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GEOLOGICAL 'AREA PICTURE' OF UPPER GAINER CREEK

An Essay submitted during the Third Year
of the Course in Applied Science
at the University of British Columbia

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November 12, 1957

Union College,
The University of British Columbia,
Vancouver 8, British Columbia,
November 12, 1957.

Dr. H.C. Gunning,
Dean of the Faculty of Applied Science,
The University of British Columbia,
Vancouver 8, British Columbia.

Dear Sir:

I submit herewith an essay entitled "Geological 'Area Picture' of Upper Gainer Creek," in compliance with the Calendar regulations for the Course in Third Year Applied Science at The University of British Columbia.

Yours truly,

William D Groves

William D. Groves

This arrived early in Dec.

Matter	25/25
Pres.	15/35
English	32/40

Total 72.

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ILLUSTRATIONS

PREFACE

One approach to a geological problem is to merely enumerate the data. This may be combined with a brief and therefore desperate attempt to sort, weigh and correlate this mass for the edification of the readers, who expect, of course, to have a succinct 'package' presented to them rather than the original mass of undigested facts. However, it should be the intent of the essay writer to clarify his problem, rather than merely hoping to tabulate its obstacles and intricacies, and then 'ship the whole thing off to the analysts' who as a result would be indeed unlikely ever to unravel the snarl of conflicting data and unintentional falsifications consequent of this sort of approach.

Geological problems necessarily involve a great deal of the aforementioned data-sorting. Nevertheless, the greatest damage that can be done to the logical development of the problem is to condense the presentation to the point where it becomes unnecessarily cryptic for the readers, who have obviously not been able to acquaint themselves with the problems at hand during a summer's field work, and who therefore need to have the situation outlined to them before embarking on the problems involved. Since there was nothing to be gained from a half hearted and superficial treatment of the area, the essay soon had expanded considerably beyond the two thousand word minimum specified. It is hoped the readers' interest in the subject will not be completely extinguished by this.

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I. Introduction

1) Definition of Purpose

Creation of the 'Area Picture' of the geology of upper Gainer Creek is the purpose of this essay. In order to produce the desired article in three dimensions, instead of substituting for it a series of disoriented thumbnail sketches, whose interrelationships never do become quite clear trends had to be extracted from the data, and then made use of in grouping the facts. While these cannot be infallible systematizations, still, they should be regarded as reasonable first order approximations of the truth of the matter, at least statistically favoured to be right in any given instance. So the essay will try not only to present the data, but embody it into a form wherefrom the trends will be evident. The main divisions of the data, as presented, are geographic; general-structural; stratigraphic and original-depositional; lithologic mineralogic; and finally detailed-structural, an aspect which is basic to the whole picture. A little more must be said on structure; but first, a look at some of the other specific topics to be considered is in order.

In a rather tabular form, then, here are some of the facets of the proposed Area Picture, in which an attempt will be made:

To establish the area by looking at its original depositional conditions, with respect to its relative position in its Geosyncline, and to reconstruct temporal and spatial correspondences between the sediments:

To present and discuss the stratigraphy of the Bunker Hill Group, whose units have Area-wide exposure:

To make a detailed analysis of the area's structures themselves, and then investigate the structural implications of the ore situation.

2) Sequence of Interdependence of the Topics

Organization of geological data implies the correct prefacing system to provide enough pre-requisite information about each main topic to permit its intelligent discussion: otherwise the mental picture of the area as a whole becomes hopelessly disjointed. In this mutually interdependent chain of discussions, the end link is favoured by virtue of its greater amount of back-reference. Necessary order for emphasis then becomes reversed from that produced by the treatment of mutually independent data, where reader-enthusiasm is an inverse function of the page number. This is the reason only for relegating two of the essay's most important considerations till the end; those of detailed structural analysis and explanation of the term dynamism as applied to geologic deformation.

3) 'Structure' and 'Dynamism'

The basic discipline of structure is to make everything else relevant to it: since structural deformation by folding has been the most recent, hence most easily recognizable condition superimposed on those of the original deposition, and subsequent lithification of these sediments, it forms a strong parameter running through the other two. The second factor, basic to any useful interpretation of field data, is to realize that geologic situations are continuously dynamic: it is the immediately pre-existing circumstances and not the original ones which determine characteristics of the immediate result of further application of the deforming forces in rocks.

4) A Reservation

A reservation must, of course, be made administered as to degree: all the essential reasons for the observed deformation cannot be legitimately extracted from within the boundaries of an Area as small as the one under consideration. Thus it should be remembered the essay is not intended to be a "shot in the dark" on the subject of megatechtonics, but rather a description-and-analysis within the bounds of a specific Area. Consequently ultimate reasons behind heretofore completed geologic activities (observed) will have to escape consideration, or be assigned to "chance," although the reasons were not (assigned to chance), of course; and so the 'picture' at any stage thus obtained, while adequate for analysis of the pre-existing conditions is not good enough to use as a basis of large scale prediction. There are too many imponderables to allow honest geologic forecasting: there is a resemblance between Geology and History in this respect.

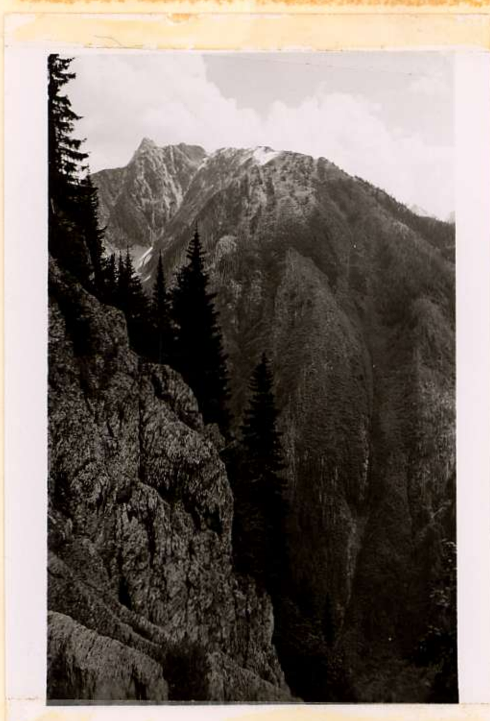
Wow!

II. General Area Description

1) General Geography

Gainer Creek is in the West Lardeau District of British Columbia. Of the creeks tributary to its upper portion, namely, Culkeen, Big Slide and Bunker Hill, named in order from the most northeast, drain the northwest side of the main valley, and Mohican Mountain, Mohican Corner and Index creeks drain the southeast side. The area is one of steeply dipping northwest striking rocks, and so

Gainer Creek, flowing approximately in a south 20° west to southwesterly arc, approximately cross-cuts the structures. It is seen that the tributary creeks flow ~~very~~ approximately perpendicular to this, and so intersect the structure at much longer angles. The mouths of Bunker Hill creek and Corner creek, being fairly close together, roughly bisect the three-mile cross strike dimension of the area under consideration. The along-strike distance between skyline ridges of the Gainer creek drainage basin is approximately four and a half miles with the creek located about in the centre.



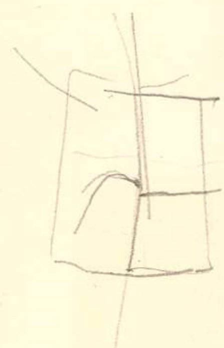


Figure 1. Considerable Topographic Relief in Upper Gainer Creek

2) Exposures

Topographic relief is considerable in the two mile plan distance from the creek, the main valley's sides rise roughly four thousand feet, and nearly all of this is in the first mile. Consequently, much naked rock exposure exists to expedite the field work, although the density of brush and forest coverage of the areas below about the seven thousand foot mark (Gainer creek's elevation is approximately 4,000 feet), and of less than 60 degree slope, is noteworthy. In short, the area is one of roughly fifteen square miles, with elevations rising to a maximum of 9,000 feet, although till coverage of a half mile astride Gainer creek, and a comparable amount belonging to the side creeks greatly reduced the area of good exposure; this created some rather enigmatic gaps in the geology due to rapid along-strike changes in major structures.

3) Naming the General Structural Localities

Major structures were named for convenience. It might be worth while enumerating the localities, and briefly describing these structures. A cross-strike section of the area would reveal three major anticlinoriums, marked by large upwarps of the basal limestone of the Bunker Hill Group: due to erosional stripping-off of the softer overlying material on the crests, the limestones have been strike-ridge formers. Between the two more southwesterly

Figure 2. Anticlines of the Bunker Hill Creek Structure, with the Badshot Peaks, and Ophir Lode Peak towards the Right in Background

anticlinoriums a small anticline with complimentary syncline exists; the two being respectively spaced between the major structures. Named localities on the major structures

Figure 3. Looking NNW at Badshot Mountain, showing the Full Ridge-forming Capacity of the Limestone

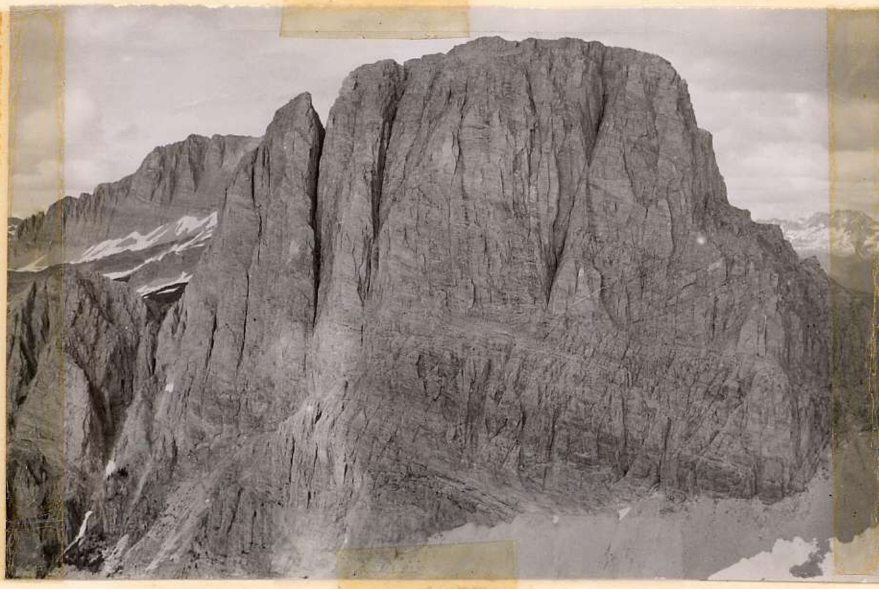


Figure 4. The 1200' Sheer Wall Face on SW Side of Mount Badshot

are to be given on the northwest and southeast sides of Gainer Creek respectively.

Mount Badshot and Mohican Mountain are the first such pair, being thousand foot thick steeply southwest dipping limestone beds, eroded to 'shark's teeth', capping the Marsh Adams anticline to the northeast; however, since the Badshot-Mohican Mountain lime forms the 'north' boundary of the area under discussion, no more is to be heard of members below the Badshot limestone except of the Mohican formation, which is preponderantly a grey shale. The complimentary synclinorium to the 'west' is known as the Badshot, or Mohican Pass area, depending upon the side of Gainer creek one is on.

Ophir Lode Peak is the next limestone anticlinorium: this corresponds to the Corner Hill region along-strike, and it is to be noted that the single major anticline on Ophir Lode Peak has become triple-crested on Corner Hill. To the southwest Big Slide Creek basin corresponds to Corner Creek basin across the valley. The small anticline lies on the southwest fringe of the Big Slide, and passes into the corresponding position to the southeast. The next major anticlinorium is marked by the Bunker Hill Creek Group of three limestone anticlines. These anticlines were examined in the following localities; on Mollie Mac Ridge and, to the southeast, in the northeast side of the Index Basin, as well as on the end of Silverchief ridge. On the northwest rim of the Gainer Creek drainage, only the most northeasterly of the three limestones persists: on the other rim the central line 'band' achieves dominance. This indicates that the variable plunges and along-strike fluctuations rather well, since all these folds mentioned possess at least four thousand feet of amplitude at some point along-strike.

The last 3,500 feet southwest across section accommodate a generally ascending northeasterly region of the overlying phyllites.

4) Topographic Consequences of the Geology

It would be well to dwell for an instant upon the large scale topograph consequences of the local geology.

The main anticlines were marked, and 'held up' by the ridge forming limestone, as has already been mentioned. The phyllites overlying this rock happened to be less erosion resistant, and so the synclinoriums were generally marked by the large valleys of tributary creeks. Due to the great amplitude of folding, the major synclinoriums had to be induced from lithology, especially since there was a general lack of consistent horizon markers in them. Their preponderantly greater width at the '0'axis, or axis-of-symmetry, level, is probably due to their relatively more complex folding pattern than that exhibited by the anticline cores.

Figure 5. Nanny and Kid, above Gainer Creek on Hillside Pasture

5) A Brief Look at the Map

At this juncture, it might be instructive to actually reference the various localities mentioned to the map. Though a general outline of the structures has now been made, still, the map is a more exact source of information about this, if such information should be desired.

III. Ideas Related to Large Scale Structure

1) On the Largest Scale

Remembering the regional northwest strike direction, let us begin this list with a note on a large member? horizon's expected movements on the northeast limb of an area-wide syncline--a regional structure documented by the main evidence of area-scale structural behavior. If such a regional fold were stratiform, the basic shape of its subsidiary folds would be of the drag fold form. But a large though relatively incompetent horizon sandwiched between two structurally stiff ones, would naturally enough suffer more intense deformation than either the upper or lower member; and if the overall relative reverse movement of over- and under-lying competent horizons were quite large due to continued folding, rather intense deformation of the 'incompetent member horizon' would be expected. Indeed such were the prevailing stratigraphic and structural conditions of

?? ? ok

the area.

On such a regional syncline's northeast limb, axial plane cleavages in the central weak horizon's [member] structure would be expected to have been dragged somewhat to the northeast themselves, resulting in a dip steeply in the opposite direction: and consistent with this would be the observed tendency toward over-thrusting of the southwesterly limb of each of the drag folds toward the northeast.

2) Local Relative Movements due to Individual Competency

So far this has been all very straightforward. The real complications of the geology ~~are~~ [arose], not out of the mere presence of these tendencies, but out of the violence with which they had been put into execution. As the large drag folds on the regional syncline continually tightened due to the persisting compressional crustal movement, individual rock-competencies would begin to modify the folds' form at each level in the stratigraphic column, with relative movements becoming thus more dependent upon the individual unit's physical properties, such as their fluidity under high pressure and susceptibility to [interfoliation] shearing-slippage. The former property was strikingly exhibited by the "clean" limestones under the prevailing conditions. Once west of Mt. Badshot, this major limestone became relatively thin, and was over and underlain by more fissile rocks: ~~their~~ respective behavior [of the two rocktypes was] ~~had been~~ markedly different due to ~~this basis of~~ [their] dissimilar properties.

3) Limestone Flowage in Folds

The tendency has been toward general "thickening" of the rocks in the Area's fold-crest with corresponding structural "thinning" to the point of faulted contacts on the limbs. Crestal flowage would better describe this action. Minor drag folds, originally situated on larger folds, have become detached by basal pinch-off and then isolated by the flowage exodus of the core-forming clean limestone's crestal movement in the main fold. These have remained near the erstwhile Index-Badshot contacts, offset just far enough into the phyllites to avoid confused identification with budinage. Where the deformation is most extreme, whole large folds have assumed this shape, although the process involved is a little more complicated. Such a fold exists on Corner Hill: the situation there is of a large, very attenuated structure, whose clean limestone has been bedding-faulted by the relative movements of the (stratigraphically) bracketing beds, with that of the cover-bed, being of course crestward, except where, low in the core, an actually reversed movement has begun acting on the downward opening wedge of the attenuated lower core rocks. The 'tension members' of this former stratiform fold (or the stratigraphically higher beds) have been forced to flow, with progressive crestward thickening into the low energy zone of the folds' crest. The action may be thought of as again due to the 'teardrop's' lower portion translating compressional loads into upward components: due to the long taper of the inverted 'teardrop' crest-mass, this right angle conversion of movement direction is accompanied by a great increase in the exodus rate of the crest mass from the west (as against its initial rate of arrival by flowage up from the limbs). But one more detail is relevant with respect to the core: the stratigraphically deeper lower core mass, drawdown by evacuating the tongue, or crest, splitting the flowage-thickened limb-remnants greatly hastened the convergence of these limbs into the lower part of the already-described crest-shape.

Under different circumstances, namely those sponsoring the "Toffee Pulling Process", described in Detailed Structural Analysis, piercement-type crests are formed above conventional, but highly attenuated folds. It essentially involves crest-deforming forces parallel to, not perpendicular to the axial-plane cleavage direction.

Instead of "free-body" isolated inverted-tear-drop shaped-structural-lenses of lime left in the phyllite, as above; another type of 'lens' less important because its local occurrence is rarer, and confined to minor fold-crests, is exhibited in the case of a less-competent bed caught between two blockier members. The interstitial bed becomes discontinuous and is "padded" into the low-energy cores (such as minor-fold crests), until each is comparable to a small nappe -- the idea could be clarified by comparison of the situation to the one where a piece of loosely-woven darning wool is pulled through the eye of a too-small needle: if only half the strand is introduced through the hole, and then pulled, the other half piles up in accordian-pleats at the far side of the hole: when the wool has all been stripped through only the "pile-up" is left as evidence of its departure. The geologic motive force is caused by reverse relative movement of bracketing beds containing low energy 'pockets'.

A similar idea, of the equilibrium of an intermediate, budinized bed caught in the relative up- and down-movements on the limb of a tight major fold, may also be applied to some very unusual structures found on Corner Hill. It will have been noted all these ideas have entailed an original interstitial member remaining discontinuously on an otherwise faulted contact between two still-continuous bracketing members.

4) Along-Strike Flowage

In addition to these primary-drag fold phenomena there are also useful things to be observed of the flow behavior of limestones in structural pinch-offs along strike. If a true pinch-off, rather than a strike bedding-thrust were witnessed, the limestone would be seen to have receded away from the pinch-off's apex rather than to have shown evidence of cut-off due to convergent movements of beds in a strike-fault. Consequently examination of contacts of the "pinched-off" bed would be sufficient to distinguish between the two actions in any reasonably well-exposed area.

5) Strike-Changes Influence on Fold-Shape

Zones of "S-" shaped strike-offset should be expected to have a bearing on the attenuation of neighboring folds. The area in which the largest local strike change occurred was also the ore in which the detached anticline just described was located: in the area where this pair of phenomena was witnessed, the probability that the two things were unrelated seems to be fairly small. Nevertheless, to link these purely on the basis of juxtaposition would not be very wise or cautious.

Consequently this idea will be given further discussion under Detailed Structure later on.

6) Folding Pattern of Discontinuous Competent Beds

The foregoing ideas are all based on a conception of the folding behavior of beds of continuous competency, even though the stratigraphic horizons involved might be dissimilar. Now consider the effect of a sudden change in the competency of one unit, or a stratigraphic group: there should be a noticeable increase in the degree of folding upon entrance into the weak part of the horizon. Oddly enough, although facies changes were common, this type of fold-variance was not: in other words, the competency changes due to facies-change in the Bunker Hill Group were not sharp enough to be the cause of structural 'tightenings' visible in the field.

IV. Ideas on the Minor Structures

1) Purpose of Observations

If, in an area of complex major structures, by observation it can be learned that certain of the minor ones,

Figure 6. Characteristic Minor Drag-Folds in the Clean Lime

such as small drag folds, are consistent indicators of relative inter-bed movement on the anticlines, for instance, then these small details become a valuable means of solving those of the major structures that may not be well exposed.

The better small-scale 'indicators' will be touched on, to give some idea which were considered useful, and which were too inconsistent to be 'read' or interpreted.

2) Minor Drag Folds

Assymetrical bounded small drags were excellent indicators of relative bed movement, though in the case of badly broken, or Z-shaped folds, more caution had to be exercised in interpretation, as they could be, and sometimes were, related to various fault and thrust phenomena. In addition, plunges of minor drag folds of the first type were consistent with regional ones, when correlated to computed plunges of major structures using cross sections along strike. Very steeply plunging 'drags' were seen associated with the strike-shifts, but they were not diagnostic indicators of the offset direction. They were a probable, but not infallible sign of this action, and so were not used for analytical purposes beyond that.

3) Shallow-Dipping Thrust Faults

The few such faults found all indicated overthrust to the northeast, which is to be expected from a general drag-movement of tops away from the trough of the area-syncline. However, they were usually only incipient, or had caused but small displacements.

4) Steeply-Dipping Cross Faults

It must be stated as a fact that steeply dipping cross-faults, while not too uncommon, were the cause of only very minor displacements. These faults occurred principally in zones already weakened by bedding fault thinning of the competent portions of the section. But there was no area wide pattern for their offset-direction, except where small left hand displacements corresponded to those in the neighboring zones of strike displacement. Hence they had to be considered as more or less independent of both the major folding and most of the along strike phenomena previously mentioned.

There were some interesting additional types of minor structure, but, as unreliable 'indicators' we must discard them from the discussion.

V. The Stratigraphy

1) Reason for Thorough Discussion

The value of using distinctive stratigraphic units in 'tracing' difficult structure could scarcely be overemphasized. The detailed behavior of the major structures could only be deciphered where such markers were present: it was then possible to follow the course of individual beds through it, with the idea of placing a fault wherever the bed disappeared. But to carry out this procedure with any degree of success, more about the bed under consideration had to be known than just its height in the stratigraphic column: the various sedimentary 'modes of disappearance' had to be considered on the basis of how the bed had behaved elsewhere. Especially in the phyllites, where lithologic changes were usually not only gradational across-section, but also along it in at least the cross-strike direction (i.e., facies changes), and where beds had frequently been simply observed by the severe attenuation and breakage of the minor structures, it was not always easy to determine just where section had been cut out. The various non-structural causes of disappearance or obfuscation of the marker beds, which is a term applicable in truth to any recognizable member of the section, briefly enumerated as 'facies', 'unconformity', and ' lens-off', had to be weighed against the desire to ascribe any such 'discontinuity' in the bed or lithology to an obscure fault. The building up of a sufficiently detailed knowledge of each stratigraphic member to the point where its behavior could be predicted with some confidence required very close observation of stratigraphy; but the effort was rewarded by the help reliable marker beds afforded in unravelling structure.

2) The 'Pancake' Theory

To avoid lengthy explanations of structural interference with members in the section, let us first describe the stratigraphic column by means of the 'pancake theory', whereby lithologies are merely located geographically and then described with respect to their "type" composition. Details of the shape of the deposit are not for the moment considered; nor are facies changes at the borders of the type-area correlated with the rock type of the corresponding period in the adjoining ones. This keeps the discussion of lithology brief and to the point.

3) The Major Divisions

a) The Badshot Limestone

At the bottom of the stratigraphic column for the Bunker Hill Group lay the Badshot Limestone. It graded from a thousand foot thick clean light grey lime on the northeast to an approximately fifty foot thick 'clean' or pure calcium carbonate limestone on the southwest, underlain by an impure limey rock of mixed thin calcareous phyllite and limestone beds and lenses. The thickness of this argillaceous limestone of the Lower Badshot was not accurately known, except that it was in the order of a few hundreds of feet.

b) The Index Facies

The Index, a medium green phyllite, representing a variably shear-deformed originally silty though rather volcanic sediment, which to the southwest was about seven hundred feet thick, decreased in thickness to three or four hundred toward the areas opposite margin, and upon reaching the border point it lensed off completely.

c) The Redcliffe Formation

Overlying this was the Redcliffe Formation, a relatively fresh-looking green volcanic rock, containing, in places, sedimentary pillow lava structure. Of maximum thickness of several hundred feet on the southwest margin of the area, it too 'disappeared' to the northeast, though much sooner than the Index.

d) The Perrylode Formation

The highest rocks in the column are known as the Perrylode Formation; a group of blackish, slightly gritty-textured sedimentary phyllites, containing minor quartzites and limestones. The 'Perrylode' was in the order of five hundred feet thick, although this varied due to, in part, structural deformations, not under discussion here. Generally, the 'Perrylode' became blacker toward its top so that, on the northeast there was a gradation between the top of the Index and basal grey Perrylode.

5) These Major Divisions, in More Detail

There were numerous minor stratigraphic members which, because of their relatively small thickness, make especially convenient 'marker beds'.

a) In the 'Perrylode'

At the base of this formation, in the west side of the Badshot Pass Synclinorium lies the Culkeen Limestone, a fine-grained blackish grey and rather argillaceous lime. In some instances, between the top and bottom relatively "clean" strata, there is an interstitial fifty feet of very thin-platey calcareous phyllite. On the northwest boundary of the Area, the Culkeen Limestone reaches a maximum thickness of approximately two hundred feet. Back in the first location described, and directly overlying the thin limestone, exists a fifty-to-hundred-foot thickness of beautifully clean lenticular greenish granule conglomerate, which unfortunately is not seen anywhere else per se, although it is involved in suspected facies changes in the Badshot Pass and Corner Hill areas, as a dirtier softer brownish to greyish sandy quartzite.

The Big Slide Limestone, in its namesake locality on the southwest wide of the Big Slide Synclinorium, forms the contact between the 'Index' and the 'Pennylode'. But it, too, is only present on the southwest limb of this major structure, being either faulted or lensed off toward the northeast side of Big Slide Creek, and not reappearing on the opposite 'limb' of the synclinorium.

The reader will at once sense a spatial similarity between these two 'thin limestones'--but there is a conspicuous absence of the overlying 'quartzite', in the case of the Big Slide Limestone, although lithologically, the two limes are quite similar.

b) In the Redcliffe Formation--The Mollie Mac Limestone

A very interesting minor member is the Mollie Mac Limestone. This band of lime is only found along the southwest margin of the Area and is not even very persistent along strike to the northwest, disappearing completely long before attaining this margin. Its occurrence is marked by heavy mineralization in the form of ~~anchorite~~ ankerite - siderite alterations, some of which contain economic amounts of lead-zinc sulphides. The Mollie Mac, the White Quail and the Index, are all mines or former mines in these zones in the limestone.

Lithologically, the Mollie Mac Limestone is very similar to the Badshot; being medium to finely-rather-re-crystallized, and the same mid grey color, but ~~of course~~ the former never exceeds a thickness of about one hundred and fifty feet. The relative structural location of this limestone is that of a southwest anticlinal limb which conforms to the regional structural picture of fairly normal "right way up" (reference to the slight northeastward overturning of the structure) limbs, and with the limestones of the 'overturned limb' faulted off or removed by flowage. It should be noted that the Mollie Mac Limestone ~~was~~ is actually a bed within the Redcliffe Formation, and not on the upper or lower contact. This will be a useful consideration for discussion of possible unconformities in the stratigraphic section.

6) Further Correlative Data Unavoidably Entangled in Structural Considerations

In the trough of the Badshot Pass synclinorium, there is an interesting correspondence in the lithology to the middle-Perrylode granule conglomerate with that of the dirty quartzite already noted.

The easiest way to explain the relationship would be first to assume the structure of this part of the synclinorium to be that of a crumpled 'core', and then apply a progressive facies change extending from the clean granule conglomerate into these dirty grey 'sands'. Then the isolated occurrencee of the former and the latter, which are present as three progressively finer grained and thinner vertically tipped beds astride the centre of the Pass, could all be linked up and called a 'bed'. This would be very interesting, although it ie perhaps not quite justifiable to accept the procedure without a few reserves. A minor but relevant fact supporting this act is that a couple of small black limey argillite lenses exist near the most southwest grey 'sand' band in the Pass. Along strike, on Corner Hill, on the same basis of convenience, a strike extension could be made to join the green conglomerate up with a brown to greyish, also rather small-scale-lenticular brown quartzite bed found in an approximately corresponding position in the section, although the Corner sediments are a couple of hundred feet thick. Then, throwing caution to the winds, we could next make an exceedingly long cross-strike extension of the quartzite horizon towards the southwest and link it with small, and very discontinuous lenses of a similar rock type in the Perrylode phyllites along the northwest skyline ridge of the Bunker Hill Basin, which is the Area-boundary-line in this direction. These quartzites are now seen to form a patchy but tantalizing 'bed' of almost area-wide extent. Its relative thinness as well as its nature suggesting a short depositional period, makes it a very attractive time marker and trace-bed. Further discussion leads out of the realm of the present general topic of lithology, but the idea will be picked up again in subsequent divisions of the report.

VI. Important Intrusives

The purpose of this section is still primarily descriptive: it could not be included under the stratigraphic description for very obvious reasons, but treatment of these two intrusive types is still on the definitive level at this point.

1) The Corner Hill Diorite

Zones of calcite-diorite intrusive activity exist in the Corner Hill region. These are well worth a few moments of consideration, especially due to their value as testers of the southeastward acting along-strike convergence of structure noted in III, but for various structural reasons as well.

Beginning with a slight dioritization of the basal 'Index' approximately a hundred feet up-section from its lower contact with the Badshot Limestone ~~Limestone~~, on Ophir Lode Peaks Big Slide Creek side, the tendency, to the southeast, becomes most noticeable amongst the structures Verb?
on Corner Hill. Here, the principal rock selected by the invading diorite has been the Badshot Lime: the clean limestone has been subjected to what appears to be complete and, very meticulous, replacement by the diorite along faulted contacts, and both the contacts themselves and to a larger extent, the lower, argillaceous Badshot facies have been subject to invasions, as large coarsely crystalline masses along the former, and as conglomerations of pods and lenses elongate along, but warping the parallel cleavage and bedding planes of the latter. The coarse diorite has, in addition, made minor excursions into the Perrylode phyllites, but these only go to show that the dioritization is post-folding, or at least occurred simultaneously with its termination. The presence of this large scale dioritization, both by percolating solutions and by influx of magma, does much to complicate the structural picture by discussing contacts and engulfing some of the members and making others mutually indistinguishable.

2) The Index Basin Diorite

At the very top of the Redcliffe Formation, in the southwest Index Basin, a hundred-to-two hundred foot thickness of another, finer grained whitish to greenish intrusive was found. But here it was impossible to determine, due to a lack of good contacts, whether it was a dyke rock of very similar general composition to the underlying volcanic top of the Redcliffe, or whether it was only a felspathized alteration of it. It plays a minor part in the considerations of this essay, which is not interested in intrusions 'per se', but only as tracers or demonstrators of structural trends. Consequently further consideration of this 'diorite' is impractical and will not be made.

VII. Depositional Conditions

1) Reasons for the Examination

Reconstruction of the original depositional environment of the Bunker Hill Group should increase the understanding of present stratigraphy. It should lead to a better appreciation of the rocks' original composition, hence competency-when-lithified were. These original competencies may then be correlated to structural peculiarities of specific parts of the section: this relationship has already been proposed in V., and so need not be explained again here.

2) Temporal Horizons

In addition, use of marker beds not only to trace structure, but also to trace 'time' will be made. Their structural use is common practice, but their importance as definite time horizons, linking all points on a one-time depositional surface is not so automatically recognized as a valuable tool to be used in making correlations of 'sections'. Temporal-marker-bed 'contouring' of the Bunker Hill Section at regularly spaced time-intervals is not possible, but some interesting measurements can be made from the proposedly linkable relics of the "quartzite period", upward from the Badshot Limestone's 'top surface' which will be soon seen to have been unsullied by erosion; less accurately from the top most black'layer of the Perrylode', and finally, quite accurately away from the Mollie Mac Limestone, for reasons to be enumerated. Convergence of these rough 'time contours' toward the northeast is one of the things to be looked for to document suspected sedimentary lense-off in that direction.

3) Elimination of Factors Obscuring Temporal Horizons

In order to free the validity of this scheme from doubt, the factors that can masquerade as stratigraphic must be eliminated by individual consideration: inter-unit unconformity, old bedding faults and obfuscation of stratigraphy by facies change being the chief offenders. Of course, a pre-assumption that the geologic structure is known here must be made. The reader will just have to take 'structure' on faith at this stage, since it was considered that the stratigraphic consideration would have to preface structure, and not vice versa, in this essay, chiefly due to structure's greater importance in a three-dimensional area picture.

4) General Environments

The top of the Badshot Limestone must be construed to represent a rather uniform, clear-water environment, probably in early Cambrian time. The overlying Index rock-types, which are sediments, and yet those of a markedly volcanic nature, represent a very pronounced change in the pre-existing environment from the still, 'mature topography' conditions favoring the limestone to the beginning of an age of volcanism which pervaded, at intervals for a very long time, for it was active during the deposition of the next five major stratigraphic members of the Area (with which we need not be concerned above the Redcliffe Formation), However, the possibility of an unconformity above the Badshot Limestone is made unlikely by both the absence of any immediately contacting overlying coarse sediments or coarse clastics which are the usual signs of initiation of a new depositional period upon the eroding surface of the potential 'unconformity', (remember that the lenticular quartzite are in the Perrylode), and also by a lack of noticeable bedding truncations of the Badshot by these overlying rocks.

5) The Badshot Fault

Before proceeding to delineate the Badshot's upper contact as a time-contour with complete abandon, it is necessary to evaluate a fault which occurs between it and the 'Upper' Perrylode black phyllites, in the Badshot pass. This contact, as it exists on Mohican Mountain across Gainer Creek is very clearly either unconformable or faulted. Remarkably good exposures reveal both a change in cleavage dip and strike at the contacts, with the 'cut-off' bed very definitely being the Upper: the black Perrylode dips more shallowly and also converges upon the limestone's striko toward the southeast with about a 15° intersection angle.

Now, this seems like an alarming fault. Investigation will prove that it is instead a relatively minor one, incapable of cutting out much section: and with whatever cutting actually done acting on the overlying member, and hence unable to be confused with considerations of unconformity.

The reader may be surprised at this turn in the argument, if the northeastward tapering of the stratigraphic units (to nothing in the case of the Redcliffe and Index), is not remembered. It is advisable to realize that the Pancake Theory has ~~long hence been~~ now outlived its usefulness and consequently has been dropped from the ~~positive~~ picture: it was only a child of convenience mothered by necessity; that of beginning a coherent discussion of contorted rocks on some sort of simple basis.

The main proof relegating the fault to unimportance is an observation made outside the area, but which is certainly pertinent to the discussion: in a four mile southeastward strike extension of this 'fault locale' onto Mount Templeman, the whole "Badshot Pass" synclinorium is completely exposed on its face, in which there is a total absence of green phyllite between the Badshot and the blackish Perrylode phyllites. Ruling out an extremely highly folded unlikely ~~folded~~ bedding fault of rather vast proportions, it must be considered that this contact is at least almost conformable here, and hence in Badshot Pass itself. The extent of the cutting-into acting on the Perrylode black phyllite in this locale will be determined by a return to the time-contour discussion as applied to the formation overlying the Badshot. The immediate upshot of the previous discussion has been to demonstrate the reliability of the top of the Badshot as a time horizon.

6) Stratigraphic Northeastward Thinning of Post-Cambrian Units

a) The Index

From a several hundred foot thickness on the southwest fringe of the Area, the Index Formation tapers away to nothing before crossing the trough of the Badshot Pass Syncline. Inasmuch as Index-Badshot contacts further to the southwest are essentially unfaulted, we must assume that the

Index lies conformably over the Badshot to the point of the former's disappearance.

b) The Redcliffe

No 'difficulty' is encountered in the contact of the overlying Redcliffe Formation against the Index, since the contact is a gradational one: the "line" between them was drawn at a certain coarseness of grain size of the phyllite-become more competent, more volcanic sediment: the pillow lava top of the Redcliffe represented the end point of the progression toward volcanism. Unsurprisingly, the Redcliffe undergoes a more rapid northeastward lensing off than the Index: the pillow lavas indicate viscous flows, probably water cooled--consequently the greatly increased rate of 'deposition' by lava flowage would cause a very marked pile-up on the beach line of the Geosyncline sea due to the chilling, congealing effect of the water.

c) Lensing Rather than Pure Facies Change

By now it will be seen that pure facies change, with the implication of parallel time-contours cannot be accepted as the modus operandi of the lithologic differences progressing through the section, due to the necessity for lensing as evidenced in these two units.

The Mollie Mac limestone's failure to persist any distance to the northeast is a case to point: the brief calm interval in the vulcanism it represents would have resulted in a more widespread deposition of the lime, "crossing" facies changes in the underlying rocks of the whole area, unless the entire area of influence of its deposition, the 'lime producing environment', had not been restricted within that of the volcanic sediments immediately surrounding it.

d) Explanation for the Mollie Mac Limestone's Placement

The last explanation for this odd-seeming association, of a locally deposited limestone in a sequence rather than coarse 'volcanics' would be to make the Mollie Mac a chemically deposited rock related to the source of the volcanics, representing a temporary southwestward shift of the focus of vulcanism, inasmuch as limestones should represent the periphery of deposition.

7) The Perrylode

So far it has been pretty obvious what the depositional conditions were: they were basically those of an era of tranquillity, of slowly accumulated clean limestone, shattered by an era of vulcanism whose clastics were transported from the rejuvenated land surface to northeastward, then water sorted by the geosynclines sea so that a tapering off in both bed-thickness and grain size occurred away from the focal point of the sediments toward the deeper waters off-shore, and finally the influx of the lavas in the extreme southwest.

The Perrylode Formation represented the reversion to a mud-producing environment. Its basic lithology has been exhaustively enough discussed already: its trends are those of the underlying volcanic sediments with respect to grain size and thickness, except that these relationships must be qualified somewhat for this rock unit. Let us plunge straight into consideration of the Perrylode in particular, and the rest of the Bunker Hill Group more generally, using various 'temporal contours'.

8) The Quartzite-Period Rocks - Key Marker

In the particular respect first, let us trace 'quartzite-period' rock, through the unit, and make some observations from the picture it affords. Between the marker and the older formations, the northeastward progression across strike yields a decreasing thickness of fairly coarse grey phyllite, which is gradational from the top of the greener clastics: there is certainly no fault or unconformity possible. Then limestone begins to appear, in the form of the Big Slide and Culkeen lines, and these finally give way to the jet black shale-phyllite found beneath the sandy grey quartzite beds in Badshot Pass.

a) Significance of the sizing Trend

The sizing trend is unmistakeable, as one of water depth-increase to the northeast. That the jet black phyllite should be relegated into this height of the column is the most pertinent point to consider: it indicates that these 'fines' were the water-sorted endpoint of the clastic deposition just discussed, and consequently should have been very slowly deposited, compared with the rate responsible for the 600 feet of coarse, grey phyllite temporally correspondent in the southwest. This is one reason why the Mohican Mountain attitude-intersection meant a fault: such fine mud would tend to settle extremely flat, and unless the Badshot line had already been tilted by the start of the Area folding, "flat" would be parallel to this surface. The disappearance of the 'quartzites' on the northeast Area-boundary, consequently, need not be taken as evidence of a cut-off by the Badshot Pass fault, since the continuation of black 'muds' above these quartzite beds indicates that the deposition in this deep-water extremes of the area was not much influenced by the 'quartzite period'. Hence the pure lens-off of the brown quartzites would be both very probable and have been reasonably rapid, while the lensing action of the two levels of 'black muds' just described would not be discernible. Hence disappearance of the 'quartzites' need not have indicated fault-~~passing~~ paring of that part of the section between the quartzites and the Badshot Limestone.

[note ref back to p32 continuous dep. on top of the Badshot: slow but continuous.

9) Above the "Quartzite Horizon"

Interpretation of the particular deposits of the Quartzite Horizon is on too small a scale to illustrate the 'tapering' trend, beyond noting their progressive fining in particle size toward the northeast, which has perhaps not been emphasized by the initial description given under Stratigraphy.

The continuity of the black muddy 'fines' above the quartzite does much to validify the existence of the quartzites themselves as a marker bed. Such fines, as very slowly, evenly deposited sediments, would be very much less subject to the northeastward lensing-off process than the preceding coarser clastics, and indeed this tapering cannot be detected in them because of a lack of distinctive minor beds coupled with structural complexity. However, the lower limit of the "black zone" is marked by the quartzite horizon wherever the latter exists. This then is the only useful information to be gained from the post-quartzite deposition in the Bunker Hill Group: the fact that it exists as a cumbersome undeniable marker bed, defining the more exact "time horizon" on its lower boundary.

A Summary of 'Temporal Horizons'

Regarding marker beds not only as tracers of structure but as very definite horizons of contemporaneous deposition should by now have been shown to be a useful method of treating inter horizon rock-thicknesses as indicators of deposition rate. In such phenomena as bed-tapering, it is necessary to know the mechanics of the lensing process in order to determine the conformability of the converging over-and-under beds that 'sandwich it'. Examination of particle size of an extant bed with respect to the known rate of its deposition determined by time-contours is a means of finding fault-or-unconformity caused thickness-anomalities, since in water sorted clastics radiating from a focal source bed thickness per unit time is proportional to the grain size of the observed deposit, and the grain size is in turn determined by distance from this "focus" of sediment source. If these two quantities are roughly determined by looking at the particle-size-endpoints of the bed under consideration normal tapering can be predicted by the trace of the bracketing time horizons, and after 'anomalities' have been carefully recognized, the Area depositional picture may be formulated. Application of this method, then, expedites the assessment of essential depositional conditions implied by the rocks.

11) Depositional Conditions on the Geosynclinal Scale

The three major "phases" of the Bunker Hill Group's lithology, 'limestone', 'volcanics' and 'mud' have now been described from a depositional-environment pointof view. When oriented, these three things may be interpreted as to place the Area astride the southwest shore of a northwest striking Geosyncline. ~~This shore~~ The crust to the southwest of the Geosyncline was rejuvenated at the end of Cambrian time, reached a culmination during the time of the Redcliffe Volcanics, and then after the shallow water transitional period represented by the 'Quartzites', sank deep beneath water level where it remained for a long period, judging by the thickness times the deposition rate of the 'black muds' of the Upper Perrylode. This picture seems to reconstruct the accepted 'text book' conditions generally ascribed to Lower Paleozoic time.

VIII. A More Detailed Structural Analysis

1) Introduction to Detailed Structure

Structure, as it has been mentioned before, is a partial function of the constituent rocks. Consequently it is to be hoped that sections III to VII will serve as a necessary reference to this section of the essay. Pre-description of rocks greatly streamlines the necessary structure-location, nomenclature, which would otherwise cause excessively large quantities of footnotes. This discussion ~~wishes~~ is intended primarily to 'extrapolate' regional tendencies from the observed folding pattern, and then to study specific effects upon the pattern of different combinations of members in the section. It is, of course, advisable to comment on the particular cases first, because they represent what was actually seen in the field.

2) Selection of Localities: Badshot Limestone as a Trace

The best places to begin the examination of structures are those locations in which the clean Badshot Limestone appeared as a bed one to two hundred feet thick. Here it provided an excellent marker, but the unit in this thickness-range was flexible enough to exhibit the flow behavior mentioned in III. Two such localities exist: the Ophir Lode-

Corner Hill region of the central anticlinorium, and the Bunker Hill Creek-Index Basin region of the southwest one.

3) The Ophir Lode Anticline

a) Systematic Description

On Ophir Lode Peak, the cross sectional trace of the clean lime outlines a single large anticline, with one relatively minor drag fold on its southwest limb. Structural attenuation is not too great, being in the order of 3 or 4 to one, and both Index contacts with it seem to be conformable. Axial plane cleavage is present, and has the typical steep southwest dip of the area.

The core of the anticline is considerably more contorted. Crumpling of the underlying thin-bedded argillaceous lime has occurred: the folds have up to 500 or 600 feet of amplitude and possess attenuations of about 6 or 7 to one: in addition their crests are overturned toward the northeast; some by as much as thirty degrees from the prevailing dip. Contacts with the overlying clean lime are not conformable: exposure did not permit investigation of the lower contact of the argillaceous lime.

b) Structural Trend-Upriding on the Southwest

The argillaceous lime has been subjected to 'bunching-up' in a mild version of 'fold-crest padding'. Overturning of the crests seems to be associated with a subsidiary flat angle thrust, striking approximately parallel to the main structure, and dipping southwest, which has caused a small up-dip displacement in one instance on the northeast Badshot-Index contact. This is not a sharply defined fault, but rather a general shearing across a thirty or forty foot core parallel to the 'thrust plane', so that the phyllites have here become very fissile and talcy. It will be seen that both the slightly overturned core-crumples and the small thrust indicate a continued tendency toward up-riding on the southwest limb after the principal folding had ceased.

c) The Cross-Faults

Finally, there are a half-dozen cross faults seen cutting the clean limestone, marked by narrow bands of re-cemented fault breccia, but there has been scarcely any movement along their loci, since there are no visible displacements at contacts where these movements would be most conspicuous.

d) Strike Shift in the Complimentary Syncline to the Southwest

The Big Slide's west rim is marked by a mass-slumping action in the phyllites. Although the topography probably accentuates the slump-change foliation attitudes, it seems apparent that these have been triggered by a strike-change, whose 'plan' would resemble a shallow S, with the effective offset being left-handed. While this could be overlooked as a minor structure by itself, the phenomenon recurs similarly on the Corner Creek Slide to the southeast almost along strike: another area where strike change and accompanying slumping or flip-over-of-the-dip from steeply southeast to shallowly north, and back along the strike changes trace, seems to have an association with the local structure. But it would be better to describe the Corner Hill Geology before returning to the Strike Change.

4) Corner Hill-The Teardrop Fold Type

a) Extreme Deformation

The relatively simple Ophir Lode Anticline experiences an almost unbelievable transformation as it enters the Corner Hill region. It becomes threefold at the 'depth' of the clean limestone, and there is a northeast increasing size progression of the folds. These become, due to similarly progressive crestward bedding fault movements, attenuated in the order of about 8 or 9 to one.

b) Correspondence between Crestal Flowage and Size Progression

At this stage, the reader will recall data pertaining to the 'teardrop' fold type, in which the end point of crestal flowage of the limbs detaches the crest from its base: examination of the contacts of the anticlines showed that there was such a tendency exhibited, increasing proportionately to the size progression of the folds themselves. However, remarkably enough, the most southwesterly contact of Index phyllites against the Badshot is conformable, as evidenced by the presence of numerous 'stratiform' drag folds.

c) Note on the Drag Folds

These minor drags had attenuations of only 5 or 6 to one, considerably less than that of the principle structure. These were found relatively close to the southwest limestone's crest, so the disparity in attenuation is as a partial crest-intensification of only slightly asymmetrical 'drags'. On the same anticlines northeast limestone-phyllite contact, drag folding near the crest is predominantly 'unfaulted', but lower down assorted broken drag folds were found.

d) The Central Anticline

This structure, being the fold of intermediate magnitude has experienced a much more drastic deformation, having been more or less completely squeezed off from the main structure at its base.

Both in plan and in strike-elevation views, the 'anticline' is a tear drop structure, due to a combination of severe crestal flowage and complete structural pinch-off in the Stevens-Creek-Corner Creek divide. The second consideration must be temporarily 'shelved' until a later point in the discussion.

e) Use of 'Horizontal Plane' Passed Through the Anticlinorium

Although Corner Hill provided 3500 feet of elevation-relief, both the central and northeast anticlines' crests were originally much higher: this means that erosion had removed at least a thousand feet from the largest anticline. Consequently, an imaginary horizontal plane passed through the anticlinorium at an elevation just below the smallest folds' crest would have cross cut the largest far down on its limbs: at this elevation "contour-sections" established the validity of flowage and interbed-slip being proportional both to the main structures size and the relative distance down along the limbs from the crest.

f) The Northeast Fold

Though by far the biggest structure, it should not simply be misconstrued however as the principal fold on which the two southwesterly folds were superimposed as major drag folds, since the original relationship has been altered to that of three independent structures, in which the normal size-competency relationship has been reversed due to the relationship witnessed in the last paragraph. The extent of crestward movement on the largest fold has been such that only a one foot thickness of the clean lime has been left on its southwest contact with the Index, and none at all remains on the other limb. Not only has the argillaceous lime been forced up into its crest, but, at the core, even the Mohican, a blackish phyllite underlying the Badshot, has appeared in turn "beneath" the latter in a completely isoclinal core-mass extending up to within five hundred feet of the crest elevation of the smallest anticline.

g) Internal Structure of the Northeast Fold

In the Corner Slide, a thousand feet below the crest elevation of the smallest fold, was contained the second major occurrence of 'strike-change'. Here, the southwest band persists strongly as a two hundred foot thickness of argillaceous and clean lime, but the centre anticline has dwindled to a "marestail" only ten feet wide where last exposed, and the limestones of the largest anticline have been completely dioritized. The chief 'picture' to be formed is to become aware of the apparent relationship of the strike change to the virtually complete upward squeeze-off of two of the three anticlines, inasmuch as it will be noted that the strike change zone has entered into the limestones in preference to the neighboring phyllites to the southwest, which had formed the previous association in Big Slide.

5) Further Processing of the Corner Hill Data

a) A Probable Oversimplification

Here is the maximum amount of tying in between the dioritization, the 'structures' and the strike change can be made on Corner Hill. As such, it is both no doubt an over-simplification and a 'slight misrepresentation', because frequently enough some of the best geologic 'correlations' can never be proved to be anything more than coincidence. But here is the picture, for what it is worth. It will be easier to qualify it after it has been evolved. Although the main facts of Corner Hill have now been presented, it will be necessary to incorporate a few more details into the argument as they become pertinent. Consequently, the following cannot be considered a summary of the analysis as much as a preliminary look at the structural picture which has previously been described as detail.

(b) Equilibrium Lenses on Flowage-Faulted Contacts

Just above the Corner Creek Slide, the crestward movements of both the northeast and central anticlines were severe enough to be capable of completely withdrawing the clean limestone from the contacts. Yet this 'complete withdrawal' occurred only in places: large lenses of the lime were left along the southwest contact of the northeast anticline: there is one very considerable lens in the Slide, which has, incidentally, subsequently become dioritized. Ore cannot help but envisage these remnant lenses kept in equilibrium by the reverse relative movements of the over-and-under beds: for by this stage in the deformation process there would be no longer any appreciable differential rates of relative movement as in a stratiform fold, but rather a general exodus from the zone of applied lateral pressure ('a folding force') of upper strata crestward and of the core strata actually back downward out of the core--still maintaining the same sense of relative movement as just mentioned, but this time with actual motions in the two directions simultaneously. These lenses might be considered as budinage; and yet their shapes are too elongate in the dip direction to categorize them thus: it is difficult to think of any other dynamic process which could strand the lenses so far below the main crest masses of the clean lime, since their alignment directly on the otherwise unconformable contact of over-and-under-beds precluded the possibility of detached minor drag folds, and for any 'static' process to exist in such an environment.

c) End Point in the Dioritization Process--Good Example of Relative Competency Control Under Severe Deformation

The complete pinch-off of the central limestone anticline at Corner Slide elevation, demonstrates the end point of this 'relative movement' process: its 'marestail' was composed chiefly of clean lime and yet as the anticline began to widen out up-dip, the contacts became again argillaceous limestone against talcy Index phyllite. Then the clean lime reappears, and gradually thickens on both limbs toward the crest. These limbs have not quite coalesced by pass-elevation, but only a few feet of the underlying argillaceous lime remains between to separate the bands there.

d) Along Strike Pinch Off of the Central Anticline

A few hundred yards southeast along strike the second pinch off mentioned in the initial description occurred. The axial-plane dip of the structures at pass elevation has reverted to the average value for the Area, since that elevation is well above the level of influence of the strike-changing agency which operates in the Slide. The 'pinch-off' has about a twenty-five degree southeastward convergence, with the necessary convergence-shift operating on the anticline's northeast limb, beginning just about in the pass, where the total width of this lime band is in the order of 150 feet. The remarkable fact about this whole along-strike squeeze-out process is that nowhere is there evidence of the necessarily faulted northeast contact of a bedding plane thrust: rather it seems as if the limestone has merely been forced to back away from the apex of convergence, so that the contacts remain actually conformable between lime and phyllite. Under these conditions the argillaceous lime acted as the incompetent member, and was forced out in preference to the clean lime: the very apex itself is of the two coalesced bands of the latter. Here again is evidence of flowage rather than that of faulting to produce what must in any case be termed a faulted contact, except that the Index phyllites on the limbs of the erstwhile anticline merge indistinguishably along strike. Incidentally this demonstrates the danger of making perfunctory inspections of structure had it not been seen where the core-limestones were still present, its existence would never have been realized.

e) Consistency of Minor Drag Folds Shape to Parent structures

On a minor scale, the behavior of detached drag folds bears many similarities to the flow tendencies of the limestones in the large structures. On the northeast contact of the central anticline, about 500 feet below pass level, just where the main contacts have become entirely faulted, traces of the clean lime have remained as inverted-teardrop-cross section-shaped drag fold cores, in sizes from a few feet to a few lens along the dip axis, and a few feet across the widest point. Their offset from the contact indicates them to be the remains of drag folds, though subjected to the same lateral forces as their parent-folds and having become almost lens-like in appearance. They are not piercement-folds, since no movement past the original fold crest had occurred. They represented interesting end points in what must be considered as a two-stage folding: the initial 'stratiform' stage to produce drag folds, and then a subsequent re-attenuation to break them loose as the flowage phenomena set in. The real importance of these minor drag fold remnants was to demonstrate very clearly the mechanism of the detachment and crestward flowage processes. Their small size enabled them to be observed in completely exposed section-views in many instances. They thus greatly helped to define the properties of this sort of a fold.

f) Dioritization of Zone of Weakness

1) Location of Dioritization

The chief effect of the second stage of folding on Corner Hill was to produce a zone of weakness. The enormous flowage movements which pervaded the main, or northeast anticline in this zone, especially, were apparently sufficient to tap a source of mafic diorite; and both solution-impregnation and wholesale ~~silt~~ ('sill') actions resulted; the first selectively replacing the clean limestone and the second forming great lenses in the more fissile argillaceous lime. All of this intrusive rock reacted vigorously with dilute hydrochloric acid, and was thus tentatively called 'calcite-diorite'. For the purposes of this essay, however, not its composition but its mere presence is the important thing. It selected the main anticline for its main location, and significantly enough occurred in only very minor instances in the other two anticlines.

2) Localization Proportional to Depth of Shear-Zone Tap

If we consider that, in the anticlines under discussion the three folds were indeed roughly comparable, so that amplitudes could be taken as approximately proportional to the widths at the 0-axis level, then the depth of the corresponding synclinal troughs below this 'axis of symmetry' could be estimated. By comparison of the large anticline to the southwest one, whose crest elevation was known, this depth must have been in excess of 8,000 feet, but under half of that for the remaining two.

Consequently, upwelling igneous material or perhaps hydrothermal solutions could quite be expected to move along the faulted contacts of the largest anticline, on which it would encounter and be evidenced by alteration of the equilibrium lenses of clean lime found in the Corner Slide.

g) Temporal Relationships of Diorite to the Deformation

It is difficult to make any very delicate temporal correlations of the dioritization to the folding pattern, except to make the following obvious statements. Of prime importance is the fact that the diorite was predominantly rather coarse, and had an unsheared appearance. The diorite had not been folded, and so it had to be more of recent age than the axial place deformation of the strike change in the Corner Slide. Because of these two things, it is obvious that dioritization postdates the last of the major deformation of the surrounding rocks. Yet this is still rather an approximate sort of dating for the dioritization: for reasons mentioned in the next paragraph it was important to gain a closer idea of its age than that.

h) Dioritization and Ore Solutions: A Parallel

Since the dioritization must be assumed to have been at least partly a hydrothermal replacement action (witness the exact reproduction of original structures in the Corner Slide "limestone" lens) it offers an interesting possible parallel to that of the hydrothermal sulphide-ore-bearing solutions. Of course, there can be no direct inter-relationship, but a study of the 'mechanics' of the dioritization, nicely documented by its 'trail' of country-rock alterations, should help to reveal the essential behavior of these hydrothermal solutions under local structural conditions.

i) Test of Along Strike Trap Properties

Chiefly, in exact determination of whether the dioritization just postdated or just coincided with the end of the areas structural deformation would decide how effective were the along-strike trap properties of the 'sudden' southeastward increase in fold attenuation, which begins to get really severe along the southeastern boundary of the area we are considering.

It is known that the wholesale dioritization of the largest anticline on Corner Hill extends into this region, hence it 'ignored' the phenomenon. If dioritization had just coincided with the last stage of structural deformation, its solutions might have entered this 'constricted' area just before the final tightening. But their coarse nature kndicates that the replacement was a slow process, and so the most natural thing would be to find quite appreciable differences in the degree of shearing of the diorite bodies in this case. That there is no striking difference between the bodies in this respect, it now seems very certain that the dioritization did actually postdate the deformation. This point may have seemed to have been laboured, but it is a very pertinent detail to the ore picture as we shall now see.

j) Application to the Ore Solutions

Consequently, the diorite's disregard for the 'trap' demonstrates that the sulphide-bearing solutions, which are also obviously post-deformation, might have transcended this apparent barrier equally well. So, although no sulphide deposits have been found along strike southeast of the Index basin properties, which correspond to the beginning of the more seriously increased fold attenuations, the apparent localization of the ore northwest of the locus of severe attenuation may not be as significant as it would appear at first sight, as it is probably purely coincidental.

6) Location of the Other Two Fold-Types

To complete the structural study of the limestone marker horizons in the anticlinoriums, it is now necessary to discuss the salient points of the Bunker Hill Creek anticlinorium.

The two major fold-types which were mentioned in V. which have yet to be dealt with in detail are those of the piercement fold situation, and of the area-trend of faulted northeast contacts on anticlines, which are best illustrated when the overall attenuations are not too severe, Both these phenomena are well illustrated by the three-fold Bunker Hill Anticlinoriums.

7) 'Stratiform' Anticline on Northwest Face of Silverchief Ridge

On the end of Silverchief Ridge, the three anticlines are all well exposed. The more northeasterly two exhibit bedding faults. The clean limestone has been completely faulted off on the northeast limb of the most northeasterly anticline, again leaving argillaceous limestone against the green Index phyllites. There is a pronounced degree of asymmetry to the structure: a contour section going southwest from the fault would reveal very black, argillaceous limestone for approximately four hundred feet, followed by about a hundred feet of the clean limestone. Broken drag folds, anomalous for an anticlines northeast limb, exist along the faulted contact of this anticline.

Their limbs of the minor drag fold are pronouncedly asymmetrical, but with the southwest dipping ore being well defined, and the short northeast are badly broken and deformed. While they might seem to indicate that the fault just mentioned had 'pared' off the anticlines overturned limb, this is contradicted by stronger evidence; the cross sectional thickness of the argillaceous limestone is much too near the unit's normal thickness to have allowed much leeway for fault-passing. Actually, such anomalous drag folds are a relative rarity in the region, despite the generally intense regional deformation. The 'anomalous drags' were thought to be possible effects resulting from the crumpling tendency of the upriding overturned limb of these major anticlines.

The central anticline preserves a little of its original clean lime, as a ten foot band of white motley limestone on the overturned limb. Also on this structure, the argillaceous lime is approximately 350' thick, with 150' of clean lime on the unfaulted southwest limb.

b) The Strike-Extension Across Gainer Creek

Where the central anticline appears on the northwest side of Gainer Creek the argillaceous limestone exhibits violent, large-amplitude internal Z-folds, which are also to some extent anomalous if interpreted solely as 'stratiform drag fold' phenomena: but it is more likely that there are excessively crumpled structures which were originally drag folds, but which later became modified by the overthrusting mentioned above. Also, in this location the single bedding fault on the overturned limbs has become a complex of at least four rather obvious ones (the longest of which has produced a 20' zone of alteration about its locus).

8) Contrast of 'Stratiform' with Corner Structures

a) Specification of differences

The basic difference between the contact details of the overturned limbs of the Corner Hill and Bunker Hill (anticlinorium) is the lack of detached drag fold and 'equilibrium' lenses in the latter. Either the clean lime, while very thin and recrystallized, was still relatively uniform and continuous (as in the Central Bunker Hill anticlinorium) or else it was entirely missing (as in the case of the most northeasterly structure of the group). Clearly, a rather different set of forces must have been at work in the two places.

b) Categorization by the Two Stage Folding Idea

In the light of the postulated two-stage folding idea, the attenuations on the two main Bunker Hill anticlines should be seen to be significantly less than anything found on Corner. It should therefore be worthwhile to attach some value to this relationship. Classifying the Bunker Hill Creek anticlines was accomplished in the following way. The respective measured cross strike widths of the three anticlines, in a southwesterly progression, of 700,850 and 350 feet were measured, and from this, coupled with thin crest-elevations (or projected crest elevation) determined from the map above the "datum" of 5000 feet elevation along the bottom of outcrop, the "attenuations" were found to be 3.2, 2.8 and 6 respectively. While the datum was not placed at the axis of symmetry of the folds, even so the departure of the two main anticlines from the 8 or 9 to one of the Corner Structure is indeed notable.

c) Consequent Definition of the 'Stratiform Limit'

In the northeast pair of the Bunker Hill Creek anticlinoriums which we are considering at the moment, it must be cited from field observations that no drastic flowage of the clean limestone occurred, inasmuch as it was not unduly thickened toward the crests, as exposed on the skyline of Silverchief ridge. In those two anticlines, therefore, we have remained well within the attenuation range capable of preserving stratiform folding in this type of lithology. The significance of the low attenuation just mentioned then is to define, in a rough sort of way, 'the upward limit' of deformation attributable to conventional folding.

d) Essential Difference Between the 'Second Stage' in the Two Localities

The bedding faulted northeast limbs of these structures of the Bunker Hill Group may be considered as evidence that the tendency of the second degree or stage of deformation was to cause relative upriding movement of the structures toward the northeast, rather than to exert on them the 'vise-like' lateral compression implied by the more drastic forms of the Corner Structures.

It would be well to bear in mind the relation of anomalous drag and 'Z'-folds in this particular locality. They possessed amplitudes of up to tens of feet, which occurred especially in the central anticline, but it can only be conjectured that there is a direct relationship between this anomality and the crumpling effect exerted upon the overriding member by the action of proposed overthrust. Nevertheless it should be reiterated that such would be at least a plausible, if not unique, explanation for these regionally un-typical minor folds.

9) The Index Basin: Piercement Fold Type

a) Its Attenuation

It will have been noticed that the third anticline of this group possessed an attenuation of approximately 6 to one, which approaches the Corner Hill anticlines' in ~~seventy~~ severity.

b) A Very Different Structure

1) Not Subject to Bodily Upriding

However, this relatively small anticline, which may here be veritably considered as a drag fold on the side of the largest, or central anticline of the group, reacted in a very different way during the 'second stage' of deformation. It was not subjected to the bodily upriding process, probably because it was not a large enough structure to behave competently, since there are no bedding faults visible along its northeast limb.

2) Upward Ejection of the Crest

In contrast to this conformability of the limbs, the top 800 feet or so of the crest has been so severely elongated that the crest assumes the form of an "injection" upward along the axial plane cleavage direction. This process has actually occurred along two separate planes, so that in the crest there is an extremely long cleft in the limestone; branches having been separated by the invaded index phyllites. Above the two true crests shown on the map, small detached 'tongues' of the limestone are found to extend almost up to ridge-crest elevation, at 8000 feet; if these are considered as remnants of a continuous fold crest, the attenuation becomes well nigh unbelievable--in the order of twelve to one. Consequently, the figure is only stated to demonstrate the necessity for the "injection" explanation for the existence of these wisps of clean limestone so far above the top of what might be termed the end point of the 'conventional fold'.

3) Smearing-Out, or the Toffee-Pulling Process

The limestone in the piercement crest, it must be remembered, did not migrate up off the limbs of the anticline. Thus, herein lies the definitive difference between 'Piercement' and 'Teardrop' folds; in the latter 'shape' was a product of flowage movement caused by the axial-plane-direction-components of compressional forces act on the 'trailing wedge' of the lower portion of the teardrop, which action might be visualized as a 'push from behind'. The opposite process is a pulling out of the crest like a long strip of toffee, leaving wisps of itself along the route it travelled. The immediate causitive agent of this dragging was the neighbouring Index, which was itself being transported in turn, except that the deformation was not so easily visible in its monotonous lithology.

Whether indeed super-imposition of the 'Corner' type of flowage on this portion of the fold accounted for the final localization as lenses above the limestones' continuous crest is really immaterial: the important thing to have appreciated is that the process of 'smearing out' of a small crestal mass up the now greatly drawn out crest, so that finally an apparent 'piercement' of younger rocks results, is one necessarily associated with this 'piercement structure'.

4) Necessity for Additional Bone Fide Flowage

However the best method of accounting for the present shape of this crest is to consider that the pulling out process occurred first, and then a second movement followed: an actual injection of limestone masses further up along planes of weakness created by the axial plane cleavage. Of course, the two processes must inevitably happen in the order stated. By definition, during the toffee-pulling process, the limestone must have lagged behind the relative movement of the "conducting agency"--the overlying phyllite: 'injection' imparts a greater relative movement to the limestone due to forces identical to the ones at work on Corner, except here pre-crested planes of weakness were provided by the 'dragging', and the limestone was able to penetrate the original crest to a considerable distance.

10) Piercement Applied to the Mollie Mac Monocline

As the reader will recall, the Mollie Mac limestone occurs toward the Index Basins southwest side. Its behavior, as a 'monocline', or single bed, was seen to be remarkably similar to that of the piercement anticline just described. It, too, pinched off in the same very gradual manner; while this may admittedly have been partially due to along-strike sedimentary lensing-off, still it is pretty obvious that the pulling-out-process would have been superimposed on any original tendency to the point where the latter would predominate. An anticline provided a more fruitful structure to analyse than the ore-bearing Mollie Mac limestone, since a ~~more~~ fairly exact idea of the degree of 'piercement' may be obtained by reference to the converging limbs of the former; ~~and how much may be confused with~~ thus avoiding much of the confusion of mis-identifying the process with the sporadic lenticular continuation of the 'wane-edges' of a stratigraphic bed.

11) To Avoid Scepticism

The reader may by now feel that too many deductions are forced out of data which does not seem to warrant such confidence, and hence begin to get sceptical as to their validity. To counteract that, it should be mentioned that the principles involved were observed in more instances than the single cases cited here; which are more largely for purposes of illustration than of proof: especially such things as crestal flowage were exhibited abundantly in thin Precambrian limestones further to the northeast, but detailed mention of them would just cause monotonous repetitions of the now-known pattern.

IX. The Ore Situation

1) Favourable Position to Make the Analysis

We are now in the position of knowing something about the area structurally, stratigraphically and lithologically. A rough outline of the original sedimentation has been formed from observations based on the rock units; a few structural-'stratigraphic' correlations have also been discussed; consequently the Area Picture has been sufficiently developed now to allow intelligent discussion of the sulphide-ore deposits. A scheme of description of the known deposits followed by an attempt at classification in various ways is the best approach.

2) Brief List of the Deposits

A rather low grade of ore occurs in anchorite-siderite

Figure 7. Small Sederite Body in the "Sharp Anticline"::The Pod Proved to be Barren

Figure 8. On the Silverchief Property--High Grade Lead and Silver Sulphides

replacement pods and irregular lenses associated with the 'clam' limestones; the Badshot, Big Slide and Mollie Mac limes all containing deposits of this nature, though the action is much more intense in the last-named.

Figure 9. The Cambourne Lead Zinc Concentrating Mill

Small very high grade galena-rich sulphides occur in essentially unaltered clean limestone, trapped in some cases by crossfaults, as in the Silverchief property, or other small nondescript faults, as in the Badshot property;

Figure 10. A Low Grade Ore Body in the Mollie Mac Limestone Above the Mollie Mac Mine

and by drag folds, of which a very small but striking example occurs in the Mollie Mac limestone considerably above the anchorite-siderite zone on which the Mollie Mac Mines has been driven.

One property, the Mohican, has tapped sulphite-quartz stringers in the blocky highly sheared Perrylode

Figure 11. Small Drag Fold in the Mollie Mac Limestone Bearing Small Crestal-Bedded Galena Deposits

phyllites themselves.

The country is, of course, scarred by all sizes of prospect holes and test pits, with the principal investigations having been made in the small, barren, altered-carbonate pods in the limestones. Rather bizarre investigations have also been conducted into small green amphibole zones associated with small cross faults in the phyllites in the Big Slide region. Some of the known zones in the grey or green phyllites have also been industriously test-pitted, but again with negligible results.

It becomes apparent then that the only productive carbonate alteration ore zones have been those naturally within the limestone, although the converse statement is not applicable in all cases by any means.

3) Search for Control Factors

The 'control' over the alteration zones mentioned has long been considered as a useful guide for prospecting. But one main reason for the field geology was to investigate more carefully how structural or other factors might have been involved, and on the basis of findings use the hoped-for 'control' as a guide to further exploration. As the findings contributed to the Area Picture, they will briefly be noted here.

Structural factors are those associated with main folding, with along-strike changes, and with small-structures, drag folds must be placed in the first category, and cross striking faults into the last.

Stratigraphic groupings might be parcelled out into favorable internal structures for retention of the mineral bearing solutions, or by the ore's occurrence only in specific rock units.

Lithologic considerations would hinge on a knowledge of the original sedimentation process, notably that involving the black Perrylode phyllites. The plan would be to chart deposits' proximity to this as a "source" remembering of course that the distinction between the 'source' rock and particular bed or horizon in which the ore may have subsequently localized is important, if one is to keep these last two considerations unconfused.

Purely geographic 'localization' may now be overlooked, as no effort has been unspared by earlier mine-hunters operating on this premise.

Naturally, the diversity of the deposits is bound to defy unique classification, but documenting various 'association' schemes is the best way to catalogue the significant data on this otherwise too general subject of these ore deposits.

4) The Structural Associations

General southeastward tightening of the folding, as the largest scale-structural trend of the area, should be expected to provide the broadest grouping of ore deposits. This seems to hold true to some extent, in that incidence of ore increases proportionate to the number of small-fault traps caused in the more deformed rocks, but as has been seen with respect to the diorite, no definite cut off or trap-point is to be expected as one travels southeast.

No area-wide correlation can be made between fold attenuation and ore occurrence--indeed to be perfectly unprejudiced, inasmuch as the limestones were not seen in the large synclines since they were deeply buried by the phyllites, even anticlinal localization of the ore cannot be thought to be anything more that circumstantial. The only evidence for collection oncrests is that of small ore deposits in minor drag fold's crests, besides the fact that they have not acted as minor trough traps in any instance encountered.

Also, with respect to drag folds; they would have been too widely distributed to warrant economic mining, and in any case the vast preponderance of them are completely barren. The same barranness of an attractive structure-pattern occurs amidst the apparently-unmineralized small cross faults of Corner Hill, which seem to bear a relationship to the strike change. Indeed the only notable mineralized cross fault known in the area is the brecciated one on Silverchief itself.

5) 'Stratigraphic' Associations

These, if treated with reserve, are of considerable use. From (2) above, the not-necessarily-reversible limestone-anchorite-sulphide chain of dependence was made clear. The one further restriction now imposed is that one specific lime band, the Mollie Mac, bears the great bulk of this type of deposit: it has been more or less continuously anchoritized, and incidentally, during the heydays of the various local mines, at most all of its outcrop was claim-staked. However, neither the distribution of concentrations of the sulphide, nor their composition has been seen to follow a pattern in the Mollie Mac, except for the tendency towards more economic ore toward the southeast of the Area. The actual anohorite bodies in this limestone take the shape of very elongate upwellings up the centre of the band, neither curbed nor controlled by structure; being only bracketed by the confines of the relatively narrow lime band itself. Consequently, the internal stratigraphy of the limestone made no contribution toward the actual localization of the base metal sulphide: 'beds' had disappeared or been engulfed with the anchorization, and had left no mark. As to the suitability of the Mollie Mac lime as a suitable medium for solution permeation, only the trite statement that results indicated this to be true may be made at this time, since no thin-section work was attempted in the field. Results of very careful comparative examination of the Mollie Mac and the other regional limestones will, of course, be made known in the forthcoming British Columbia Department of Mines Report upon the area, and so with regret, this aspect must now be left upon that expectant note.

6) Recognition of the Original Sulphide Bearing Horizon

'Lithologic considerations' have already been more or less outlined in (2). It should be realized that such would be a last-resort method of practical ore-location work, since this method does not define the present day ore zone but merely the original source of the sulphides. That the blackest Perrylode phyllites, as those deposited in the strongest 'reducing' chemical environment, should be the sulphide-carrier has been propounded quite adequately by now. The trouble with this is that several sulphide deposits, notably the Silverchief-cross fault one have occurred on a close to a clean-lime-Index phyllite contact, with no black phyllites nearer spatially than those of the Precambrian Mohican deep below. Thus, from a practical point of view, assuming for the moment that the just mentioned relationship is not in favour of up-seepage from the Mohican, we are faced with accepting the Index as an equally rich erstwhile 'sulphide horizon', or with discarding the whole theory of depositional environment's control over original sulphide content. In the first case, the 'theory' would have such general application that the zone of influence of the sulphide horizon would encompass the entire Area and hence be rendered useless as a spatial localizing means. The alternative case is not any more attractive, though its acceptance is not necessarily justified when one remembers the possibility of the 'solution permeation' explanation with the deposited sulphides originating in the Precambrian shales. It may be seen that from a specific point of view, the so-called 'Lithologic Considerations' are ineffective because they contain too many imponderable quantities; the original medium of the sulphides would provide a valuable reference if a more detailed knowledge of the actual movements of the ore solutions co-existed with it. Hence, 'Lithologic Considerations' are but an interesting, and rather academic classification, incapable of providing any very detailed information for the mine-hunter.

7) Summary: Re Emergence of the Useful 'Controls'

In summary, we see that the along-strike structural and so-called 'stratigraphic' systems of classification combine to specify the Mollie Mac limestone bed in the Index Basin region as a very favourable location for sulphide deposits. Unfortunately, this fact was pre-eminently well known already; so it must be concluded that the ore picture was not changed much in the actual Area studied by the researches. However, the wealth of data obtained during the field work can easily and rather accurately be 'extrapolated' onto areas along strike to clarify the ore-picture elsewhere.

X. Assembling the Area Picture

Stepwise evolution of individual topics has now been accomplished, so now let us briefly pick up the threads of their separate arguments, retracing them just far enough to be sure of their inter-connections in the Area Picture.

The actual organization sequence was demanded by the necessity of acquainting the reader with the local structural principles, then with geography; before going into the actual mechanics of stratigraphy and lithology, which because of the rapid local facies changes, would only have added to confusion without some referencing them to some pre-existing system of geographic orientation, as the one provided; with all of this material required as a preface to intelligent discussion of the three main divisions of the geological picture: the detailed description of local stratigraphy in order to throw light on the depositional processes responsible for them; secondly, of course, a look at these conditions themselves; and thirdly an attempt to recognize the effects of superimposition of the local lithologies upon structural trends to produce the specific fold forms actually observed. The last-mentioned consideration, the correlation of lithology to fold-form, is to be considered more specifically as evidence that whole present day competency of the rocks of these individual folds is a function of the degree of physical deformation consequent to the folding; the degree of folding was instead originally more, of course, a function of initial competency of the rocks involved. This statement obviously requires further clarification: it may be paraphrased as a necessity to distinguish between the physical strength of the various lithologies, as deduced from considerations of their original composition, and their present day competency after an era of intense physical deformation: and with this twofold distinction then firmly in mind, to apply the idea of progressive weakening of the rocks by deformation to explain, in part, both the rate and final degree of this deformation.

2) Folding--A Dynamic Process

a) "Practical" Explanation

The above chain of dependencies alone should be sufficient to show that folding is not a 'linear' process, or one involving linear variables. Rock competency not only affects the folding process but is in turn affected by the shearing action inherent in fold-deformation, so that causal and 'effect' roles of competency become reversed between the end-points of any period of severe structural but low-grade-thermal metamorphisms. There is a progressive weakening of competency: this causes a progressive susceptibility of the rock toward further folding; hence the process gradually sets up a zone of weakness which predisposes the area to the forces acting on the region.

b) More Succinct Mathematical Explanation

All of the foregoing, one fears, sounds involved; but let it not be thought of as deliberate vagueness: there is no adequate English in existence to describe the 'mathematical elegance' of the exponential function, and that is precisely the type of relationship involved here between the quantities just mentioned.

c) Definition of Some Basic Variables

The 'exponential functions' concept is one of the ideas which should be really mercilessly beaten into any analysis of structure. 'Structure', as such, is only the instantaneous expression of a dynamic process, in which all the factors he can think of have been evolving during that change from original conditions quite different from those actually in evidence. If calculus were brought to bear on the situation, derived equation for the conformation of the folding pattern (perhaps the equation for the centre-line of a bed at mid depth, with amplitude pressured along 'y', and the axis of symmetry corresponding to the 'x'-direction) would be a function in at least the three basic variables: the changing competency (decreasing): the changes in regional deforming forces and thirdly, the modification of the second variable by local stress concentrations arising from the actual physical shape of the fold at any given stage in its production. Each of the three variables could similarly be related to several sybsidiary variables, but that would not help simplify the Area Picture materially.

1) The Structural Data

'Structure' in this region will now be seen to have been almost synonymous with folding. The terminology will now be understood if it is said these folds have largely passed from the first, or stratiform fold conformation into the second, or "isoclinal form", with the transition occurring in the attenuation range of about three to one. The characteristic markers of the second stage are inauguration of crestal limestone flowage and the phenomenon of "piercement".

Folds remaining within the stratiform limit also suffered further deformation but it took the form more of bodily upriding movement with a consequent loss of section on northeast overturned limbs of the anticlines.

2) Rock Competency

As has been explained, the second stage of folding brings the dynamic competency-deformation rate considerations into play, whereby shearing of the weaker rocks is a function of the degree of deformation: also, original pre-shearing competencies are retained proportionate to the original strength of the lithologies. For this reason, the soft black rocks of the Perrylode and the fine green sediments of the Index have exhibited the greatest shearing. The Badshot limestone, where too thin to be the dominant strength-member of the Bunker Hill Group, has been subjected to the pronounced flowages just mentioned. Deformation is accelerated by both the progressive susceptibility due the growing incompetency of the rocks and also shape-disposition to increased movement away from the applied forces. Both topics have, of course, been previously dispatched. In extreme cases of the teardrop folding, as on Corner, "equilibrium" lenses were left stranded on lime contacts, as well as numerous detached drag folds. It should have also been noted the useful consistency existing between major fold shape and that of these minor 'detached drags'. In connection with small drag fold phenomena the same consistency, as an indicator of stratigraphic 'tops' was noted in the folds, especially in the more rounded forms.

Finally, it should be noted that the fold-size-competency relation was reversed from a direct to inverse proportionality when very high attenuations were reached.

3) Structural Trends

In extreme cases of teardrop folding, as on Corner, 'equilibrium' lenses were left stranded on limb contacts, as well as numerous detached drag folds. The useful consistency between major ~~old~~ fold shape and that of these minor 'detached drags' should have also been noted. In connection with small drag fold phenomena, this same consistency, as indicators of stratigraphic 'tops' was displayed by these folds, especially in the more rounded forms.

On a larger scale, it is now obvious the structure was consistent with the picture of movement of a "sandwiched", generally incompetent horizon on the northeast limb of a regional-scale syncline (not Geosyncline). Cleavage dips, overthrusting tendencies, and the one small shallow-angle "thrust" demonstrate this trend.

With respect to sub-area-scale-structure again, the large differences in observed folding dependent upon the northeastward stratigraphic tapering (hence weakening of the section) were not seen materially to 'tighten' the folding in the direction, which is surprising.

However, a definite tightening trend was found to operate progressively going southeast, so that the most attenuated structures were found on that margin of the area.

4) Structure Ore Control

While the lithologic associations of the ore, particularly those elevated to the Mollie Mac limestone were borne out anew by the investigation, structural repercussions of the ore picture remained slight: main structure indeed become difficult to relate in any significant way to the deposits of the valuable sulphides. Neither 'piercement' nor 'teardrop' traps were effective; but some mineralization occurred on the faulted northeast limbs of one of the stratiform anticlines, besides that of the cross faults.

5) Secondary Alterations

With respect to the various secondary alterings of the rocks; these seemed to associate with the most drastic structures. Also significant is the idea of placement of the diorite up along what should have been shown was the deepest flowage-bedding fault zone. With respect to the minor siderite anchorite diorite alterations in the phyllites, which were notably barren in the base metal sulphides, no such correspondence could be seen.

The main considerations made of the diorite as to the determination of its cause: whether its parent-shear zone, the so-called "zone of weakness", had been induced more by the strike shifts phenomena or by the fold-tightening, gave ground to the latter.

The diorite was decided to be post-deformation, both on the basis of coarseness and uniformity; and its disregard for the along-strike structural trap was extrapolated onto the situation of sulphidation and sulphide-carbonate-alteration in the same relative position across strike in the Index Basin.

Finally the mechanism of the dioritization was realized to be both of hydrothermal solutions, and of an intrusive activity. By and large, replacement favoured the clean limestone, whereas fissile rocks tended to be "filled" by diorite lenses along their cleavage planes, in many places causing considerable warp-in-the-dip. The 'diorites' composition was not chemically determined.

6) Depositional Data

Depositionally, the picture of northeastward tapering units cannot be shaken by "fault" explanations or unconformities. Each of the post-Cambrian units had a progressively westward-moving periphery, which meant, in the case of the two lower ones, that they were stratigraphically extinguished before the northeast boundary of the Area was reached. Erosional cutting of the under beds could not have produced such a conformation.

Use of the temporal contour method of interpreting stratigraphy demonstrated the unlikelihood of bona fide facies change, but rather eastward thinning, to accomnt for the fact that theoretical parallel planes, themselves parallel to the top of the Badshot, were seen to pass through progressively changing lithology which consisted of the oriented triangle of limestone, volcanic sediments and mud, with the former as base and others arranged in northeastward order. The causes of this tapering were predominantly those of the usual sorting processes, with "fines" being carried further off the west shore of the Geocyncline on which the Area was located, before deposition. However, in the case of the Redcliffe pillow lavas, water-contact chilling and consequent flow arrestment at the erstwhile beach line was also seen as a "cause" of this rapidly "wedging" Volcanic member.

The appreciably pyrite content of the post-Cambrian phyllites marked them as the most probable carrier of the original sulphides: however, they did not lend themselves to trap structures: consequently some of the deposits thought to have leached out of the 'phyllites' were found along limestone contacts in small faults just within the limestone itself. No attempt was warranted or made to correlate the 'sulphide-altered-carbonate' processes with the sulphidous horizons.

7) Use of the Summary

A summary such as this could be further protracted, but that would only have defeated its purpose. The main data have now been restated in skeletal form and so it is now possible to look at these as an index to the fuller detail of the body of the essay, and draw the obvious conclusions.

XI. General Conclusions

The Picture Emerges

Over the skeletal geographic-geologic frame of our Area Picture has by now been draped a good deal of verbiage. Most of it has been facts, and the rest has been attempted systematizations of the facts. The data has now been summarized, or indexed, and may be referred to: but facts by themselves are only "one dimensional quantities." So now let us cut them away from the Area Skeleton, and view this object once again covered with just the basic ideas of the area now incorporated into it in what it is to be hoped, approaches a correct and adequate perspective.

The actual creation of the picture has been the prime concern of this essay: so essentially the purpose of the essay can be thought of as having been descriptive as well as correlative.

These descriptions have now been condensed into trends. These have been the trends, to wit:

With respect to structure of three highly developed types of major folds, coupled with a southeast structural 'tightening' along strike of the structures:

Depositionally, for affirmation of the Area as being towards the southwest shore of its depositional Geosyncline:

Lithologically, as an area, which, above the known Cambrian limestone experienced increasing volcanic influence originating in the southwest, culminated by viscous lava flows before waning into a mud "decline" of activity;

Stratigraphically, as an area of conformably contacting but northeastward tapering units above the Cambrian, with the particle size in the post-Cambrian decreasing in the same direction and accounting in part for the thinning.

Correlative themes have been adhered to throughout the essay, namely:

A generalization-to-particularization-to-regeneralization-sequence method of developing the components of the Area Picture, so as to avoid destroying it with the detail necessary to fully document it:

A sequence in which foregoing material serves as a reference to the argument at hand, to avoid footnotes:

An emphasis on correlation itself so that this process was carried on at as many levels of detail as advisable in the space:

Demonstration of the essential dynamic nature of the relationships, in which the immediately pre-existing, and not the original, conditions were seen to be the agents at work at any specific period of the deformation process: examples of which were modification of its effects of regional compression forces by zonas of weakness, by the actual shape of the structure involved, considered as a "free body", and by the other considerations of rock-competency.

These correlative methods achieved conclusions more or less consistent with common sense. Especially the dynamic-change idea, first used as a trend, must now be considered to be a useful fact.

More detailed conclusions must be drawn on the ore situation, inasmuch as it provided the economic raison-d'etre for the geological study in the first place.

XII. Specific Conclusions about the Ore

Primarily, we must conclude that the ore's deposition cannot be correlated to the large scale structures nor can it be located relatively in any position on these folds with any degree of accuracy. For instance, regional upriding movement of the rocks onto the limbs of the area syncline, producing the tendency toward faulted northeast limbs on the large 'stratiform' anticlines of the area did not necessarily serve to localize ore in exclusively this type of 'fault traps'.

Though some important localizations of very high grade galena rich sulphides are associated with cross faults, no patterns could be established for this cross faulting beyond the obvious and inconsequential one that these faults maintained a perpendicular cross-strike direction with a fairly high degree of consistency.

Original depositional considerations, while useful in making both the cross strike stratigraphic correlations and also providing the springboard for further investigation of the structural pattern from the progressive competency change relationships already discussed, did not provide any very specific results with respect to localizing the area containing ore deposits. While they seem to be a source of the sulphides, they seem to lack the necessary lithologic and structural properties to concentrate and 'trap' much of these. They cannot be correlated to the anchorite-siderite activity.

The most potent 'control' has seemed to be the one associating a specific 'bed' of rock with intensive mineralization, in the form of the just-mentioned carbonate replacements, which have selected the Mollie Mac limestone as their chief locus of activity. Though such an empirical sort of relationship, that of ore to rock type, more or less irrespective of structural factors, is disappointing from an enlightened point of view, nevertheless it exists; and, as far as ore tonnages go, this lead (not Pb.) has been more extensively tapped in the area considered than the small fault or drag-fold-trapped high grade deposits.

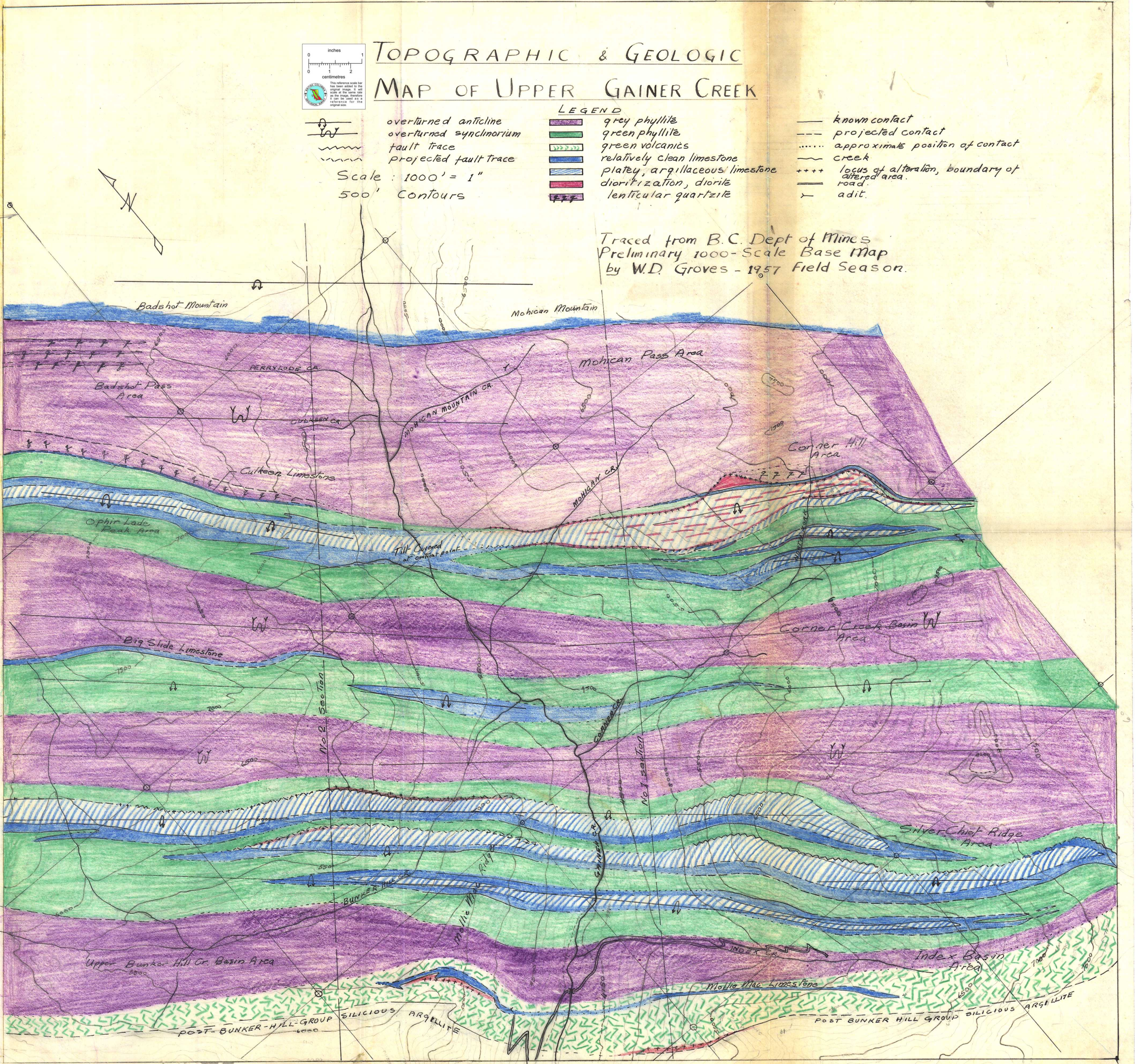
The most general conclusion which can be made about the ore picture is that since the only fairly consistent 'ore control' was found to be the one which had been long known and hence extensively made use of in exploratory operations, the ore picture does not seem to have been appreciably brightened by the investigation.

However, the very fact that the rich replacement sulphide deposits along the Badshot Limestone contacts are not continuous, and by their lack of a large altered 'envelope' do not advertise their presence would indicate that geophysical methods of prospecting along this limestone, to locate any completely concealed ore bodies, would be one of the more useful programmes of future prospecting work in the area.

It should be noted in closing that while from an economic point of view the geological mapping of this particular area of the West Lardeau did not produce any "pay dirt"; still from the point of view of structural geology, the project was probably successful.

Appendix A

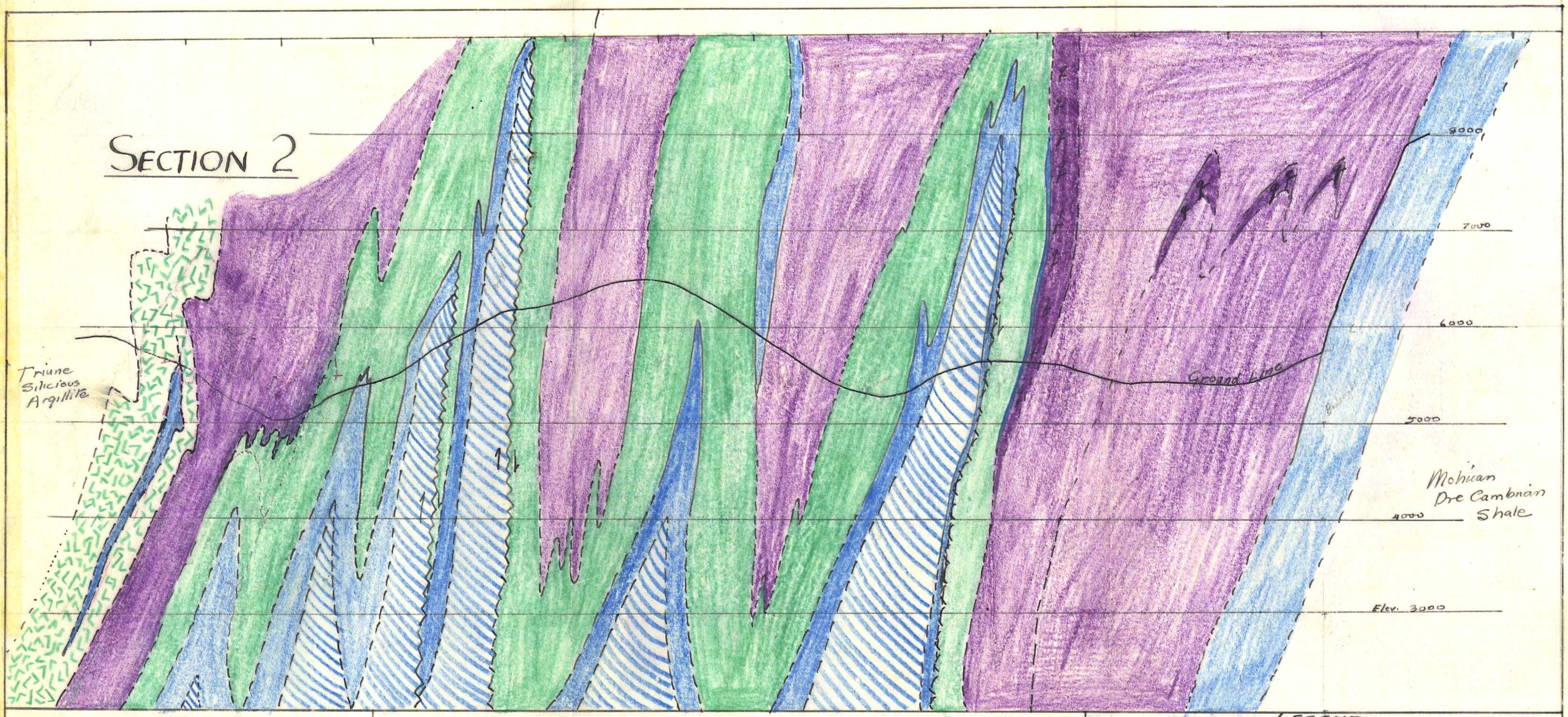
Fold-out of Area's Map



Topographic & Geologic
Map of Upper Gainer Creek
Legend
overturned anticline
overturned synclinorium
fault trace
projected fault trace
Scale: 1000' = 1"
500' Contours
grey phyllite
green phyllite
green volcanics
relatively clean limestone
platey, argillaceous limestone
dioritization, diorite
lenticular quartzite
known contact
projected contact
approximate position of contact
creek
locus of alteration, boundary of altered area.
road
adit.
Traced from B.C. Dept of Mines
Preliminary 1000-Scale Base Map
by W.D. Groves - 1957 Field Season.
Badshot Mountain
Mohican Mountain
Mohican Pass Area
Perrylode Cr.
Badshot Pass Area
Culkeen Cr.
Mohican Mountain Cr.
Mohican Cr.
Corner Hill Area
Culkeen Limestone
Ophir Lode Peak Area
Big Slide Limestone
Corner Creek Basin Area
No 2 Section
No 1 Section
Silver Chief Ridge Area
Bunker Hill Cr.
Mollie Mac Ridge
Gainer Cr.
Index Cr.
Index Basin Area
Upper Bunker Hill Cr. Basin Area
Mollie Mac Limestone
Post-Bunker-Hill-Group Silicious Argellite
Post Bunker Hill Group Silicious Argellite

Appendix B

Fold-out of Cross Section



Horizontal & vertical scale: 1000' = 1"

NOTES

1) Interpretation has been made where necessary for clarity

2) Faulted contacts due to 'flowage' of beds are not shown as faults unless such faults are of major importance.

APPROXIMATE CROSS-SECTIONS OF THE BUNKER HILL GROUP IN UPPER GAINER CREEK

DRAUGHTED BY: W.D. Groves

1957 FIELD SEASON

LEGEND

- grey phyllite
- green phyllite
- green volcanics
- relatively clean limestone
- platey, argillaceous limestone
- dioritization, diorite
- lenticular quartzite