correlated the eastern sediments with the Upper Jurassic to Lower Cretaceous Nooksack Group of northwestern Washington. His correlation was based on personal communication with Misch and Armstrong.

Moen (1962), who worked on the portion of Vedder Mountain which extends into the United States, mapped the extension of the eastern sediments as Chilliwack Group. He redefined the Chilliwack Group and suggested that the sediments were deposited during Late Palaeozoic time.

B. Crystalline Rocks - Other Workers.

Daly (1912) placed the crystalline rocks in the Chilliwack Group with the sediments. He called them the Vedder Greenstone and thought the crystalline body was a sill.

Crickmay (1930) thought that the crystalline rocks were altered volcanic rocks of Triassic age. He suggested that they were conformably underlying the eastern sediments.

Armstrong (1956) listed the crystalline rocks as highly metamorphosed rocks of uncertain age on the Pitt Lake sheet.

Moen (1962) refers to similar rocks in the Van Zandt quadrangle and compares them to crystalline rocks exposed in the San Juan Islands. Danner (1957) showed that the San Juan Island rocks were pre-Devonian in age. Moen thought that the crystalline rocks which he mapped were also pre-Devonian and refers to them as upthrust basement slices.

C. Eastern and Western Sediments - Present Work.

In the east, the conglomerate, which is the oldest unit exposed sometimes contains numerous granitic pebbles. The significance of these pebbles is not certain. Granitic rocks were supposedly not prominent until Jurassic time so the conglomerate might be post-Jurassic in age. However, the pre-Devonian granitic rocks which crop out in the San Juan Islands cast doubt upon this interpretation.

No fossils were found in the eastern sediments despite the presence of argillite, limestone pods and chert beds which were potentially fossiliferous. Consequently, no positive age can be assigned to these rocks.

From the western sediments, radiolarian bearing chert fragments

were found in the chert lenticule arenite and the chert arenite breccia. Since the radiolaria found probably originated during Devonian time and range to the present (Danner, personal communication), it is possible to say only that the western sediments contain fragments which are probably post-Silurian in age. However, since the radiolaria involved probably originated during Devonian time and since they are contained within fragments of the rock in which they were deposited, it seems likely that the sediments are post-Devonian in age.

The eastern and western sediments cannot be correlated directly from lithologic or palaeontologic evidence. However, correlation on the basis of lithology has been attempted in a tentative way (Figure 2). In this correlation, it has been suggested that the limestone-bearing horizons are equivalents.

The volcanic rocks near Sinclair are thought to correlate in part with the oldest member of the western sediments, the quartz plagioclase porphyry. This suggestion is based on the lithologic similarities between the porphyry and some of the rocks near Sinclair. Since the rocks are more extensive near Sinclair, it seems likely that they are in part older than the porphyry and hence the western sediments as a whole.

D. Crystalline Rocks - Present Work.

The crystalline rocks are believed to have been emplaced along steep, southeast dipping faults, presumably from great depth. Metamorphic components are from the regional metamorphic Almandite-Amphibolite Facies and were derived from basic and pelitic rocks. Their absolute age is unknown. Since they have pushed aside the sediments it is probable that the crystalline rocks are older.

The granitic components of the crystalline complex appear to intrude the metamorphic components. Consequently, they would be younger than the date of metamorphism. Within the granitic rocks themselves, the quartz diorites and pegmatites appear to be younger than and to intrude the diorite. The time lapse between formation of the metamorphic rocks and intrusion of the granitic rocks is not known; nor is the time between intrusion of the granitic rocks and emplacement of the crystalline complex. It seems probable, however, that the granitic rocks were solid prior to emplacement of the slice, since no contact metamorphic effects were present in the sediments.

a. Emplacement of the Crystalline Slice.

Moen indicates a fault along the southwest margin of the United States extension of Vedder Mountain. This fault affects sediments which he assigns to the Chilliwack Group and uplifted them with respect to upper Eocene continental sediments. He suggests that what is now Sumas Valley originated as a result of this late Pliocene (?) block faulting. In Canada, Armstrong (1959) reports that Tertiary bedrock is as much as 1,100 feet below the valley floor.

This fault is the western bounding fault of the crystalline slice in the map-area. Although movement occurred along this fault during the late Pliocene(?) orogeny, it is unlikely that the crystalline complex was emplaced at that time. If it had been emplaced then, the Tertiary continental rocks and western sediments should have acted as a structural unit. However, the block faulting bypassed the western sediments and down-dropped the Tertiary rocks with respect to them. The age of emplacement of the crystalline slice can only be bracketed as post-sediment, pre-Tertiary at

this time.

Section V - SUMMARY OF GEOLOGIC HISTORY.

Pelitic sediments and basic volcanic rocks were deposited. [redacted] With time these rocks were buried and eventually subjected to metamorphism of the Almandite Amphibole Facies. Amphibolites, hornblendite, epidote amphibolite, epidote and amphibole white mica schists, and garnetiferous amphibole and mica schists and gneisses formed.

Since folds in the metamorphic rocks are outlined by the foliation, it follows that deformation post-dates formation of the foliation. Minor folds within these rocks have been subjected to rheid deformation since fold crests are much thickened and limbs thinned. Evidence from thin section examination suggests that deformation was synkinematic. From this data it seems likely that the metamorphic rocks were subjected to rheid deformation during metamorphism but before they were cooled, that is, folding probably occurred under roughly the same pressure and temperature conditions at which the minerals formed. Lack of retrograde metamorphic effects despite recrystallization during folding further supports this hypothesis.

Some time after their formation, the metamorphic rocks were intruded by diorite. Along the contact [redacted] the diorite was fairly quickly cooled and more basic mixed rock resulted. Subsequently, small bodies of quartz diorite and pegmatite derived from the crystallizing parent magma intruded the diorite. Whether they intrude the metamorphic rocks also was not determined from the field work. All phases of the granitic

intrusion are characterized by extensive saussuritization of the plagioclase. Presumably, this alteration resulted from late stage deuteric solutions within the crystallizing bodies since the metamorphic and sedimentary rocks are not saussuritized.

Post-Devonian(?)sedimentation resulted in what are now referred to as the eastern sediments. The base upon which they were deposited is not exposed. Judging from the nature of the pebbles to cobbles of the oldest unit exposed, the chert, volcanic granitic pebble to cobble conglomerate, the source area probably had interlayered chert and volcanic rocks cut by granitic bodies. The conglomerate has plagioclase volcanic arenite both as interbeds and as its matrix. The relationship of well rounded, mature cobbles with angular immature matrix components and interbeds is easily visualized if the rocks are turbidites.

As time went on, conglomeratic material became scarce and arenite more prominent. Eventually, conglomeratic material stopped being supplied to the depositional area. [redacted] About that time, argillaceous interbeds began to appear in the arenite. The arenite unit, which is capped in places by argillite was succeeded by micro-volcanic arenite. Argillite, plagioclase volcanic arenite and chert interbeds are common within the micro-volcanic arenite. One band, which has been used as a marker, consists of impure silicious argillite which contains pods of impure crystalline limestone. At the northeast end of the map-area, considerable thicknesses of chert were being deposited while the micro-volcanic arenite predominated to the southeast. Micro-volcanic arenite is the uppermost exposed unit of the eastern sediments.

From the conglomerate to the top of the plagioclase volcanic

arenite, it seems likely that the sediments were deposited from turbidity currents. Graded beds, sole marks, current marks and other typical features of turbidites were lacking. The constitution of the rocks is the fundamental reason for suggesting that they were deposited from turbidity currents. Whether the micro-volcanic arenites are turbidites remains in doubt. Mineralogically, they are nearly identical to the plagioclase volcanic arenites but are much finer grained.

The marker horizon represents a period of slow introduction of argillaceous material which mixed with silica to form an impure gel. The limestone pods represent local high concentrations of carbonate in the water. Whether the carbonate and silica to form the cherty and limy deposits resulted from vulcanism outside the area of deposition of the eastern sediments is not known. If vulcanism did supply these substances, the limy horizon would correlate with the limy horizon from the western sediments which is underlain by volcanic rocks and probably resulted from emanations associated with the vulcanism.

At some time before, during or after the eastern sediments were deposited, sediments of post-Devonian(?) age which are now referred to as the western sediments were laid down. Vulcanism apparently preceeded sedimentation but how important it was is uncertain. Diabase and porphyritic dacite predominate. Argillaceous sediments followed by micro-volcanic arenite overlie the volcanic rocks. It is possible that pyroclastic activity was the source of breccias which overlie the arenite. These breccias include chert lenticule arenite and volcanic chert lenticule arenite breccia. Chert from these breccias contains radiolaria which have

long ranges but originated during Devonian time. Whether these rocks are of pyroclastic, sedimentary or turbidity current origin is not certain. A limestone horizon within the breccia unit suggests water with high calcium carbonate content which might have resulted from volcanic emanations. At the same time, the jumbled arrangement of some of the fragments from these rocks suggest turbulent, perhaps turbidite, deposition. The question of origin cannot be answered from present data. Introduction of clastic material into the area decreased and a fairly thick argillite unit was deposited upon the breccias. Later, deposition of clastic material almost stopped and slightly argillaceous ribbon chert formed. This ribbon chert is the youngest unit of the western sediments which is exposed.

After both eastern and western sediments were deposited, tectonic activity caused a slice of the underlying, more deeply buried, crystalline and medium grade metamorphic rocks to move up along bounding faults which dip steeply toward the southeast. As the "basement" slice pierced the sediments, it pushed them aside and caused what is now referred to as phase I folding. The eastern sediments were primarily deformed into a syncline with its fold axis plunging less than 1° toward the northeast and axial plane trending 050/75 SE. While the incompetent argillites were folded similarly, the more competent conglomerates, arenites and cherts were folded concentrically. The western sediments were pushed up by the slice to form an overturned monocline with steep southeast dip.

A second period of deformation affected both the sediments and the crystalline rocks. Folds produced during this deformation have vertical axial planes which trend between 090° and 140°. Fold axes vary widely in

plunge and trend. Since folding during phase II deformation was concentric, the axes and to a lesser extent the axial planes of the folds depend on the strike and dip of the plane being folded. Most of the beds and foliation planes were steeply dipping after phase I deformation and the introduction of the crystalline slice so most of the axes of phase II folds plunge steeply.

During Tertiary time, continental sedimentation occurred in what is now Sumas Valley. Movement along the western bounding fault of the crystalline slice which Moen suggests occurred during Upper Pliocene(?) time is thought by him to have caused Sumas Valley to form. Armstrong (1959) reports that drilling reveals these Tertiary sediments 1,100 feet below the present valley floor. Unfortunately, rotary, non-coring drills were used so no information on the attitude of these rocks is available (Armstrong, personal communication). Since the western sediments are still exposed, it seems likely that the embayment which they occupy in the crystalline rocks caused the Tertiary block faulting to occur along their western edge rather than following the crystalline rock - sediment contact. Field evidence to support this speculation is lacking since the probable locus of this fault zone is covered by overburden.

During the Pleistocene epoch, the map-area was covered by an ice sheet which was of continental proportions. Scour by the ice streamlined the mountain and gouged out softer rocks to some extent. Glacial erratics on the mountain were dropped as the ice retreated and its sides were plastered with Surrey till (Armstrong, 1959).

Since the ice retreat, Vedder Mountain has been much as it is today,

although incised by several important and numerous small intermittant streams. Subaerial erosion primarily through plant and water action continues.

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Plate 1 Photomicrograph showing well-rounded granitic and volcanic pebbles in plagioclase volcanic arenite matrix in which the fragments are angular (plane light, x20).

Plate 2 Photomicrograph of immature plagioclase volcanic arenite containing a dark colored lens-like argillite fragment (plane light, x20).

Plate 3 Hand specimen of color banded argillaceous chert showing intense brecciation and disruption of the banding. The scale divisions are millimeters.

Plate 4 Hand specimen of brecciated argillaceous white chert. The scale divisions are millimeters.

Plate 5 Photomicrograph of micro-volcanic arenite. Quartz, feldspar and volcanic fragments predominate. The matrix is argillaceous (plane light, x55).

Plate 6 A hand specimen of argillite from the western sediments in which steps resulting from movement along shear joints are preserved. The scale divisions are millimeters.

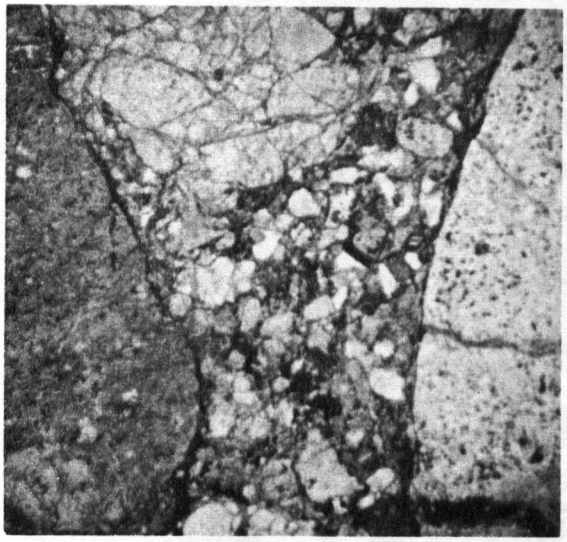
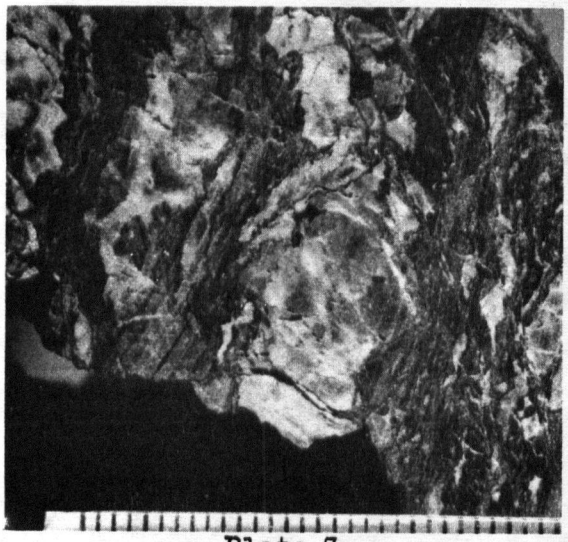


Plate 1

Plate 2



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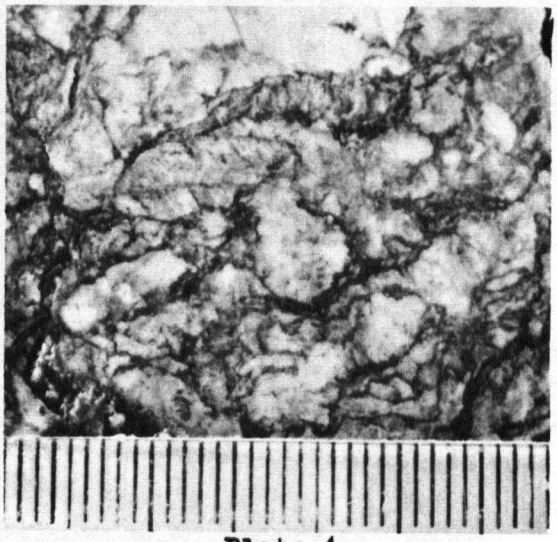

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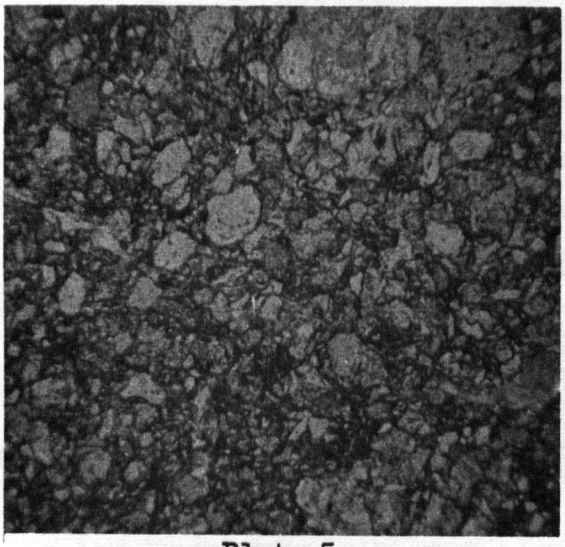

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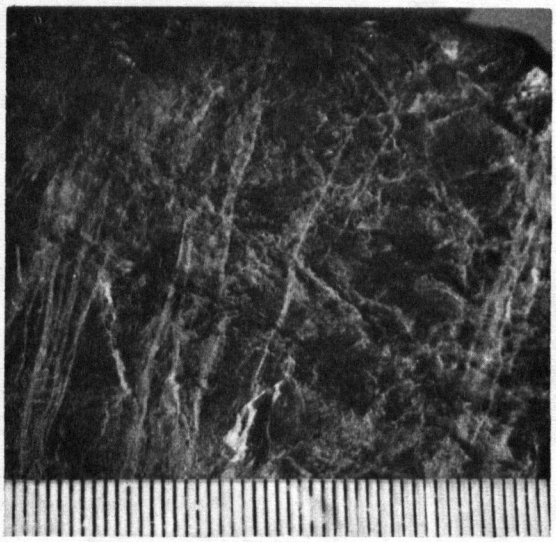


Plate 6

Plate 7 Photomicrograph of rounded radiolaria from an argillaceous chert fragment in radiolarian chert lenticule arenite. The texture of the radiolaria is similar in appearance to the surface of a golf ball (plane light, x50).

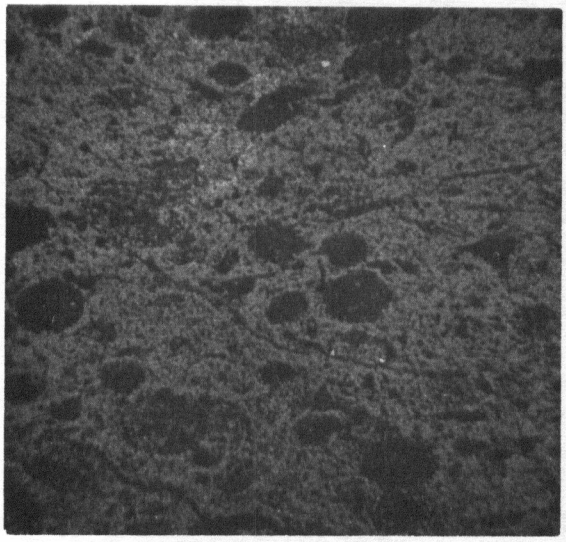
Plate 8 Photomicrograph of cigar-shaped radiolaria with rounded cross section from a chert fragment in radiolarian chert lenticule arenite. The longitudonal section is similar in appearance to a cob of corn (plane light, x85).

Plate 9 Photomicrograph of lawsonite from the matrix of radiolarian chert lenticule arenite. The mineral has fibrous habit (plane light, x60).

Plate 10 Hand specimen of radiolarian chert arenite breccia showing the jumbled distribution of the fragments. The scale divisions are millimeters.

Plate 11 Photomicrograph of quartz feldspar volcanic porphyry with strained and broken phenocrysts (crossed Nicols, x25).

Plate 12 Photomicrograph of foliated epidote amphibolite. Hornblende, epidote, quartz and feldspar predominate (crossed Nicols, x30).



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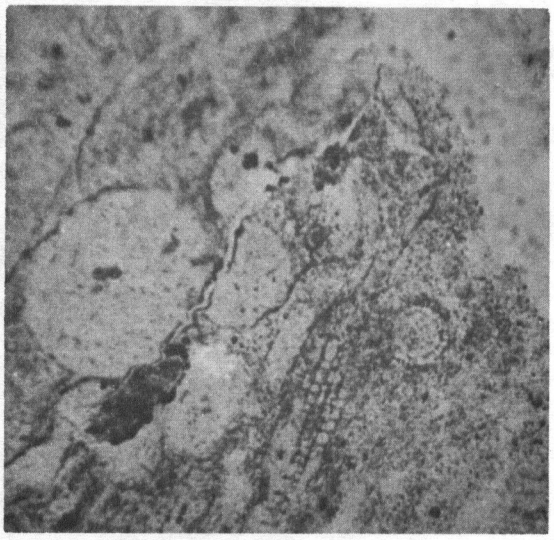

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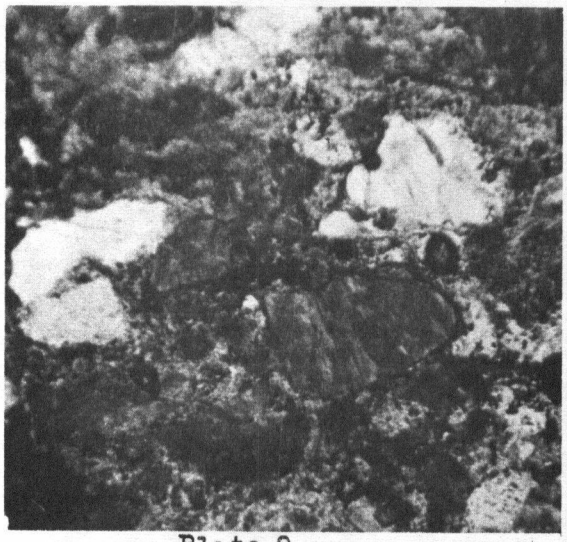

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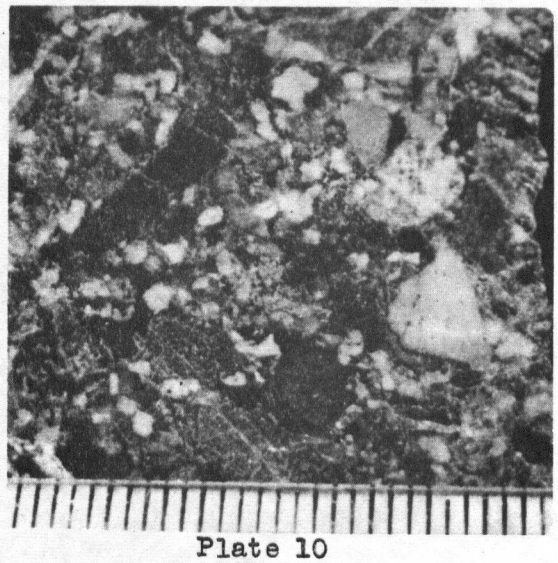

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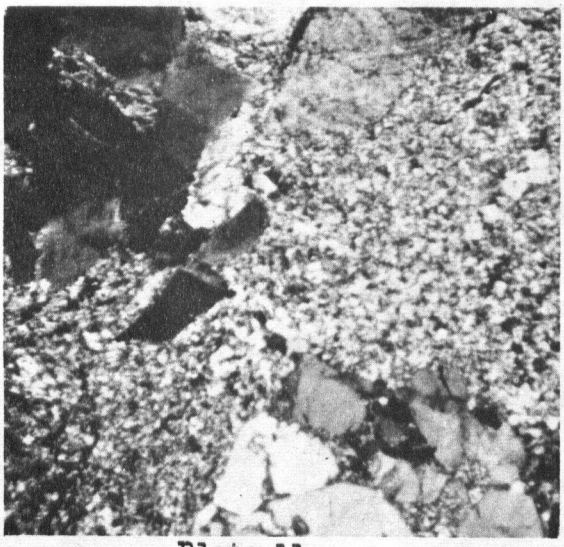

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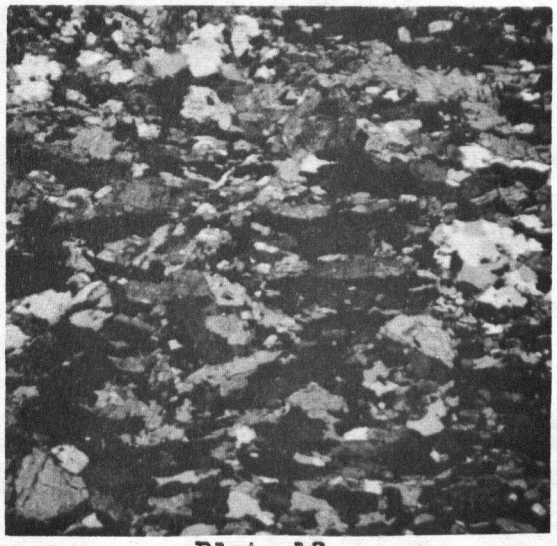


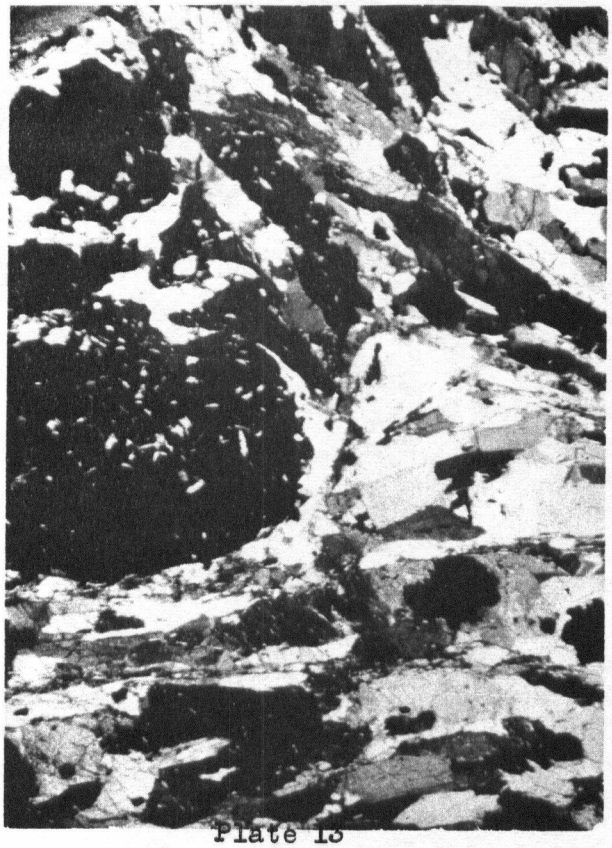
Plate 12

Plate 13 Photomicrograph of foliated garnet white mica hornblende quartz feldspar rock showing bending of the foliation around the garnet porphyroblasts (crossed Nicols, x20).

Plate 14 Photomicrograph of garnet sphene schist. Garnet is black, embayed; sphene roughly diamond-shaped and strung out parallel to the metamorphic foliation. White mica outlines the foliation (crossed Nicols, x20).

Plate 15 Dike of lighter colored diorite cutting darker colored diorite. Note unevenness of the border of the dike but the definite crack-filling offset from the dike. The scale divisions are millimeters.

Plate 16 Photomicrograph of foliated quartz diorite in which the quartz stringers are characterized by pronounced undulatory extinction (crossed Nicols, x20).



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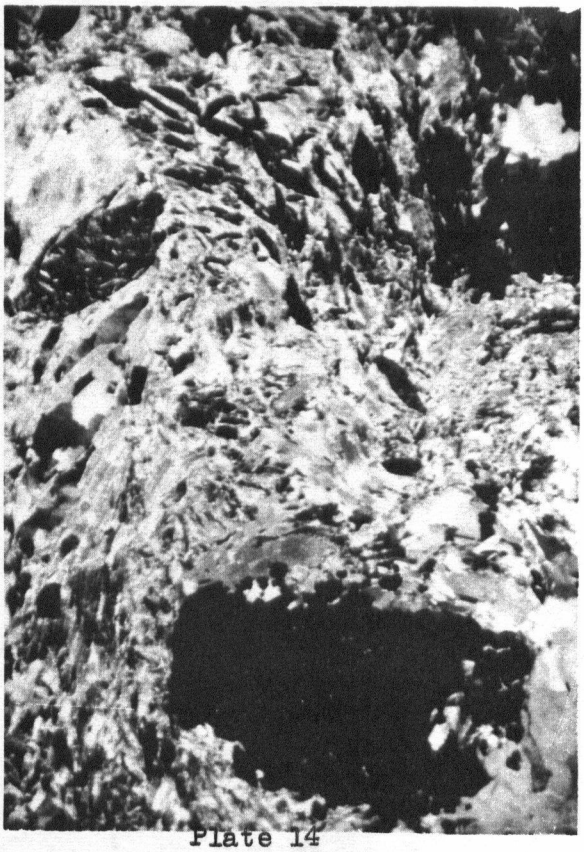

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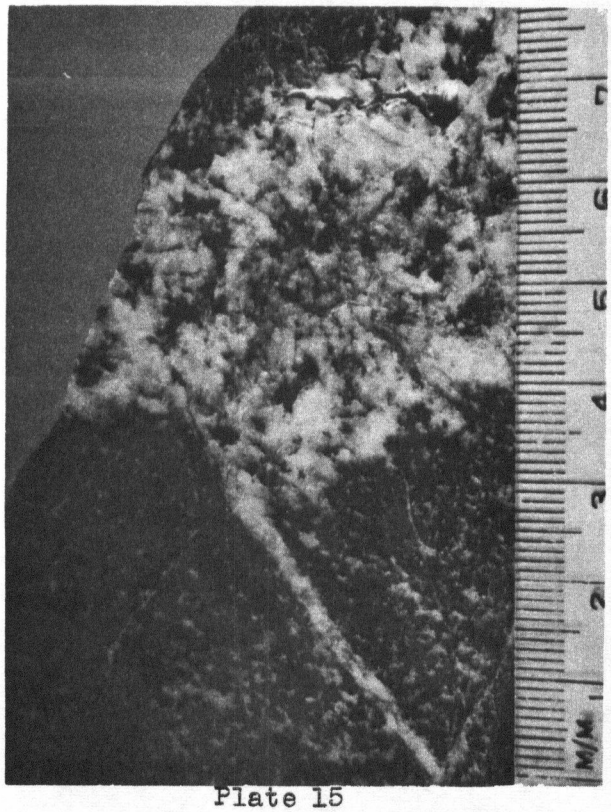

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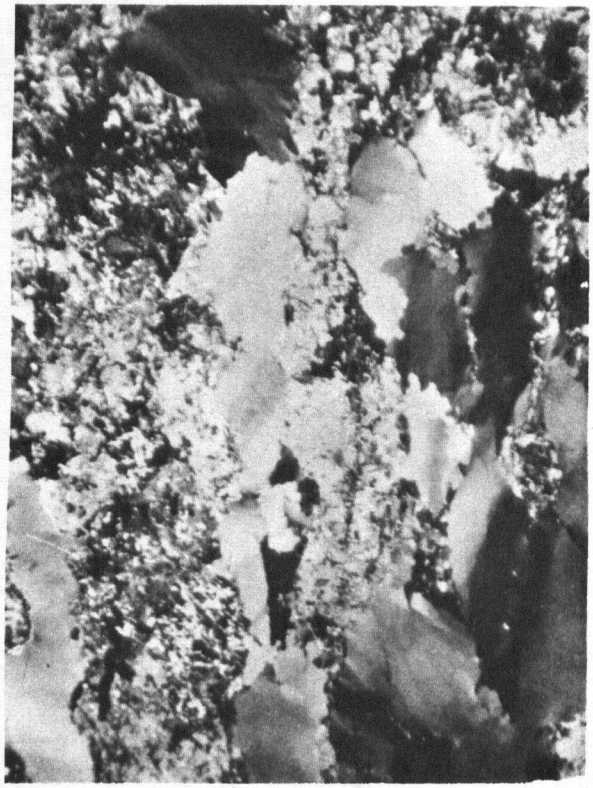

Plate 16

Plate 17 Photomicrograph of foliated diorite in which feldspar has been completely saussuritized (plane light, x20).

Plate 18 Photomicrograph of thin prisms of prehnite from a veinlet which crosses foliated diorite. Many of the prisms are roughly perpendicular to the veinlet walls (crossed Nicols, x30).

Plate 19 Photomicrograph of basic mixed rock with very high hornblende content. Feldspar has been completely saussuritized (plane light, x20).

Plate 20 Photomicrograph of a subrectangular mesh comprised of blade-like antigorite crystals with interstitial massive antigorite (crossed Nicols, x20).

Plate 21 Photomicrograph of tiny, pale green, needle-like crystals which project from the "walls" of the bladed antigorite meshwork into the massive antigorite seen in plate 20 (plane light, x210).

Plate 22 Hand specimen of epidote amphibolite containing a minor fold in which the crests are thickened and the limbs are thinned. The scale divisions are in millimeters.

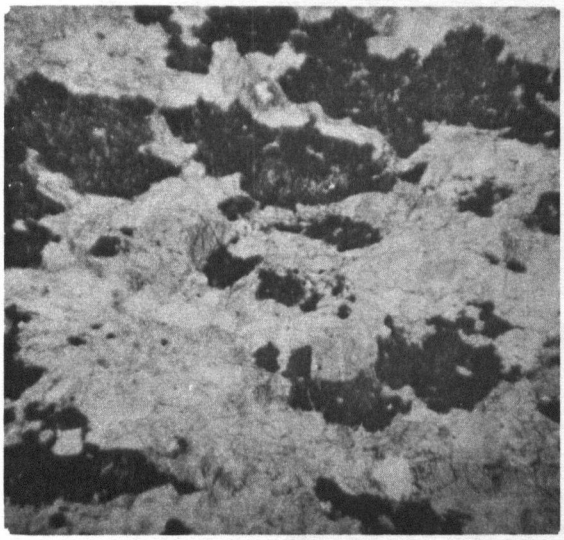

Plate 17

Plate 18

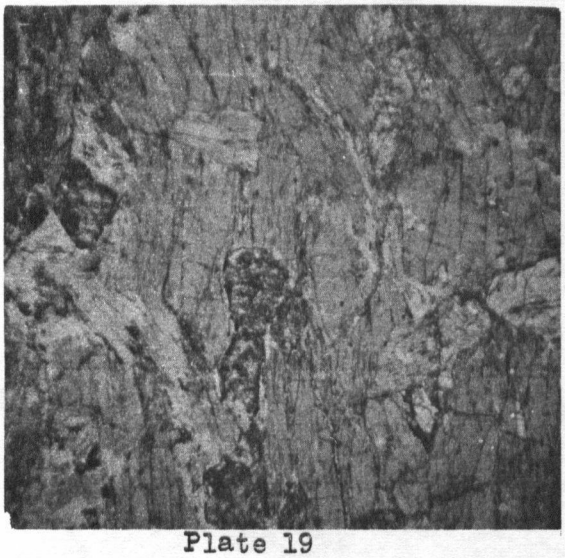

Plate 19

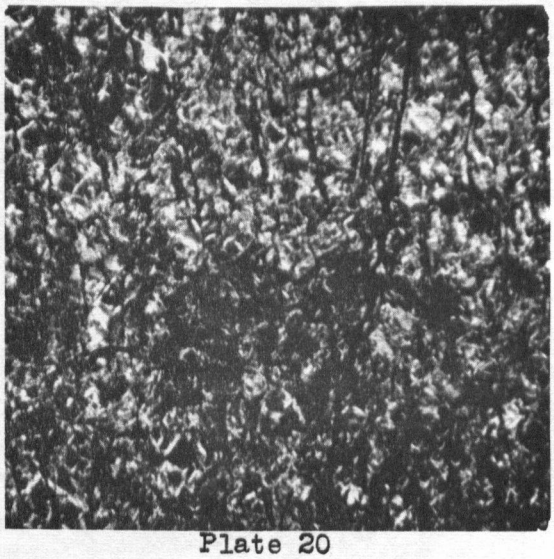

Plate 20

Plate 21

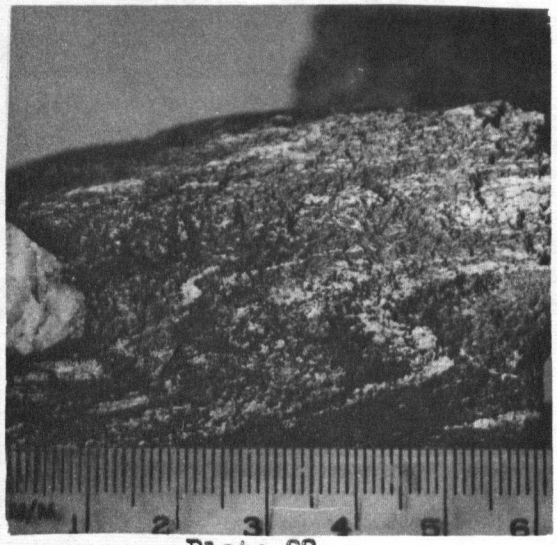

Plate 22

Plate 23 Photomicrograph of a minor fold formed under synkinematic conditions and outlined by elongated prisms of actinolite which were bent but not broken during the deformation (crossed Nicols, x60).

Plate 24 Photomicrograph showing a mylonite zone crossing granitic rocks near the southwest contact with the western sediments (plane light, x25).

Plate 25 Photomicrograph of cataclasite derived from quartz plagioclase porphyry at the southwest contact of the western sediments block with the granitic rocks (plane light, x20).

Plate 26 Photomicrograph of cataclasite derived from granitic rock at the southwest contact of the western sediments block (crossed Nicols, x20).

Plate 23

Plate 24

Plate 25

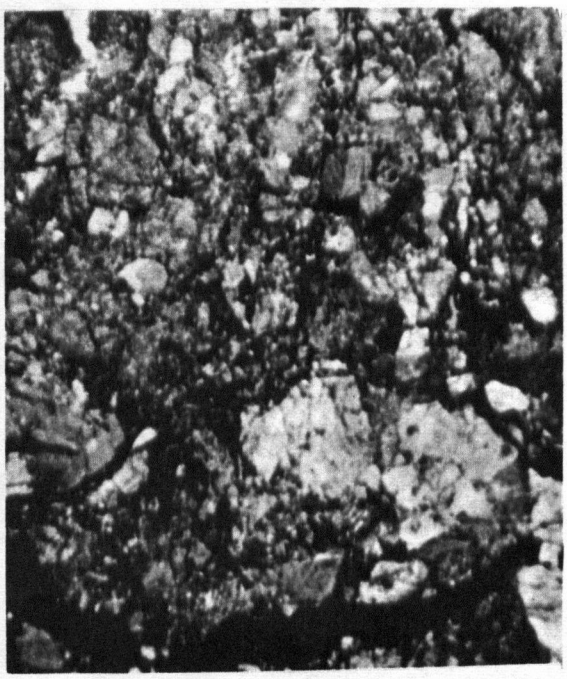

Plate 26

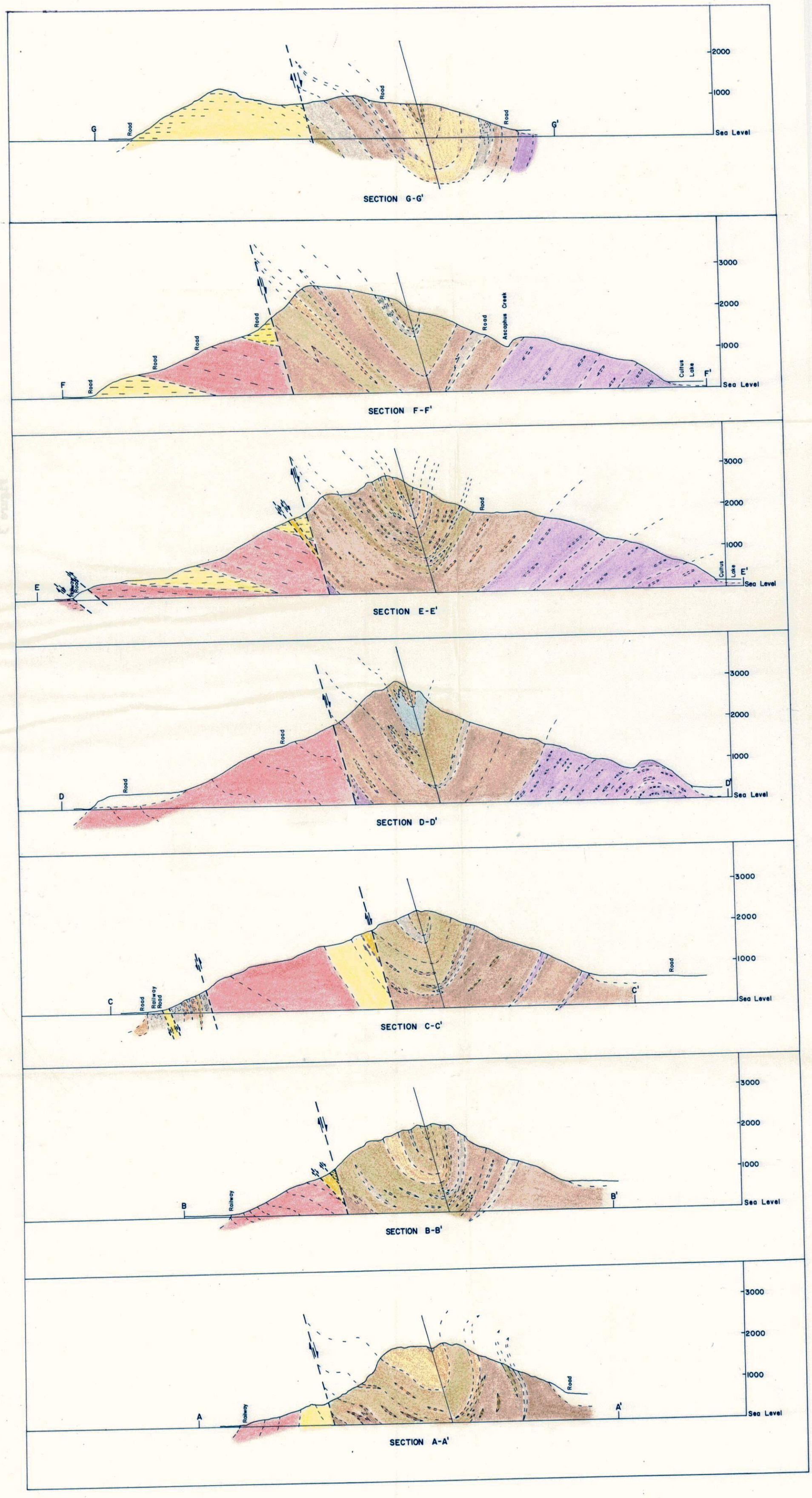

Figure 3.

VEDDER MOUNTAIN CROSS SECTIONS

FOR LOCATIONS AND LEGEND SEE FIGURE 1

SCALE

0 1000 2000 3000 4000 5000

Geology of Vedder Mountain

Figure I.