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INTERIM GEOLOGICAL REPORT ON

HORSETHIEF STOCK

by

K. SCHRIJVER, November 1971

for

CANADIAN JOHNS-MANVILLE COMPANY LTD.

Frontispiece: Spire of Spicebox Peak, 9000 feet above sea level

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ABSTRACT

52.24 sq. mi (C.P. Lin May 1972)

The Horsethief Stock, a Mesozoic post-tectonic granitic pluton, underlies a mountainous terrane of 100 sq. mi. in southeastern B. C. Its outline is semi-elliptical. Its contacts are sharp and steep-standing.

Petrographic zones in the interior of the stock form a roughly concentric elliptical pattern located asymmetrically with respect to the external outline of the stock. The outer and largest zone (83% areally) consists of very coarse-grained quartz-biotite-monzonite. The inner and smallest zone (1.5%) is also of granitoid texture but is much finer grained. Facies transitional between these two zones occupy the intervening area.

Detailed field work in a zone straddling the boundary of the stock reveals a spatial sequence of rock types from (i) the common coarse-grained quartz-biotite-monzonite, to (ii) a similar rock with slightly reduced grain size, to (iii) a similar rock with aplitic matrix, to (iv) aplite dikes, and, finally, to (v) quartz pods and veins. This sequence, approximately in reverse order, can be thought of as a temporal sequence of progressive solidification of a quartz-monzonitic parent magma.

The position of the inner and intermediate zones of the stock cannot be fitted into this sequence without ambiguity. Nevertheless, some speculative hypotheses on the evolution of the whole pluton are offered. Petrographic and isotopic work is proposed to check these speculations.

Phyllic hydrothermal alteration, accompanied by propylitization and pyrite mineralization, is common along joints in the Horsethief Stock. Degree of alteration increases from the outer to the inner lithological zone of the stock but within anyone zone remains roughly constant. Pervasive, "disseminated" products of alteration and mineralization are rare and are confined to the inner zone.

Whether the sequence of progressive solidification outlined above forms an uninterrupted whole with the later hydrothermal alteration is unknown. It revolves around the same ambiguity concerning the position of the inner and intermediate zones of the stock with respect to the sequence of events in the outer zone.

Molybdenite is the main economic mineral of the Horsethief Stock. In the contact zone of the stock, it is (i) common but sparsely disseminated in aplitic rocks and aplite dikes, (ii) rare but locally concentrated in and along quartz veins, and (iii) rare but locally concentrated along fractures. In the last mode of occurrence it is invariably associated with pyrite as well as with some hydrothermal alteration products. Characteristically, sericite, the most common product of hydrothermal alteration, is rare or absent.

With the notable exception of the contact zone, molybdenite has not been observed in the outer and largest zone of the stock.

In the inner and intermediate zones, molybdenite occurs (i) rarely and sparsely disseminated in aplite dikes, and (ii) rarely and sparsely in common quartz-sericite-pyrite joint fillings. Geochemical samples from the inner zone tend to suggest that molybdenite is more abundant than suspected from the observed mineralization.

Chalcopyrite and bornite are absent from the interior of the stock. They occur locally in the contact zone along tight "dry" joints, in association with pyrite and pink feldspar.

one chalcopyrite float INNER ZONE, STATION FDT 325 in May 1979

Proterozoic sedimentary rocks envelope the Horsethief Stock. Remote from the pluton the metasediments are not or very slightly metamorphosed. Close to the pluton they are moderately to highly metamorphosed and form a 1-mile wide contact-metamorphic aureole. Andalusite, cordierite, garnet, wollastonite and forsterite characterize the nodular phyllites and the hornfelses in the inner part of the aureole.

Commonly, the contact-metamorphic rocks less than ½-mile from the stock are moderately to highly mineralized. Thus they form a contact-metasomatic sulphide halo around the stock. Common sulphides are pyrite and pyrrhotite; chalcopyrite, bornite, and molybdenite are rare and scarce.

In conclusion, a detailed description is given of prospects and showings in the contact zone of the stock and a list of detailed recommendations is appended.

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(in pocket)

INTRODUCTION

This report is an "interim" account of D. GARDNER's and the author's geological field work in and around the Horsethief Stock for the CANADIAN JOHNS-MANVILLE COMPANY LTD. during the summer of 1971.

A final report, incorporating the microscopic petrography of selected rock samples and K/A isotope studies, will be prepared in the spring of 1972. At the moment (October 1971) all rock- and mineral names are based on macroscopic identification.

Thorough documentation of the program planned, the work carried out, and the material collected is a necessity where people of different backgrounds work for a number of years on the same target of exploration. Therefore, the author of this report has not aimed at maximum brevity. He has, however, subdivided the report in essential, double-spaced parts and in accessory, single-spaced parts, so that the former constitute a fairly concise, self-contained narrative.

Location and Access

The Horsethief Stock, a post-tectonic granitic pluton, underlies an area of about 100 sq. mi. between the headwaters of Forster, Frances, Howser, and Horsethief Creeks in the Purcell Mountains of southeastern British Columbia (Fig. 1). The center of the semi-elliptical area underlain by the stock is approximately 20 mi. due west of the village of Radium, also called Radium Hot Springs. Gravel and lumber roads lead from this settlement along Forster and Horsethief Creeks to the northeastern and southeastern border of the stock respectively. Access to other parts of the stock is possible only on foot or by helicopter, and by ski or snow-mobile in winter and spring.

Physiography

The terrane is alpine, rugged and mountainous. Total relief in the stock is more than a mile, as measured from the lowest point at which the stock is exposed (4000' a.s.l. near the contact of the stock on Horsethief Creek) to the highest point (10200' a.s.l. near the center of the stock: Black Fang and North Star Peak). Local relief is also considerable, near-vertical walls of 1000' or more not being exceptional (see Frontispiece).

A remarkable pattern is evident in the topography of the area centered on Horsethief Stock (Fig. 1). The central part of the stock is high and is partly covered by permanent snow and ice (Catamount and North Star Glaciers). Outward, toward the north, south and west, parts of major stream valleys - Forster, Edouard, Stockdale, Horsethief Creeks - mark the low part of the area. Curiously, these valleys are within the stock, although close and subparallel to its boundary. Further outward again, across the valleys, locally at elevations approaching those of the central part of the stock, lies the contact of the stock with metasediments and the contact-metamorphic aureole associated with the stock. This is well illustrated in Figure 1 where the 8000' contour line (marking approximately the timber line) has been taken as a guide. The central two-fifths of the area underlain by the stock are above, and the outer three-fifths are below this line, with very few exceptions. The metasediments enveloping the stock form isolated ridges and peaks above the 8000' contour line. These ridges are separated by parts of major stream valleys - Forster, McLean, Howser, Stockdale, Horsethief, McDonald Creeks - which, like the ridges, are underlain by metasediments.

It seems that differences in resistance to weathering and erosion between the various rock types that make up the terrane, including non-metamorphosed sedimentary rocks, hornfelses and plutonites, have not played a dominant role in the development of these broad topographic features. For instance, it is unlikely, although not impossible, that the valleys within the stock are underlain by readily weathering plutonites, say highly altered rocks, whereas the plutonites nearer to the contact of the stock as well as those closer to the center of the stock are less altered.

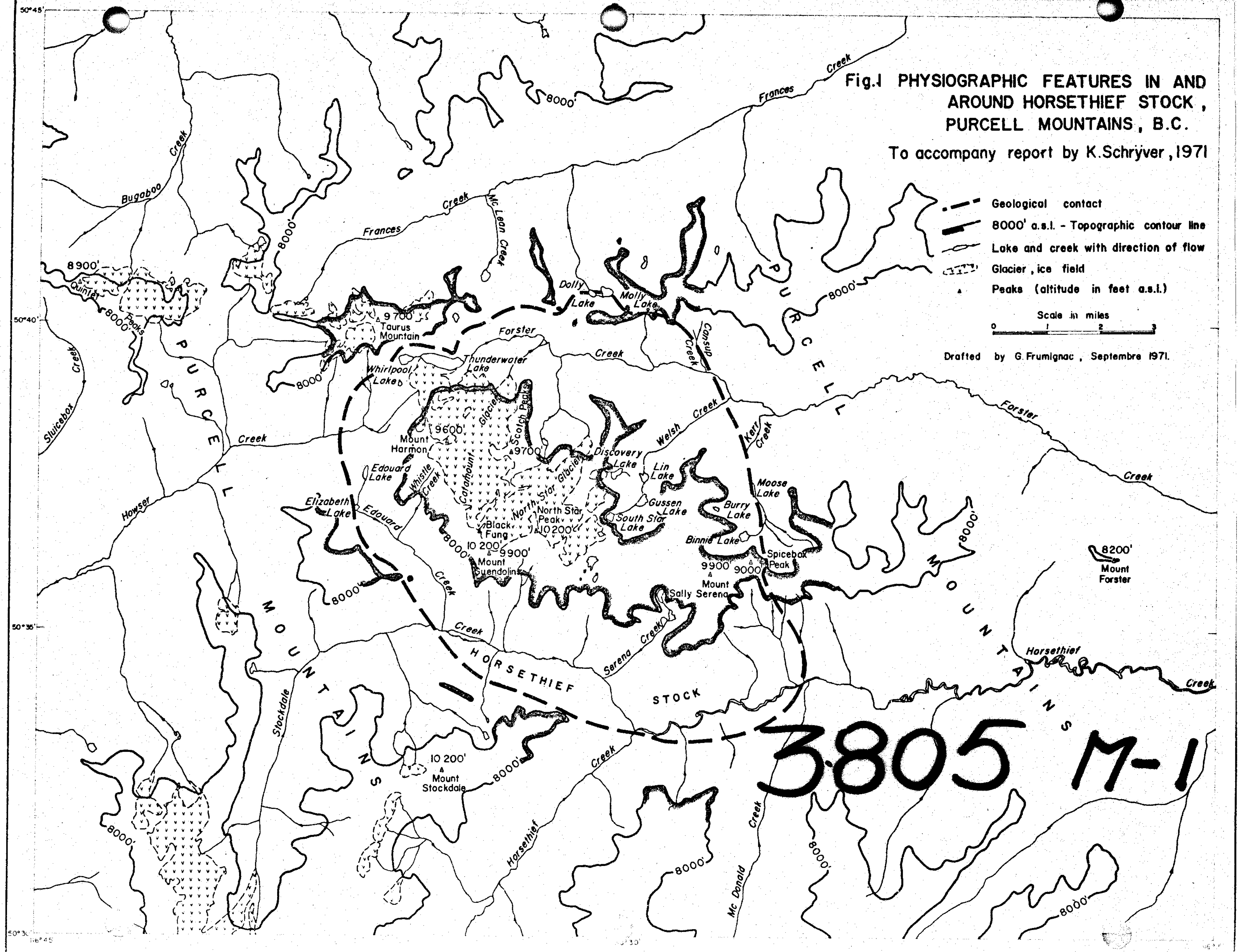

Fig.I PHYSIOGRAPHIC FEATURES IN AND AROUND HORSETHIEF STOCK, PURCELL MOUNTAINS, B.C.
To accompany report by K.Schryver, 1971
Geological contact
8000' a.s.l. - Topographic contour line
Lake and creek with direction of flow
Glacier, ice field
Peaks (altitude in feet a.s.l.)
Scale in miles
0 1 2 3
Drafted by G. Frumignac, Septembre 1971.
PURCELL MOUNTAINS
HORSETHIEF STOCK
Taurus Mountain
Mount Harmon
North Star Peak
Black Fung
Mount Guendoline
Mount Sally Serena
Spicebox Peak
Mount Forster
Mount Stockdale
Thunderwater Lake
Whirlpool Lake
Dolly Lake
Molly Lake
Discovery Lake
Lin Lake
Gussen Lake
South Star Lake
Burry Lake
Binnie Lake
Moose Lake
Edouard Lake
Elizabeth Lake
Frances Creek
Bugaboo Creek
McLean Creek
Forster Creek
Welsh Creek
Consup Creek
Kerr Creek
Horsethief Creek
Howser Creek
Stockdale Creek
Serena Creek
McDonald Creek
Sluicebox Creek
Quintet Peaks
Catamount Glacier
North Star Glacier
Scotch Peak
Whistle Creek
Edouard Creek
50°45'
50°40'
50°35'
50°30'
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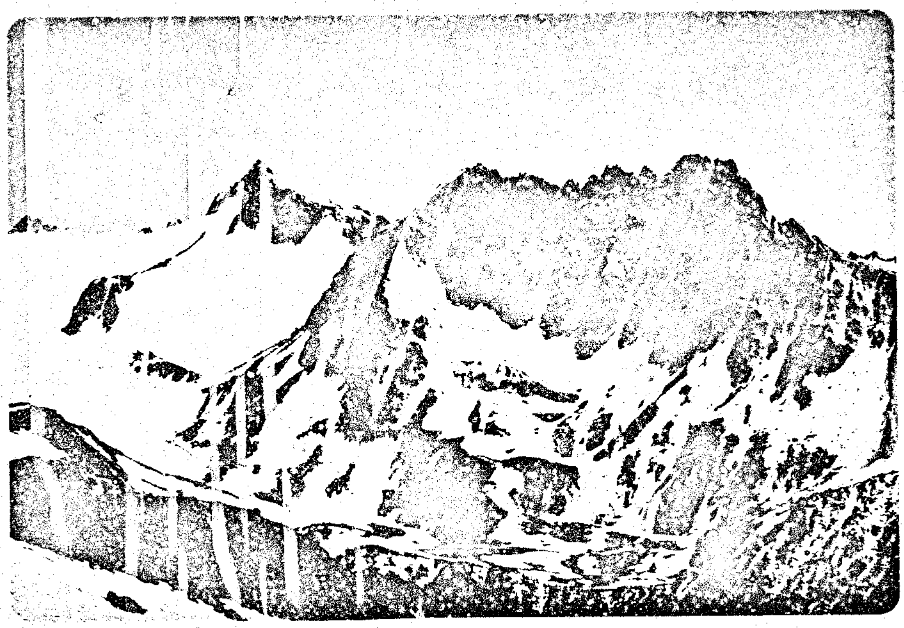


Figure 2. Scotch Peaks, looking south-south-west from Cansup area. Basin to left of ridge is northern extremity of North Star Glacier.

To explain these curious features, uncommon around young post-tectonic plutons in the author's experience, it is tentatively suggested that the major drainage channels had formed before the level of erosion reached the pluton and that, subsequently, these old channels guided Pleistocene glaciers, were incised further, and presently are occupied by the main streams draining the glaciers that still cap the stock.

If this explanation is correct, it is probable that (i) the present level of erosion is relatively shallow with respect to the total vertical extent of the stock, and that (ii) little if any time was available for the formation of a pre-Pleistocene regolith on the stock.

It will be clear from this description that the stock is well exposed, although some parts are covered by permanent snow and some parts are accessible only to mountaineers. Helicopter transport is practically a necessity to reach some of the high ridges. But even under the best of weather conditions, helicopters cannot land on many sharp ridges traversing and surrounding the two glaciers in the area (Fig. 2).

The contact-metamorphic rocks around the stock are equally well exposed in numerous places. Even the very contact of the stock can be studied at leisure in many places, although locally it is burried under thick glacial overburden or is situated on inaccessibly steep rock faces.

Some indication of the lithology and mineralization can be obtained from most inaccessible parts of the area by inspection of strategically located talus slopes and analyses of geochemical samples collected on such slopes. "Strategically located" is used here because large morains of greatly mixed materials of unknown provenance occur up to considerable elevation. The tops of the morains - side morains - are commonly marked by "shoulders" in major stream valleys. Such "shoulders", however, are not invariably present. Therefore, it is advisable to collect material, particularly in detailed prospecting and sampling, right at the base of inaccessibly steep slopes where little doubt exists about its provenance.

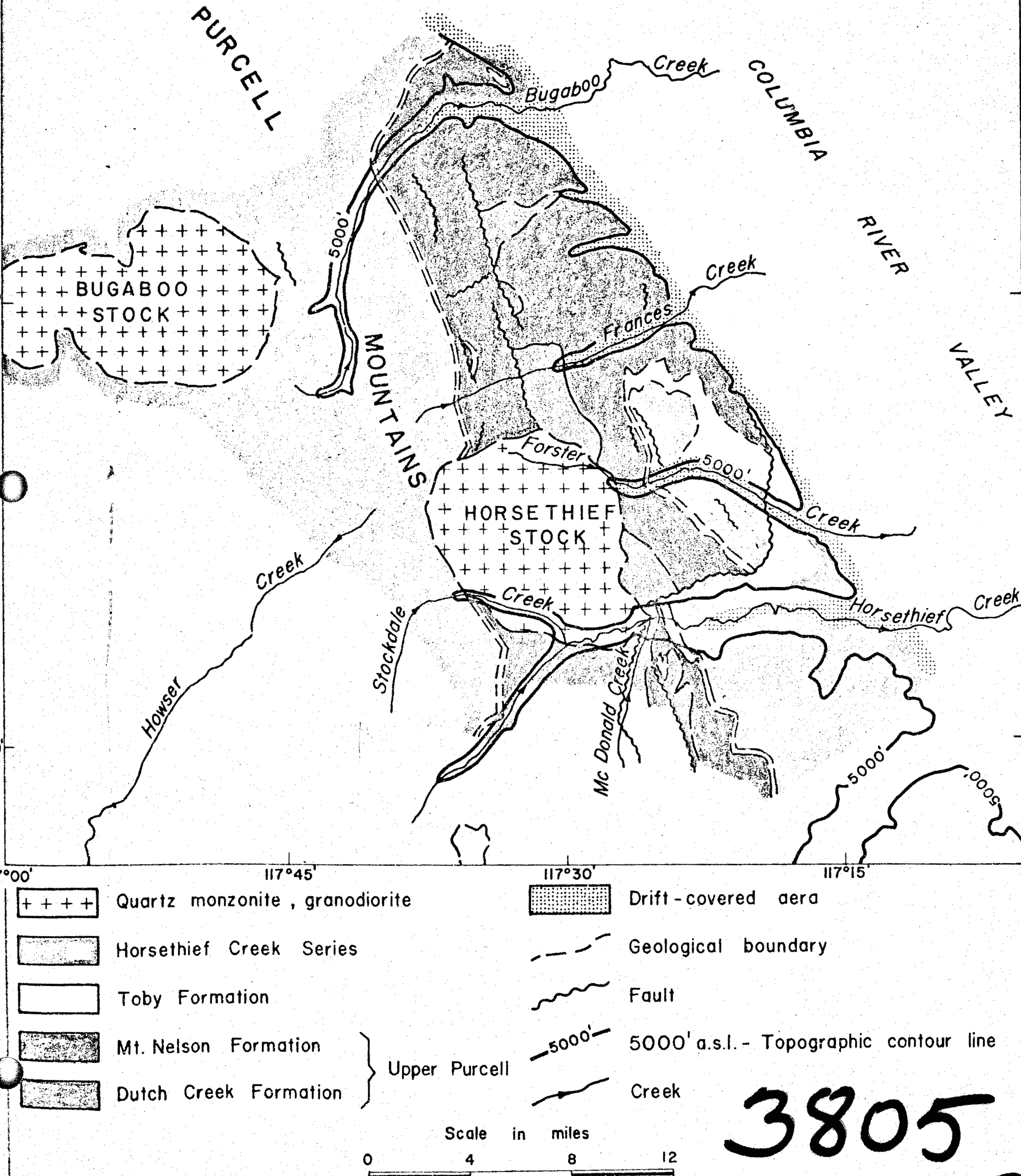
Previous Work

REESOR's (1957) one-inch-to-four-miles map is the only modern, first-hand geological work published about the area. More recent or more detailed work, by either government or company other than C. J-M, has not come to the attention of the author.

Fig. 3 REGIONAL GEOLOGY OF HORSETHIEF - BUGABOO AREA

(simplified after J.E. Reesor, 1957)

To accompany report by K. Schrÿver, 1971



Drafted by G. Frumignac, Septembre 1971.

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REESOR mapped a large area, a small part of which is occupied by the Horsethief and the similar Bugaboo Stock (Fig. 3). The sedimentary rocks in the area with which we are concerned are subdivided by him into the Proterozoic Upper Purcell Series (Dutch-Creek and Mount-Nelson Formations) and the younger but also Proterozoic Horsethief-Creek Series. The two series are separated from each other by a relatively thin formation, the Toby Formation, which consists of conglomerates and breccias and lies with a slight angular unconformity on the Upper Purcell Series.

"Quartz monzonite, granodiorite" of the Horsethief and Bugaboo Stocks are classed by REESOR (op. cit.) at the top of the geological column, as the youngest (post-Triassic) rocks. The evidence on which the latter part of this age classification is based is not evident from his map and is not given in the notes accompanying the 1957-map. It will probably appear in his forthcoming memoir (REESOR, written comm. 1 June 1971).

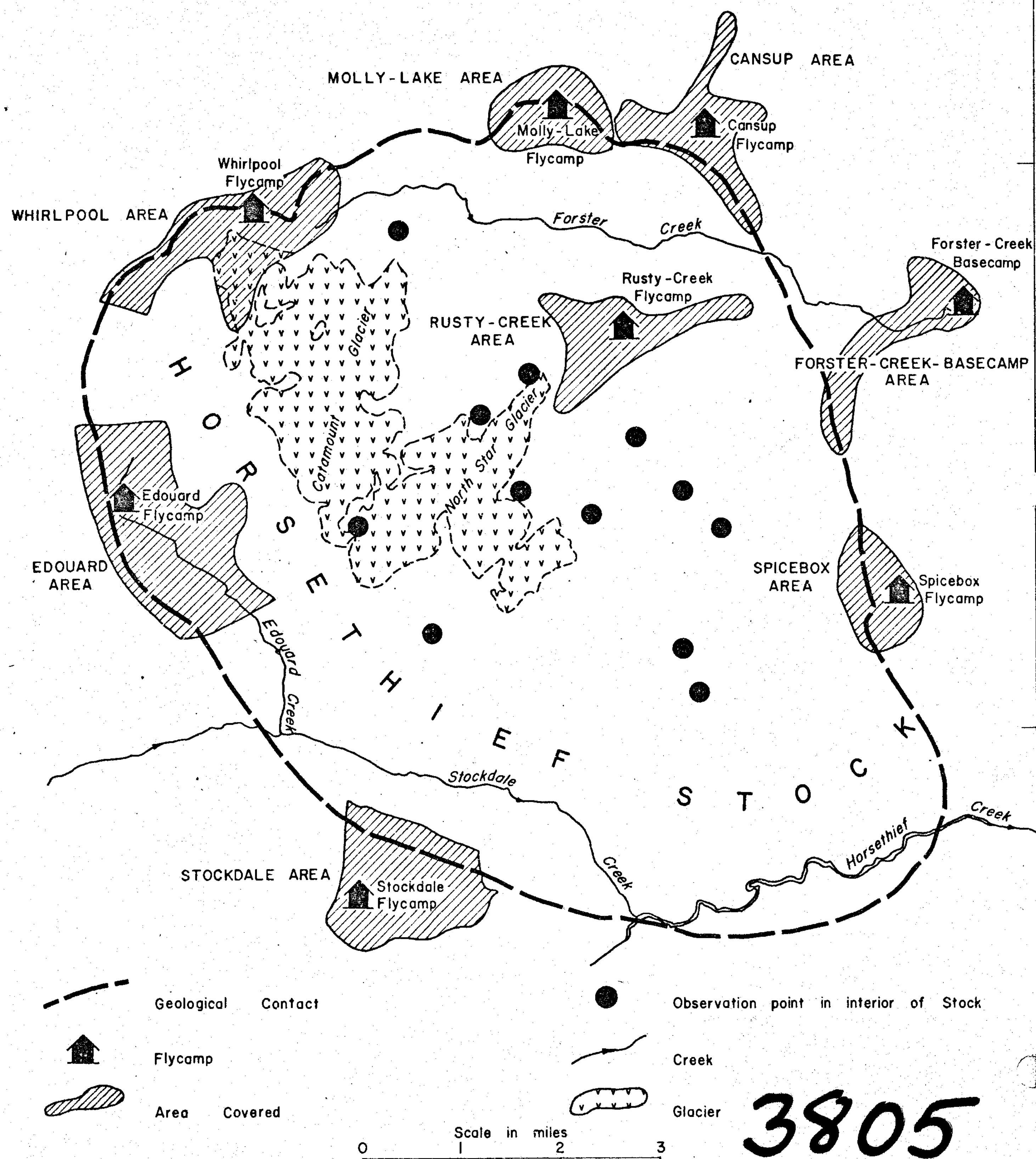
We have been able to confirm and add to, but certainly not improve on, REESOR's regional work in the Horsethief-Stock area. The remarkable, astonishing, accuracy of the contact of the Horsethief Stock mapped by him is worthy of special mention, particularly so in view of our interest in future work in the Bugaboo Stock.

Up to the summer of 1971 work by personnel of C. J-M consisted of geochemical and biogeochemical exploration, initially on a broad reconnaissance scale, quickly followed by claim staking and detailed geochemical and geological exploration of areas found to be "anomalous" during the initial phase of the work (KERR, 1970; LIN, 1970). The blocks of claims staked up to the summer of 1971 are situated mostly within the eastern part of the Horsethief Stock and include a considerable part of the eastern and southern contact-aureole of the stock.

Since the history of the Company's work in the area is known better to most readers of this report than to the author, it would suffice to single out one point to which we shall have to return in the sequel. Namely, primary interest in the exploration program

Fig.4 LOCATIONS OF WORKING AREAS AND FLYCAMPS IN AND AROUND HORSETHIEF STOCK

To accompany report by K. Schrÿver, 1971



Drafted by G. Frumignac, Septembre 1971.

116°30'

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has shifted, with increasing knowledge of the mineralization in the area, from placer deposits, to the suite of economic minerals associated with uranium in granites and pegmatites, and, finally, to "porphyry-type" molybdenum and copper mineralization. It must be remembered that some claims held today were staked on the basis of previous interests. Such claims are not necessarily the most favourable targets for further work in the light of better knowledge of the mineralization in and around the Horsethief Stock.

Present Work

Geological work by the team consisting of D. GARDNER and the author was carried out from the Company's Forster-Creek Basecamp, from six flycamps dotted along the boundary of the Horsethief Stock, and from one flycamp within the stock (Fig. 4).

In the period from the date of arrival at Forster Creek (July 10) till the day of departure (September 6), 35 days were spend in the field. From each camp, roughly 4 days were spend in geological field work. Helicopter transport to, and commonly from, flycamps reduced time-consuming back-packing and unnecessary travel on foot to a minimum. In addition, helicopter-supported reconnaissance in the high central part of the stock was carried out during two days at the end of the season. Most of the remaining time was spend in office work and preparation for flycamps. An extremely dry and hot season - a total of 2 days of rain in 51 days - enabled us to work without major interruptions, except for five days in mid-August when pilot and helicopter were engaged in forest-fire fights.

Figure 4 shows that by far the major part of our field work was carried out along the contact between the Horsethief Stock and metasediments. In fact, most well-exposed and readily accessible parts of the contact were inspected on the ground.

Such was not according to the program initially outlined by Dr. E. L. MANN (written comm. 27 May 1971). According to the program geological work was to be concentrated on the major Mo-anomalies previously (1969-1970) found. However, based mainly on work carried out from one flycamp at the contact of the stock (Cansup Flycamp), and from one flycamp within the stock (Rusty-Creek Flycamp), the author suspected that much of the Mo-mineralization might be concentrated near the boundary of the stock. In consultation with Mr. H. K. CONN (July 1971) it was decided to pay more attention to the contact of, and the contact-metamorphic aureole around, the Horsethief Stock than was originally planned. Subsequently, each "working area", each centered on a different flycamp near the contact zone, revealed some Mo-mineralization, three of which seemed sufficiently attractive to pursue with claim-staking and detailed work.

Our first-hand knowledge of the interior of the stock rests entirely on the work done in the vicinity of Rusty-Creek Flycamp (5 days) and on helicopter-supported reconnaissance in the high central part of the stock (2 days; see Fig. 4). Since the company geologist, Mr. C. P. LIN, has worked in the interior of the stock, around Lin and Gussen Lakes in the so-called "Target 1 Area", the combined knowledge available to the Company should suffice to make a plausible choice for future work.

We shall close this rather lengthy section on plans, changing plans and actual work with some comments on the maps used and the material collected during our work.

All field observation, outcrop numbers and sample numbers were assembled in notebooks and plotted on topographic maps. The 1:50,000 maps of the National Topographic Series (Howser Creek 82K/10E and Radium Hot Springs 82K/9) proved to be indispensable for accurate localization of outcrops and thus for accurate mapping. The 1":½ mi. maps provided by the Company are much less useful since (i) their contour interval is 500' instead of the 100' of the 1:50,000 N. T. S. maps, and (ii) they are enlargements of small-scale 1":2 mi. maps. Air photographs were not used during the field work, the 1:50,000 maps, in combination with a good altimeter, proved sufficient for all practical purposes.

Our common procedure has been to make the initial map on the 1:50,000 topographic base, and to project this onto the 1":½ mi. map. In basecamp, the projection was transposed onto a reversed "screened" sepia copy of the same scale. Reproductions of the latter constitute Plates 1 and 2 of this report. We emphasize that these maps are not more accurate - in fact, are less accurate - than the 1:50,000 topographic base allows.

A major effort was made to collect (i) a representative suite of common rock types of the Horsethief Stock; (ii) the gamut of contact-metamorphic rocks around the stock; and (iii) all types of alteration and mineralization products encountered in either stock or contact aureole. Although some - very little - work was done outside the contact aureole, no samples have been collected there. A total of 149 rock specimens was gathered, 40 of which were selected by the author for further petrographic work, the remainder being housed on shelves in the Kamloops office.

A description of each specimen is given on an index card, whereas the location and number of each specimen is plotted on Plate 2 of this report. The 40 rock specimens and 149 index cards, now in possession of the author, will, upon completion of the laboratory work and final report, be returned to the Kamloops office for display and storage.

Very few geochemical samples (talus fines or soils) were collected in the first part of the season. However, upon realization that considerable parts of the contact zone had not adequately been sampled previously, geochemical samples were collected routinely, particularly in those places where the contact zone is situated on inaccessibly steep cliffs. A total of approximately 150 samples of talus fines and soils was collected and analyzed (Bondar & Clegg) for one or more of the elements Mo, Cu and U. The locations and numbers of these samples as well as the analytical results are shown on Plate 3 and in the Appendix.

Most sketches in this report are overlays of photos taken by polaroid camera. However, too few photographs were made. It was realized too late in the season that the entire route of most "traverse days" could have been photographed. Figure 17 shows the advantage of such a procedure: sample locations and major features not easily described in words or numbers can be shown in true-to-scale pictures.

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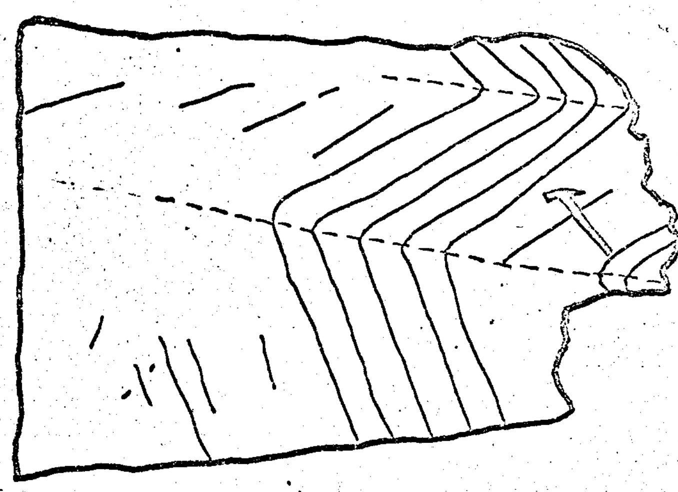

Figure 5. Strongly overturned fold in fissility (and bedding?) of siliceous slates. Looking north at subvertical face along fold axis (plunge 26° south); axial plane dips 27° south. Location: 6000' a.s.l. on northern valley wall of Forster Creek, 0.7 mi. northwest of Forster-Creek Basecamp (outcrop 7-12).

PROTEROZOIC ROCKS

Stratigraphy and Structure

The stratigraphy of the Proterozoic rocks has been worked out by REESOR (1957) and has been discussed briefly under "Previous Work". The boundaries between the Proterozoic formations shown in Figure 3 and Plate 1 have been taken from REESOR's map, although we have not been able to distinguish the Dutch-Creek from the Mount-Nelson Formation.

The main difference between these two formations on the one hand, and the Horsethief-Creek Series on the other, is the presence of coarse detrital rocks (quartz pebble conglomerate, grit) in the latter and their absence from the former. Furthermore, the characteristic conglomerates and breccias of the Toby Formation intervene between the Mount-Nelson Formation and the Horsethief-Creek Series.

The absence of the Toby Formation along the west side of the Horsethief Stock is noteworthy. Most likely this is due to late movements associated with the emplacement of the stock (no xenoliths of conglomerate have been observed in the stock, however).

Little is known about the structure of the Proterozoic rocks. REESOR's map shows (i) a number of major folds with gently northward plunging axes on NNW trends, and (ii) faults of greatly varying strike. These two structural elements have been taken from REESOR's map and are shown on Plate 1.

In addition, two faults shown on Plate 1 are based on our own work: the fault along Forster Creek, from Forster-Creek Basecamp westward, and the fault parallel to Cansup Creek passing through Cansup Flycamp.

Numerous minor, strongly overturned to recumbent folds with gently southward plunging axes (Fig. 5) but steep-standing enveloping surfaces are present in siliceous slates on the valley wall of Forster Creek, 0.7 mi. northwest of Forster-Creek Basecamp. The shape ("style") of these folds is unlike that of the upright to gently overturned major folds and suggests a complex deformational history of the Proterozoic sediments.

In view of the scarcity of detailed structural data on the Proterozoic rocks remote from the Horsethief Stock, it is not surprising that we have not found any structure or structural disturbance that can unequivocally be ascribed to the emplacement of the stock.

Metamorphism

Regional metamorphism--. Regionally, the Proterozoic rocks are non- to slightly metamorphosed. Although extremely fine-grained, chlorite and a white micaceous mineral have been observed on cleavage planes in shales and slates of roadcuts outside of the area covered by the map (Plate 1). Presumably, metamorphism is transitional between diagenesis and "burial metamorphism", and has not reached the lowest facies of "regional metamorphism" as defined by WINKLER (1967).

Contact metamorphism--. Younger metamorphism of an entirely different nature - "contact metamorphism" - has taken place in the Proterozoic rocks under the influence of the thermal gradient associated with the Horsethief Stock.

Obviously, the main difference between this metamorphic event and the one mentioned above lies in the spatial distribution of the rocks affected, the contact-metamorphic rocks forming an aureole around the stock. Moreover, many contact-metamorphic rocks are easily recognized by their characteristic textures and mineralogy, at least within ¼ mi. from the stock. Spotted slates, spotted or porphyroblastic phyllites, micaceous schists, and more massive dark hornfelses are easiest to recognize as products of metamorphosed pelitic and semi-pelitic rocks in the aureole. Characteristic metamorphic minerals provisionally identified include muscovite, biotite, andalusite, cordierite and garnet.

Except for an increase in grain size, the textures of calcareous and dolomitic rocks are not as diagnostic for contact metamorphism. But their mineralogy is equally characteristic. Tremolite-actinolite, scapolite, epidote, garnet, diopside, forsterite (mostly serpentinized) and wollastonite have been provisionally identified.

The partial limit of the contact-metamorphic aureole, shown on Plate 1 at a distance corresponding to 1.25 mi. from the stock, is based on the "first appearance" of tremolite in quartz-bearing dolomitic limestones. This mineral and rock type were selected to define the limit of the aureole because of the presence of dolomitic limestones in that part of the area where traverses were not confined to the vicinity of the stock. The distance of 1.25 mi. is probably the true width of the aureole since the boundary of the stock is - and thus probably the isotherms were - subvertical. At distances exceeding 1.25 mi., contact effects, mineralogical or other, were not observed in any rock type.

"First appearance", as used above, refers to the spatial distribution of tremolite. Remote from the stock, quartz-bearing dolomitic limestones do not contain tremolite. Toward the stock, tremolite appears in these rocks at a distance of 1.25 mi. from the boundary of the stock. The mineral is quite abundant and of easily recognizable acicular crystal habit right from its "first appearance" onward (specimens HORSETH.KS71.7-17-1, 7-20-1, 7-13-4). Its use as an index mineral is enhanced by its occurrence as envelopes around quartz veins and along joints in dolomitic limestones that are, themselves, quartz-free.

The transition from tremolite-bearing rocks to rocks without tremolite has been observed only twice (once near Forster-Creek Basecamp and once north of Cansup Flycamp). The line connecting these two localities has not been drawn much further for two main reasons. Firstly, rocks of appropriate bulk composition are absent from the Horsethief-Creek Series. Secondly, it is not known with certainty that the boundary of the stock is subvertical everywhere.

In pelitic and semi-pelitic rocks, the effects of contact metamorphism in an aureole extending from 0.5 to 1.0 mi. from the boundary of the stock seem to consist solely of an occasional induration and a closely spaced, blocky fracture pattern. At a distance less than 0.5 mi. from the stock, "spots" appear and the rocks may or may not show an increase in the grain size of micaceous minerals and attain the luster and habit of porphyroblastic phyllites or even schists.

Such a progressive increase in grain size and change in habit have been observed best north of Stockdale Flycamp. There, spotted slates and phyllites are followed, toward the stock, by porphyroblastic andalusite-bearing phyllites, and finally by more massive cordierite- and cordierite-garnet-bearing hornfelses (specimens HORSETH.KS71.7-30-1 to -8).

In other places, e.g. south of Cansup Flycamp and west of Spicebox Flycamp, pelitic rocks remain, right up to the contact, spotted laminated hornfelses without idioblasts of high metamorphic grade. In fact, near Cansup Flycamp, the only difference between the pelitic hornfelses remote from, and contiguous to, the contact are (i) a better, more pronounced, development of lamination, and (ii) occasional, relatively small idioblasts of biotite in the latter position (specimens HORSETH.KS71.7-16-1, 7-19-2).

Contact-metamorphic effects in rock types other than pelitic or calcareous are not easily detected. Coarse detrital quartzose rocks are probably partly or wholly recrystallized, but this can only be substantiated by microscope work.

The fabric of the contact-metamorphic rocks is, for a great deal, a "relict" sedimentary and tectonic fabric, overprinted by contact metamorphism. Bedding lamination, small folds, cleavage planes, lineations, etc., are visible in the metamorphic aureole, but they are similar in shape and direction to those outside of the aureole. Clearly, no pervasive deformation has taken place during or subsequent to the emplacement of the stock. In other words: the emplacement of the stock and the development of the contact-metamorphic aureole, at the present level of erosion, were post-tectonic.

The interface of the Horsethief Stock and metasediments is occupied by a narrow zone of intimately "mixed" rocks, including apophyses of the stock, aplite dikes, quartz veins and xenoliths of hornfelses, to be described in another chapter.

Metasomatism, Sulphide Halo

Leaving early, regional metasomatic processes out of consideration (e.g. carbonate- and quartz-vein formation), we turn immediately to the chemical or "metasomatic" effect of the Horsethief Stock on the enveloping Proterozoic metasediments.

This effect is indicated by the presence, locally great abundance, of sulphides in a halo of greatly varying width around the stock. The halo, which is responsible for the intensive staining of many contact-metamorphic rocks (rusty brown, ocre red, yellow, bluish black), has a width ranging from a few hundreds of feet to 0.5 mi. All types of rock seem to be affected whether they belong to the Upper Purcell or Horsethief-Creek Series.

The sulphides are nearly exclusively iron sulphides (mostly pyrite, locally abundant pyrrhotite). Chalcopyrite, bornite, malachite, covellite as well as molybdenite have rarely been observed and then only in trace amounts. Geochemical soil and talus samples, however, indicate that copper mineralization is more common and may be more abundant locally than field inspection tends to suggest (see pp. 62 - 68).

Excepting the rarest mineral, molybdenite, the sulphides occur mostly as thin stringers of fine (< 1 mm) grains aligned along cleavage planes and tight fractures or joints[1]. Disseminated sulphides form a minor portion of the total amount present, although locally tiny disseminated pyrite cubes make up 1% of some hornfelses[2].

Similar to the width of the sulphide halo, the spatial distribution of the sulphides within the halo varies erratically. At some places (e.g. Cansup area) the hornfelses contiguous to the stock contain little sulphides, whereas those a few hundred feet from the contact contain the greatest concentration of sulphides. Perhaps more common is a gradual increase in sulphide contents, from spotted slates with a few specks of pyrite, to cordierite-garnet hornfelses with abundant (1% to 5%) pyrite and pyrrhotite contiguous to the contact (e.g. Stockdale area).

As described previously, the thermal effect of the stock on the metasediments is clearly shown by the presence of suites of high temperature - low pressure metamorphic minerals that are absent from similar metasediments remote from the stock. On the other hand, the metasomatic effect of the stock on the metasediments is deduced from the relatively great abundance of sulphides around the stock. These sulphides, however, are also present in similar metasediments not affected by contact metamorphism. The only fact to our disposal is that most sulphides close to the stock appear to have been deposited - or remobilized and redeposited - during or after emplacement of the stock.

The induration of pelitic rocks in the contact aureole, referred to on p. 10, and the occasional abundance of quartz veins in the contact zone of the stock (Cansup and Molly-Lake areas), suggest that the aureole is also enriched in quartz. Perhaps silicon (in the form of $Si(OH)_4$?) and complex ionic base-metal species travelled in a hydrous fluid solvent from the stock outward. This classical hypothesis of "hydrothermal" ore transport and deposition is commonly accepted even in the case where the intrusive itself does not contain any ore minerals. The Horsethief Stock, however, contains significant amounts of all ore minerals, except pyrrhotite, found in the contact aureole.

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[1] For instance specimen HORSETH.KS71.8-8-3 (Whirlpool).

[2] Specimen HORSETH.KS71.7-19-1 (Cansup).

HORSETHIEF STOCK

Map Pattern

The contact of the Horsethief Stock (see Plate 1) separates relatively homogeneous granitoid[3] rocks from a zone of variable width but not exceeding 600' in which apophyses of granitoid rocks and dikes of aplite cut across and enclose highly metamorphic metasediments. The reliability of the "line" so defined can be gauged from the distribution of "observed bedrock" (see Plate 2). Those parts of the contact that were not inspected on the ground are based either on observation from the air or on G. S. C. Map 12-1957 (REESOR, 1957).

The outline of the stock is roughly elliptical and encloses an area of approximately 100 sq. mi. The long axis of the semi-ellipse is 9 mi. long and is oriented north-northwest, subparallel to the "regional trend" of the Proterozoic metasediments (i.e. trend of major fold axes) as well as to the strike of some large faults.

The map pattern within the stock - two roughly concentric semi-ellipses located asymmetrically with respect to the outline of the stock - reflects a petrographic subdivision into three rock types, all of granitoid texture. Texturally and presumably compostionally the rock types grade into each other so that the selection of "contacts" is arbitrary. It should be emphasized that this pattern is but one of the many that would be consistent with our few and scattered observations in the interior of the stock.

As drawn on the map, the outer and largest zone accounts for 83% of the surface area of the stock. Pending modal analyses, the rock type underlying this zone as well as the zone itself is called "Granitoid I" or "GI". The inner and smallest zone accounts for 1.5% of the surface area of the stock; it is called "Granitoid III"

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[3] rocks of granitic to dioritic composition and hypidiomorphic-granular texture, very coarse-, coarse-, or medium-grained (grain size > 1 mm), with or without phenocrysts. The term does not include aplites nor porphyritic rocks with an aphanitic matrix (i.e. porphyries). See STRINGHAM (1966).

or "GIII". Facies transitional between the distinct rock types GI and GIII occupy the intervening area. Again, pending modal analyses, they will be referred to collectively as "Granitoid II" or "GII".

The numerals I, II, III do not imply relative age: unambiguous dikes or inclusions of one granitoid rock type in another have not been observed.

Granitoid Rock Types

The essential minerals of all granitoid rocks of the Horsethief Stock are alkali-feldspar, quartz and plagioclase. Biotite is a characterizing accessory constituent. Hornblende is very rare and never present in more than trace amounts. Some muscovite in GIII may also be primary.

Common secondary minerals, mostly occurring as joint coatings, are quartz, muscovite, pyrite, chlorite, epidote and calcite. Rare secondary minerals are tourmaline, molybdenite, magnetite, specular hematite, chalcopyrite, bornite, fluorite and, possibly, potassic feldspar.

In addition to the above minerals, REESOR (written comm. 1 June 1971) mentions the following minor accessories of GI: uraninite, euxenite-polycrase, ilmenite, rutile, titanite, apatite, and zircon.

In the sequel we shall describe GI and GIII first since they are distinct, relatively homogeneous rock types, neither varying in habit nor, presumably, in composition throughout their respective zones. Subsequently, we shall describe the progressive changes taking place in the zone intervening between GI and GIII, and thus "catching" GII in this description.

Granitoid I-. Barring an approximately 200'-wide zone along the contact of the stock (to be described in the next chapter), Granitoid I is dominantly greyish purple to greyish red purple and very coarse- to coarse-grained[4].

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[4] Specimens HORSETH.KS71.7-14-1, B-2, E-1, F-1, L-1.

The rock owes both properties to its most abundant mineral, alkali-feldspar. The mineral makes up 40% or 45% of the rock. It is euhedral to subhedral, stubby prismatic, and ranges in size from 5x2 cm to 1x½ cm. Carlsbad twins, a coarse perthitic structure, and zoning are common. Zones may have slightly different hues of greyish purple or thin white zones may alternate with broader purplish zones. The center of the crystal is commonly purplish but may be white. A characteristic feature is the oval shape of internal zones and the angular, euhedral shape of the outer. Inclusions other than plagioclase(?) are remarkably rare in the alkali-feldspar grains; a few small flakes of biotite may be present.

Quartz, constituting 25% to 30% of the rock, is next in abundance to alkali-feldspar. The mineral occurs in anhedral blebs up to 1 cm in diameter; its minimum grain size cannot be estimated by naked eye.

Approximately 20% of GI is made up of a whitish to slightly waxy-green mineral (plagioclase?), the grains of which are of indefinite shape (anhedral?) and commonly range from a fraction of a millimeter to a few millimeters in diameter. A few relatively large (up to 1x½ cm), stubby prismatic crystals of the same colour are occasionally present. Polisynthetic twins in these crystals are diagnostic for plagioclase.

Commonly biotite is the only dark mineral present. In abundance it ranges from 5% to 15%, in shape from platy subhedral to perfectly euhedral, in size from 0.5 mm to 2 mm.

At the scale of a hand specimen, all minerals are generally homogeneously distributed. At the scale of a large outcrop, however, the distribution of biotite may be heterogeneous. Most common is the presence of vague biotite-rich "schlieren", separated from each other by homogeneous, relatively biotite-poor GI. Unfortunate for the structural geologist, the schlieren occur at a scale too large for measurement by compass and their preferred orientation is but weakly developed.

Primary structures other than schlieren are rare and elusive. Preferred form-orientation of alkali-feldspar prisms has rarely been observed[5] and has not been identified as either being a planar or linear structure.

Since GI does not show any trace of a fabric superimposed on its orthomagmatic - late magmatic (-hydrothermal) texture, the rock can be referred to simply as biotite-adamellite or quartz-

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[5] possibly a steeply plunging lineation, ¼ mi. north of Mt. Guendolin

biotite-monzonite. The adjective "porphyritic" may be used. However, the rock should not be called a "porphyry" since that term has a particular connotation in the literature of porphyry-type deposits and is not applicable to the present rock type (see footnote 3).

A rock type somewhat different from GI sensu stricto forms a zone of approximately 1 mi. wide along the boundary of the stock in Edouard area[6]. Microscope work is necessary to determine whether significant mineralogical differences are present and whether these differences are primary or secondary features.

Granitoid III-. Granitoid III[7] is the finest-grained granitoid rock of the Horsethief Stock although it occurs close to the center of the stock.

The rock is homogeneously light grey, essentially equigranular, and its grains seldom exceed 3 mm in diameter. Feldspar phenocrysts are commonly absent but may make up to 3% of the rock. Although the phenocrysts are invariably white, simple Carlsbad twins indidate that the mineral is an alkali-feldspar. Despite the fine-grained nature of the rock, small subhedral grains have been identified as plagioclase by their characteristic polisynthetic twins. These plagioclase grains are either white, or glassy grey with high luster.

The grey colour of the rock is provisionally ascribed to the abundance of quartz. LIN (1970) estimated 40% quartz, but the rock is too fine-grained to substantiate this by macroscopic identification.

Biotite, minor muscovite and pyrite (disseminated) are present in grains of a size similar to those of the major constituents. A characteristic feature of GIII is the presence of a few small clusters (1cm diameter) of a green micaceous mafic mineral. A provisional estimate of the colour index of GIII is 10.

As indicated on the map (Plate 1), a rock very similar to GIII occurs near the highest point of the ridge southwest of Rusty-Creek Flycamp. Neither its genetic relation with, nor its structural

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[6] Specimens HORSETH.KS71.8-9-1, 8-25-27

[7] Our description of GIII rests on one specimen collected at the northwest end of Lin Lake (HORSETH.KS71.K-1). According to LIN (oral comm. September 1971) this specimen is representative of GIII although it is uncommonly fresh.

[8] Specimen HORSETH.KS71.7-26-2. The ridge consists of broken and slightly displaced, frost-heaved blocks. A sharp contact may remain unnoticed in such an environment. A gradual change, however, should be detectable. Thus we opt for the sharp-contact alternative.

position with respect to, the major GIII-zone is known. It is noted that rocks intermediate between GIII of this minor occurrence and surrounding GII have not been observed[8].

Granitoid II-. The essential properties on which the distinction between the granitoid rocks of the Horsethief Stock is based, are (i) average grain size, and (ii) abundance of large alkali-feldspar crystals. It will be clear from the foregoing descriptions that these properties are closely related. In turn, they are correlated with size, shape and colour of alkali-feldspar grains, making the subdivision of the stock into a number of rock types - at least three - possible. However, the gradational nature of most (or all?) changes in these correlated properties makes the drawing of boundaries between rock types an arbitrary procedure.

Remarkable aspects of these gradual changes are the following. Most alkali-feldspar in GI occurs in large euhedral, greyish purple to greyish red purple crystals. White feldspar grains of similar size are rare. The presence of polisynthetic twins in some of these white grains shows that at least some are plagioclase. In Granitoid II, however, both white and purplish (occasionally pinkish) alkali-feldspar megacrysts are present in a matrix containing exclusively white feldspar, probably mostly plagioclase[9]. The phenocrysts are generally smaller and less well euhedrally developed than those in GI. If any major rock type of the Horsethief Stock deserves the adjective "porphyritic", it is GII. Toward the GIII-center of the stock, the megacrysts become less abundant, smaller, and most are white. The rare megacrysts in GIII are again smaller, all are white, and they are embedded in a still finer-grained light grey matrix.

Clearly, microscopic and X-ray studies are necessary to substantiate and elucidate the coexistence of two types of alkali-feldspar in GII.

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9 Specimens HORSETH.KS71.7-25-2, 7-25-3, C-1, D-1, G-1, H-1, I-1, J-1

Quartz-diorite?-. An isolated occurrence of a light greenish grey rock of granitoid(?) texture is on the ridge 0.4 mi. west-southwest of Rusty-Creek Flycamp at an altitude of 8500' a.s.l. (not shown on Plate 1; speciman HORSETH.KS71.7-27-4). The rock body is less than 500' in diameter, measured horizontally along the ridge. The rock is fine-grained ($\leqslant 1$ mm) equigranular and consists of white feldspar, quartz and dark minerals. Biotite has been identified, but another mafic mineral (light green) is also present. Colour index is 22. The rock is probably a quartz-diorite. It contains stringers and irregular blebs of GII, which tends to suggest that GII occurs enclosed in the quartz-diorite. However, unambiguous inclusions of a rock very similar to the present quartz-diorite are present in GII 1.75 mi. southwest of Rusty-Creek Flycamp (specimen HORSETH.KS71.D-3).

Non-Granitoid Rock Types

Rocks other than granitoid in the Horsethief Stock are inclusions, aplite dikes, quartz veins and pegmatite pods. All are more abundant in the contact zone than in the interior of the stock, and all will be more extensively described in the next chapter.

Inclusions-. Inclusions[10] are generally fine- to medium-grained dark rocks (colour index 40 to 60) and consist essentially of white feldspar, biotite, hornblende and, perhaps, clinopyroxene. Titanite(?) may be present in considerable amounts. The inclusions range from 3 cm to 3 m in diameter, and from subrounded to rounded, oval in shape. Smaller inclusions (diameter from 1 cm to 3 cm) may be angular. Large angular inclusions occur only contiguous to the contact of the stock.

The contacts of most inclusions are sharp; partly "digested" inclusions are rare, except locally in the contact zone. Sharply bounded inclusions and vaguely bounded "schlieren" may occur in the same outcrop so that the latter cannot simply be considered as remnants of assimilated inclusions. It is noted that a preferred orientation of the inclusions has not been observed.

The inclusions occur sparsely throughout GI; their abundance is markedly less in GII, and they have rarely if ever been observed in GIII (LIN, oral comm. September 1971).

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[10] Specimens HORSETH.KS71.B-3, D-3

PROSPECTS AND SHOWINGS

Hereinbefore mineralization and mineral showings have been introduced in their proper geological context. In the present chapter our tasks are the following.

First, there are some details to be added to our previous descriptions of the three showings in the area (Whirlpool, Molly-Lake 2, Molly-Lake 1). A considerable number of geochemical samples has been collected near the showings. The Mo- and Cu-concentrations of these samples should be compared with the observed mineralization.

Second, we must evaluate the mineral occurrences near Stockdale and Spicebox Flycamps. Furthermore, the area around Spicebox and Edouard Flycamps should be considered in the light of Mo- and Cu-concentrations of geochemical samples collected there.

Finally, the areas should be mentioned where field inspection as well as geochemical prospecting tend to indicate the absence of possibly economic mineralization at or near the surface.

Whirlpool Area

Whirlpool Showing[43]-. Discovered August 8, 1971, by D. GARDNER and the author in Whirlpool Pass, the showing and its neighbourhood were staked ("Zen" claims), and have been sampled by a geochemical crew (B. BURRY and D. BINNIE). Subsequently, a geological party (C. P. LIN and N. COOK) mapped the showing in detail and collected chip samples for assay.

The reader is referred to pp. 45-46 of this report for a geological description of the showing. A more detailed description is not desirable here as follow-up work covered the showing at a scale of 1":200'. In fact, the follow-up work covered an area larger than the August-8 discovery, since the slope from Whirlpool Pass to Whirlpool Lake became virtually ice-free in the interval between the author's and Mr. LIN's work.

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[43] Mineralized rock specimens from the showing include HORSETH.KS71. 8-8-5, -6, -8, -9.

The geochemical samples collected by Messrs. BURRY and BINNIE might suffice to indicate the maximum surface extent of significant molybdenum mineralization. However, these samples show beyond doubt that the surficial dispersal of molybdenum in whatever form is surprisingly restricted both in space and concentration (750 ppm Mo being the highest value obtained). Quite likely, the restricted distribution of Mo is related to the semi-permanent snow- and ice-cover of Whirlpool Pass, which restricts chemical weathering severely (although ferrimolybdite and limonite are present). Since weather conditions in the Whirlpool area are not more severe than in the major part of the Horsethief Stock, account should be taken of the results at Whirlpool Pass in evaluating Mo-anomalies elsewhere in the stock.

Contact zone-. The contact zone in the Whirlpool area is very well exposed and has been inspected in detail for a considerable distance. Therefore it can be stated with some confidence that the contact zone is remarkably poor in molybdenite (and chalcopyrite) with the notable exception of the showing. One geochemical stream sample (SCHRI.8-6-19) was collected because the stream drains a debris-covered basin straddling the contact north of Thunderwater Lake.

Whirlpool Lake - Mount Harmon traverse-. Intensive rust staining of cliffs protruding from the ice cap, visible from Whirlpool Flycamp, was the incentive to collect talus samples (SCHRI.8-7-1 to -5: see Appendix and Plate 3) at the interface of Catamount Glacier and some of the cliffs (Fig. 16). Analytical results of 2 to 5 ppm Mo and the presence of abundant pyrite locally (specimen HORSETH.KS71.8-7-6) indicate that pyrite is the only product of mineralization here.

is similar to the joint-bound mineralization of the talus block (see p. 50) but, contrary to the latter, quartz veinlets may be present and pyrite may be less abundant[45]. Chalcopyrite has not been observed in bedrock. The "veins" strike approximately north-south and dip steeply east or west. These orientations are not parallel to any major joint set in the outcrop or in the neighbourhood.

Geochemical samples SCHRI.9-3-1 to -5 (see Appendix and Plate 3) were taken below and on the showing. The Mo- and Cu-concentrations of the samples collected further downslope, along Molly and Dolly Lakes (SCHRI.9-1-1- to -19) appear to be in accordance with the presence of one limited area of mineralization. However, samples SCHRI.9-2-1 to -18 clearly show that the major Mo- and Cu-mineralization is very closely associated with the boundary of the stock, Mo being nearly as abundant and Cu being <u>three</u> times as abundant as the richest sample from the showing. Note should also be taken of the high values of Mo in samples from a talus slope consisting dominantly of hornfels (SCHRI.9-2-8 to -11).

Finally, attention is drawn to the combination of 830 ppm Mo, 199 ppm Cu, and 105 ppm U in sample SCHRI.A-7 from rusty, disintegrated aplite bordering the streamlet between Molly and Dolly Lakes. Mineralization has not been observed in this well exposed rock!

In conclusion, <u>there is little doubt that Mo-Cu-mineralization, more abundant and possibly more extensive than that in Molly-Lake Showing 1, is present in places other than the two showings in the Molly-Lake area</u>.

<u>Stockdale Area and Stockdale Occurrence</u>

Originally, work from Stockdale Flycamp was to determine the provenance of molybdenite-bearing skarns found by J. BINNIE and B. BURRY near the base of the talus slope west of the confluence of Stockdale and Horsethief Creeks. Owing to large-scale disintegration

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[45] Mineralized rock specimens collected in the neighbourhood of the showing include HORSETH.KS71.9-3-2, -3.

of the ridge above the talus slope and near-continuous, summer-long rock fall from the ridge into Stockdale Creek, neither the ridge nor the talus slope could be visited at the desired places.

Nevertheless, during work close to the flycamp but remote from the target area, molybdenite was found in virtually all places where the contact could be inspected at leisure. The mineral is generally scarce and occurs exclusively in the plutonites in the contact zone of the stock[46]. Skarns are absent here.

An exceptional occurrence of molybdenite is present in a large talus block of white homogeneous aplite (specimen HORSETH.KS71. 8-1-8) found at elevation 6500' a.s.l. The block is probably derived from the location, indicated on the map (Plate 3) as Stockdale Occurrence, where numerous large aplite dikes cut across hornfelses (between altitudes 6900' and 6600' a.s.l. on east side of valley). In this aplite block, one vein occurs, ½ to ¾ cm wide, consisting of 40% to 60% coarse molybdenite flakes (½ to ¼ cm diameter), quartz, and traces of muscovite, biotite and pyrite. The occurrence of biotite in the vein is even more exceptional than the occurrence of abundant molybdenite. The aplite is not altered contiguous to the vein, and does not contain any disseminated molybdenite.

On the basis of (i) the presence of this vein, (ii) the great frequency of accessory molybdenite in the contact zone, and (iii) the molybdenite-bearing skarns found in the talus further east, it was considered worthwhile to stake a large part of the southern valley wall of Stockdale Creek. The mode of occurrence of aplite dikes such as HORSETH.KS71.8-1-8 in the contact zone (see Fig. 12) makes it unlikely that economic deposits of molybdenite are present in this setting. Mineralization in skarns (and contiguous aplites or quartz veins?) is probably a better target in the Stockdale area.

The geochemical samples collected thus far along Stockdale Creek are located too low and too close to the creek to trace significant mineralization to its locus of provenance on the valley wall.

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[46] Mineralized rock specimens from this area include HORSETH.KS71. 7-30-10, 8-1-5, -7, -8.