Skarns and ore deposits of the Whitehorse Copper Belt, Yukon Territory, Canada: Some aspects of petrogenesis and mineralization at the Arctic Chief, Little Chief, and Black Cub South localities.

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SKARNS AND ORE DEPOSITS OF THE WHITEHORSE COPPER BELT, YUKON TERRITORY, CANADA: SOME ASPECTS OF PETROGENESIS AND MINERALIZATION AT THE ARCTIC CHIEF, LITTLE CHIEF, AND BLACK CUB SOUTH LOCALITIES

(PART 1 OF 2)

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PREFACE

As reflected by the revised title, "**Part 1" of the present report** represents a somewhat more expanded version of "Part 1" of :

Mowatt, T. C. and J. C. Mowatt, 2007, Investigations of Some Mineralogical, Petrological, Geochemical, and Geological Relationships at the Arctic Chief (West) Locality, Whitehorse Copper Belt, Yukon Territory, Canada; Alaska Geologic Materials Center Data Report No. 344, Eagle River, Alaska, 136 pp.

It was prepared in response to queries, comments, points raised, and suggestions, from a number of interested individuals who had read the original "GMC#344" version.

This "revised" version is intended to present additional material, discuss in more detail interpretive aspects of petrogenesis and related mineralization at the Arctic Chief ore deposit, as well as other ramifications of our research. As well, comparisons with other localities in the Whitehorse Copper Belt are discussed, as feasible. In particular, we also report here on our earlier recognition, and confirmation, of the presence of periclase (brucite) marbles in specimens from the Little Chief and the Black Cub South ore deposits. To our knowledge, representing the initial confirmed report of periclase (brucite) marble at either of these other localities. Which is noteworthy in itself, of course. Various other remarks are put forward, here and there, in this version, on topics/aspects which were deemed deserving of the attention not given them, due to time factors, in our previous GMC#344 report.

This present report thus is supplemental to the somewhat more descriptive, fundamental treatment offered in Part 1 of GMC#344. While Part 2 of the latter, the "Data Supplement", has been slightly modified accordingly, as well. **Represented by a new "Part 2", under the revised title.** Though remaining essentially as basic background information relevant to our investigations. This presents additional information, including sketch maps showing general locations of sample sites, abstracted field notes, results of 30x/60x stereo-microscope examination of samples, petrographic microscope examination of selected materials as grains-in-oil, analyses and other comments.

Due to convergence of circumstances (time/age, space/distance, funds, "world affairs"), this report has been prepared solely by the first author. For the same reasons it has been neither edited nor reviewed independently (other than informally via the above-mentioned readers).

Nor has S. M. Aleksandrov had the opportunity to do so either. Many valuable written comments were offered to the first author by Dr. Aleksandrov during the course of his studies of samples sent to him representing various aspects of the Arctic Chief locality. Selected comments presented herein are set within full quotation marks. Though of course these are not necessarily "attributable", strictly speaking, given the ever-present "context", language problems, etc. in such matters, as well as the overall circumstances attendant to working "across-the-miles". However, his recent paper "Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns" (published in Geochemistry International, volume 45, number 2, pages 152-169, 2007) affords direct access to some of his views as related to magnesian skarns, and our investigations of the Arctic Chief locality.

Thus responsibility for the contents of the present paper remains with the first author. Including, in particular, for various "interpretations", etc., based on previous communications with Aleksandrov. The first author may be contacted at the Haines, Alaska mailing address given above.

ABSTRACT

Investigations of certain geological aspects of the Whitehorse Copper Belt, Yukon Territory, Canada were initially pursued during 1980-1982, and subsequently continued, after a hiatus of some twenty-two years, during 2004-2007. Principal ultimate concerns were with regard to petrogenesis and associated mineralization.

The initial work resulted in the (then) first-known recognition, and confirmation, of the "magnesian-skarn" character of the Arctic Chief (west) locality.

Analytical procedures featured stereo-microscopic sample examination, petrographic as well as ore microscopy, x-ray diffraction, and x-ray emission (fluorescence) spectrometry.

At this locality (as well as sites at Little Chief, and Black Cub South), a key feature, also initially recognized and confirmed at that time, was the occurrence of "periclase (brucite) marbles", with "classic" examples of the type present. Other significant features at the Arctic Chief characteristic of magnesian skarns -- initially identified as such -- included rocks of "calciphyre" character, the presence of a number of other magnesian minerals (in addition to pyroxene[s]) -- including forsterite, serpentine, spinel, phlogopite, Mg-chlorite, talc, clinohumite(?) --, and the presence of typical "rhythmic banding", or its vestiges, in rocks, as well as in "ores". In addition, the (quite) speculative presence of Mg-Fe borate minerals of the ludwigite-vonsenite series was indicated, though this remained unconfirmed at that time.

Unfortunately, this initial work remained unreported, formally, at the time. The subsequent work (2004-2007) provided an expanded sample base. Some one hundred selected specimens were sent to S. M. Aleksandrov at the Vernadsky Institute, Russia, for use in his own research. His subsequent definitive work on them confirming, as well as significantly extending, our previous findings. Providing confirmatory evidence for the formation of the borate mineral magnesian-ludwigite (pseudomorphously replaced by magnetite) at the Arctic Chief . As discussed in a portion of a paper by Aleksandrov in Geochemistry International, (2007).

The Arctic Chief (west) locality is demonstrably an example of a "magnesian-skarn". Additionally, our work, collectively, has shown that it features a version of "primitive-type zoning", formed under conditions of the "hypabyssal periclase facies", as considered in the context of the model of skarn-formation developed and refined by Aleksandrov and co-workers.

This approach merits consideration regarding the nature and origin(s) of "skarns", particularly with regard to those associated with "host" rocks of "dolomite/ dolomitic/ magnesium-rich" character. It offers a conceptual, as well as substantively based, framework of theoretical background, fundamental knowledge, and experimental work. As well, it affords ample evidence, from a wealth of experience and analytical work, supportive of the validity of this approach to the genesis of skarns. Including our work on the Arctic Chief.

Appreciation, and utilization, of this model ought to be an essential aspect of investigations intended to further the understanding of such geological occurrences. In turn, potentially yielding insights of "more practical" value in the exploration for, evaluation of, and production of mineral resources from deposits related to magnesian skarns. Such as has been the case in many areas, worldwide (cf. Aleksandrov: 1998, and numerous other publications).

Our 2004-2007 investigation also resulted in the recognition of some interesting occurrences of molybdenite, and other mineralization, near the Arctic Chief.

Implications of any/all of the above points, locally, elsewhere in the Whitehorse Copper Belt and environs, as well as elsewhere regionally, remain to be evaluated.

PART 1: Introduction; studies, results, interpretations, discussion; summary and conclusions; acknowledgements; references.

INTRODUCTION:

A study of the Arctic Chief locality/ore deposit, in the "Whitehorse Copper Belt", Yukon Territory, Canada (cf. Tenney, 1981; Watson, 1984; Morrison,1976, 1981; Heon, 2004; Meinert, 1986; Wheeler, 1961; Kindle, 1964; Grabher, 1974; Dawson and Kirkham, 1996; Aleksandrov, 2007; etc.), was initiated by the first author ("TCM") and the second author ("JCM") during 1980-1982 (cf. Mowatt and Mowatt, 1982). At the time, TCM was employed as Supervisory Geologist, Alaska Field Operations Center, Bureau of Mines ("USBM"), United States Department of the Interior, Douglas (Juneau), Alaska.

The intent was to attempt to add to the understanding of the nature of this "skarn-type" ore deposit, by investigating various aspects of the mineralogy, petrology, geochemistry and geological relationships. The goal being public dissemination of such knowledge as might be gained, per the Bureau's charge as "....... a research and information organization, concerned with matters related to mining and mineral resources...... ", as well as utilizing this knowledge in other USBM mineral resources-related activities elsewhere, especially in Alaska.

Of particular interest were a number of key features of deposits elsewhere of "contact-metasomatic magnesian skarn-type". As recognized and elucidated over the course of a number of years by the extensive -- and intensive -- work of S. M. Aleksandrov ("SMA"), and colleagues at the V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian (formerly U.S.S.R.) Academy of Sciences, Moscow, as well as associates with affiliations elsewhere.

According to Aleksandrov (2007, p. 153), ".....Korzhinskii [1955] regarded bimetasomatic and contact-metasomatic magnesian skarns as an individual petrochemical association, which is genetically related to the replacement of dolomites and magnesite, as was proved at numerous deposits in Russia, China, and other countries".

Using this concept, and other fundamental knowledge, as a point of departure, this research has made important contributions to the understanding of this aspect of geological science. As well as significant additions to the recognition, definition, and development of related mineral deposits. Including cooperative research on some localities in the Whitehorse Copper Belt, Yukon Territory, Canada. As discussed in Aleksandrov (2007).

The "REFERENCES" section of the present report affords access to further particulars of much of this work, and related matters. Featuring Aleksandrov's definitive monograph on the subject (1998), and his recent (2007) paper.

The first author had the privilege of working with Dr. Aleksandrov, while serving as his professional host in Alaska on his two "scientific/cultural exchange program" visits to the U.S.A. (1973, 1979). These visits were made possible, jointly, by the Academies of Sciences of the U.S.S.R. and of the U.S.A. Thus began a collegial relationship which has continued since 1973 to the present time. Working together in the field (Seward Peninsula and elsewhere in Alaska), laboratory and office proved most informative, and quite valuable. Hence the subsequent initiation of the USBM project in 1980.

In 1980 knowlege and/or appreciation of the significance of the work on contact metamorphic/ metasomatic "skarns" -- especially "magnesian skarns" -- and related mineralization/ore deposits by SMA and his associates was not notably widespread elsewhere. Thus, implications of this work with regard to understanding of the formation of skarns and related contact metamorphic/metasomatic mineral deposits, as well as associated subsequent derivative types of deposits, were not widely appreciated outside the U.S.S.R., and other places where geologists from the U.S.S.R. had worked.

Thus it was felt appropriate to pursue further the possibilities of this approach to skarns and skarn-related mineralization/ore deposits. Especially in geographic areas where this had not yet been done, or at least not done to any appreciable extent. Alaska certainly being one such area, and of course also the principal concern of the Alaska Field Operations Center, USBM. While the presence of known "skarn-type" ore deposits, featuring relatively well-exposed geology, existing nearby in adjacent Canada (Yukon Territory, and Northwest Territories, in particular) afforded excellent opportunities for the "investigative" type of studies felt to be a requisite initial step in an envisioned research program. This latter to consist of delving into the implications, ramifications, realities, value, "usefulness" of this (for want of a simpler yet informative term) "SMA approach/model" of skarn formation, etc.

Following the well-known mineral resources exploration philosophy of "going to elephant country if one wishes to find elephants", the "skarns" and associated mineralization of the Whitehorse area, Yukon Territory seemed a good, as well as convenient, place to start.

The Whitehorse Copper Belt and many of its localities were known to TCM from previous "visitation/information gathering"-type activities in that area while Geologist/Supervisor for Mineral Analysis and Research with the Alaska Geological Survey, 1970-1974. These activities having taken place both before, and soon after, having met and worked with Aleksandrov in Alaska in 1973. With some decided "alterations" in professional perspectives and appreciations having resulted from the experiences with, and knowledge gained from having had the opportunity to work collegially with this outstanding scientist.

VIsits in 1970, facilitated by the staff of New Imperial Mines Limited, featured time, and some sample collecting, at Little Chief, Arctic Chief, Best Chance, and War Eagle. Similar visits in 1973, now under the aegis of Whitehorse Copper Mines Limited, included these localities, as well as underground at the Little Chief.

Thanks to the interest, generosity, hospitality of the knowledgeable hosts on these occasions, the experiences were informative and fruitful. Providing much in the way of substantive "real world grist" for pondering upon. At the time, too, it was stimulating for an Alaskan geologist to experience this sort of activity in this part of Canada, given the relative dearth of such across the border. Opportunities to see, learn. As graciously afforded in good-spirited and open fashion by knowledgeable and interested individuals. It is a pleasure to be able to acknowledge them all -- you know who you are --, collectively, here. As well as express appreciation.

(Writing this portion of this report mostly from memory in the year 2007, it is, hopefully, ample testimony to all of those Whitehorse area folks who have been so cooperative over the years that I have managed to recapture as much in the way of memories as I have. Or chose to return for yet "another round" on the Copper Belt in 2004.)

Some years later, in 1980 the authors visited the then-still-reasonably-accessible, as well as exposed, known deposits or occurrences along the trend of this "belt". From the War Eagle at the north, to the Cowley Park area at the southern part. Access being provided accomodatingly by the fine folks at Whitehorse Copper Mines once again. Though names and faces had changed some in the interim. While more than a few "field" features had undergone some changes too.

This work consisted of general reconnaissance, and limited "character" sampling at each site. Featured was another tour underground at the Little Chief. While attempting to decide upon "THE" site for our proposed initial detailed investigation.

Features characteristic of "magnesian skarn" (per the usage of SMA) were noted in several of the localities visited. Principal among these of course being the presence of appreciable proportions of constituent magnesium-rich minerals. Especially such as forsterite, diopside, spinel, serpentine, phlogopite, humite/clinohumite, talc, Mg-chlorite, periclase, brucite, Mg-bearing borates. As well as other key features of the lithologies present (textures, structures, overall compositions; "alterations"). And the geological relationships; the "zonality"; the "positions" -- geochemically, lithologically, spatially, temporally. These aspects are discussed further, in some detail, elsewhere in the course of this report.

By our criteria, "magnesian skarn" did in fact appear to be in evidence at Arctic Chief, and Little Chief, in particular. "Likely" at Black Cub South (?). While perhaps (?) present, at least in places/to some degree, at Valerie, Best Chance, the Grafter area.

By this time, published findings of other investigators (eg. Grabher, 1974; Tenney, published in 1981) had indicated, stated, or presented evidence supporting similar observations. Certain fundamental aspects of magnesian skarn, principally concerning the presence of a variety of magnesian minerals, and the "dolomitic" nature of associated host rocks, having been recognized. Though appreciation of some related features, characteristics, remained somewhat vague. While other key features such as periclase (brucite) marble, "calciphyres", "rhythmic banding" in rocks -- and in ore materials, Mg-Fe-borate minerals, had apparently escaped recognition, and/or appreciation of their significance.

Though at that stage, the focus was more-compellingly on "keeping the mill fed" at Whitehorse Copper. Since, ore reserves were "running out". A particular memory remains of some capable, knowledgeable "geo-type" individuals we had met on previous occasions. This time chancing to meet them, at the southern end of the Belt, garbed in head-nets, etc., and laden with geophysical equipment. Heading off -- again -- into the "bush", pursuing possible extensions of the Copper Belt. "One more time". Concerns as to such esoterica as the subtleties of "magnesian skarns", and so forth, not exactly priority items just then. Quite understandably.

Adding, however, a certain aspect of "perhaps/possibly/maybe" to our own activities. Though realizing that the likelihood of making any contributions of positive significance, at least in timely fashion, was probably rather small. Our focus, of course, being somewhat different, though certainly not unrelated.

So we did what we knew how to do. And wished our colleagues well. As they did what they knew how to do; doing it quite well, from our perspective. One might be able to "find ore". If ore happens to be where one happens to look. But if ore does not happen to exist in that particular place, all the "sophisticated" knowledge accrued thus far is unlikely to be of much help.

Though we continued to try to "add to the sum total of human knowledge" in our own chosen "geo-speciality/sideline" of endeavor. Since one never knows ..... As Einstein once chose to put it, "If we really knew what it was we were doing, it would not be called research, would it?"

No special effort was made at this, or subsequent stages of our work, to search for the dolomite, dolomitic limestone, or other magnesium-rich "original/precursorial/host" rocks presumably requisite as a/the principal source of the magnesium for the formation of the "magnesian skarn" minerals. It being deemed sufficient for the purposes of our initial studies that the other criteria directly related to/evident in the skarns/etc. themselves be present.

Though of course, where readily available, "apparently unmetamorphosed" (?!?) carbonate rocks were collected. Upon analysis (initially testing with HCL; with confirmation via petrographic microscopy, x-ray diffraction, x-ray emission spectrometry) those associated with the Arctic Chief and the Little Chief, in particular, included a substantial proportion proving to be at least "dolomitic" in character. While specimens associated with the other localities were characterized by a relative paucity, to absence, of "dolomitic" rocks (collected). This observation leading to another "observation".

Namely, that a potentially important aspect of the exploration for magnesian skarns and related mineral deposits ought to be ascertaining the nature of any and all "carbonate rocks" encountered, with the view to following up especially diligently on those which prove to be appreciably "magnesian/dolomitic".

Since "magnesian skarns" do of course require some geologically reasonable source of magnesium for their formation. While the majority of related magmatic materials are most commonly of "moderate/intermediate" to "low" basicity. Ie. "Granitics" -- granodioritic-quartz dioritic-granitic-syenitic-monzonitic-, etc. Ie. relatively low in magnesium content, inherently. Dioritic materials such as may be present likely generally reflecting (variously) contaminated less basic melt material. Though magmatic materials of "higher" basicity are known to be associated with skarns -- "magnesian" and otherwise. However these are generally not of appreciable size, relative to the larger ones which are more often associated with less basic (generally more "fluid-rich"; a factor in metasomatism) igneous activity.

Thus it seems likely that "magnesian skarns" of any appreciable mass presumably require appreciable magnesium from some "other than magmatic" source. The host rocks of course being the prime candidates. The nature of these most likely being the principal geochemical determinant for the presence -- or absence -- of sufficient magnesium to facilitate the formation of magnesian skarn, given the other appropriate geological conditions.

As is manifest in the literature, exemplified by the materials in the "REFERENCES" section, and also discussed, variously, elsewhere in the present report, the presence -- or absence -- of magnesian skarn in a particular "contact metamorphic/metasomatic" geologic environment/occurrence of skarnlike character has decided relevance in terms of the likelihood, and nature, of associated mineral deposits.

Extensive experience worldwide has indicated that magnesian skarns are particularly "fertile ground" for the formation of genetically related mineral deposits of several kinds. Reasons for this are related principally to the geochemistry, mineralogy, petrology (including textural features) characteristic of magnesian skarns, as well as the geologic circumstances attendant to their formation and subsequent history/"evolution". Hence the (original) presence of magnesian skarn (or recognizable subsequent modifications thereof) implies a reasonable possibility, if not a distinct likelihood, that associated mineralization of possibly significant character might be anticipated to be present in those environs as well.

In1980 the Arctic Chief locality seemed to afford the best opportunities to carry out the proposed initial investigation. Accessibility, exposures, available information, cooperation of property owners were principal determining factors. While initial impressions of lithologies, mineralization, geological relationships were rather compelling. Among other reasons, this locality seeemed to display certain decided similarities to some magnesian skarns TCM had seen elsewhere, with SMA.

Fundamentally the initial principal concern of the study thus begun in 1980 was with regard to the nature of the skarn(s) present. Ie. whether or not this was indeed a demonstrable example of a magnesian skarn (per the usage of SMA) situation/occurrence.

If so, as preliminary impressions obtained by TCM and JCM -- featuring the nature of the rocks -- had suggested, of what particular "facies/variety"? What key features -- mineralogical, petrological, geochemical, geological -- did this locality manifest? What relationships were recognizable/present? What implications might this have with regard to mineralization at the Arctic Chief ore deposit? To other -- known, as well as, perhaps(?), otherwise -- deposits/localities/occurrences of mineralization in the Whitehorse Copper Belt? The neighboring area? And perhaps regionally, as well? Including Alaska, of course. While certainly not excluding "elsewhere", either........

These considerations were addressed in -- though not restricted to -- the context of the concepts (featuring an emphasis on metasomatic aspects) which had been developed as the result of the work of SMA and associates. Featuring extensive and effective applications elsewhere in the world, in terms of mineral resources: exploration, development, production, and uses -- some rather innovative. One of the more noteworthy aspects of their work having been the elucidation of previously unrecognized types of deposits of boron, and of tin. This resulting in some innovative exploration, production and utilization methods. Raising reasonable questions as to possible implications/applications elsewhere (cf. Mowatt, 1984; Mowatt and Jansons, 1985).

On the basis of the information and insights obtained as the result of working with SMA, the skarns of the Whitehorse Copper Belt were of obvious interest, in terms of the geology per se, and relationships to mineral resources, known as well as potential. At the time (1980), the definition(s), the recognition, of "magnesian" skarns as such, the geological significance of their presence -- or absence --, and implications as to related mineralization, were topics remaining, in general, somewhat ill-defined. "Geo-esoterica" whose relevance, other than "academically", was yet to be determined. At the time (other than in the U.S.S.R., and a few other places) this aspect of "skarns" was not a topic of widespread apparent interest in geological science. A "skarn" was, essentially, simply a skarn..... A term meaning various things, to various people. And more often than not, the "meanings" seemed rather vague.

[As an aside, the following remarks seem not inappropriate here:

To a certain extent, with some notable exceptions (prominent among which was recognition by other investigators {eg. Grabher, 1974; Morrison, 1981; Tenney, 1981; Watson, 1984; Meinert, 1986} of "magnesian skarn" as such, in the Whitehorse Copper Belt), in many respects this state of affairs regarding "skarns" appeared not to have changed all that substantially between 1980 and 2004, as it turned out. Though by 2004, the technical literature (and TCM's personal library, thanks to SMA) contained even more numerous contributions on the subject by SMA, and associates, including books. Cf. the REFERENCES section of this report; especially Aleksandrov, 1998; and, now, 2007.

The 1998 reference is "the book", the definitive treatise, on the subject: "Geochemistry of Skarn and Ore Formation in Dolomites".

The 2007 paper (Aleksandrov, S. M., 2007, "Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns"; Geochemistry International, v. 45, no. 2, pp. 152-169, Pleiades Publishing Ltd. {Springer}), though with a broader theme, offers a concise yet informative summary of the approach/"model" espoused by Aleksandrov.

As well, this paper features the initial publication, and discussion, of the results of our work on the Arctic Chief, by way of an example. In the context of a thought-provoking presentation of the subject given in the title. With clear implications as to the matter of magnesian skarns, their significance, "fertile ground" aspect, etc.]

STUDIES:

Initially, field investigation and sampling of bedrock outcrop/pit wall exposures, associated "rubble-crop", and related "float" materials were carried out by TCM and JCM at the Arctic Chief locality in 1980-1981. This was done in the context of consideration of various key features, and relationships, of minerals and rock types, and their "position" (geological, geochemical, temporal and/or spatial) as developed and elucidated by SMA et al.

This study was carried out by two experienced geologists, equipped with knowledge of, familiarity with, appreciation and consideration of this "SMA model". However, following the "keeping of an open mind" philosophy inculcated by various mentors and colleagues over the years, it was recognized as "only" a model. The "method of multiple working hypotheses" remaining a paramount concern. Striving at all times for that all-too elusive spectre termed "objectivity".

Realizing that our backgrounds since having become familiar with "the SMA model", and also having experienced its apparent applicabilty/value/utility elsewhere via first hand experience, had in all likelihood resulted in at least a certain "predilection", if not exactly a distinct bias. Hence the approach adopted was relatively straightforward. The principle concern was to endeavor to "allow the rocks, the geology, to speak for themselves", as it were.

Though admittedly we had the perspective, advantage, of appreciable familiarity with a certain "dialect" of the language, per Aleksandrov's work, and knowledge gained by association with him. Thus of course it was rather satisfying to recognize that our own findings, during the course of this study, strongly supported the relevance/appropriateness of the "SMA model". At least with respect to the Arctic Chief locality. In a word, it "fit". It "worked". According to what the rocks, the geology, appeared to demonstrate themselves.

Subsequent analyses of samples ("many") were carried out at TCM's laboratory at the Alaska Field Operations Center, USBM, facility in Douglas (Juneau), Alaska. Analytical capabilities featured stereo- and petrographic microscopy (transmitted and reflected light), x-ray diffraction ("XD"), x-ray emission (fluorescence) spectrometry ("XRF"), and fire-assay.

[It seems relevant to note that toward the end of the 1981 field season, TCM and JCM visited the "Cantung" mine in the Northwest Territories, just east of the border with the Yukon Territory. Serendipitously, the Mine Superintendent happened to be a former acquaintance of SMA and TCM from their 1973 work on the Seward Peninsula, in the Lost River region.

W. Fotheringham, Mining Engineer, having been in charge of work being done evaluating the tin deposits at the Lost River mine and environs in 1973. As well as proving an excellent, amiable, knowledgeable and informative host at that time.

Bill, once again the good host, and well-remembering Aleksandrov and our work together in 1973, provided a memorable and enlightening underground tour of this impressive operation. The two fortunate guests seeing, learning much. A most informative experience. Providing appreciable food for thought. Affording valuable perspective. Also facilitating some "high-grading" of specimens of likely interest. "Skarns" being...... "skarns" (?!).]

COMMENTS ON RESULTS FROM THE 1980-1982 STUDY:

Gleaned, insofar as feasible, from an incomplete collection of various items exhumed in 2004 from personal materials long-stored-away. (See remarks below regarding the regrettable "affair of the missing/lost report".) Featuring battered and tattered copies (TCM, JCM) of aged field notes, sketch maps, "rough-drafts", the odd scrap of paper resurrected from an old book, etc.; also some long-retained "paperweight"-type pieces of "choice" specimens; other sundry oddiments. Supplemented by thoughts recaptured, variously, from personal memory.

Perhaps first and foremost, the matter of the exposures of those splendid white-light grey rocks at the Arctic Chief. Gleaming and sparkling -- "basking"? -- in the Yukon summer sunshine. Eye-catching, even from afar. Essentially unforgettable. Well-nigh irresistible to a field geologist. Beautiful rocks, these. In a variety of ways, actually.

"Marble(s)", apparently. Indeed, as it turned out on closer examination. In fact the not-unanticipated "periclase (brucite) marble". This of course a key to the "magnesian-skarn" character of these rocks --; to the ("hypabyssal periclase facies") type of magnesian skarn so-represented; to the nature of this locality/occurrence/deposit. Per SMA: publications, personal communications, and remarks quoted elsewhere in the present report; as well as, now, discussion in his 2007 paper; as well as our experiences together in the field.

The formation of the mineral periclase in these rocks is of course an aspect of decided petrogenetic significance (cf. Turner, 1968; Winkler, 1979; Aleksandrov, 1998. Among numerous others, over the years.......).

While the brucite-after-periclase relationship similarly is an important key to events subsequent to the formation of the periclase, during the further course of the "evolution" of a/this magnesian skarn locality. For details of this, see Alexandrov, 1998, 2007, as examples, among others, from his publications.

An additional significant nuance regarding the physico-chemical conditions indicated by the formation of periclase in dolomitic host rocks during contact metasomatism was stressed by Aleksandrov, in a letter to TCM, November 15, 2004:

"I see in Russian translated the book Helmut G. F. Winkler, who give T crystallized gabbro magma as 1200C, syenitic = 900C and 800-700C for granitic, that are similar with data F. G. Smith. **From Winkler's data T host rocks is 150C (?) only. The metasomatic process of alteration of dolomite started in halo intrusion under action magmatic Si and Al-bearing solution and give primitive skarn zonality as first stage process (300-400C), but not 150C). The reaction CaMg[CO3}2 ---> MgO + CaCO3 + CO2 is 600-7--C/1Km depths (see fig. 1, 14, 19 and 32 in my book)"**. [Emphasis by TCM]

Our initial recognition at the Arctic Chief was based upon hand-lens, +/- acid-bottle, specimen examination in the field. "Marbles", comprised predominantly of calcite; associated with appreciable proportions of "brucite pseudomorphing/replacing periclase".

This latter feature often rather evident, even with the unaided (though of course somewhat "knowledgeable") eye; especially obvious on weathered surfaces of some of the rocks. While "letting the rocks speak for themselves". Rather apparent, in this case, if one happens to be "attuned to their language". Is fortunate enough to be properly equipped to recognize, interpret, the features fairly clearly displayed. And strives to "keep an open mind".

Bringing certain recollections (TCM) of 1973, working in the field on the western Seward Peninsula, Alaska. Quoting Dr. Aleksandrov, on one particularly memorable occasion:

(("Is periclase marmor. If you want to see periclase marmor, here it is. If you do not *want* to see periclase marmor. Well......... But, *is* periclase marmor."
While displaying a chunk of light grey rock, with a certain knowledgeable flourish. Since Aleksandrov was, after all, my guest, I elected to at least look. See. Possibly even learn (?!). While our "otherwise-pre-programmed as to skarns", as well as somewhat "politicized", colleague of that day shrugged skeptically and wandered off.))

Memories of that foregoing double-bracketed bit of (somewhat short-sighted) "geo(political)-byplay" remaining with me ever since. From a personal first-hand introduction -- education -- provided, in 1973, on an upper flank of Brooks Mountain, in the Lost River region.

Followed, some years later, by recognition of similar features, in the field at the Arctic Chief. Duly followed by laboratory confirmation under the microscope(s). Further confirmed via x-ray diffraction and x-ray emission (fluorescence) analyses of numerous specimens. Interesting rocks, these. With much information to offer. If afforded the opportunity to "speak for themselves".

Mineralogy recognized featuring calcite, +/- dolomite; brucite (pseudomorphous after periclase; not infrequently with associated relict periclase present as well); minor/trace amounts (varying among specimens) of spinel, forsterite, magnetite, phlogopite, serpentine, talc, "hydrotalcite", amphibole, pyroxene, (+/- ?). The "carbonates" featuring crystalline "marble-like" textures, with traces of variously-well-developed/-vague, not infrequently "patchy", mineral and textural banding in places.

Many truly exemplary -- "classic/textbook" -- examples of periclase (brucite) marbles were examined in specimens collected from this locality. (As well as in some "character/grab samples" from several sites elsewhere in the Copper Belt). As SMA was to observe, even more years later (2005), the Arctic Chief indeed features "splendid" periclase (brucite) marbles.

Hitherto unrecognized by other investigators, to our knowledge. If recognized, not reported, to our knowledge. If the latter is actually the case, one might speculate as to, perhaps, the degree of appreciation regarding the fundamental petrogenetic/geochemical significance of the formation of the mineral periclase, as well as its subsequent replacement by brucite, in these -- or any -- rocks. Not to mention the relevance to mineral deposits.

This apparently "initial recognition" -- with subsequent full confirmation by SMA in the course of our 2004-2007 study -- of periclase (brucite) marble at the Arctic Chief (west) suggests that perhaps further reinvestigation/reconsideration is merited of these, as well as associated rocks, "skarns", and mineralization in the area, the region, and elsewhere.

As also indicated by our (1980) recognition, and confirmation (via petrography, x-ray diffraction), of a number of examples of periclase (brucite) marbles in the "character/grab samples" mentioned above, from sites at both the Little Chief and Black Cub South localities.

Such periclase (+/- brucite) marbles -- and associated/related materials -- perhaps (likely) lurking, as-yet-unrecognized/undetected/(unsought), elsewhere, in this, and other, regions. With attendant implications, scientific and "otherwise", regarding any such yet-to-be-recognized occurrences.

Among which implications,"practically speaking", recognition -- distinction as such -- of periclase (+/- brucite) marbles (and/or dolomite/"dolomitic" carbonate rocks as well) perhaps representing a potentially useful "exploration guide/tool".

The presence of dolomite/dolomitic carbonate rocks in a particular area affords at least the geological/geochemical possibility of magnesian skarn in the vicinity. While the presence of periclase (brucite) marble strongly indicates, if not essentially assures, it.

The latter indicative of metasomatism/metamorphism of appropriate character, sufficient to have resulted in magnesian skarn formation from precursorial dolomite/dolomitic carbonate rocks. Such periclase (brucite) marble characteristically representing the "outer zone of the contact aureole" (Aleksandrov, 2007) of such skarn. Definitive of the "hypabyssal periclase facies" of magnesian skarn, per SMA et al.

Should, additionally, rocks of "calciphyre" character also be recognized, this would afford further information as to the likely "whereabouts" of any associated "mineralization"/ore deposition. "Clues" as to "where to look next" in the vicinity, surface and subsurface. As related to the matters of "zonality", "positions", as manifested in/by magnesian skarns.

As discussed elsewhere in the present report.

In addition to these "splendid" marbles, there were also other variations on the theme of "carbonate" rocks to be found at the Arctic Chief. Those somewhat "marble-like" rocks we termed "calciphyres" in the field. Confirmed as such in the laboratory.

In addition to predominant calcite (+/- some dolomite), characterization of other minerals -- microscopically, supplemented by XD and XRF -- in these specimens revealed, variously, forsterite, pyroxene, spinel, serpentine, phlogopite, chlorite, clinohumite (?), amphibole, magnetite; +/- talc, magnesite.

With relationships, textures characteristic of "calciphyres". Banding, of (varying) "rhythmic" character, likely attesting to metasomatic activity of non-equilibrium character, manifested.

All of these factors indicative of the "magnesian skarn" nature of this locality. As well as consistent with the concepts developed by SMA and colleagues. As the rocks continued to "speak for themselves". Though in a certain particular "dialect", apparently.

Also recognized was similar ("rhythmic") banding in "ore" specimens. Featuring in these materials magnetite, +/- sulphides, (+/-?); these alternating with associated "bands"/"layers" of, variously among samples, forsterite, serpentine, phlogopite, clinohumite(?), amphibole, +/-?. Further attesting to the "magnesian skarn" character of this deposit. As well as presenting significant evidence as to the genesis of these "ores". A key feature. Per the SMA "model".

These characteristics interpreted as indicative of/evidence for metasomatic replacement of pre-existing ("banded") calciphyres. The carbonate portions of the precursorial rocks having been preferentially replaced -- predominantly/completely -- by magnetite, initially. (The sulphides now present in the ores having been deposited later, as "overprinting" during subsequent/continuing "postmagmatic"/"retrograde" metasomatism.) While the silicates such as forsterite, etc., originally present in the calciphyres were partially/completely altered to other magnesian silicate minerals, such as serpentine, phlogopite, clinohumite, +/.

With the original rhythmic banding remaining as "relict structure", having been "inherited", and now manifest as repeatedly alternating bands of ore minerals and bands of silicates. The mineralogies having changed, while evidence of metasomatic replacement remains in the form of the "relict structure" of the rhythmic banding, as well as by the continued silicate mineral character of the "non-ore" bands in the "newer" rocks.

Also present (though admittedly recognized, eventually, principally because we searched most diligently, hoping to find them), in some marbles and calciphyres collected in this initial study, were some rather small "needle-like/-shaped" black crystals. Suggestive of, possibly, a member of the Mg-Fe-borate mineral series "ludwigite-vonsenite"(?). Such morphology being a characteristic feature of ludwigite (cf. Ramdohr; Uytenbogaardt and Burke; Aleksandrov). Ludwigite being a mineral characteristically occurring in magnesian skarns. In our specimens, these crystals unfortunately too few for definitive XD analysis.

X-ray emission (fluorescence) spectrometry of bulk sample and partial-concentrate materials (the samples proving not readily amenable to sufficiently effective concentration of enough of these small "needles" -- even though magnetic -- for meaningful XD or XRF analysis) indicated relatively high iron contents. Suggesting that the black mineral could be magnetite. Apparently corroborated by the magnetic character of some few of these grains obtained, recognizably, as "separates", after appreciable effort.

And of course magnetite is not uncommon -- rather characteristic, actually -- as a pseudomorphic replacement of Mg-Fe-borates. As indicated in the literature by Ramdohr; Uytenbogaardt and Burke; Aleksandrov.

All affording, at the time, the (quite) speculative possibility (subsequently confirmed, in another specimen, by Aleksandrov [2007]) of original needle-shaped crystals of Mg/Fe-borate having formed as a mineral of the "ludwigite-vonsenite" series in these rocks. This recent confirmation providing additional evidence supportive of the magnesian skarn nature of the Arctic Chief locality. As well as providing further insight into other petrogenetic and geochemical particulars of its character. The geochemistry and mineralogy -- as well as mineral/ore deposits -- of the element boron being another aspect of magnesian skarns having been studied, extensively and intensively, by SMA and associates over the years.

During the 1980-1982 study, it appeared that similarities of the Arctic Chief to the Brooks Mountain, Tin Creek, etc. localities in the Lost River region (western Seward Peninsula, Alaska) were rather intriguing. This impression enhanced by samples and photographs from other localities furnished by SMA during the course of our ongoing association since 1973. As well as confirmed in a letter from him in 2005 (quoted elsewhere in the present report), during the course of his subsequent study of materials from the Arctic Chief locality.

(As Dr. Aleksandrov once observed wryly, though with his usual sense-of-humor, in a somewhat different, though not totally unrelated context, after watching a rock specimen break the "wrong way" under his hammer in Alaska: "Every country ----, same result"..........)

Thus, in summary:

The "rhythmic-banding".......... in rocks, and in ores. The mineralogies........ The plethora of mineralogic, petrologic, geochemical indications as to the apparent "magnesian skarn" character of the Arctic Chief........ As gleaned from the "collected works", on-going correspondence, and first-hand personal experiences working with SMA....... As manifested in the rocks of the Arctic Chief locality.

Further including, as a matter of "position" (geologically; spatially, as observed in the field), the apparent relationships (displayed at various scales, from hand specimen up to deposit dimensions) of:

igneous rocks, generally of granodioritic-quartz dioritic-dioritic character;
"(calcic-)skarn" materials --- pyroxene, garnet, +/- ;
relative to the principal "ore" occurrences of magnetite and other ore-minerals;
the (generally) more "distal" calciphyres;
relative to the further-distally-positioned periclase (brucite) marbles; these constituting the "outer zone of the contact aureole".

Manifesting the sequence of geochemical events, petrological processes, and geological relationships recognized and elucidated by SMA and co-workers; the "position(s)"; and the "processes" attendant thereto.

An initial lesson from Dr. Aleksandrov in the field in 1973 was that "It is a matter of position". Easily remembered, but less readily deciphered; let alone "mastered". Though certainly well worth the effort, as it turned out. Professionally as well as personally, over the years. As our initial study at the Arctic Chief showed, "it fit; it worked; it made sense". Sort of an "order out of chaos" experience for the first author, over the years, with regard to "skarns". At least a "relative" degree of order; appreciation; comprehension; understanding.

Recapitulation of the "evidence":

Periclase (brucite) marbles.
Calciphyres, with predominant calcite (+/- dolomite); as well as, variously, forsterite, pyroxene, clinohumite (?), magnetite, chlorite, phlogopite, serpentine, spinel, +/-.
Pseudomorphs ("possibly?", at the time of the earlier study) of magnetite after "borates"; later (2007) confirmed by Aleksandrov to be Mg-ludwigite .
Ores of magnetite, forsterite/serpentine/phlogopite, +/- sulphides.
Rhythmic banding in rocks, and in ores.
"Zonality"; "position"; and the character thereof. Spatially, geologically and geochemically. Exhibited at various scales.
Relationships (and nature) of successive "magmatic" ---> "postmagmatic" events/minerals/etc. (Ie. "prograde", and "retrograde", respectively.)

Representing "recognition", by the criteria used by us in 1980-1982, of the Arctic Chief locality as a "magnesian skarn" occurrence/-related deposit. With attendant implications as to geological, petrological, geochemical, and mineral resources considerations.

The principal geochemical determinant for the sufficiency, or paucity, of the required magnesium for magnesian skarn formation being the nature of the "precursorial" host rocks intruded by the related igneous material(s).

As now manifested, in particular, by the geochemical, mineralogical, petrological character of the "outer zone of the contact aureole" at the Arctic Chief deposit (and, evidently, at least portions of the Little Chief and the Black Cub South localities as well).

Namely, those "splendid" periclase (brucite) marbles; derived from dolomite/dolomitic host rocks, under conditions of the "hypabyssal periclase facies" of "contact-metasomatic magnesian skarn" formation.

Manifested similarly, and complemented by, the nature of the other rocks, relationships, in evidence as well.

These rocks merely "speaking for themselves". Though with a certain decided eloquence.

Per "standard procedures" in the agency, a U. S. Bureau of Mines "Open-File Report" was prepared dealing with the results of this1980-82 work. The "final-draft" of this report (cf. Mowatt and Mowatt,1982), together with files, rock and mineral samples, petrographic specimens, and related analytical data, were left with the Juneau office of the Alaska Field Operations Center, upon TCM's resignation from the USBM in mid-1982.

Unfortunately this report, as well as the related sample materials, files, and analytical data, subsequently "were lost/went missing". Not -- heretofore -- "standard procedure" (?). Likely similarly disappearing completely, upon abolishment of the U. S. Bureau of Mines by the U. S. Congress, ca. 1995. "Geopolitics"...... in one guise or another(?).

However, "science marches on"....... As the saying goes. Some people being "obstinate".

CONTINUING STUDIES:

Results from the ongoing work by SMA and colleagues continued to appear in the technical literature. Summarized, in particular, by the publication of Aleksandrov's comprehensive book "Geochemistry of Skarn and Ore Formation in Dolomites". Initially appearing in 1990, in a Russian-language version; an updated version was published, in English, in 1998.

This monograph (the "[SMA, 1998]" book) providing a valuable, as well as timely, integration and summarization by an increasingly well-known, respected investigator. An acknowledged authority, with extensive experience (of fundamental research, as well as "applied", nature) with this complex subject. The breadth as well as depth of the work of Dr. Aleksandrov and his colleagues most impressive, and seemingly ever-expanding in scope. It was a privilege to retain our relationship. A continuing education; an ongoing "post-doc".

In combination with continuing correspondence, exchange of books, papers, data, samples, photos, ideas, etc. with SMA over the intervening years, the "synthesis" afforded by this particular book spurred TCM to revisit the Arctic Chief locality in 2004, upon retirement and relocation to Haines, Alaska. Though admittedly a certain level of lingering professional frustration, as well as personal "annoyance", regarding the unfortunate "disappearance" of the previous efforts of 1980-1982 might well have provided an additional motivating factor. Scientists generally dislike losing "hard-won data"; among other fundamental concerns.

Further strong incentive was the opportunity afforded to work with Aleksandrov once again. Though this time, "across-the-miles". Providing him information, samples, literature, etc. from yet another locality, to add to the many others he'd already studied. As well, adding to the first author's knowledge.The subsequent work in Canada and the USA was "unfunded"; carried out at the personal expense of TCM. Sort of an ad hoc "post-doc", as it were; though a rather "low budget" one. As well as an acknowledgement, a testimony, a "professional courtesy", as it were, to a valued colleague -- and mentor; friend -- of longstanding.

With the view to rexamining this "mined-out" ore deposit, in hopes of confirming -- or improving upon -- the information obtained in our earlier "lost" study. Field sampling was done -- again -- by TCM during the summers of 2004-2006. The "retired" field geologist/ "sampler" for this project reaching the age of seventy in 2006 (?!). Now truly a "mature", as well as experienced geologist. Though perhaps no longer quite as agile -- nor nearly as well-funded -- as in days of yore. But "motivated".

As before, samples of bedrock (outcrop/pit walls), as well as associated "rubble-crop" and related "float" materals were obtained. Taken, insofar as feasible, from the same general areas of the Arctic Chief as had been sampled during the previous work. While working principally from memory in this regard. While emphasizing the "west" pit this time, for reasons of economy, efficiency, while seeking optimum "representative" sampling of the spectrum of materials, and relationships, "positions", afforded at this fine locality. A substantial collection -- rocks; related field information, photographs -- resulted.

All of the "many" samples collected were subsequently examined further, in preliminary fashion (essentially "triaged", as it were), by TCM in Haines. Utilizing hammer, chisel, hand lens, acid bottle, and a 30x/60x stereo microscope on rock surfaces (freshly-broken and otherwise). In some select cases, also examining grains-in-oil materials using a personally-owned petrographic microscope. Deferring to SMA -- the acknowledged authority -- for decisions as to thin-/polished-section petrographic analysis, etc., as he saw fit. The "low-budget" circumstances of the "project" essentially precluding petrographic-section preparation and analysis by TCM, in any case.

Selected "triaged" materials (some one hundred-plus specimens, in all) were then mailed to S. M. Aleksandrov, at the V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow, for examination, evaluation, and further analysis as he deemed appropriate to his own ongoing research. This latter work included hand specimen, petrographic microscope, microprobe analysis, etc., of representative materials of particular interest. As well as his astute observations, insightful comments, definitive interpretations.

Following sections of this present report deal with results of these examinations, evaluations, analyses; summaries, comments and interpretations.

(While Part 2 of this report, the "Data Supplement", presents additional information: sketch maps showing general locations of sample sites, abstracted field notes, results of 30x/60x stereo-microscope examination of samples, petrographic microscope examination of selected materials as grains-in-oil, and other comments, principally by TCM.)

COMMENTS (TCM) REGARDING THE PAPER "Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns" BY S. M. ALEKSANDROV, PUBLISHED IN GEOCHEMISTRY INTERNATIONAL, 2007, VOLUME 45, No. 2, pp. 152-169:

In the context of the present report, first and foremost among comments which might be put forward is that, in portions of Aleksandrov's paper, the results of our work, variously, on the Arctic Chief locality over the years are nicely summarized, and utilized. Representing the initial publication of any of this information in the open literature.

In addition to material from other cited sources, his paper uses the results of our investigations to present the Arctic Chief as one of several mineral deposits selected to exemplify aspects of the broader concerns discussed. The known occurrence of valleriite at this and other nearby deposits is particularly relevant, given the role of such hydroxisulfide minerals in several aspects of the geochemistry of gold (as well as platinum-group elements), as discussed in this significant paper.

As evident from its title, this paper overall is of a more general nature. Quoting from the informative Abstract, "The paper presents materials on the genesis of gold deposits of the magnesian-skarn association. ...... The materials presented in the paper characterize the behavior of gold in the endogenic and supergene processes at magnesian skarn deposits."

In addition, as essential background information antecedent to dealing with its principal topic, the "Introduction", and the immediately following "Genesis and Zoning of Magnesian Skarns", sections of the paper, pages 152-153, offer a valuable and concise summary of magnesian-skarn per se, from the viewpoint of a recognized authority on the subject.

In the "Introduction", in the first two paragraphs, besides commenting on the mineral resources aspects of magnesian-skarns, also offering some other rather cogent observations in the process. Observations which, from personal experience, seem quite appropriate. Since they concern themselves with matters of fundamental significance to geological science. In pursuit of increased "sophistication, efficiency", etc., as scientists we continually need to remind ourselves not to do disservice to the "basics" in the process. Lest, among other things, we fail to "let the rocks speak for themselves", as it were. A fundamental tenet of geological science perhaps at times followed somewhat less conscientiously than might be desirable.

The "Genesis and Zoning of Magnesian Skarns" section offers a veritable tour-de-force in one page, nicely summarizing the accrued knowledge, experience, and perspective of many years, many localities/deposits, many rocks, and much thought on a complex subject. Leading into the following section by ending as follows:

> "Sulfide ores, including those with gold, in hypabyssal skarns are very diverse and are deposited during the postmagmatic stage, selectively replacing compositionally diverse metasomatic zones of the contact aureoles. This can be illustrated by the example of the Arctic Chief Cu-Au deposit, Yukon Territory, Canada......."

The next section, "Arctic Chief Skarns and Ore Mineralization", pages 153-156, then proceeds to develop this theme, utilizing information obtained from other sources, principally Tenney (1981), and Meinert (1986), as well as the results of our own studies.

Among others, one important point in particular seems worthy of special note here in this commentary. On his page154, Aleksandrov observes: "The magnesian skarns of the Arctic Chief deposit occur not only at contacts with the [main] intrusion but also around injections of diorite melts into dolomites (Fig. 2). The rocks preserve their zoning and inclusions of Mg-ludwigite in the forsterite calciphyres but contain no magnetite ore mineralization" [associated directly with the latter, smaller/minor 'injections', ie.].

Illustrative of this, his Figure 2, on page 156, offers a fine drawing of a rock specimen.

This specimen happens to be the one designated "TM-04-10-12-22-B-104" when it was collected in the field at the Arctic Chief on October12, 2004, at sampling locale "22-B".

Described (TCM), upon recognizing, then collecting, this particular specimen in the field: "Ah yes. He (SMA) ought to like this one." Subsequently, in his "triage" phase of analysis terming it a "VERY NICE SPECIMEN", among other comments (cf. Part 2 of the present report). This specimen was subsequently sent in its entirety to Aleksandrov. Studied, depicted and discussed by him. Who also apparently found it a 'nice-enough', if not indeed a "very nice specimen".

Collected in the near vicinity of a larger skarn/apophysis/lens of tongue-like aspect, featuring zoned igneous and "skarn" materials within carbonate host rocks, with green, blue, +/- "rusty"-/copper-staining present in places along its margins.

This larger feature is a rather "gaudy"/spectacular one; well-photographed, 2004 and later. Subsequently, in 2006, sampled in detail as "TM-06-8-22-2-........". All of which, samples as well as selected photographs, were duly sent to Aleksandrov for his use.

The location (mentioned, and depicted, in Heon, 2004, "Sheet 2") is at the northern *edge/margin* of the entrance cut of the Arctic Chief (west) pit, exposed up on the side/wall of the cut. In the vicinity of the core/crest of a tight/overturned fold in the carbonate host rocks. Below map #3 (ie. TM-04-6-9-3 locality).

[Cf. maps, descriptions, etc. in Part 2 of this report, the separate "Data Supplement".]

Other comments on this specimen in earlier letters, SMA to TCM:

"Ludwigite is in serpentine-bearing marble TM-[04]-10-12-22-B-104... May be in contact with marbles you can see kotoite Mg3(BO3)2? ...."

"....... (The best you can see in TM-04-10-12-22-B-104 --- [the sequence] around diorites' injection in marbles: exchanged ["altered"] diorite--clinozoisite rim--pyroxene skarn--<u>banded ludwigite-bearing forsteritic calciphyre</u>--banded periclase (brucite) marble.)".

According to its caption, this Figure 2 illustrates "diorite injection in dolomite and zoning in magnesian skarns".......... Recognized as such in the field, too. Collected with precisely this intent, this specimen is used as an example -- "in miniature/microcosm", as it were -- of the general relationships ("positions", "zonality") typical of magnesian skarns, at various scales from hand specimen, as here, through "deposit scale".

Per the "model" for the "geochemistry of skarn and ore formation in dolomites" as developed and set forth by Aleksandrov and his associates. "It is all a matter of position", as the mentor here once confided to me, in the field, early on ....

Providing further illustrative bonuses, as observed, and depicted, this informative specimen also features "rhythmically banded forsterite calciphyres", and "disseminated crystals of magnesioludwigite". In addition to the other compositional and textural features characteristic of magnesian skarns so nicely displayed in this one specimen.

Collectively, "the rock speaking for itself", as it were...... Though an appreciation, comprehension, understanding, of the "language" is, admittedly, important to this.......

This Figure, this specimen, the evidence afforded, supplemented by Aleksandrov's comments, sufficiently informative to merit incorporation in the present report. A "key" item. Thus this Figure 2 and its entire caption are reproduced below:

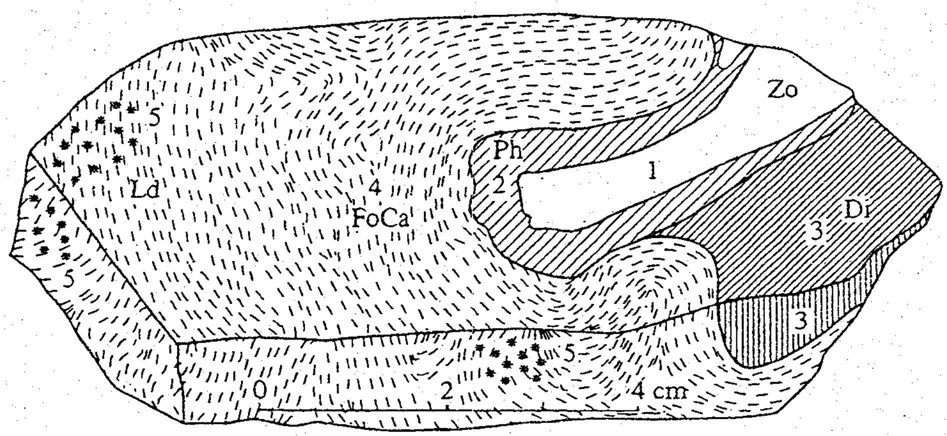

Fig. 2. Diorite injection in dolomite and zoning in magnesian skarns. Arctic Chief deposit (sample of T.C. Mowatt). (1) Diorite replaced by zoisite (Zo); (2) phlogopite–diopside skarn (Ph); (3) diopside skarn (Di); (4) rhythmlically banded forsterite calciphyre (FoCa); (5) disseminated crystals of magnesioludwigite (Ld). Magnification 2.5×.

The remainder of the Aleksandrov paper deals in some detail with the broader topic of concern, as to gold (+/-PGE), sulfides, and magnesian skarns. Providing much material worthy of further attention. Especially the role of "hydroxisulfides" of the valleriite-tochilinite, etc. genre. Note especially p.160, comments re/ "brucitization", etc.; also similar observations elsewhere throughout his paper. All with implications of fundamental scientific, as well as "applied", significance. Summarized well in his "Conclusions" section.

In terms of the aspects of magnesian skarn, petrogenesis, mineralization, etc., under consideration in the present report, some observations come to mind.

The fundamental importance of the initial formation of magnesian skarn. Key to the entire sequence of subsequent events, processes, results discussed in the Aleksandrov paper. An example of the concept/notion of magnesian skarns as "fertile ground" for formation of associated mineral deposits. In this particular case, the potential for the subsequent/eventual formation of hydroxisulphides such as valleriite, etc. Thus providing attendant further geological/geochemical possibilities. And so on........ As discussed in his paper.

The pathways, geochemically, mineralogically, of chemical elements of principal concern, including "precious metals" as well as essential other components of the required "carrier" minerals, during the sequence propounded by Aleksandrov. These being critically dependent upon the overall magnesian skarn physico-chemical environment, during the magmatic/ prograde as well as subsequent postmagmatic/retrograde stages of the evolution of such skarns.

The "overarching" general mineralogical/petrological/geochemical// "PTC" aspects of the evolution of a magnesian skarn per se are complex. Likely subject to perturbation(s), if not outright significant change(s), during the course of geological events and accompanying pressure/temperature/geochemical environment(s) -- ie. the "PTC" conditions -- attendant to the formation and continued evolution of any given/particular magnesian skarn occurrence.

While the "fates" of associated "minor/trace" elements such as gold, platinum-group elements, key base-metals, as well as other "minor" constituents (featuring of course sulphur, H2O/"OH", +/-) required as essential major constituent components of sulphides and hydroxisulfides, are intimately connected to this evolution of the predominant geochemical components constituting the major constituents of the "magnesian skarn" materials, as well as the overall geochemical environment in which the skarn exists. Which latter of course varies with time, along with the evolution of the skarn occurrence; and geological "vicissitudes".

Thus the ultimate formation/behavior of discrete "micron-/sub-micron-sized" particles of precious metals, their relationship to such hydroxisulphide minerals as may be developed, are dependent upon the previous initial formation of magnesian skarn, and subsequent essentially "normal" evolution of skarn and associated mineral phases. Essentially, much, if not indeed all, is contingent upon this.........

In turn, further growth in mass of these "seed" particles, possibly leading eventually to "nugget" formation, though perhaps directly related to this-- in part/for some period(s) of growth/time -- , eventually reaches another stage.

At which dependence becomes/is, rather, principally -- essentially entirely -- upon the subsequent (rather than, directly, the prior) "physico-chemically"- determining course of geological events, and accompanying geochemical responses of these "seed" particles.

At which juncture the direct effects of magnesian skarn-related processes and materials in this aspect of the scenario essentially have come to an end. Merely lingering on as a "legacy"; having served basically as a "template" of sorts. An essential template. Providing a/the key element: affording "fertile ground"; providing "opportunity/ies".

The title "Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns" seems particularly well-chosen. It conveys the essence of the matter. This paper offering a thought-provoking treatment of a subject of appreciable interest in geology/ geochemistry. A subject of long-standing interest, discussion, research; controversy. Regardless of the ultimate outcome of the pursuit of this particular concept, as presented, in terms of furthering the understanding of "nugget" formation, the presentation does -- at least -- indeed serve to convey some of the "singular" aspects of magnesian skarns.

Without which singular aspects, the scenario discussed in the Aleksandrov paper would be most unlikely. Hence, again, the demonstration of one particular facet of the "fertile ground" aspect of magnesian skarns. There are other facets, including especially those of (other) chemical, textural, temporal nature as well; the physical geochemistry involved is complex indeed. The implications these facets present by their mere existence in a magnesian skarn geological setting, the "fertile ground" possibilities inherent, would seem to merit due consideration.

This is an important paper. As suggested previously, above, it is "thought-provoking". Stimulating. A valuable contribution to the technical literature. For the discussion of the chemistry/geochemistry per se, as well as other more peripheral concerns regarding geological science; including of course mineral resources.

As a bit of a digression here, one intriguing line of thought thus-"provoked" has to do with the sort of "legend" that seems to develop in many mining districts. Interestingly, seemingly most commonly those in the "north country". Perhaps in this case attributable to those long dark cold winters "up north". Giving folks something different to think about, talk about, if nothing else. While, on the other hand, perhaps there just might in fact be some other factors involved. Such as geochemistry, "cryogenics", etc. (?).

The genre featuring various whisperings, mumblings; or "more substantially"(?), rumors, stories, tales......... All having to do with the supposed, alleged, sometimes strongly avowed, "once upon a time" observation(s) of large -- or at least of unusual size -- particles of "visible" gold during the course of milling-type operations somewhere in the area. Some such "reports" featuring alleged "nuggets" in ores, concentrates, etc. generally otherwise devoid of recognizable-size material of that nature.

The Whitehorse area of course has by no means been immune to the growth of this sort of "legend". Nor perhaps the growth of "nuggets" either -- per Aleksandrov, R. W. Boyle, etc. papers -- over the years (?). Since the recovery of "free gold" in the course of the milling process at the Little Chief site has been reported, substantiated.

While details of certain other such related stories tend to vary with the source of the information, being shared generally only after the recipient has been sworn to secrecy. Though inevitably, or so it seems, not infrequently there appears to be at least some semblance of credibility to the story. A "grain of truth", as it were (?). Just sufficiently enticing......

Featuring "reports" of fair-sized gold being noted, recognized (perhaps even, at times -- perish the thought -- "short-circuited") by keen, attentive folks in the mill. Not necessarily always folks formally assigned such removal of recognized sizeable gold from the circuits. Hence of course maintaining that certain element of surreptitiousness so vital to perpetuation of any such legend worthy of the name.

"Covert operations" of a sort, in the mill. By the keen, the alert. "Souvenir hunters". Or merely an informal/ad hoc variation of a program of "on-the-spot awards" for superior performance on the job. In this case, presumably for "attentiveness". Whatever........ (??).

In light of the material presented in Aleksandrov's paper, perhaps (?) some "considered reconsideration" of tales of "nuggets in the skarn/at the mill", etc. just might be merited. Since Whitehorse has been shown to be "valleriite country" (Petruk et al, 1970; Harada et al, 1973; etc.). All of which would be merely one more "interesting" aspect of the line of reasoning put forward in Aleksandrov's rather intriguing discussion.

While of course the present author of these comments is not unqualified to raise the issue, or offer perhaps-dubious commentary. Since, among other things, he happens to be, at least relatively speaking, a "Variag" in the Whitehorse country. Aleksandrov once having told me about the "Variag". The "Viking"; "the man from out-of-town with all the answers". Seems this phenomenon is known worldwide. Be the visitor from Ottawa or Washington, D. C.; Moscow or Magadan. Or other points "out there"; even such unlikely spots as Haines, Alaska......

But, now, "end of semi-serious digression". Leaving the foregoing "nugget question" as a somewhat open -- "thought-provoking" -- one, in all of its many nuances, to return now to the main thread of the present report.

To our knowledge, our work, as presented in Aleksandrov's cogent discussion, represents the first such treatment (at least published in the open literature) of the Arctic Chief from this particular viewpoint of the genesis of skarns and related ore formation. As such, it offers a somewhat different perspective than apparently has heretofore been brought to bear on this subject, at this particular locality/deposit, or in the Whitehorse Copper Belt, or in the region.

This would seem to be a perspective meriting more extensive appreciation, consideration, application than previously has been the case. Aleksandrov's comments regarding the Arctic Chief, based on information/data derived from the other sources mentioned above, as well as our own, demonstrate the apparent applicability, "utility", relevance of this "model" to this particular locality/deposit. As well, in the context of this approach, and its demonstrated usefulness elsewhere, suggesting possible implications with regard to skarn and ore formation in this region too. The "SUMMARY AND CONCLUSIONS" section of the present report, below, also offers a bit more commentary ("grinding-of-the-axe"?) on this theme.

With regard to the analytical and interpretive details, Aleksandrov's findings confirm, are in agreement with, the results, tentative and otherwise, of our initial work carried out in 1980-1982 on the Arctic Chief (see above). Not too surprisingly, of course, given the background of the professional relationships among the investigators.

The subsequent work since 2004 confirming those earlier observations, in general, as well as in most all of the details. As well as, importantly, providing confirmation of the formation of Mg-ludwigite at the Arctic Chief.

While adding a substantial increase in the level-of-confidence in the previous analyses and interpretations of two of his "students", with S. M. Aleksandrov as the Principal Investigator this time. Including utilization of microprobe and other capabilities at the V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences. Providing definitive results from our cooperative efforts.

Featuring the salient contributions of S. M. Aleksandrov, some selected observations, comments, etc. resulting from our 2004-2007 study of the Arctic Chief are presented in the following portion of this report. These are intended to offer additional perspective, insights, supportive information, some relevant details, etc., in the context of our research.

The matter of the nature ("magnesian" vs. "non-magnesian") of the host rocks, and of the associated skarns, appears to merit an additional brief comment at this point.

Various observations, over the years, in the papers cited previously above (viz. Grabher, 1974; Tenney, 1981; Morrison,1976, 1981; Watson, 1984; Meinert, 1986; Wheeler, 1961; Kindle, 1964; Dawson and Kirkham, 1996; Heon, 2004), have, in one fashion or another, collectively shed appreciable light on the subject.

The material compiled and presented as to "major host rock type", and associated "skarn minerals" in Watson nicely summarizing the data, and rather clearly showing the direct relationship, in the deposits of the Whitehorse Copper Belt, as discussed elsewhere in the present report.

The Arctic Chief is certainly a fine example of a "magnesian" skarn situation. While the Grafter Extension, visited by TCM per the suggestion of Mike Burke (YGS) in 2004, affords, apparently, a relatively small but nicely displayed version of an essentially "non-magnesian" skarn situation (cf. Heon, 2004).

This latter occurrence, as presently exposed, offering a ready opportunity for further detailed study of the rocks, and their relationships, "in miniature" as it were. Even upon somewhat cursory field examination (TCM), a number of *significant features* were evident. "Granitoid" intrusives; "alteration(s)"; endoskarn; "inclusions"; exoskarn; carbonate host rocks, with some "interesting" features. Though some apparent "complications" -- possibly noteworthy -- were observed in this sequence as well.

The section immediately below presents some of the general comments, observations, results, interpretations, etc. shared with TCM by SMA, during the course of this investigation.

As such, they represent definitive "counsel" as to the topic(s) of concern. Essentially an abbreviated "Short Course" of sorts, on the subject. If not in fact a cogent "Mini-treatise". A fine overview, synopsis, in any case. Offered from -- by any reasonable measure -- the "premier consultant" in this particular field.

"Gratis"......... ; scientist to scientist. Cooperating. Collaborating. Sharing. Learning. In our particular case, as has been ongoing since 1973. Exemplifying -- epitomizing -- "scientific/ cultural exchange".

Though "supplemental" reading(s) -- especially Aleksandrov, 1998; etc. -- is/are certainly recommended to those interested in delving into this aspect of geological science further.

GENERAL OBSERVATIONS, COMMENTS, ETC. OF S. M. ALEKSANDROV:

- -

Selected portions of a letter from SMA to TCM, Sept. 14, 2004:

"What I say about samples? Of course this is magnesian skarn. I read article [sent by TCM with an earlier letter] by L. Meinert about Whitehorse copper belt deposits (1986), that contain its characteristic analytical data for rock-forming and ore-minerals and composition of intrusive rock (see all tables in his article). [Bold emphasis by TCM]

As first result I think that temperature of skarn formation after dolomites in contact with intruded granodiorite melts (content 58.3% SiO_2) was near 1000C (after F. G. Smith). The granodiorite is product of assimilation of country rocks by over-heating granitic melts (see my articles from 90's years). The absence in skarns of monticellite zone are given possibility to suppose its belonging to hypabyssal periclase facies of dolomite progressive metasomatism in magmatic stage (see fig. 16, 17, and 18, 24 in my book,1990).

Its zonality is: granodiorite contact//pyroxene skarn with spinel --- (+/- forsterite skarn) --- forsterite calciphyre --- periclase (brucitized) marble --- host dolomites.

All early pyroxenes are diopsides (Di > 90 mol%), but all salites are secondary (postmagmatic new formed) and content Fe-component more as 10 up to 14-20 mol % hedenbergite. Forsterites are high Mg. May be are black magnetite?

Diopside + spinel paragenesis on postmagmatic stage transformed in [into] a little Fe-content phlogopite as also forsterite + spinel rocks too. In the same time formed clinohumite after forsterite in calciphyres. (Note: valleriite in this time of process is absent, it is low temperature mineral. Only at last stages clinohumite is altered into brucite and magnesite, fully losing F, and appearance of sulphides may be doing its reaction with formation of hydroxosulphides.)

Near intrusive rocks took place development postmagmatic secondary calcskarns after part pyroxene zone of Mg-skarn rocks with appearance salites, vesuvian?. Mg-amphiboles (actinolites after salite), garnet andradite-grossulare composition and wollastonite near granodiorite (fig. 63 in book). Mg-spinel is transformed into gahnite.

After granodiorite appear garnets of grossulare composition and Fe-bearing epidote as endoskarn minerals in postmagmatical associations.

Sulphide mineralisation is next at the last ore step after secondary calc skarn (and greisen).

At low temperature, minerals you can see are brucite (after periclase), serpentine (after forsterite) and Mg-chlorites (after phlogopite). The presence of valleriite (in ores at Arctic Chief up to 30% !?, and North Star, see Meinert's article. Also see data of K. Harada, 1973, about Little Chief, Yukon and W. Petruk et al, 1971).............

The name valleriite is going for honor Swedish mineralogist Prof. G. Wallerius (1683-1743, see Dana, et al, Sulphides).

About genesis and role tochilinite-valleriite. Are common low temperature minerals in all pyrrhotite or mackinawite basic rocks (Mg-skarns, kimberlite, gabbro, dunites, etc.) and in its are tochilinite or haapalite (as Ni-analog in pentlandite ores). The presence in those rocks of Cu-sulphides is given start for formation valleriites (for example, Chamberlain, J. A., Delabio, R. N., Mackinawite and valleriite in the Muskox intrusion. Amer. Mineral., 1965, v. 50, #5-6, 682-695). Its formation after Au, Ag, Pt, and Pd-bearing sulphides assume appearance free micron [size/scale] particles of noble metals in mass of hydroxosulphides. The presence this shirt [coating] are giving big difficulty for sulphides flotation in extraction process and evoke loss of Au and Pt.

Probable these particles in hydrothermal and supergene conditions are easily soluble and redeposited on larger metal grains as first steps for growth of nuggets.

For Yukon climate is actual the presence of permafrost effect. This is promoted to [facilitates] increasing in many times concentration Au in rest solutions in ice freezing up to oversaturation and pass electrolytical reaction with redeposition as "new gold" of intermetal compound (see valleriite article).

New data about sulphides (with Au and Pt) from Mg-skarns of world and valleriite-tochilinite will be published in Geochemical International in 2004 (#5, see Lebedinoe, Yakutia and others and #9) and 2005 (#3 and oth.) and I will be send its for you."

....

"A few questions from me to you, Tom, if You permit:

1. What are spatial (geographic) correlation lode and placer Au deposits in Whitehorse belt?

2. Are or not any boron minerals in deposits in the copper belt?

3. In copies of article that you sent me, are very often data about presence in skarn hematite or specularite, that are very seldom for Mg-skarns. Probable this is Mg-Fe-borates: ludwigite or hulsite and its magnetite pseudomorphoses?

4. From publications I know about presence Mg-Fe-borates (ludwigite? or hulsite?) on Swift River near Seagull batholith (southern Yukon). In contact zone Thompson, R. M. from Univ. of B. C. (see introduction in Petruk article) and Gower, L. A. have described Mg-Fe-borates in sphalerite ores (American Mineral., 1954, v. 39, #5-6."

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Selected portions of a letter from SMA to TCM, November 15, 2004:

"All enclosed materials by D. Tenney and others are fully interesting to me. I am sure, that ore-bearing magnesian skarn may be more widely distributed in western Canada (see article about borates in North America). **Of course, it is necessary to remember, that near contact with granitoids calc-skarns minerals can have altered/replaced Mg-skarns and mask its presence, but magnesian minerals (forsterite, clinohumite, phlogopite and periclase) are constantly present in marbles.** [Emphasis by TCM.]

Thank you for description to deposits near Arctic Chief in Whitehorse ore belt.

About molybdenite: it is one last sulphide on gold skarn localities. I encountered it in phlogopite rocks in Eastern Chukotka, in altered granodiorites in Yakutia, and in pyroxene-garnet-skarns with Bi-sulphides and Au in Hol-Kol, North Korea.

Green mica-like minerals in skarns may be clintonite or phlogopite."

....

....

"About temperatures of initial granitic melts: It in normal dry granitic melt with 72% SiO_2 (T melt is near 820C - after F. G. Smith:"Physical Geochemistry", who is giving data about T melted dry magmatic rocks from gabbro - 1250C up to pegmatite) is a little more for melting exocontact pyroxene skarn. For it T must be near 1200C (See articles #28, 31, 32, 33). [[In SMA "BIBLIOGRAPHY"/publications list, sent in a recent letter to TCM. See "REFERENCES section of present report.]]. For assimilation basic host rocks is necessary presence high-heated granitic melt. What are any data?

I see in Russian translated the book Helmut G. F. Winkler, who give T crystallized gabbro magma as 1200C, syenitic = 900C and 800-700C for granitic, that are similar with data F. G. Smith. From Winkler's data T host rocks is 150C (?) only. The metasomatic process of alteration of dolomite started in halo intrusion under action magmatic Si and Al-bearing solution and give primitive skarn zonality as first stage process (300-400C), but not 150C). The reaction $CaMg[CO_3\}_2$ ---> MgO + $CaCO_3$ + CO_2 is 600-7--C/1Km depths (see fig. 1, 14, 19 and 32 in my book). [Emphasis by TCM]

It is before the complication of zonality skarn column on stage of melting near-contact rocks, that demand more high T and be accompanied with appearance new zones in column: monforsteritic and enstatitic as plus Mg from melted part of exoskarn. The thickness of high magnesian zones = 1/2 the same [thickness] melted skarns. This process impossible on contact with 800C granitic melt. As you think about this?

From my practical work I see, that near contact with skarn after dolomite, granites may transformed in granodiorite......... up to gabbro under assimiliation of skarn material! Or may be leucocratic granites, too. All progressive Mg-skarn processes have place on contact with magmatic melts. After consolidation intrusion, took place regressive transformation the mineralogy of early formed skarns."

....

"The presence Mg-Fe borates on Whitehorse and other area is possible. I send you copy of Thompson & Gower article."

....

"**I send you my book in English (15th November)**, bibliography (articles published in English), and a copy of my former essay about ludwigites in first edition of "Geochemistry", that received good compliment from W. T. Schaller many years ago."

==

Selected portions of a letter from SMA to TCM, March 15, 2005:

"**You are doing the large investigation and supported magnesian skarn nature of Arctic Chief!!! It is good start for future regional observations in Canadian deposits!"** .... [Emphasis by TCM]

"First commentaries for your samples: Common look - as also in Brooks Mountain and Tin Creek [Seward Peninsula, Alaska] in Arctic Chief rocks. [Emphasis by TCM]

You can see rhythmically-banded textures, that inherit, and in magnetite ores. (The best you can see in TM-04-10-12-22-b-104 --- [the sequence] around diorites' injection in marbles: exchanged ["altered"] diorite--clinozoisite rim--pyroxene skarn--<u>banded ludwigite-bearing forsteritic calciphyre</u>--banded periclase (brucite) marble; in TM-04-10-12-22-a-134 and -131 and -102 --- banded phlogopite--magnetite ores, in -126 --- serpentine/forsterite rhythm in magnetite; in TM-04-6-9-4-2 --- is forsterite--calcite rhythm, etc....). [Underlining emphasis by TCM]

These textures have origin on progressive stage of metasomatic exchange of dolomites and reflected in ores-- see book [SMA, 1998], pages 77-87. It is non-equilibrium process.

My first question: what is position these little finger-like projections of diorites in marbles find on contact with big (main) intrusive massif? It ['projection/s'] is shown in a few of your samples! You can see similar [features] in a few figures in book [SMA,1998] from skarn areas.

Next my second question: Magnetite is absent near those injections in marbles. What is position magnetite ores in metasomatic contact? They are only in immediate contact zone of big intrusion?

<u>**In your collection is splendid periclase marbles,** but in literature are not this information.</u>

<u>**In many samples in marbles and forsterite-calcite environment are a bit to big black crystals of LUDWIGITE (see TM-04-10-12-22-b-115; -23-110, -23-108, etc. See Brooks Mountain!** This fully are not in literature about Whitehorse copper belt!</u>

[Underlining in above is original in letter from SMA; bold emphasis added by TCM.]

Third: In your collection I can not see monomineralic forsterite skarn, only calciphyres! You check up this fact? The presence the last [monomineralic forsterite skarn] is possible after magmatic melting of the pyroxene skarns (see exchange types of zonality --- see it in book [SMA,1998]).

About typical lime skarn (TM-04-08-09-2) [of] pyroxene-garnet composition: What is its position with magnesian skarns? I believe that it has postmagmatic origin from Si-bearing marbles. What, how much, are sulfides in this type skarns?? Or absent?

In forsterite marble (TM-04-6-9-5-1) is spinel. The part of pyroxenes is Al-bearing. In this situation is formed late phlogopites in rocks and ores. ....

Conclusion: Contact aureole at Arctic Chief was formed in normal dolomites. Its zonality is near the primitive type, but it is [in/of] the hypabyssal periclase facies (see pages 31-37, and fig. 24, in book [SMA,1998]) in the time of progressive metasomatism of these rocks. The first postmagmatic ore mineral in marbles is ludwigite; after forsterite formed clinohumite (TM-04-6-9-4-2) and phlogopite after spinel. The part magnetite is inherit texture of calciphyres, other - the same with phlogopite - from pyroxenic skarns. All sulfides are late. [Emphasis by TCM.]

In Whitehorse copper belt are [many] deposits and prospects. .... [How many/what proportion] of [these] are seated in dolomitic rocks? If only part of [this total], what are the differences in the composition of skarns and ores composition in not-dolomitic environment?"
[Which of course is another matter/study yet to be dealt with. {TCM}]

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Selected portions of a letter from SMA to TCM, June 16, 2005:

"Answers to your questions:

1. **For study (investigation) all pure dolomites, periclase marbles and forsterite + spinel calciphyres [it is] very useful to see its weathering surface. You can see all silicates as prominences, but in place of brucite will be caverns! It is important to watch!!!**
   [Emphasis by TCM. Remindful once more of the personal/learning experience on Brooks Mountain in1973, recounted previously, above.]
2. About magnetite ores in skarns. Yes, it is common in direct contacts with main intrusive bodies, but near magmatic injections in marbles are rare. Presence iron you can see as ludwigite or late sulphides (pyrite and pyrrhotite).
   Magnetite is often replaced of silicates in skarns. All iron is coming from solutions in time of postmagmatically exchanged iron-rich minerals in basic intrusive rocks.
   Only from leucocratic granitic magmas Fe is going on magmatic stage and giving magnetites of syngenetic with the formation of magnesian skarn zonality (see book [SMA,1998]).
3. Monomineralic forsterite skarn zone [indicates] magmatic stage replacement of magnesian skarns near intrusive rocks by melt. Half thickness of monoforsterite zone = thickness melted skarns.
4. **Typical skarns are formed after postmagmatically changed silicate-bearing carbonate rocks. After pyroxenes is formed zoning garnet.**
   'Arsenopyrite'? in sulphide ore can be loellingite -FeAs2!!! Check it!!!
   [Emphasis by TCM]
5. **The CaCO3 marbles in contacts with granodiorite melts are not transformed into skarn. Ca is assimilated by melts and involved in Ca-bearing minerals - plagioclase, hornblende and etc. CO2 increases."**
   [Emphasis by TCM]

==

Selected portions of a letter from SMA to TCM, June 25, 2005:

"About dykes and its composition. In last letter I note about leucocratic hornblende quartz monzonite dyke. It is possible that monzonite from massif will be more basic! If this so /well then/ you can think that monzonite magma of massif is result of assimilation of host rocks and primary melt was more close to granitic composition and was superheated. Last dykes from deepest magmatic camera must be leucocratic. **In book [SMA, 1998] (Fig. 13) is illustrated this, and similar with Arctic Chief locality.** [Emphasis by TCM]. (In text, epidote = clinozoisite). Plus, see green amphibole with plagioclase in quartz-monzonite dyke- TM-04-10-12-23-108, 110 with pyroxenes and quartz."

===

Selected portions of a letter from SMA to TCM, January 11, 2006:

"I am believed that Arctic Chief and other deposits in Whitehorse ore belt are best objects for investigation position and zoning Mg-skarns and ores in its. The understanding of genesis and mineralogy must be given the key in exploration (discovering) new ore bodies in skarns and marbles and <u>its relation with placer accumulation of gold</u> in Yukon region in all.

[Bold emphasis is by TCM; underlining is by SMA]

In my works I only want to demonstrate (show) that skarns after dolomites are sources many metals and raws [materials] in any parts of all world. Of course in past and to-day its was mining and without this understanding, but aplay [applied] geochemistry may be given good results for its prognose."

[Emphasis by TCM]

===

Selected portions of a letter from SMA to TCM, May 11, 2006:

"Your commentary in letters, best slides [photographic] from quarry, and, of course, the good samples has given me the possibility to support the magnesian skarn nature of (this) Canadian Fe-Cu-deposits in Whitehorse ore belt."

....

"Your last samples is very best: its illustrated of rhythmically-banded structure of metasomatites !!!" [Emphasis by TCM]

===

Other selected comments (SMA):

'Periclase marble' [ie. marble featuring brucite after periclase, and calcite, +/-] is the predominant 'host rock' represented in the [many] specimens studied. [Emphasis by TCM]

Forsterite and low-F clinohumite occurs in calciphyres.

Phlogopite-magnetite ores.

Zoisite occurs after plagioclase-pyroxene zone (or diorite) in rocks studied.

In comparison with the areas such as Lost River, Brooks Mountain, Tin Creek, etc. on the western Seward Peninsula, Alaska, [where SMA and TCM worked together in 1973 and 1979] at the Arctic Chief locality the situation appears to be not as complex. [Emphasis by TCM]

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OBSERVATIONS ON SPECIFIC SPECIMENS (S. M. ALEKSANDROV):

TM-05-5-25-1-Q:

"Probably in this specimen is ludwigite in the marble part near contact with forsterite-magnetite ore. ...."

"Marble with ludwigite (??????) as black needles. ...."

"I will be send you new [[microprobe]] analytical data for sample #TM-05-5-25-1-Q (marble with Ldw?????? and + magnetite ore...........)"

[An excerpt from a letter from SMA to TCM, May 11, 2006 states: "All black needles are pseudomorphoses magnetite after borates............"]

"Other minerals in this specimen:

Mg-bearing magnetite- (>90% FeO, and 1.5% MgO)
Dolomite- (22% MgO, 30% CaO)
Serpentine- (36% MgO, 3% FeO, 45% SiO2)
Phlogopite, altered to clinochlore- (with MgO, SiO2, and Al2O3)
Talc- (MgO, SiO2)
Are [also] Fe-Mn species dolomite/ankerite."

....

==

Selected portions of a letter from SMA to TCM, June 16, 2005:

"Ludwigite is in serpentine-bearing marble TM-[04]-10-12-22-B-104, very little. May be in contact with marbles you can see kotoite Mg3(BO3)2??? [Emphasis by TCM]

Near monzonite plag and prx -- transformed into zoisite and calcite; and prx -- into Mg phlogopite.

All periclase in marbles fully transformed to brucite, with calcite; its form is pseudomorphic after periclase. In these rocks are a few grains of forsterite and clinohumite.

In magnetite ores forsterite is transformed into serpentine near calciphyres, or into other silicates --- into Mg-phlogopites (after diopside). Mg-pyroxene is in TM-04-10-12-22-A-137 and actinolite........ 22-B-117, amphiboles........ 22-A-101.

Green amphibole with plagioclase in quartz-monzonite dyke- TM-----23-108, 110 with pyroxenes."

....

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Other comments on selected specimens (SMA):

TM-04-10-12-23-111:

Skarned zone on contact with dike. Content anorthite, pyroxenes (fassaites) and garnet. The typical in contact magnesian skarn plagioclase-pyroxene composition and secondary [-ily] transformed in [into] salite-garnet bearing associations.

Microprobe analysis: P-67-1. Salite, plagioclase (anorthite), garnet (grossularite 70%, andradite 30%), pyroxene.

TM-04-10-12-22-B-104:

Forsterite-bearing brucite (after periclase) marble, with calcite, serpentine and phlogopite.

Microprobe analysis: P-67-2. Forsterite, serpentine, brucite, phlogopite.

TM-04-10-12-22-B-119:

Brucite-periclase marble.

Microprobe analysis: P-68-1. Brucite with relicts of periclase, and dolomite + spinel + hydrotalcite (after spinel) and magnesite.

TM-04-10-12-22-A-113:

Brucite-periclase marble, with forsterite and clinohumite.

Microprobe analysis: P-68-2. Brucite and periclase, some dolomite.

TM-04-10-12-23-B-115:

Brucite (after periclase) marble with forsterite.

TM-04-10-12-23-110:

Plagioclase rock with hornblende and pyroxene (dike?).

TM-04-10-12-23-109:

Clinohumite calciphyre with magnetite.

TM-04-8-9-2-Z:

Vesuvianite (idocrase)-pyroxenic typical barren skarn.

TM-04-10-12-22-A-130:

Magnetite ore with phlogopite.

TM-04-10-12-23-108:

Plagioclase rock with amphibole (dike???).

TM-04-10-12-22-B-141:

Magnetite ore with serpentine.

TM-04-10-12-22-A-131:

Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-134:

Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-132:

Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-135:
Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-137:
Diopsidic skarn with prismatic magnetite.

TM-04-10-12-22-A-133:
Phlogopite-magnetite ore.

TM-04-10-12-A-126:
Rhythmically-banded serpentine-magnetite ore.

TM-04-10-12-23-106:
Rhythmically-banded serpentine-magnetite ore. Serpentine after forsterite.

TM-04-10-12-22-B-114:
Rhythmically-banded serpentine-magnetite ore. Serpentine after forsterite.

TM-04-10-12-22-A-101:
Actinolite in magnetite ore.

TM-04-10-12-22-B-117:
Actinolite after diopside, in magnetite ore.

TM-04-10-12-22-A-121:
Phlogopite in magnetite ore.

TM-05-10-13:
Rhythmic-banded marble with sulphides.

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SOME OBSERVATIONS (TCM):

The foregoing (2004-2007) work of S. M. Aleksandrov -- analyses, results, observations, interpretations, comments, etc. -- provides definitive characterization, and elucidation, of a number of key aspects of petrogenesis and associated/related mineralization at the Arctic Chief ore deposit. Affording insights previously not perceived-- or if perceived, apparently not fully appreciated -- at this, or other/similar localities within the Whitehorse Copper Belt, or elsewhere in this region.

While, additionally, offering definitive confirmation of the comparable interpretations developed, and conclusions put forward -- though somewhat more tentatively, by two of his "apprentices/proteges" -- , during the course of our earlier (1980-1982) study. The results of which, regrettably, remained unpublished, unremarked upon, since that time.

This research, collectively, convincingly revealing a number of features of appreciable geological significance. These having been apparently unrecognized prior to our studies. In particular, "shedding some new light", as it were, on the Arctic Chief locality. With attendant implications elsewhere in the Copper Belt; perhaps regionally, and elsewhere.

As well, our collective studies of the Arctic Chief have provided additional evidence -- yet one more example -- supportive of the approach to magnesian skarns, and associated mineralization, developed by Aleksandrov and his associates, over the course of many years of extensive, as well as intensive, investigations. Affording an important perspective for further consideration.

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Our initial (1980-1982) studies at the Arctic Chief entailed fieldwork and sampling of the gamut of materials, and field relationships, available for study/exposed at that time. This included the "calc-skarn" materials, and the "late dykes", as well as the (variously) "carbonate" rocks and the "ore" materials. Selected representatives (a substantial number) of the spectrum collected were analyzed in the laboratory (utilizing optical microscopy, in transmitted as well as reflected light; x-ray diffraction; x-ray emission spectrometry), as appropriate. Results of this are presented, discussed, variously, in the present report, above.

Due to constraints of time, distances, budget, our subsequent (2004-2007) work was focussed principally on the "carbonate" rocks and the "ore" materials. These considered to represent/feature the major portion of the significant "keys" to the aspects of petrogenesis and mineralization fundamental to this locality, and other similar occurrences.

Though some attention was again devoted to investigating the "calc-skarn" materials, as well as the "late dykes", as convenient, and/or deemed appropriate. This included fieldwork and related sampling. Subsequently, a number of "selected/triaged" representatives being mailed to Alseksandrov for his information, and use as he deemed appropriate.

Results of these later, somewhat "more limited" efforts, regarding calc-skarn and dykes are presented, variously, in the present report. Essentially "supplemental", as it were, to our principal concerns at this stage of our rather lengthy -- though interrupted/perturbed -- "over the course of the years" studies here.

Featuring a number of comments, etc. by SMA, interspersed among the others in the selections from the "SMA to TCM" correspondence (the "Aleksandrov short course/ treatise"), presented above in this report.

While most of the first author's observations on these -- and the other -- collected materials are to be found in Part 2 of this report, the separate "Data Supplement" addendum. Somewhat scattered about, among results of fieldwork, photography, sample collecting; preliminary examination, subsequent 30x/60x stereo-microscope examination, petrographic microscope examination of selected materials as grains-in-oil, and other comments.

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With regard to another issue (just one of many) of "reality-related", "less-clearcut", geological character. Namely, those not at all uncommon situations (eg. the Whitehorse Copper Belt, as summarized in Watson, 1984) in the realm of sedimentary petrology/stratigraphy, featuring "interbedding", and/or variously "impure" lithologies within beds. With a range of possibilities thus afforded as to the "nature of precursorial host rocks", vis-a-vis skarn formation and associated mineralization. "Geological trash cans", sedimentary rocks; to varying extents of course. "Pure" being a relative term in the lexicon for these materials.

Variously "muddy/argillaceous/dirty" carbonate rocks as a relevant example. Featuring various proportions of fine/very fine/"clay-size"(<2microns e.s.d.) constituents. Generally consisting principally of silicate minerals, such as one or more varieties of "clay minerals";

variously weathered micas, feldspars; quartz, +/- etc. While other complications are not unlikely, in terms of chemical/mineralogic composition, due to diagenetic, alteration, effects.

Combined with "interbedding" of sedimentary deposits, somewhat complicating matters of interpretation, "prediction", of skarn-type/details thereof from a given host rock assemblage. Certainly "variations", "ranges", are not unlikely. Though remaining, principally, a function of "the nature of the host rock(s)".

This of course relevant to the comments in the present report as to the importance of the nature of the precursorial host rocks with regard to skarn formation, etc. Implications including characteristics, and genetic aspects, of calciphyres, and calc-skarns, in particular.

It should be pointed out that the characteristics of "calciphyres", as put forward in the foregoing discussion of these rocks in an earlier portion of the present report (COMMENTS ON RESULTS FROM THE 1980-1982 STUDY) have been subject to alternative interpretations, past and present. Such principally having to do with presumed inhomogeneities (viz. sedimentary layering, and/or interbedding; and/or "impure/dirty" lithologies) within the precursorial host rocks.

Though in the case of "calciphyres" as treated by the present authors, the extensive, as well as intensive, detailed work of Aleksandrov and his associates (cf. the REFERENCES section of this report; especially Aleksandrov, 1998) seems to relegate proposed alternatives of this sort to a "less-likely" status, if not in fact refute them. Appreciable evidence having been developed indicating metasomatic processes, at the elevated temperatures /"PTC" conditions attendant to the associated igneous/metamorphic environments clearly present, as responsible for the formation of the features observed in these rocks. While the similarities of spatial "position", "zonality", which are common to magnesian skarns also suggest origin(s) other than due to the more inherent vagaries of sedimentology/ stratigraphy.

The matter seems somewhat more complex, as to the "calc-skarns". Though not dissimilar. As mentioned in various comments by Aleksandrov elsewhere in the present paper; dealt with in more detail in a number of his other publications. The "nature of the host rocks" remaining a/the key factor. In one guise or another.

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Some "asides", from a "friend of skarns, etc.":

The Arctic Chief locality represents a fine example of contact-metasomatic magnesian skarn, and associated mineralization. Manifesting rather well various key characteristics of its petrogenetic, and related ore deposit, aspects. As such, it has afforded we three investigators much in the way of opportunities in terms of geological research. Appreciably furthering our individual, and collective, levels of knowledge. Enabling us to develop the interpretations presented in this report. While it is fully appreciated that, in all likelihood, there remains much more to be learned here, at this fine locality.

Thus, while carrying out fieldwork, sampling, etc. chores, over the years, the first author also found himself becoming increasingly "fond" of the Arctic Chief and environs.

From the admittedly perhaps somewhat biased point of view of this former (among other things) Professor, this locality seems well-deserving of further studies. Preferably of "thesis-type". Bringing to bear youthful vigor, agility; "new ideas/methods", etc. With the view to extracting as much information as feasible from this wonderful site. As well as exposing another generation of geologists to this locality, its features. As a fine example of its kind. In hopes of continuing the always-tenuous thread of knowledge, as focussed in this case on the principal theme addressed in the present report.

With the view to further advancing the state of knowedge as to this particular realm of geological science. Building upon the previous efforts here, and elsewhere. Adding to the sum total of human knowledge regarding the subject matter of concern. Before the inexorabilities of time and exposure to the elements -- natural, as well as "cultural/anthropogenic" -- take their inevitable toll here.

Which unfortunately has occurred recognizably between earlier and more recent experiences at this excellent example of the type. These fine rocks, etc., are too good to merely go to waste. Without at least studying them -- the rocks and ore materials, the relationships at this locality -- further. As thoroughly as at all feasible. Extensively, intensively. All sorts of possibilities come to mind as to "opportunities/ avenues of research/investigations" which might be pursued here. The list expands each time one gives the matter any thought at all. A "Geology Museum", the "AC"; as is the Whitehorse Copper Belt, for that matter.

The mere notion of "exploiting" these "splendid" periclase marbles, or other "eloquent" rocks hereabouts, for cement material, rip-rap, decorative stone, fireplace rock, road metal, landfill, etc.; or of using the site as a "dump"; or whatever, is disquieting. To say the least. Such possibilities probably ought not to even be *mentioned* . While of course, to this writer, "selective exploitation", such as re/ geological specimens in particular, on the other hand, seems to represent a legitimate, somewhat "higher", use.

Pursuing this thread in another direction. Surely numerous individuals in the Whitehorse area, as well as elsewhere, who have had considerably more experience working on -- and "in" -- the Copper Belt than the present writer, potentially have a great deal to offer as to various aspects of the work presented in this, or other such, reports. Likely much of such valuable "info" not "published"; nor even "disseminated". Experiences, perceptions, notions, ideas, whatever. Perhaps even data, etc.

In the context of this "new millenium" in which we now find ourselves, in particular as regards mineral resources, economies, "world affairs", etc., it would seem to behoove us to not overlook potential further contributions of "skarn-related" mineral deposits. The accrued experience, knowledge, examples, of such, as epitomized by the Whitehorse Copper Belt, and elsewhere in the region, ought to merit some serious efforts at "solicitation; unearthing; collection, compilation". With the view to assembling as all-encompassing a "corpus" of information, knowledge regarding the subject, the region, as is reasonably readily attainable.

Perhaps facilitated, initially/early on, by some sort of "geo-forum" affair/seminar/etc. Whitehorse representing an obvious choice of venue. Featuring, insofar as feasible, utilization of the available "geo-materials" themselves.

The localities; such as remain reasonably accessible, with the geology, the rocks, similarly accessible. Providing opportunity for the sites, their constituent materials, to "speak for themselves". To geo-types, young and otherwise.

Hopefully catalyzed by those other "geo-materials". Those knowledgeable individuals alluded to above. The ones with the extensive, and intensive, first-hand experiences on the Copper Belt. Featuring those erstwhile New Imperial Mines/Whitehorse Copper Mines types -- now "alumni" -- in particular. Among others, certainly.

Just some ideas. "Geo-phantasy", perhaps. From yet another of those "Variags". The "Vikings"; "the ones from out-of-town with all the answers" (S. M. Aleksandrov, personal communication,1973). Which the Whitehorse Copper Belt has seen so many of, suffered so much from. Yet -- generally -- graciously accomodated, humored, over the years.

For which this particular example of the ilk offers grateful acknowledgement, sincere appreciation.

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SUMMARY AND CONCLUSIONS:

The present report is intended to convey the following points:

These investigations were pursued in the context of concepts regarding skarns which have been developed and elucidated over many years. As summarized and presented by S. M. Aleksandrov in his definitive monograph "Geochemistry of Skarn and Ore Formation in Dolomites" (1998), and also dealt with in his numerous other contributions to the technical literature.
Including his recent (Geochemistry International, 2007, v. 45, No. 2) paper, entitled "Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns". A portion of this paper features the initial publication of our cooperative work on the Arctic Chief, and results, interpretations. This locality serving as one of several deposits exemplifying key features relevant to his topic.

Provide a statement of the recognition and confirmed occurrence of periclase (brucite) marbles at the Arctic Chief (west) locality. As well as recognition and confirmation of similar occurrences at the Little Chief and Black Cub South localities in the Whitehorse Copper Belt.

Comment on the significance of the formation of periclase (brucite) marble, in terms of the results of experimental petrology, known phase relationships, mineralogy, geochemistry, etc. Note the importance of this, in the context of these localities, and elsewhere.

Emphasize that the formation of periclase, as well as its (partial to apparently complete) replacement by brucite, both provide substantive insights as to petrogenesis, geochemistry, geological relationships, and mineralization, of potential value in a number of ways.

Observe that this apparently "initial recognition" of periclase (brucite) marble at the Arctic Chief (west), as well as at the Little Chief and the Black Cub South, suggests that perhaps further reinvestigation/reconsideration is merited of these, as well as associated rocks, "skarns", and mineralization in the area, the region, and elsewhere.
Such periclase (+/- brucite) marbles -- and associated/related materials -- perhaps (likely) lurking, as-yet-unrecognized/undetected/(unsought), elsewhere, in this, and other, regions. With attendant implications, scientific and "otherwise", regarding any such yet-to-be-recognized occurrences.
Among which implications,"practically speaking", recognition -- distinction as such -- of periclase (+/- brucite) marbles (and/or dolomite/"dolomitic" carbonate rocks as well) perhaps representing a potentially useful "exploration guide".

Provide as well the initial reported recognition of the presence of "calciphyres" at the Arctic Chief (west) locality. "Marble-like" rocks of predominantly carbonate composition, featuring a number of key mineralogical, geochemical, and textural characteristics, as well as spatial relationships, indicative of a magnesian skarn situation. Displaying typical banding of (variously) "rhythmic" character, attesting to metasomatic activity.

Note also the initial reported recognition of similar ("rhythmic") banding ("inherited") in "ore" specimens; featuring magnetite, +/- sulfides, (+/-), and associated "bands"/"layers" of forsterite/serpentine/phlogopite, +/-. Further indicative of the "magnesian skarn" character of this mineral deposit. While also affording significant evidence as to the nature of the deposition of the ore material(s).

Provide the initial reported recognition, and confirmation by Aleksandrov, of the formation (with subsequent pseudomorphous replacement by magnetite) of Mg-Fe borate mineral(s) -- "magnesian-ludwigite" -- in rocks at the Arctic Chief (west) locality. This is of relevance as additional evidence as to the "magnesian-skarn" character of this locality, and is also of decided interest in a number of other ways.

Thus, to our knowledge, this work has resulted in the first recorded elucidations, and confirmations, of the presence -- individually; and as a geological "spectrum" of significance as well -- of periclase (brucite) marbles, associated calciphyres, rhythmic banding in rocks, and in ores, as well as the occurrence of Mg-Fe borate mineral(s) of the ludwigite-vonsenite series, at the Arctic Chief (west), or elsewhere in the Whitehorse Copper Belt and environs.

Compositionally, texturally, spatially manifesting the sequence of geochemical and geological events, relationships, recognized and elucidated by Aleksandrov and co-workers; the "position(s)", and the "processes" attendant thereto. As recorded in, evidenced by, the rocks and the ores.

Featuring, as a matter of "position" (geologically, spatially, as observed in the field), the apparent relationships (displayed at various scales, up to deposit dimensions) of:
igneous rocks of granodioritic--quartz-dioritic--dioritic character;
"(calcic-)skarn" materials --- pyroxene, garnet, +/- ;
relative to the principal ("ore") occurrences of magnetite and other ore-minerals;
the (generally) relatively more "distal" calciphyres;
relative to the further-distally-positioned periclase (brucite) marbles; these representing the "outer zone of the contact aureole".

Individually, and collectively, these factors provide clear evidence of the "magnesian skarn" nature of this locality. As well as being consistent with the concepts developed by Aleksandrov and colleagues.

Supporting a suggestion, here, for consideration of the foregoing, in the overall context of "skarns", related mineralization, etc. Advancing a recommendation for "reconsideration" of (at least some/certain aspects of) "skarn" -- and related ore -- formation. As well as implications -- geologic, petrogenetic, geochemical; mineral resources. Per Aleksandrov (1998, 2007, and numerous other contributions to the technical literature).

The Arctic Chief (west) locality is demonstrably an example of a "magnesian-skarn". As our work has further shown, in particular it features a version of "primitive-type zoning", in this case developed/formed under the geological conditions of the "hypabyssal periclase facies", as considered in the context of the model of skarn-formation elucidated and refined by Aleksandrov and co-workers over a period of many years.

This model merits attention regarding the nature and origin(s) of "skarns", particularly with regard to those associated with "host" rocks of "dolomite/dolomitic/magnesium-rich" character. The composition of the precursorial/host rocks being a principal geochemical factor. The model affords a valuable conceptual, as well as substantively based, framework of theoretical background, fundamental knowledge, and relevant experimental work. As well, it offers ample evidence (the Arctic Chief, as just one more example), from a wealth of experience and analytical work, supportive of the validity of this approach to the genesis of skarns.

Appreciation, and utilization, of this approach ought to be an essential aspect of investigations intended to further the understanding of such geological occurrences. In turn, potentially yielding insights of "more practical" value in the exploration for, evaluation of, and production of mineral resources from deposits related to magnesian skarns. Such as has been the case in many areas, worldwide, as attested to by the experiences of Aleksandrov and associates.

The presence -- or absence -- of magnesian skarn, or subsequent modifications thereof, in a particular "contact metamorphic/metasomatic" geologic environment/occurrence of skarnlike character has decided relevance in terms of the likelihood, and nature, of associated mineral deposits. Extensive experience elsewhere has indicated, essentially demonstrated, that magnesian skarns are particularly "fertile ground" for the formation of related mineral deposits of several kinds. Including, possibly, precious metal(s) "nugget" formation.

Further pursuing the theme, to our knowledge, this work, per Aleksandrov's discussion in his 2007 paper, represents the first such treatment (at least published in the open literature) of the Arctic Chief from this particular viewpoint of the genesis of skarns and related ore formation. As such, it offers a somewhat different perspective than apparently has heretofore been brought to bear on this subject, at this particular locality/deposit, or in the Whitehorse Copper Belt, or in the region. Or in many other areas.

This would seem to be a perspective meriting more extensive appreciation, consideration, application than previously has been the case. Dr. Aleksandrov's comments regarding the Arctic Chief, based on information/data derived from the other sources he cites, in addition to our own, demonstrate the apparent applicability, "utility", relevance of this "model" to this particular locality/deposit. As well, in the context of this model, and its demonstrated usefulness elsewhere, suggesting possible implications with regard to skarn and ore formation elsewhere in this region too. Possible relevance to the formation of placer deposits being among these implications.

Our 2004-2007 investigation also resulted in the recognition of some interesting occurrences of molybdenite, and other associated sulphide mineralization, in the Arctic Chief area. Aspects of this are discussed in this report, Part 2, the "Data Supplement" addendum.

Implications of any/all of the above points, locally, elsewhere in the Whitehorse Copper Belt and environs, as well as regionally, remain to be evaluated. As may be appropriate, pursued further.

(Per our late lamented colleague R. S. Dietz, who once told me that he "always liked to try putting a little different spin on things".)

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1980-1982 Study-

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Gold Behavior during Endogenic and Supergene Alterations of Sulfides in Magnesian Skarns

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Abstract—The paper presents materials on the genesis of gold deposits of the magnesian-skarn association. It is demonstrated that sulfides are precipitated at these deposits late in the course of the mineral-forming process and often contain visible and fine gold. Post-sulfide mineral-forming processes resulted in the widespread development of hydroxisulfides: tochilinite and valleriite in high-Mg rocks and borate ores affected by serpentinization, brucitizatin, and szaibelyitization. The newly formed hydrosulfides inherit gold from the replaced sulfides. The endogenic or supergene decomposition of tochilinite and valleriite in endogenic and supergene environments stimulates the dissolution of the fine-grained gold and its remobilization, first, by hydrothermal solutions and, subsequently, by meteoric waters. The possibility is discussed of the later regeneration of gold as a consequence of electrochemical processes or at geochemical barriers. The deposition of "newly formed" gold in weathering crusts and placers is discussed, along with the significance of this process for assaying the potential of the weathering crusts and placers. It is emphasized that a significant role in this process is played by cryogenic processes, which can increase gold concentrations in naturally occurring solutions and facilitate its later regeneration. The data presented in this paper are compared with data on gold and PGE deposits of other genetic types, which are hosted in ultramafic rocks and carbonatites, i.e., rocks petrochemically similar to magnesian skarns. It is demonstrated that the occurrence of hydroxisulfides in the ores is a significant geochemical and technological problem during the exploration for sulfide ores and their mining and processing. The magnesian skarn ores of the deposits discussed in this publication were determined to be a significant source of both primary and placer gold and, perhaps, PGE also. The materials presented in the paper characterize the behavior of gold in the endogenic and supergene processes at magnesian skarn deposits.

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INTRODUCTION

Contact metasomatic mineral deposits localized in magnesian skarns are characterized by a broad spectrum of mineral resources: large deposits of iron, boron, tin, tungsten, beryllium, lithium, base and precious metals, etc., as well as economic deposits of sellaite, fluorite, phlogopite, brucite, nephrite, minerals utilized in the ceramic industry and as abrasive materials, gems, and colored stones. Marbles and calciphyres are used in cement production. This genetic group of skarn deposits still remains, however, poorly examined, as also is the potential of these deposits as sources of gold and accompanying PGE.

The main reason for this is the still inadequate scarcity of information on the chemistry and lithology of the host carbonate rocks, which are often combined in geological practice under collective names of limestones or marbles, without determining their Mg contents, their affiliation with certain types, and the character of their metasomatic alterations. Consequently, even at thoroughly examined deposits, there is often no clear classification of their carbonate rocks with limestone or dolomite, whose distinguishing is a problem of great applied significance for the exploration and revision of skarn mineral deposits.

Magnesian skarns are formed via the metasomatic transformation of dolomite in contact with magmatic melts. No calcic skarns develop after dolomites during the prograde stage, and when more mafic and ultramafic melts are emplaced, skarns at their contacts consist of abyssophobe high-temperature minerals (larnite, spurrite, and others). Calcitic rocks and even dolomites are transformed during the postmagmatic stage into calc skarns (wollastonite, salite, hedenbergite, and garnet types), and rocks with rhodochrosite compose their manganoan varieties.

Sulfide ore mineralization is precipitated late in the postmagmatic ore-forming stage and is typical of all types of skarns. This research is centered on magnesian skarn gold deposits in eastern Transbaikalia (Zheleznyi Kryazh, Bystrinskoe, and Kultuma ore fields), Aldan Shield, Norilsk, and the northwestern Baikal area in Russia, at the Hol Kol and Suan region deposits in North Korea, and the Arctic Chief in the Yukon Territory, Canada (the samples of ores and skarns were made available for us by courtesy of T.C. Mowatt of the United States Geological Survey).

We also used our original materials, as well as those of other researchers, on magnesian skarns in Central Asia and the Carpathian–Balkan region, which were determined to contain sulfides with gold also. These data were compared with materials on genetically distinct occurrences of precious metals in high-Mg rocks. A feature common for all of these deposits is the development of post-sulfide mineralization in the gold ores in the form of hydroxisulfides: tochilinite and valleriite.

GENESIS AND ZONING OF MAGNESIAN SKARNS

The types of skarns recognized according to the lithological compositions of the replaced rocks differ not only in their mineralogy but also in many other genetic aspects. Because of this, Korzhinskii [1] regarded bimetasomatic and contact–metasomatic magnesian skarns as an individual petrochemical association, which is genetically related to the replacement of dolomites and magnesites, as was proved at numerous deposits in Russia, China, and other countries [2–7].

Prograde-stage magnesian skarns replace dolomites at contacts with magmatic melts of various compositions (from granites to dunites) [5]. They are characterized by clearly pronounced metasomatic zoning, which reflects the introduction of magmatogenic Si, Al, and, partly, Fe. Intrusive rocks and their injections occur in direct contact with the outer-contact rocks, contain their xenoliths, and were not skarnified during this metasomatic stage.

The developing metasomatic aureoles have different complicated inner structures, which were controlled by the *P–T* parameters under which the hypabyssal skarns developed, from the periclase-free metasomatic facies to the gehlenite–merwinite and even spurrite–larnite facies. The magmatic replacement mechanisms of dolomites are also different: they can be infiltration-controlled, when the magma near the contact does not change its composition, or diffusion-controlled, associated with an increase in the basicity of the magma (from granodiorite to gabbro) and/or its alkalinity (up to nepheline syenite) as a consequence of the assimilation of the host rocks by the magma [7].

Existing data on economic copper and gold skarn deposits [8, 9] indicate that these deposits are genetically related mostly to intrusions of elevated basicity. The SiO_2 concentrations in granodiorites and diorites vary from 59.5 to 49 wt %, and these rocks contain 2.5–5 wt % MgO, 6.5–11 wt % CaO, 5.8–10.1 wt % Fe_2O_3, 4.8–2.6 wt % Na_2O, and 2.5–0.6 wt % K_2O, respectively.

The spatial restriction of gold deposits to the outer contacts of intrusions of this composition is clearly pronounced in the Altai–Sayan region, eastern Transbaikalia, Central Asia [8, 10, 11], Canadian Cordilleras [9, 12, 13], and the Rocky Mountains in the United States [14], as well as in several other areas around the world where gold-bearing magnesian skarns were found [14, 15], as, for example, in the Asian portion of the Pacific Ore Belt.

Compared to normal granites (with 72 wt % SiO_2), the rocks of the succession granodiorite $\longrightarrow$ diorite $\longrightarrow$ gabbro contain more mafic minerals (biotite, pyroxene, amphiboles, and magnetite), which are able to concentrate ore elements during magma crystallization and alterations by postmagmatic processes, which modify the original compositions of magmatic rocks and can produce ore mineralization.

Magmas of intermediate basicity, with SiO_2 concentrations specified above, are higher temperature than granites. The data in [16] on the melting temperatures of anhydrous magmatic rocks as a function of their silicity indicate that rocks of intermediate composition melt at 1220–1025°C, normative granites melt at approximately 800°C, their leucocratic varieties melt at even lower temperatures, and dunites melt at >1300°C.

Skarns develop in dolomites during the heating of the host rocks under the effect of transmagmatic fluids before the emplacement of the melts. Consequently, contact skarns are formed at temperatures close to those of magmatic melts, which assimilate dolomite marbles that have already been metasomatized. This is reflected in the mineral assemblages of the rocks and in the absence of chill zones in the intrusive rocks in contact with magnesian skarns at the deposits discussed in this paper.

The skarns with gold ore mineralization considered here are hypabyssal [5], and hence, their metasomatic aureoles are characterized by primitive zoning: granodiorite // fassaite and/or diopside skarn (± spinel) $\longrightarrow$ forsterite calciphyre (± spinel) $\longrightarrow$ (±brucitized periclase marble) $\longrightarrow$ dolomite marble. This zoning can be more complicated in contacts with diorites and gabbro, with the appearance of zones made up of high-temperature abyssophobe minerals (periclase marbles and monticellite skarns) [17–19]. These magnesian skarns ubiquitously contain no quartz-bearing associations, which occasionally occur in the overprinted calcic skarns and their greisenized varieties. The skarn bodies are localized in the contact zones of the intrusions and marbles and/or form steep veins, stockworks, and chimneys up to >400 m long in the latter [5].

Sulfide ores, including those with gold, in hypabyssal skarns are very diverse and are deposited during the postmagmatic stage, selectively replacing compositionally diverse metasomatic zones of the contact aureoles. This can be illustrated by the example of the Arctic Chief Cu–Au deposit, Yukon Territory, Canada. The materials on this deposit were provided for us by courtesy of T.C. Mowatt of the United States Geological Survey. His collection of ores and rocks represents magnesian skarns from deposits in the Whitehorse copper belt in the upper reaches of the Yukon River, where gold placers are also known.

ARCTIC CHIEF SKARNS AND ORE MINERALIZATION

In contrast to magnesian skarn deposits in Russia [1–8 and others], their analogues abroad were studied relatively poorly. Literature data on the Whitehorse belt are scarce [12, 13]. It is known that primary lodes mined in 1967–1982 yielded 10 million tons of ores that contained 121600 tons of copper, 9.7 tons of silver, and 7.7 tons of gold. The dumps of underground and opencast mines (~9 million tons) are thought to contain ~1.5 tons of Au, whose contents in the slimes can be as high as 250 ppm. These 32 deposits (including minor ore occurrences) are under exploration and considered promising as prospecting targets for Cu, Au, and Ag. The ore mineralization is hosted in Triassic rocks dominated by dolomites, whereas the quartzites, arkoses, graywackes, and younger porphyry dikes are barren [12].

The gold contents in sulfides from the Arctic Chief and related deposits vary [12, 13]. Chalcopyrite from the Arctic Chief deposit occurs in association with gold of the composition 92.29–88.02 wt % Au, 11.52–7.40 wt % Ag, and 0.21–0.40 wt % Cu and contains 0.2 wt % Au, and the bornite and chalcosine contain 0.04 wt % Au each. Valleriite, a younger hydroxisulfide, from the North Star deposit contains 0.05 wt % Au, i.e., as much as in the bornite (0.05–0.06 wt %), whereas the chalcopyrite contains no Au at all [13].

The deposits of the Whitehorse copper belt (Arctic Chief, Little Chief, North Star, and others) are restricted to the western contact of the intrusion and are hosted by metasomatically altered dolomites (Fig. 1). In the aureoles of the massif of biotite–hornblende granodiorites and diorites, these rocks are transformed into magnesian skarns, whose genesis and mineralogy are still known inadequately poorly. Geologists paid much attention to the composition of the Au- and Ag-bearing Cu ore mineralization [12, 13]. The results of the examination of skarn and ore samples from T.C. Mowatt's collection (~100 samples) allowed us to partly bridge this gap.

The dolomites of the Arctic Chief deposit are monomineralic and were progradely transformed during the magmatic stage into snow-white periclase marbles affected by brucitization. They compose the outer zone of the contact aureole of the granodiorite massif, whose contact zones consist of hornblende diorites. Closer to the intrusion, marbles give way to a zone of forsterite calciphyres with locally occurring boron mineralization, which was not found by previous researchers. The Mg–Fe borates are aggregates of ludwigite crystals.

These rocks give way to magnetite ores. At the boundary with the calciphyres, these ores contain forsterite and show a clearly pronounced rhythmically banded structure with repeatedly alternating monomineralic bands of forsterite and magnetite. Note that analogous structures, which were produced already during the prograde metasomatic stage in dolomites, also occur in the periclase marbles and calciphyres.

The magnetite ores are of postmagmatic genesis, as follows from the selective replacement of the carbonate constituent of the calciphyres by iron oxides and the preservation of the early forsterite. The rhythmically banded structures of metasomatites and ores were demonstrated [3, 5, and others] to have been produced by the thermodynamically unequilibrated process of dolomite replacement. According to I.R. Prigogine's theory, this is reflected in the spatial self-organization of the minerals. A necessary precondition of this process is the higher rates of the mineral-forming reactions than the inflow rates of endogenic fluids into the skarnified dolomites [3, 5].

Closer to the intrusion, the mineralogy of the magnetite ores that replaced the near-contact pyroxene zone of the aureole changes. The ores there contain variable (up to significant) amounts of phlogopite, which partly or completely replaced the spinel–diopside skarns. The barren varieties of the latter are in physical contact with the intrusion. The metasomatic zoning of the Arctic Chief skarns is generally characterized by the inheritance of the Mg/Ca ratio in each zone (excluding that of magnetite) from the pristine dolomites. The structures and compositions of all zones correspond to the *P–T* conditions of the periclase hypabyssal facies [5].

The magnesian skarns of the Arctic Chief deposit occur not only at contacts with the intrusion but also around injections of diorite melts into dolomites (Fig. 2). The rocks preserve their zoning and inclusions of Mg-ludwigite in the forsterite calciphyres but contain no magnetite ore mineralization.

During the postmagmatic stage, the zones of the contact aureole of magnesian skarns are replaced by magnetite ores, newly formed Mg-bearing minerals, including endogenic borates, and, later, calcic associations. The latter developed in the pyroxene zone, in intrusive rocks in contact with the skarns, and in the vein diorites. The overprinted associations of the periclase marbles consist of brucite pseudomorphs and, in the calciphyres, of clinohumite, which locally replaces forsterite, is syngenetic with the ludwigite, and contains <25 mol % of the vonsenite end member. The pyroxene zone contains phlogopite and younger salite (which bears 15–22 wt % of the hedenbergite end member [13]), vesuvianite, and tremolite. The calcic skarn minerals developing after the intrusive rocks are clinozoisite, epidote, and scapolite. Analogous transformations of the mineralogy of rocks are also typical of the contact zones of many magnesian skarn deposits [5] and are commonly identified in the American literature with postmagmatic-stage calcic skarns proper [13]. At deposits in the Whitehorse belt [12, 13], the latter are barren substratiform bodies of salite–garnet composition. They are bimetasomatic in genesis and replace silicate-bearing dolomite intercalations in the carbonate sequence.

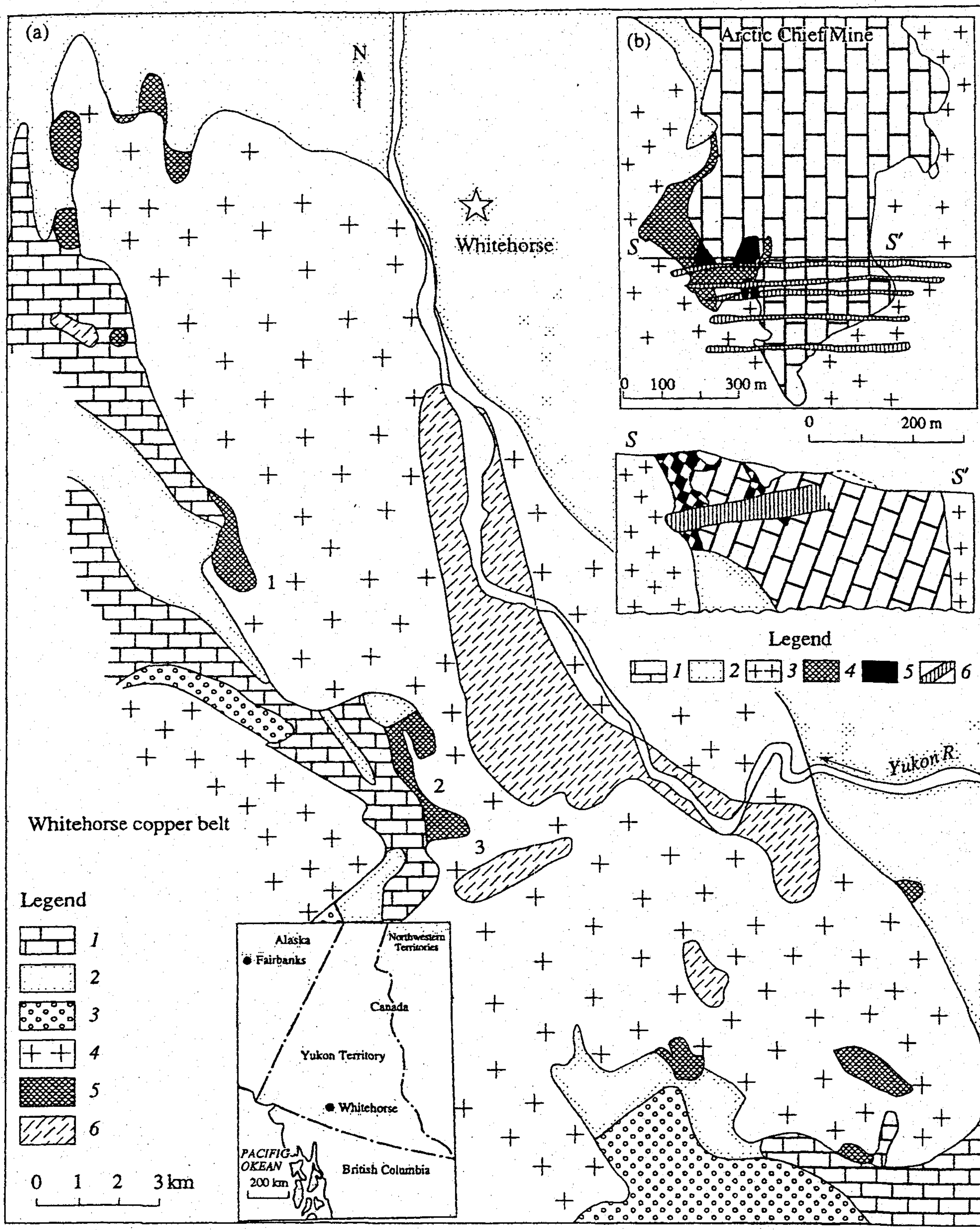

Fig. 1. Whitehorse copper belt and the Arctic Chief deposit in the Yukon Territory, Canada [17]. (a) Whitehorse copper belt. (*1*) Triassic dolomites; (*2*) Triassic terrigenous rocks; (*3*) conglomerates; (*4*) Jurassic intrusive rocks (granodiorites and contact-facies diorites); (*5*) Jurassic skarns with ore mineralization; (*6*) Quaternary basalts. (b) Map and cross section of the Arctic Chief deposit. (*1*) Dolomites; (2) quartzites; (*3*) diorites and granodiorites; (*4*) skarns; (*5*) orebodies; (*6*) postmineral porphyry dikes. Mineral deposits in the proximity of the town of Whitehorse: (1) Arctic Chief; (2) Little Chief; (3) North Star.

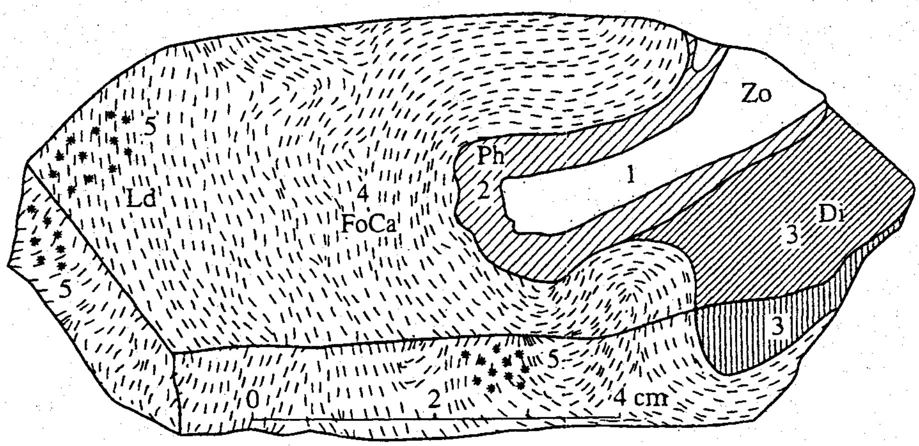

Fig. 2. Diorite injection in dolomite and zoning in magnesian skarns. Arctic Chief deposit (sample of T.C. Mowatt). (1) Diorite replaced by zoisite (Zo); (2) phlogopite–diopside skarn (Ph); (3) diopside skarn (Di); (4) rhythmlically banded forsterite calciphyre (FoCa); (5) disseminated crystals of magnesioludwigite (Ld). Magnification 2.5×.

Sulfide ore mineralization at the Arctic Chief and other deposits in the Whitehorse belt is overprinted onto the skarns and magnetite ores. It consists of lean pyrrhotite disseminations in marbles and calciphyres and of pocket-disseminated Au-bearing pyrrhotite–chalcopyrite and Ag-bearing bornite ores with chalcosine in magnetite bodies. The ores also contain electrum, native Ag, and subordinate amounts of tennantite, tetrahedrite, and Co-, Bi-, and Te-bearing minerals. The chalcosine in association with electrum contains up to 0.54 wt % Te [12, 13]. The ores sometimes contain molybdenite (T.C. Mowatt, personal communication in 2004).

The younger mineral-forming processes resulted in the replacement of the Mg-bearing minerals by brucite, serpentine, and talc. These processes at the Arctic Chief, Little Chief, and North Star deposits were related to the development of valleriite after the gold-bearing sulfide–magnetite ores [13, 20, 21].

The oxidation zone of the sulfide ores locally contains supergene cuprite, malachite, azurite, and iron hydroxides. The position of the Whitehorse belt in the permafrost zone with acutely continental climate in the Yukon Territory caused the more intense physical weathering of the rocks and ores than the chemical alterations of their minerals.

It can be concluded that the skarn deposits of this mining district in Canada show genetic and mineralogical features of their ores and rocks, including the presence of Mg–Fe borates, are similar or analogous to gold deposits in Transbaikalia, Aldan Shield, and the Russian Far East, which are localized in metasomatically altered dolomite sequences that were intruded by magmas of moderate basicity [5]. Tracing the genetic links of the gold–sulfide ore mineralization in magnesian skarns with magmas of other composition, it seems to be necessary to consider the setting of the ore mineralization at contacts of dolomites with granites or ultrabasic rocks.

SKARNS AND ORE MINERALIZATION IN CONTACTS WITH GRANITES

There are still scarce publications dealing with the gold potential of magnesian skarns genetically related to granite intrusions. Available data shed light onto the compositional features of the skarns and the *P–T* conditions under which the metasomatic zoning developed in the exoskarn aureoles and which controlled the origin of certain mineral assemblages that predated the sulfide mineralization and were coeval with it [5, 8, 17–19].

The lowest temperature types of skarns are genetically related to intrusions of leucocratic granites and alaskites into dolomites. The inner structures of their bodies correspond to the primitive type of metasomatic aureoles with the complete inheritance of the Mg/Ca ratio of each zone from the pristine carbonate rocks.

Skarns in contacts with granites are often greisenized, a feature that is weakly pronounced or is absolutely absent in contacts with more basic intrusions and is mineralogically accentuated by the occurrence of F-rich minerals (sellaite, fluorite, and fluoborite) that are associated with Sn and rare-metal (Be and Li) and with younger Au–sulfide ore mineralization [3, 5, 11, 22].

During the postmagmatic stage, the mineral composition of magnesian skarns is modified, and associated types of magnetite and borate mineralization are formed in these rocks, together with phlogopite and humites. This process is followed by the variably pronounced replacement of the metasomatites and nearby intrusive rocks by overprinted calcic skarns [2, 5, 22, 23]. This replacement can be seen most clearly in the compositional modification of the spinel–pyroxene zone in contact with intrusive rocks. The metasomatites are transformed into associations of Fe-rich pyroxenes (salite), clintonite, tremolite, vesuvianite, andradite-grossular garnet, zoisite, and even wollastonite, which are often accompanied by scheelite mineralization and high-Fe borates (vonsenite and paigeite) [2, 5, 22]. The

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near-contact magmatic rocks contain newly formed wollastonite, garnet, epidote, and axinite. The outer zones of the metasomatic aureole (phlogopitized skarns, forsterite- and clinohumite-bearing calciphyres, brucite–periclase marbles, and dolomites with borate mineralization) are preserved. This confirms that the earlier replaced magnesian and newly formed calcic skarns belong to the magnesian association.

It should be mentioned that magnesian skarns and their surrounding carbonate rocks are often "greisenized" in contact with leucogranites. The F-bearing mineral assemblages are associated with cassiterite and Li–Be ores, which predate the sulfide mineralization. The ores of these deposits are known to contain not only arsenides and various Cu and Fe sulfides but also Au and Ag tellurides and economic concentrations of native Au, Ag, and Bi, which are localized in both the skarns themselves and their greisenized zones, for instance, mica–fluorite rocks.

Deposits of this type in Russia are Lupikko in the Pitkjaranta ore field, Karelia, Arkinskoe, and other deposits in the Argun area, eastern Transbaikalia, magnesian skarns with ore mineralization in Khabarovsk region (Vostok II) and the Voznesenskoe ore field in Primorye in the Russian Far East. The greisens typically contain cassiterite, Li micas. and Be-bearing minerals, including helvite. Fluorite and sellaite develop (often in economic amounts) in dolomitic marbles. Many of these deposits are accompanied by genetically related gold placers.

Sulfide and gold ore mineralization of greisenized magnesian skarns in contacts with leucogranites is characterized by the following features. According to E.N. Nefedov (personal communication), he found gold grains at Lupikko in the Pitkjaranta ore field, Karelia, in mica–fluorite rocks, in which gold grains are spatially restricted to the cleavage planes of biotite and occur in association with Ni- and Co-bearing loellingite and Bi minerals. The gold inclusions were formed after the arsenide and are rimmed by younger tellurides. The magnetite ores contain graphite (?) in association with loellingite, sphalerite, and chalcopyrite and show evidence of valleriitization of Cu sulfides (Gerbets I deposit, Pitkjaranta), a process quite usual at deposits of this type.

SKARNS AND ORE MINERALIZATION IN EXOSKARNS AT ULTRABASITES

The highest temperature type of hypabyssal magnesian skarns develop in dolomites at contacts with ultramafic intrusions. The inner structures of their aureoles are largely controlled by the types of magmatic replacement of the carbonate rocks.

For example, at deposits in the Norilsk district, infiltration monomineralic forsterite skarns adjacent to monomineralic periclase rocks developed at contacts of dolomites and ultrabasites [24]. The skarns bear economic Cu–Ni postmagmatic vein–disseminated pyrrhotite and chalcopyrite ore mineralization (Table 1) with PGE, Au, and Ag. Diffusion skarn found in the area affiliate with the shallowest depth melilite- and spurrite–merwinite association [25] and are surrounded by periclase marbles (replacing dolomites) in the peripheries. These skarns are also accompanied by sulfide mineralization.

The magnesian skarns developing after dolomite xenoliths in the dunites of the Ioko-Dovyren Massif in northwestern Baikal area should also be attributed to the low-depth metasomatic facies [24, 26]. These skarns also show evidence of both infiltration and diffusion prograde metasomatism, with the former expressed in the transformation of the dolomites into monomineralic forsterite and periclase rocks in contact with dunites [24], and the latter is responsible for the development of a more complicated metasomatic zoning in dolomites: dolomite $\longrightarrow$ periclase marble $\longrightarrow$ forsterite calciphyre $\longrightarrow$ zones of abyssophobe skarns. The abyssophobe skarns belong to the monticellite and gehlenite–merwinite associations [26, 27]. The adjacent hybrid melts were characterized by decreasing basicity and crystallized in the form of plagioclase peridotites [24, 26].

Both the skarns and the ultrabasites of the Ioko-Dovyren Massif contain sulfide ore mineralization (pyrrhotite, Co-pentlandite, chalcopyrite, valleriite, and other minerals) accompanied by gold and PGE. This is not the only example of deposits of this type in Siberia. These deposits are known in Transbaikalia (Chiniiskii and Konder massifs) and elsewhere, but their gold potential is still known relatively poorly.

PRECIOUS METALS IN THE ORES OF COPPER–NICKEL DEPOSITS AND CARBONATITES

Ultramafic rocks accompanied by Cu–Ni deposits in the Norilsk district, near the town of Monchegorsk, in eastern Siberia, and elsewhere [28, 29] and carbonatites with Au–Cu ore mineralization (Kovdor in Karelia [30], Loolekop in South Africa [31], Jacupiranga in Brazil [32], and others) are petrochemically comparable with magnesian skarns and surrounding them calciphyres [30, 31] . Similarly to skarns, they often have rhythmically banded structures [33], which reflect the thermodynamically unequilibrated crystallization processes [3, 5] of carbonatites in hypabyssal environments.

Analogously to skarn deposits, they are characterized by the development of ore mineralization in a high-Mg environment, similar or identical mineral assemblages and the succession of post-sulfide modifications of the mineral composition of the host rocks, including their serpentinization, and the occurrence of endogenic hydroxisulfides (predominantly valleririte [30, 31, 34–38] and, more rarely, tochilitine) in these rocks.

Table 1. Composition (wt %) of sulfides in outer-contact disseminated ore, Norilsk deposit

Component	1	2	3	4	5	6	7	8	9	10	11
S	37.39	37.81	34.45	34.35	34.50	34.73	34.12	34.65	34.86	36.40	33.55
As	0.04	0.04	0.04	0.09	0.00	0.00	0.11	0.06	0.08	0.00	0.01
Fe	61.98	60.43	30.89	30.67	30.59	29.92	29.80	30.21	25.23	2.45	2.16
Cu	0.20	0.06	33.11	33.63	33.22	34.13	33.88	34.23	26.83	0.10	1.42
Zn	0.06	0.08	0.06	0.07	0.00	0.00	0.02	0.02	0.00	0.01	0.01
Ni	0.87	0.92	0.09	0.00	0.03	0.03	0.01	0.05	12.21	60.77	62.62
Co	0.18	0.11	0.00	0.01	0.00	0.04	0.05	0.01	0.15	0.02	0.00
Si	0.06	0.08	0.40	0.23	0.25	0.29	0.23	0.25	0.02	0.00	0.00
Ca	0.02	0.02	0.34	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.02
Mg	0.12	0.25	0.33	0.49	0.43	0.58	0.41	0.46	0.06	0.07	0.08
Al	0.00	0.02	0.17	0.07	0.09	0.13	0.08	0.10	0.00	0.06	0.06
Total	99.92	99.82	99.88	99.62	99.12	99.86	98.71	100.06	99.45	99.89	99.93
					Cation proportion						
Fe	0.935	0.992	1.03	1.02	1.00	0.99	1.00	1.00	0.83	0.04	0.04
Ni	0.015	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.91	1.00
Co	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cu	0.97	0.00	0.97	0.99	0.99	0.99	1.00	1.00	0.78	0.00	0.02
ΣM	0.95	0.93	2.00	2.01	1.99	1.98	2.00	2.00	1.99	0.95	1.08
S	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00

Note: (1, 2) Pyrrhotite, (3–8) chalcopyrite, (9) Ni-bearing chalcopyrite, (10, 11) millerite. Microprobe analyses, analyst V.G. Senin, Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences.

In carbonatites, the former mineral replaces Cu-bearing sulfides (mackinawite, pyrrhotite, chalcopyrite, and others), while the latter replaces pyrrhotite (author's data).

Evidence of analogous processes can be observed in sulfide-bearing metasomatically altered dunites of Mount Jumbo, Washington, United States, which contain Cr-ludwigite mineralization. In these rocks, chalcopyrite is also replaced by valleriite $Cu_{0.82}Fe_{1.09}S_2 \cdot 1.6(Mg_{0.77}Al_{0.23})(OH)_{2.23}$ [39].

It was mentioned above that dolomites in contact with ultramafic intrusions also contain magnesian skarns. Their sulfide ores commonly contain Ni, Co, intermetallic compounds of PGE, and Au (including native Au).

These facts testify that the ore deposition processes in ultramafics and carbonatites and their subsequent hydrothermal alterations are geochemically comparable with analogous processes in magnesian skarns. This also pertains to the endogenic and supergene transformations of minerals containing precious metals in these rocks.

Supergene processes responsible for the migration and possible regeneration of gold and PGE during the denudation of hyperbasites, phoscorites, and carbonatites are still known relatively poorly. These metals are known to occasionally occur in placers, often in the form of large nuggets, which have never been found in the primary rocks, whose concentrations of precious metals are at the clarke levels. An example is unique placers in the Urals and the Konder deposit in Khabarovsk region.

GENESIS AND COMPOSITION OF SULFIDE ORE MINERALIZATION

The deposition of sulfide ore mineralization takes place in skarns during the latest postmagmatic stage of the mineralizing process [2, 5, 22, 28, 40]. Dolomites at some of these deposits contain anhydrite as a possible source of sulfur. This does not rule out the significant role of magmatic sulfur, as also follows from its isotopic composition in sulfides from these deposits [5].

The ore minerals are S-undersaturated pyrrhotite, arsenopyrite or loellingite, chalcopyrite, cubanite, and bornite at subordinate amounts of Fe, Cu, Zn, Ag, Bi, Sn, Te, and Se sulfides containing Au in the form of an isomorphic admixture and as a native metal. The ores contain younger As and Sb sulfosalts [4, 22, 28, 41–43] and native Ag and Bi. Pyrite is rare but is occasionally contained in the marbles and overprinted calcic skarns in the outer and inner contact zones.

Sulfides of Fe (pyrrhotite and more rare troilite and mackinawite) and Cu (chalcopyrite, bornite, cubanite, and others) are typomorphic of all zones of the magnesian skarn bodies and often replace earlier magnetite. Loellingite and arsenopyrite additionally replace Fe–Mg borates of the ludwigite and paigeite series [28] or are contained as disseminations and pockets in phlogopite and in pyroxene (salite), tremolite, vesuvianite, and garnet skarns. Other sulfides, sulfosalts, and native metals are disseminated in all of the metasomatic rocks or compose stringers in them. The highest concentrations of Bi minerals were found in overprinted calcic skarns, for example, at the Hol Kol deposit in North Korea [2, 5, 22, 40, 42, 44].

Literature on gold deposits of various genesis contain information on the occurrence of Co, Ni, and PGM in sulfide ores. Gold and PGE coexist in mineralized magnesian skarns in Siberia (Gornaya Shoriya, Norilsk mining district, northwestern Baikal area, Transbaikalia, and Khabarovsk krai) [5, 28, 43, 45] in Russia and, in Europe, at the Banat, Romania; Rhodope Mountains, Bulgaria; and elsewhere [41, 46].

GOLD IN ARSENIDES AND SULFIDES

Our data on the gold potential of sulfide ores at many magnesian skarn deposits both in Russia and elsewhere [28] make it possible to identify the occurrence modes of precious metals in them. The loellingite contains variable amounts of Au, up to 0.24 wt % at the Titovskoe borate deposit in the Cherskii Range and 0.33 wt % Au in the greisenized skarns of the Lost River Mine, Alaska, United States. At other deposits, Au concentrations are about 0.04 wt % or below the detection limit of microprobe analysis. Arsenopyrite from paigeite ores from the Moral'nyi Prospect of the Titovskoe deposit contains 0.08–0.31 wt % Au, and kotoite-bearing calciphyres of the Baita Bihor deposit in Romania, which also bear tellurides, contain up to 0.11 wt % Au. Arsenopyrite in sulfide ores from the Serdtse-Kamen' deposit in Chukotka was determined to bear up to 0.25% Au.

Iron sulfides can also contain gold. For example, troilite in sakhaite rocks from the Dokuchan deposit in the Cherskii Range contain 0.12 wt % Au. More widespread pyrrhotite from the ludwigite-bearing calciphyres of the Lebedinoe deposit in the Aldan Shield contains 0.04–0.12 wt % Au, and the analogous values are 0.06–0.20 wt % for the ludwigite ores of the Gol'tsovoe deposit, Cherskii Range, 0.06–0.10 wt % for the Krumovo deposit in Bulgaria, 0.15 wt % for the sulfide–ludwigite ores of Mount Brooks, and 0.08 wt % for the Bessie and Maple occurrence in the Lost River ore field in Alaska. Pyrrhotite in ludwigite–magnetite ores from the Dokuchan deposit contain 0.02–0.10 wt % Au. Diopside skarn in Gijhdarva, Tajikistan, contains pyrrhotite with 0.12–0.16 wt % Au, and this mineral contains 0.07–0.1 wt % Au at the nearby Taror deposit and 0.02–0.11 wt % Au in the ludwigite–kotoite marbles at Hol Kol, Suan, North Korea.

Sphalerite often is barren of gold, but marmatite contains 0.06 wt % gold when occurring in ludwigite ores at the Titovskode deposit and 0.05 wt % gold at the Baita Bihor deposit, Banat, Romania. This is likely caused by the occurrence of 2 wt % Cu in ZnS in the form of emulsion chalcopyrite dissemination.

Chalcopyrite contains variable Au concentrations, which are sometimes as high as 0.25 wt % in greisenized skarns with aikinite, bornite, and Bi-bearing minerals at the Karadjhal deposit in the Digilenskie Mountains, in Kazakhstan. Low Au concentrations (no more than 0.04 wt %) were detected in chalcopyrite from valleriitized borate ores from the Zapadnoe deposit in the Bystrinskoe ore field, eastern Transbaikalia, and 0.01 wt % in sulfide-bearing calciphyres of the Lebedinoe deposit in the Aldan Shield.

Chalcopyrite in the ores from calciphyres of the Baita Bihor deposit in Banat, Romania, contains 0.02–0.15 and 0.30 wt % Au, whereas this mineral from sulfide-bearing spinel–fassaite skarns of the Traversella deposit, Italy, contains no more than 0.05 wt %. Gold (up to 0.10–0.22 wt %) was detected in chalcopyrite from the ludwigite-bearing calciphyres of the Grizzly Gulch, Little Cottonwood Canyon, Utah, in which chalcopyrite is associated with pyrrhotite and Ag- and Bi-bearing minerals and is replaced by valleriite. Gold (0.02–0.07 wt %) is contained in chalcopyrite from the suanite–ludwigite ores of Blind Mountain, Nevada [28]. This mineral from the Bessie and Maple occurrence, Lost River, Alaska, contains variable Au concentrations, from 0.05 to 0.17 and even 0.38 wt %.

Pyrite from the Taror skarns contains 0.04–0.09 wt % Au, and this mineral from Gijhdarva, Tajikistan, bears more than 0.08–0.32 wt % Au. Analogous gold concentrations were found in iron disulfide contained in calciphyres from the Lebedinoe deposit. High Au contents (0.18–0.23 wt %) were detected in pyrite from ludwigite–magnetite ores of the Chingatai deposit in eastern Transbaikalia. Pyrite from Grizzly Gulch, Little Cottonwood Canyon, Utah, contains 0.19 wt % Au, and this mineral from the Bessie and Maple occurrence, Lost River, contains 0.42 wt % Au. Pyrite from the Hol Kol deposit in Korea bears 0.36 wt % Au.

Younger Cu-bearing sulfides also contain Au. For example, chalcosine from harkerite rocks of Camas Malag, Skye Isle, Scotland, contains 0.12 wt % Au, and the accompanying bornite contains 0.05–0.08 wt % Au.

Lead sulfide also contain gold and, often, also silver. Galena from sulfide ores of the Serdtse-Kamen' deposit in the Chukot Peninsula bears up to 0.12 wt % Au. This mineral contains 0.09 wt % Au when occurring in greisenized skarns of the Karadjhal deposit in Kazakhstan, 0.05–0.17 wt % Au in calciphyres of Baita Bihor, Romania, 0.05 wt % Au in Skye Isle, Scotland, 0.15 wt % in the Mount Brooks skarns, and 0.11 wt % at the Bessie and Maple occurrence in Alaska. Boulangerite from kotoite marbles from Baita Bihor contains up to 0.21 wt % Au, and tetrahedrite from the Hol Kol deposit, Korea, bears

0.29–0.33 wt % Au. Molybdenite from this deposit contains variable Au concentrations, from 0.03 to 0.19 and even 0.45 wt %.

The data presented above on the gold-bearing sulfides were obtained by examining hand-specimens of boron-bearing calciphyres, ludwigite and magnetite ores, and magnesian skarns from the author's collection [5, 28, 40, 47]. This study was not associated with the systematic sampling of the orebodies, and the results presented here should be considered provisional and can be taken into account when the gold potential of the sulfide ores of these and other skarn deposits is assayed.

Literature data indicate that sulfides (except their Ag-, Bi-, and Te-bearing species) contain almost no isomorphous Au. Conversely, micrometer-sized to visible inclusions of native gold occur at dislocations of their crystals and in the intergranular space [4], as was confirmed by the results of this research. Gold also forms veinlets in skarns and marbles, for example, at the Hol Kol deposit in North Korea, thus reflecting gold migration and redeposition by hydrothermal solutions.

The data presented above on gold concentrations in magnesian skarns and the contact zones of leucogranites and alaskites that were intensely greisenized with the development of fluorite and F-bearing silicates (norbergite, phlogopite, and Li-micas) and the overprinting of sulfides and tellurides indicate that this magnesian-skarn type of gold mineralization deserves more detailed examination. This also follows from the find of Au (2 ppm), Ag (5 ppm), and Pt (0.5 ppm) in rhythmically banded fluorite metasomatites of the Voznesenskoe ore field in the Russian Far East [11], which contains Be ores.

The materials presented above imply that skarns having various mineral composition and affiliating with different facies are favorable for the deposition of sulfides with gold. Their concentrations can be mined from the orebodies and related placers, as is currently done at some deposits or can be considered for future development with the application of more advanced technologies of the recovery of precious metals.

Magnesian skarns at contacts with ultramafic intrusions also contain sulfides. The hypabyssal spinel–monticellite (±perovskite, melilite, and merwinite) skarns that replaced dolomite xenoliths in dunites in the Ioko-Dovyren Massif, northwestern Baikal area, were determined to contain Co-pentlandite (38.57 wt % Co, 9.63 wt % Ni), mackinawite (9.7–10.6 wt % Co), troilite, galena, clausthalite, native gold, silver, and tin, and valleriite [26]. This is consistent with the composition of the sulfide ore mineralization in the hyperbasites, which contain troilite–pyrrhotite ores with pentlandite, chalcopyrite, and cubanite that contain unevenly distributed PGE and Au. For example, the anorthosites of this massif contain 4.1 ppm Pt, 7.8 ppm Pd, and 3.2 ppm Au, whereas the Cu–Ni ores in dunites are richer in Pd [26].

The metasomatic aureoles in marbles around hyperbasite intrusions in the Norilsk mining district are tens of meters thick. The dolomites are replaced by hypabyssal skarns, calciphyres, and overprinted calcic skarns. Their sulfide ore mineralization corresponds to the types of Cu–Ni pyrrhotite–chalcopyrite–pentlandite ores with cubanite known at the Norilsk I, Talnakh, and Oktyabr'skoe deposits. The ores ubiquitously contain valleriite (0.5–5 vol %) and precious metals: PGE (Pt, Pd, and others), Au, and Ag [33].

The ore mineralization in the outer contact zones is hosted in brucite rocks (pyrrhotite, pyrite, and magnetite), serpentinized magnesian skarns (Table 1), calciphyres, and calcic skarns (pyrrhotite, pentlandite, chalcopyrite, and millerite). These stringer–disseminated outer-contact ores pervasively contain PGE (0.5–7 ppm Pt, 1–35 ppm Pd, and 0.01–0.21 ppm Rh), Au (0.01–10 ppm), and Ag (0.77–17.6 ppm) [37].

The highest valleriite concentrations were found at the Talnakh (up to 15 vol %) and Oktyabr'skoe (up to 9.5 vol %) deposits (data of V.M. Isoitko, 1978 [37]). This provided grounds to distinguish millerite–pyrrhotite–valleriite ores as an individual type, which contains 5–7 vol % hydroxisulfide. This mineral was also found in the mineralized serpentinites and brucitites. Valleriite and tochilinite are formed during the post-sulfide stage (see below) of the hydrothermal process, simultaneously with significant transformations of the mineralogy of the gold-bearing ores.

POST-SULFIDE MINERAL-FORMING PROCESSES

Sulfide ores in magnesian skarns and other rocks of similar petrochemical composition (ultrabasites and carbonatites) typically contain mixed-layer hydroxisulfides, such as tochilinite, valleriite, and more rare haapalaite ($(Fe_{1.26}Ni_{0.74})S_2 \cdot 1.61(Mg_{0.84}Fe_{0.16})(OH)_2$ and yushkinite $V_{1-x}S \cdot (Mg,Al)(OH)_2$) [28, 40, 41, 44]. They replace sulfides and/or magnesioludwigite [2, 28, 40] and are syngenetic with the serpentinization of Mg silicates and, what is important, are coupled with the brucitization of skarn minerals, including Mg oxides and carbonates, and the szaibelyitization of Mg and Mg–Fe borates [28, 40]. Many magnesian-skarn gold deposits at contacts with granitoids, as well as copper–nickel deposits related to ultrabasites and carbonatites, ubiquitously contain tochilinite $2FeS \cdot 1.67(Mg, Fe^{2+}, Al)(OH)_2$ and, more often, valleriite $CuFeS_2 \cdot n(Mg, Fe, Al)(OH)_2$ (Table 2). Their composition reflects both the position of these minerals in the mineralogical systematics and the occurrence of $Mg(OH)_2$, $Fe(OH)_2$, $Mn(OH)_2$, $Al(OH)_3$, and other components in the oxide group of these minerals [28, 34–36, 38, 40].

Valleriite and, later, also tocilinite were first found in Cu–Ni ores genetically related to ultrabasites, in which hydroxisulfides are often rock-forming minerals. Laputina [34] and other researchers [29, 35, 36] have demonstrated that these minerals actively replace various types of sulfide ores, predominantly pyrrhotite,

Table 2. Composition of tochilinite and valleriite: $n(Fe,Cu)_{2-x}S_2 \cdot m[(Mg, Fe)(OH)_2 + Al(OH)_3]$

Deposit	Fe	Cu	ΣM *n*	S	$Mg(OH)_2$	$Fe(OH)_2$	$Al(OH)_3$	Σ *m*
				Tochilinite				
Zheleznyi Kryazh, Transbaikalia*	1.95	0.05	2.00	2	0.85	0.00	0.15	1.51
	1.93	0.01	1.94	2	0.86	0.05	0.09	1.49
Titovskoe NE Russia*	1.80	0.14	1.94	2	0.54	0.23	0.23	1.53
Same* (replacing troilite)	2.00	0.00	2.00	2	0.88	0.01	0.11	1.38
Same* (replacing pyrrhotite)	1.98	0.00	1.98	2	0.84	0.11	0.05	1.40
Gavasai, Kyrgyzstan*	1.86	0.00	1.86	2	0.00	1.00	?	1.47
Kamaisi, Japan [34]	1.34	0.34	1.68	2	0.78	0.00	0.22	1.67
	1.26	0.48	1.74	2	0.79	0.00	0.21	1.65
Pensilvania, United States [38]	1.62	0.00	1.62	2	0.79	0.00	0.21	1.79
Jacupiranga, Brazil (C) [32]	1.78	0.00	1.78	2	0.39	0.31	0.30	1.67
				Valleriite				
Zapadnoe, Transbaikalia*	1.12	0.88	2.00	2	0.77	0.23	0.00	1.33
	1.37	0.63	2.00	2	0.96	0.00	0.04	1.08
	1.34	0.66	2.00	2	0.94	0.00	0.06	1.16
	1.56	0.38	1.94	2	0.91	0.00	0.09	1.47
Kultuma, Transbaikalia*	0.96	1.04	2.00	2	0.90	0.10	0.00	1.64
	0.90	1.01	2.00	2	0.88	0.12	0.00	1.63
Baita Bihor, Romania*	0.93	1.07	2.00	2	0.86	0.14	?	1.67
Hol Kol, North Korea*	0.98	1.02	2.00	2	0.85	0.06	0.09	1.24
	0.92	1.08	2.00	2	0.87	0.02	0.11	1.35
Grizzly Gulch, Utah, United States*	0.99	1.01	2.00	2	0.80	0.00	0.20	1.80
Little Chief, Yukon, Canada [21]	0.81	1.19	2.00	2	0.71	0.06	0.23	1.64
	0.80	1.20	2.00	2	0.73	0.21	0.06	1.67
	1.07	0.93	2.00	2	0.68	0.00	0.32	1.53
North Star, Yukon, Canada [13]	0.80	1.20	2.00	2	?	0.12	?	–
Kaveltorp, Sweden [38]	1.16	0.84	2.00	2	0.73	0.00	0.27	1.30
Norilsk, Siberia [34]	0.95	1.05	2.00	2	0.86	0.14	–	1.51
Same**	1.61	0.39	2.00	2.2	0.05	–	0.34	1.65
Kovdor, Karelia (C) [30]	1.18	0.82	2.00	2	0.79	–	0.21	1.61
Same (C)	1.47	0.53	2.00	2	0.78	–	0.22	1.63
Loolekop, South Africa (C) [38]	1.03	0.95	1.98	2	0.73	0.00	0.27	1.57
Same (F) [38]	1.02	0.98	2.00	2	0.65	0.34	–	1.70
	1.05	0.95	2.00	2	0.76	0.22	0.02	1.66
	0.96	1.04	2.00	2	0.75	0.16	0.09	1.67
Jumbo, Washington, United States *(D)	1.09	0.82	1.91	2.1	0.77	0.00	0.23	1.60

Note: From sulfide-bearing magnesian skarns and calciphyres according to * our [28, 39, 40, 44, and others] and literature data, including hydrozisulfides from sulfide-bearing carbonatites (C), phoscorites (F), and dunites (D). **Valleriite with 61 mol % $Ca(OH)_2$ in its oxide constituent.

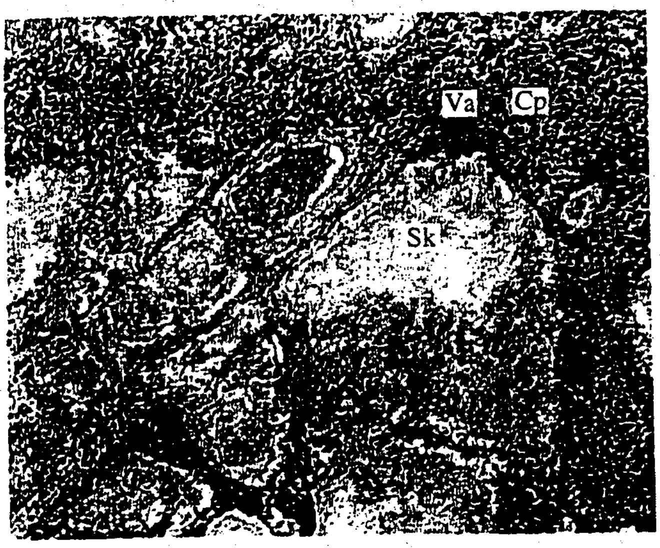

Fig. 3. Outer-contact stringer–disseminated copper–nickel ores, Norilsk. Valleriite (Va) surrounds chalcopyrite (Cp) in skarns (Sk). Magnification 2×.

Cu–Ni, and containing magnesian minerals ones, at the Norilsk group of deposits. The hydroxisulfides have variable compositions (Table 2) of their sulfide and hydroxide constituents at significant structural differences between them [35].

It was established [34] that valleriite of the Norilsk deposits contains 7–16 wt % Cu in pentlandite–chalcopyrite–pyrrhotite ores and 17–22% Cu in the millerite–bornite–chalcopyrite and pentlandite–chalcopyrite ores. The pentlandite–pyrrhotite ores with subordinate amounts (3–5 vol %) of chalcopyrite contain mostly tochilinite.

The composition of the hydroxyl constituent of hydroxisulfides is controlled by the composition of the silicates, first of all, serpentinized forsterite and iron oxides, including magnomagnetite. They are contained in both the magmatic rocks and the adjacent metasomatites that replace dolomite and often contain anhydrite. The valleriite of these associations commonly contains Mg (11–12 wt %), whereas the tochilinite bears up to 14 wt % Mg.

Hydroxisulfides of other composition (Table 2) occur less frequently at the Norilsk deposits. The massive chalcopyrite, cubanite, and talnakhite ores contain newly formed Mg-free valleriite of the composition $CuFeS_2 \cdot nFe(OH)_2$, and tochilinite of the composition $2Fe_{1-x}S \cdot nFe(OH)_2$ replaces troilite and hexagonal pyrrhotite in the monticellite skarn. The melilite–merwinite skarns were determined to contain high-Ca valleriite $CuFeS_2 \cdot n[(Ca,Al)(OH)_2]$, which replaces cubanite and pyrrhotite. The sulfides have variable Cu concentrations, from 11 to 3–4.5 wt % [35].

Valleriite (whose composition was not determined) was also found in gehlenite–spurrite skarns of shallow-depth facies at the Fuka deposit, Okayama Prefecture, Japan. I. Kusachi found this mineral in association with loellingite, arsenopyrite, chalcopyrite, cubanite, pyrrhotite, witticherite, and other sulfides (I. Kusachi, personal communication on August 27, 1998).

We established [28, 40, 43, 44] that valleriite and tochilinite are also typomorphic post-sulfide minerals at gold deposits of the magnesian skarn ore association. This significantly expands our knowledge of the occurrence of hydroxisulfides in various genetic types of sulfide ores (Table 2).

The genetic role of the replacement of Fe and Cu sulfides by hydroxisulfides in the endogenic and supergene geochemistry of Au and PGE is still poorly understood [28, 39, 40, 43, 44]. The significance of the problem of the tochilinization and valleriitizatin of sulfides in serpentinized ultramafic rocks related to the genesis of Cu–Ni ores with PGE and Au was first highlighted by the data obtained by Ramdohr [37] and other researchers of these minerals [34–36, 38].

Tochilinite and valleriite have a low hardness and are ductile and layered, i.e., possess characteristics hampering the identification of these minerals. In association with pyrrhotite, chalcopyrite, and other sulfides, these minerals are commonly misidentified as graphite based on their optical characteristics. In the ores of Cu–Ni skarn deposits, valleriite and tochilinite develop along the grain boundaries of sulfides and rim sulfide grains (Fig. 3). When these ores are technologically processed (crushed and floated), it is practically impossible to get rid of hydroxisulfides, and thus, the technological concentrating process of these ores is associated with significant losses not only of Cu but also of precious metals [31, 48].

As was recently demonstrated in [2, 28, 40, 44], when replacing Au-bearing sulfides, Fe and Cu hydroxisulfides inherit their Au in the form of fine-grained native metal. For example, tochilinite from Zheleznyi Kryazh, Transbaikalia, contains 0.01–0.4 wt % Au, and valleriite from the Zapadnoe deposit contains 0.05–0.15 wt % Au (the chalcopyrite contains 0.04 wt % Au). These concentrations are comparable with those published for deposits in the Whitehorse belt in Canada.

In the process of endogenic and supergene alterations, minute gold particles contained in hydroxisulfides are dissolved more easily than large gold grains (because of the greater specific surface of smaller grains). This process is additionally facilitated by the general chemical instability of tochilinite and valleriite in surface environments. These minerals are replaced by magnetite with the release of dissolvable Mg, Fe, and Cu sulfates. The latter, in turn, create favorable conditions for gold migration in acid hydrothermal solutions and its redeposition when conditions change, for example, at geochemical barriers (as at reactions with carbonates). Evidence of this process is the development of thin veinlets of native gold along cleavage planes of calcite in marbles, for example, at the Hol Kol borate magnesian-skarn deposit, the largest in North Korea (author's data). At this deposit, gold-bearing marbles occur near chalcopyrite–magnesioludwigite ores, which are replaced by valleriite [28, 40, 44].

Eastern Transbaikalia (at the Bystrinskoe, Koltuminskoe, Zheleznyi Kryazh, Arkinskoe, and many other deposits in the Argun–Gazimur divide), Aldan Shield (Lebedinoe and other deposits), and the Yukon Territory in Canada (Whitehorse copper belt) contain economic gold-bearing alluvial placer deposits. Their genesis was predetermined by the denudation of primary magnesian skarn deposits with gold-bearing sulfides and provide evidence of their significant role as a source of placer gold. The gold potential of these deposits is still not depleted.

For example, it is thought that mineralized skarns in the Bystrinskoe field contain 0.6 ppm Au and 1.5% Cu at predicted reserves as large as 130 tons of Au, 4 million tons of Cu, and 93000 tons of Ag [11]. Placers at the Bystrinskii group of deposits ubiquitously contain scheelite, which was mined in the Bystraya and Il'dikan river valleys in the 1940s. The sources of the valuable minerals of these placers were the Zapadnoe (Fig. 4), Vostochnoe, Malyi Mednyi Chainik, and other deposits of magnesioludwigite ores with pocket and disseminated pyrrhotite–chalcopyrite ore mineralization that is extensively replaced by valleriite during the serpentinization of the forsterite skarns and calciphyres and the replacement of the borate ores by szaibelyite [2, 5, 28, 40]. Although the black-sand panning samples contain no preserved minerals of magnesian skarns other than magnomagnetite, these samples contain garnet and, near primary deposits, also pyroxenes, scheelite, and gold (905–976 fineness) [28]. When these placers were washed for gold by small diggers, the first priority targets were sands with magnetite and scheelite as those richest in gold.

The Zheleznyi Kryazh sulfide-bearing ores and, particularly, the pyrrhotite-bearing borate ores of the Rudnichnaya body are also significantly replaced by tochilinite and valleriite (Fig. 5) [2, 28, 40]. The ludwigite and magnetite ores are localized in magnesian skarns that developed in dolomites of the Bystrinskaya Formation of Paleozoic age. They contain up to 29% fine (no larger than 0.07 mm) and coarser grained (up to 1 mm) gold, as well as lumpy and amoeba-shaped unrounded gold grains in aggregates with chalcopyrite. The denudation of the orebodies of the deposit gave rise to related alluvial gold placers in the valley.

In the oxidation zone, sulfides and hydroxisulfides are supergeneously replaced by Fe and Cu hydroxides, which can adsorb Au and release it under the effect of sulfate- and thiosulfate-bearing groundwaters. This can be exemplified by deposits in eastern Transbaikalia, whose tochilinite- and valleriite-bearing ores are transformed into magnetite sands loosely cemented with calcite. We identified such newly formed rocks at the Zheleznyi Kryazh and at the Zapadnoe deposit in the Bystrinskoe ore field. At the latter, they occur in the most deeply eroded orebodies in the southern flank of the deposit.

At many other skarn deposits, hydroxisulfides are completely oxidized but still can be identified in supergeously unaltered ores [28, 40, 43]. For example, the supergene alteration products of chalcopyrite that has been replaced by valleriite (Table 2) in the ludwigite-bearing calciphyres at Grizzly Gulch in Utah are iron hydroxides and malachite with 0.19–0.52% fine gold.

A similar situation occurs at the Kultuma ore field on the Gazimur River, but the predominant primary sulfide of the boron-bearing skarns and calciphyres is chalcopyrite, which is partly replaced by valleriite [43]. Gold-bearing placers in the valley were mined for more than one century (until 1958) and were thereby repeatedly rewashed.

Genetically analogous placers promising for gold and cassiterite are widespread along some tributaries of the Argun in the Bogdatsk–Arkia mining district in Transbaikalia. These placers are genetically related to sulfide-bearing magnesian skarns with magnetite, cassiterite, beryllium, and bismuth ore mineralization at contacts with leucogranites [11].

In the Aldan district in Siberia, gold is produced by the long-term development of the Lebedinoe deposit, which is hosted in skarnified dolomites intruded by Mesozoic syenites [49]. In addition of sulfide ore mineralization of chalcopyrite, pyrrhotite, and pyrite with subordinate amounts of galena, Bi-bearing minerals, sulfosalts, and tellurides, including calaverite, the marbles contain native gold and disseminated magnesioludwigite and szaibelyite. Our data indicate that the latter minerals sometimes contain valleriite. Along with primary deposits, gold was extracted in this area for more than 50 yr from alluvial placers. The reserves of the ore mineralization are comparable with that at the Hol Kol deposit in North Korea. Recently other gold-bearing skarn deposits (Samolazovskoe and others) were found in this area, and this confirms that the area is promising for exploration for gold.

"NEW" GOLD IN PLACERS AND WEATHERING CRUSTS

The data presented above on the spatial relation of gold placers to its primary deposits call for the analysis of gold geochemistry in supergene environments.

In spite of inconsistencies in literature data on the possible scale of supergene gold migration with groundwaters, the possibility of this process is taken for granted and is generally not questioned any more. This is directly related to the applied aspect of this problem, namely, the possibility of the origin of supergene "new" gold as a consequence of its remobilization and, what is

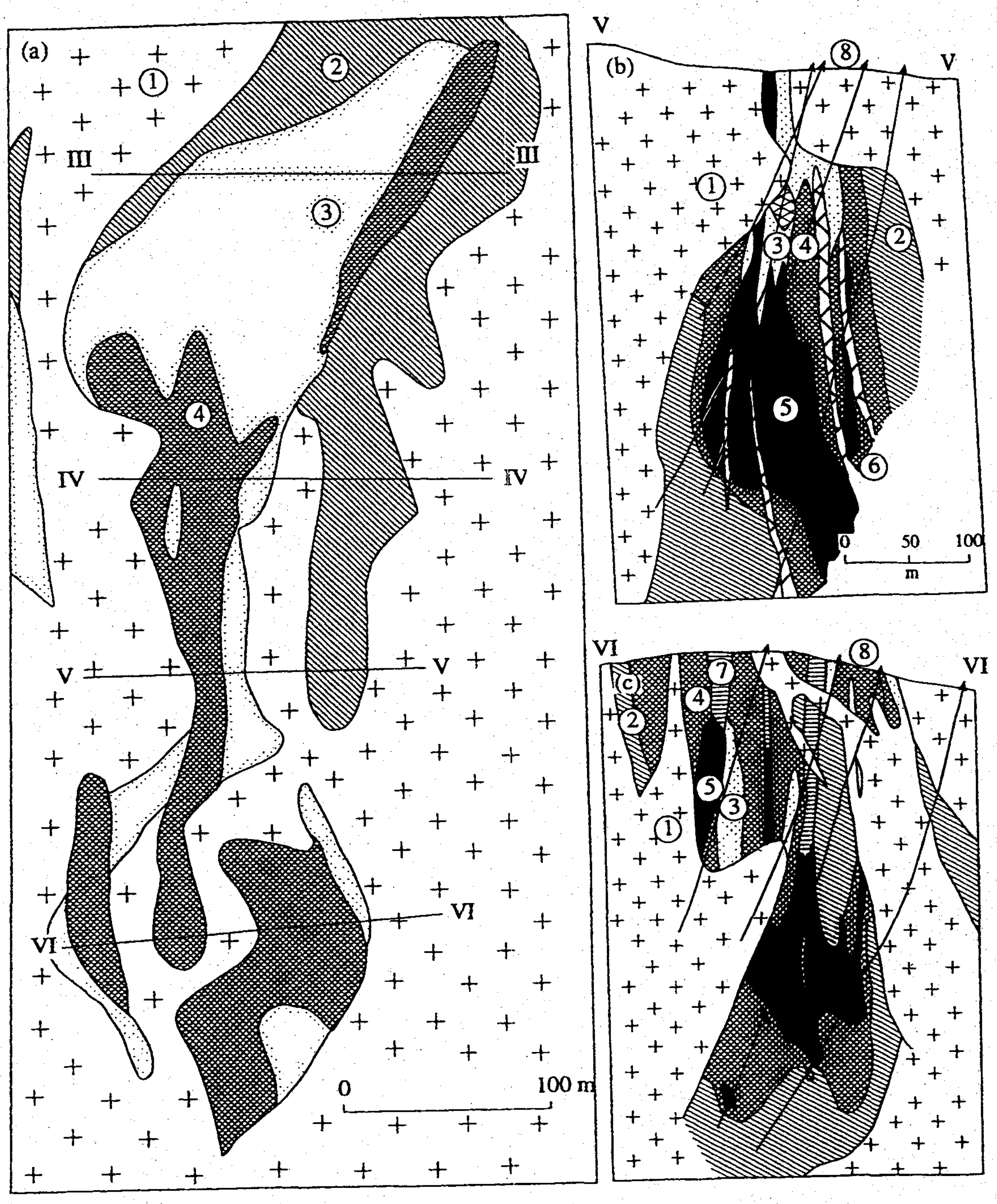

Fig. 4. Map of the Zapadnoe deposit, eastern Transbaikalia and profiles across this deposit. (a) Schematic map of the Zapadnoe deposit, eastern Transbaikalia. (1) Hercynian granodiorites; (2) pyroxene skarns; (3) forsterite skarns; (4) ludwigite–magnetite ores. (III–VI) Exploration profile. (b) and (c) Geological profiles across the deposit. (1–3) same as in Fig. 4a; (4) boron-bearing magnetite ores; (5) monomineralic ludwigite ores; (6) postmineral dikes of Mesozoic porphyries; (7) supergeneously altered ludwigite ores; (8) exploration boreholes.

particularly important, regeneration when gold-bearing weathering crusts and placers are formed.

Facts confirming the occurrence of newly formed gold in placers and weathering crusts are numerous, but the role of this phenomenon in the precipitation of economic gold concentrations was not quantified and sometimes provokes doubt. This is related, first of all, to the still poorly understood geochemistry of supergene gold regeneration.

The data of Petrovskaya [49], Nikolaeva [50], Yablokova [51], Novgorodova et al. [52], and many other researchers indicate that gold migration and redeposition in supergene environments does take place. It was definitely demonstrated that newly formed supergene gold occurs as thin films, flakes, dendrites, globules, and small crystals. It is believed that gold is transported in both solutions and colloids.

The morphology and texture of supergene gold were analyzed by Petrovskaya [49]. It was established that newly formed gold occurs at several placers in the area along the Lena River in Siberia in the form of spongy crusts and humps at the surface of gold grains or cement these grains. Other researchers confirmed and specified these observations.

According to Nikolaeva [50], newly formed gold was deposited (as humps and crystals) on pale yellow to tin-white silver-bearing rounded gold grains of low fineness. It was found in placers that were produced by the destruction of rocks that had contained sulfides (pyrrhotite and pyrite with inclusions of low-fineness gold 0.01–4 mm across). At the same time, gold was never found in placers produced by the erosion of gold-bearing quartz veins.

Newly formed gold was found in placers in the Aldan Shield by Yablokova [51], who determined that rounded coarse-grained gold in these placers is 900 to 923 fine, whereas the newly formed gold is 794–880 fine and clearly differs from the primary gold in texture. Overgrowths of newly formed gold on the primary one are fine-grained, polyhedral, and twinned.

According to Novgorodova et al. [52], newly formed gold occurs in weathering crusts in Orenburg oblast as ungeometrical lumps, angular fragments, and spongy masses of dull brownish and red-brownish color; the gold grains are never larger than 0.3 mm. In addition to high-fineness (898–982) gold, these researchers documented its new mineralogical mode of occurrence of violet–purple and purple color, which consisted of a mixture of gold hydroxide and fine-grained polymineralic aggregates of iron hydroxides and iron and bismuth tellurates.

These data and other extensive information provides evidence that supergene gold can be formed in placers and weathering crusts and can migrate with groundwaters. It was hypothesized [51, 53] that this process can be productive and can even regenerate the gold potential of previously worked out placer deposits.

For example, Voronin and Goldberg [54] believe that this process can be facilitated by electrochemical reactions related to a weak electric field around liquid flows filtrating through porous rocks. These researchers demonstrated that the separation of electric charges during the flow of solutions brings about a voltage difference and generates volumetric electric fields, which, in turn, induce the concurrent reactions of cathode reduction (precipitation) and anode oxidation. Electrons can thereby be conducted by particles of gold, sulfides, and other minerals. It was established that higher concentrations of electrically positive metals (such as Au and PGE) in the solutions are favorable for the more active precipitation of these metals on primary mineral

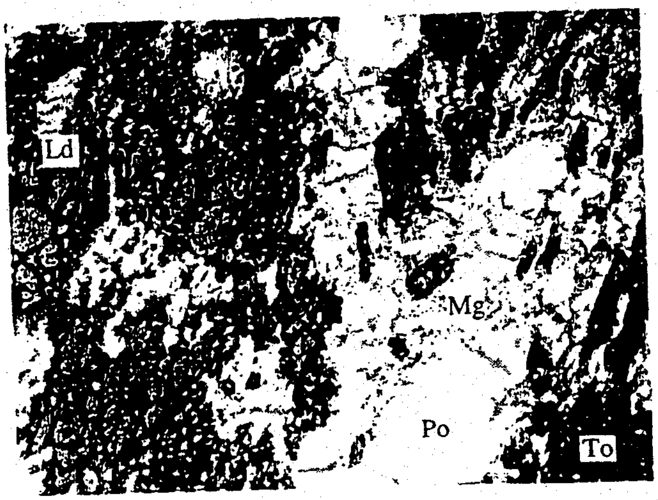

Fig. 5. Pseudomorphic replacement of magnesioludwigite crystals (Ld, dark gray) by tochilinite (To, black) and of pyrrhotite (Po, white) by stringers of magnetite (Mg, pale gray). Zheleznyi Kryazh deposit. Polished section, magnification 30^{x}.

particles. Ag and Cu, which are more electrically negative metals, occur much more rarely in placers. It is thus commonly believed that the margins of gold particles should not become enriched in silver and copper when newly formed gold is precipitated on these particles.

It is known that the margins of gold particles sometimes have a higher fineness of the gold. The higher fineness of gold particles in the margins is sometimes believed [49 and others] to be caused by the partial depletion of these particles in silver as a more mobile element in supergene environments. This does not rule out the possibility of the galvanic overgrowths of gold particles with newly formed high-fineness gold in placers. This issue deserves, however, its further studying.

In spite of the fact that newly formed gold occurs much less widely than "old" gold in placers, modern technologies make it possible to extract all gold, including its nanometer-sized particles regardless of their genesis. This approach to the problem discussed in this paper highlights the economic significance of newly formed supergene gold.

GOLD MIGRATION IN SUPERGENESIS ZONES

Vernadsky [55] evaluated the average gold concentration in riverine waters at 3×10^{-10}%. Other researchers [51] assayed this concentration in mine waters at 1×10^{-7} to 9×10^{-7}% [51]. Roslyakov et al. [56] determined that the Au solubility in waters with Ca sulfate is higher than in waters with Mg sulfate: 4.27 and 2.65 μg/l, respectively. The pH of these waters varies from 6.5 to 8.0. The supergene concentration of gold was demonstrated to be controlled by the occurrence of geochemical barriers, such as oxygen, reducing (hydrogen sulfide, sulfate, and carbonate), alkaline, and acid, as well as the evaporation of mineralized waters in arid environments or in the presence of mineral adsorbents.

Data on the role of heterotrophic microorganisms (bacteria) in the dissolution of gold particles and the later reduction of gold in the form of its newly formed masses are scarce [57]. Nevertheless, available information suggests that gold can be involved in the biological cycles of the bacteria, and this is associated with changes in the surface topography of native gold grains with the development of humps and pores whose sizes are commensurable with those of the microorganisms. The gold particles (0.1–0.2 mm across) used in the experiments lost half of their masses during experiments that lasted for one year, and the dissolved gold was reduced and occurred in the solutions in the form of very fine colloid particles. Their concentrations in the sols were 166 mg/l. The authors argue that gold oxidation and reduction proceeded concurrently, as follows, for example, from the development of newly formed crystals, botryoidal aggregates, spongy masses, and lumps of newly formed gold on the surface of primary gold particles. The fineness of this gold varies from 954 to 746, whereas the primary gold is 843 fine.

Furthermore, gold migration (and reduction) is facilitated by the presence of organic fulvic acids in the waters and the biological activity of microorganisms (fungi and others). This phenomenon is reflected in gold precipitation from groundwaters by plants, for example, reindeer lichen and other species, as was repeatedly documented during the biogeochemical studies of gold ore fields, including their magnesian skarn types.

ROLE OF CRYOGENESIS IN GOLD MIGRATION

In the context of our research and with regard for the location of the deposits described in this publication in permafrost and seasonal freezing areas, we attach particular significance to the cryogenic migration and regeneration of gold.

Studying the hydrochemical effects of cryogenic processes on the origin of aqueous solution flows disseminating gold, Plyusnin et al. [58] have demonstrated that gold concentrations in waters are usually equal to 6.6×10^{-7} g/l and increase to 11.2×10^{-7} g/l in thawed waters and to 15.0×10^{-7} g/l in waters that were preliminarily frozen at a temperature of –6°C. The authors explain these differences by the unusual properties of thawed waters, which can dissolve more gold, but do not consider the possibility of gold regeneration.

Fedoseeva [59] published data on gold migration in frozen soils and snow, a process controlled by the physicochemical characteristics of ice surface and the properties of intercrystalline liquidlike films. The presence of these films was identified within the temperature range of 0 to –10°C. It was demonstrated that Au and Cu are contained in the pore solutions in the form of ions that can form complex compounds. Gold can occur as dithousuilfate-aurate, which is stable within a broad pH range and can be readily reduced to the elementary form.

The processes of permanent (seasonal) freezing of groundwaters in certain areas in Siberia, North America, and other regions where the gold deposits discussed in this paper are situated should notably affect the concentrations of dissolved gold. The freezing of water in the active soil stratum produces ice that contains practically no dissolved salts, which are thus concentrated in the residual liquid contained between ice crystals. The gold concentrations in this liquid can increase by almost two orders of magnitude. This creates favorable conditions for gold precipitation from these solutions on the surface of gold particles in placers or at the surface of ice crystals.

The occurrence of this process in nature is confirmed by the finds of thin gold films between ice crystals at the Yellow Knife deposit in Canada [60]. The possible growth of gold dendrites from gold-oversaturated residual solutions during the seasonal freezing of the thawing stratum in placers in the Kolyma area was reported by Kolyasnikov [61], who believed that the morphology of these dendrites inherited the shapes of dendritic snow crystals and admitted that these dendrites could be overgrown by equant gold crystals and thus thickened to the sizes of normal flat gold particles. Kolyasnikov also believed that the gold potential of depleted placers in the Arctic can be naturally restored by the permanent regeneration of gold from periodically freezing groundwaters of the active stratum.

The role of cryogenesis in the migration and redeposition of native gold, including the mechanical transport and concentration of gold particles in soil polygons at the bottom of the active stratum during its seasonal freezing and thawing [62, 63] deserves more detailed study.

The materials presented above generally characterize the geochemistry of the evolutionary behavior of gold in the endogenic and supergene processes forming magnesian-skarn ore deposits. It was demonstrated that Fe and Cu hydroxisulfides (tochilinite and valleriite) are a previously unknown important link of the genetic mineralogy of gold. Our results can be used during the mining operations not only at contact–metasomatic (skarn) deposits but also at precious-metal deposits hosted in dolomites, carbonatites, and ultrabasites. The results of our research confirm the importance of and the necessity of studying the processes of gold regeneration in supergenesis zones at ore deposits, placers, and the dumps of gold deposits.

CONCLUSIONS

1. Magnesian skarn deposits of gold-bearing sulfide ores are a promising source of this metal in the form of its primary lodes and spatially related alluvial and other types of placers. A common feature of these deposits is

their spatial restriction to contacts of dolomites with intrusions of predominantly mafic composition or those of syenites, although this does not rule out the necessity of assaying the ore potential of skarns in contacts with granites and ultrabasites and in carbonatites.

2. Gold-bearing sulfides are contained at these deposits in pyroxene and forsterite skarns and calciphyres, periclase marbles, dolomites, and magnetite–ludwigite ores, including overprinted calcic–skarn associations.

3. Iron and copper sulfides contained in magnesian skarns are ubiquitously replaced by hydroxisulfides (tochilinite and valleriite) under the effect of hydrothermal solutions. These hydroxisulfides inherit fine gold from the replaced sulfide. The hydroxisulfides are unstable and are endogenically replaced by magnetite and Cu, Fe, and Mg sulfates, and this facilitates the migration of readily dissolved fine Au and its regeneration on the surface of larger Au particles or in nearby rocks. In the zone of supergenesis, tochilinite and valleriite are easily oxidized, and their gold is inherited by masses of magnetite dust and is partly adsorbed by iron and copper hydroxides and/or is dissolved in meteoric waters.

4. The problem of the tochilinization and valleriitization of sulfide ores is significant for genetically diverse deposits of copper and precious metals and is of great scientific and applied importance. This problem can be solved both by the improvement and modernization of technologies of gold recovery and, perhaps, also PGE from ores and dumps and by the deciphering of the geochemistry of the supergene migration and regeneration of native metals in placers.

5. In permafrost areas, where several gold deposits occur in Russia and Canada, dissolved gold is concentrated in the residual unfreezing liquid of the active stratum during its seasonal freezing and thawing. The gold concentration in the liquid can thereby increase by almost two orders of magnitude. The cryogenic concentrating of gold-bearing solutions in intercrystalline liquid films in ice can facilitate gold regeneration in placers on the surface of gold grains and particles or at adsorbents. The permanent freezing of soils activates this process and can result in the restoration of the gold potential of depleted placers and mine dumps.

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Short Communications

SKARNS AND ORE DEPOSITS OF THE WHITEHORSE COPPER BELT, YUKON TERRITORY, CANADA: SOME ASPECTS OF PETROGENESIS AND MINERALIZATION AT THE ARCTIC CHIEF, LITTLE CHIEF, AND BLACK CUB SOUTH LOCALITIES

(PART 2 OF 2: DATA SUPPLEMENT)

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October 4, 2007

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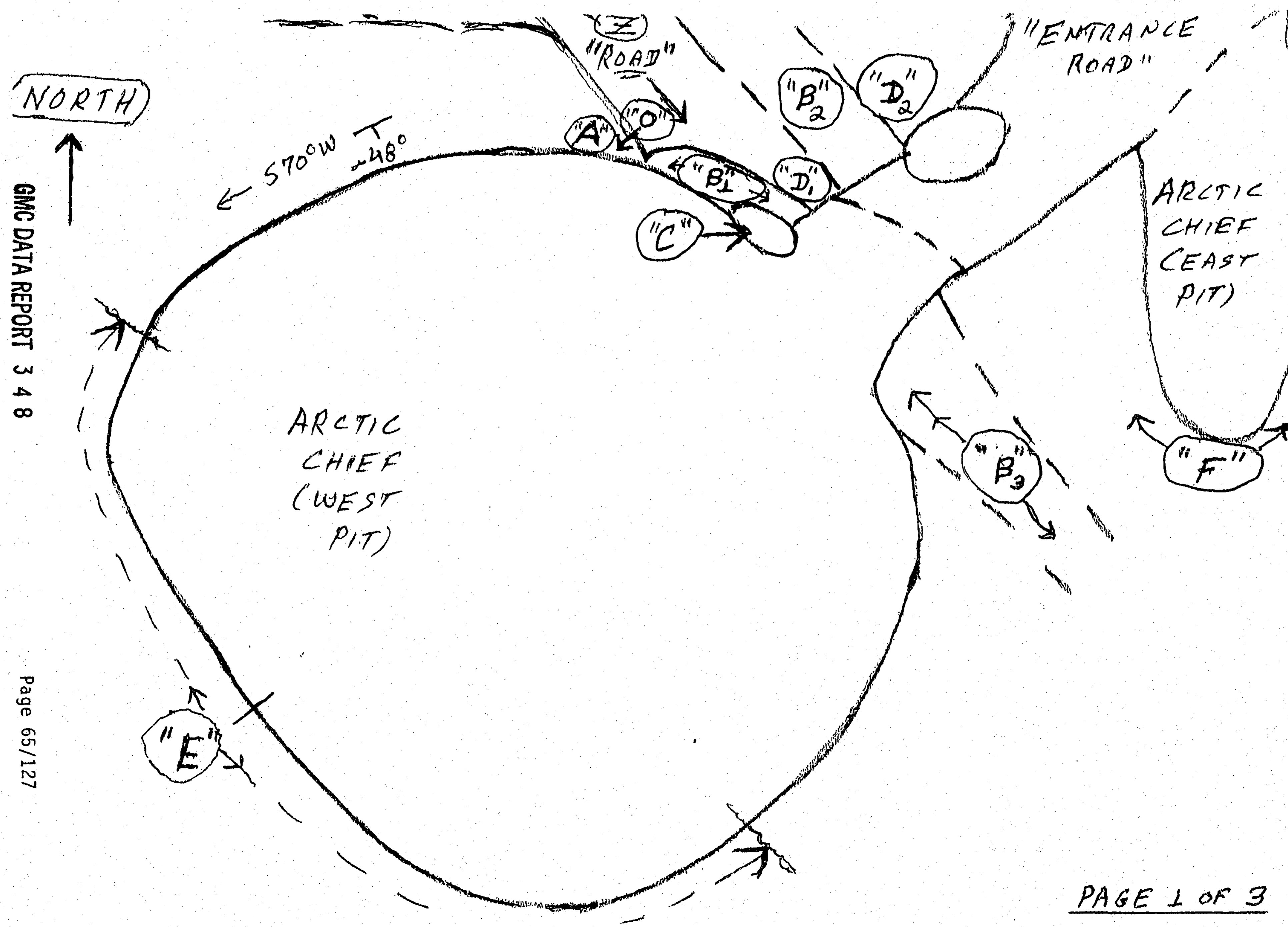
(2) Geologist (Deceased, 1992)

SKETCH MAPS OF SAMPLE LOCATIONS (2004-2006), ARCTIC CHIEF, WHITEHORSE COPPER BELT, YUKON TERRITORY, CANADA:

- -

Three sketch maps follow. Labelled "Page 1 of 3", "Page 2 of 3", "Page 3 of 3". They are not drawn to scale (ie. "cartoons").

Each map depicting, variously, the locations from which sample materials discussed in this report were obtained. The numbers, and/or letters, representing such locations on these maps are those referenced elsewhere (above) in the present report, as well as in the condensed/abstracted field notes, and the initial analyses resulting from the preliminary examination/"triaging" of specimens, which make up the two sections of "supplemental data", below, comprising the remainder of this report.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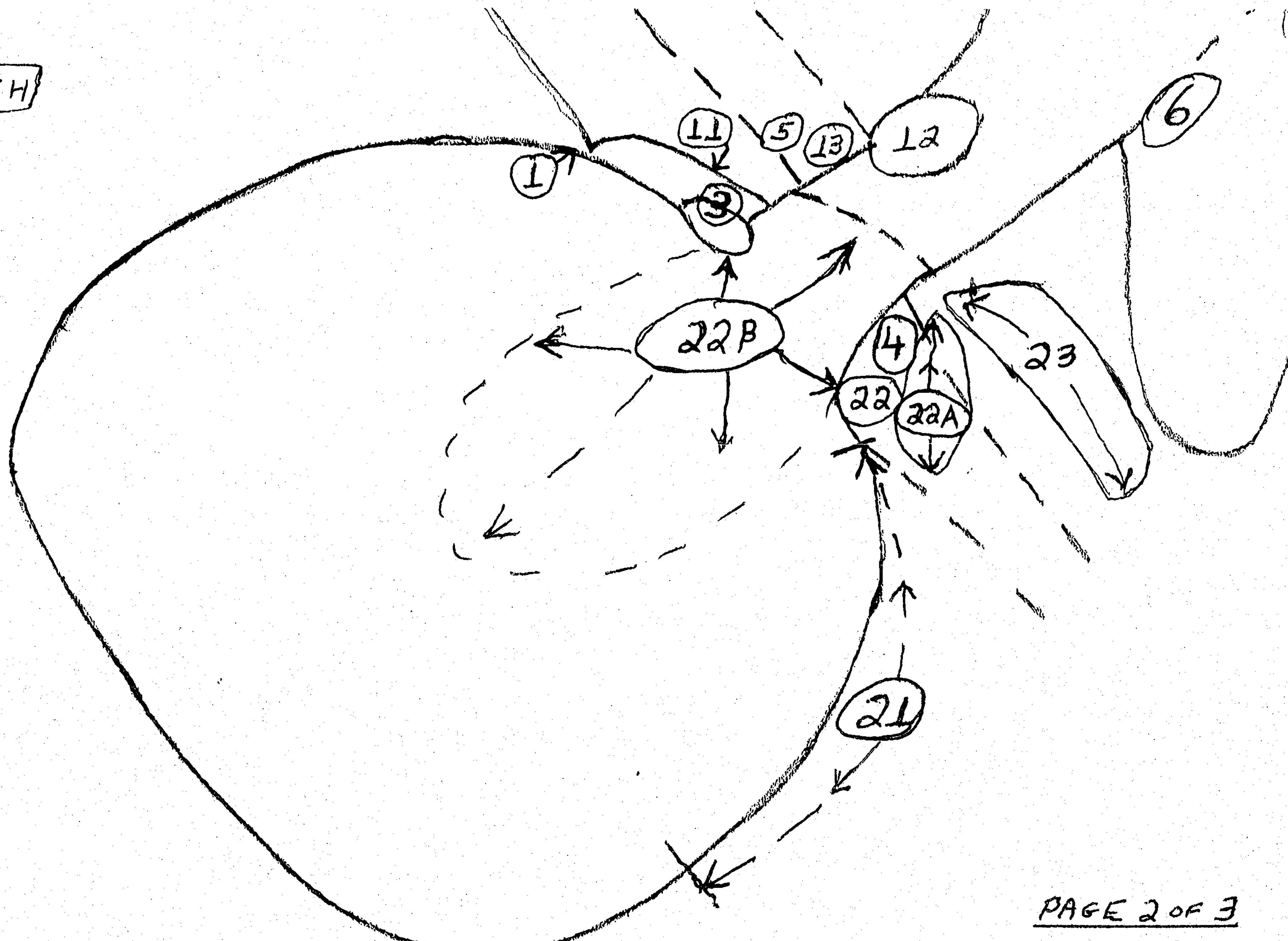

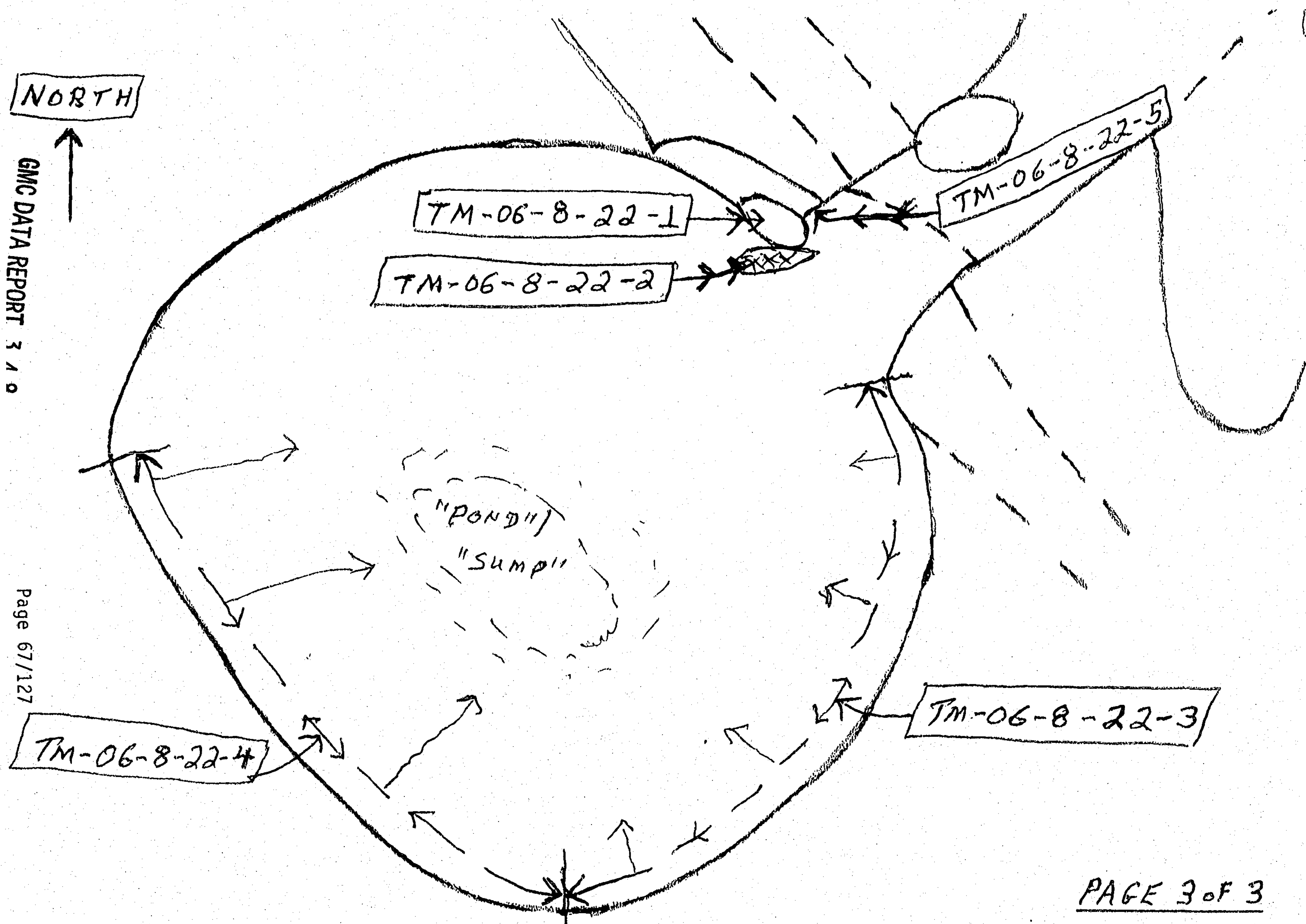
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TM-06-8-22-1
TM-06-8-22-2
TM-06-8-22-5
"POND"
"SUMP"
TM-06-8-22-3
TM-06-8-22-4

FIELD NOTES/COMMENTS ON SAMPLES COLLECTED AT THE ARCTIC CHIEF ("AC") LOCALITY (TCM):

- -

The sample labeling scheme used is exemplified as follows: TM = sampler's initials; "04" = the year, 2004; "6" = the sixth month, June; "9" = the ninth day of that month; "3" = the sample locality/site for that day, per the field notes; the final number ("N") is that assigned to a/this particular specimen.

Ie., in this instance: [TM-04-6-9-3-N].

- -

Sample locations are shown on the sketch maps ("Pages 1 of 3, 2 of 3, 3 of 3 ") above.

- -

FIELD NOTES, 9 JUNE 2004---

9 June 04-

1- Character samples (carbonate rocks -- [apparently "marbles, calciphyres"]--, "skarn" materials, "ores") from rubble-crop/rubble. Note some "brownish specks" (perhaps brucite, after perclase?) in some of the carbonate rocks? Locality is on the "north" rim of the mined-out pit (the "west pit", the larger of the two pits at the Arctic Chief). The other ("east pit") is lower down the hillside, to the south and east of the larger pit, and features "granitic" rocks at the western end.

[TM-04-6-9-1](Map# B1)

2- No samples thus labelled.

3- Just southeast of locality #1. "AC (west)" pit, along "north" rim, just above the entrance to the pit. Samples in-place, or immediately below pit-margin outcrops/exposures, "tricky" to work on alone. Carbonate rocks ("marbles") immediately adjacent to "skarn" materials +/"calciphyre(s)"?, /+/-?. The skarn here appears to occur as an (originally igneous?) apophysis/projection/finger/lens-like mass into/within the carbonates. Analogous to a "crushed zone" setting? Note some "brownish specks" (perhaps brucite, after perclase?) in some of the carbonate rocks?

Presumably the "igneous?"-appearing rocks here are - or are related to - those termed in the literature as "mafic dike[s]"? As observed here: porphyritic (light buff-colored phenocrysts of altered plagioclase, +/-), with green-grey fine-grained matrix. These rocks are hard ("ringing"-"bell-banging" when hammered, with sharp-edged fragments), and are in evidence as apparent rubble-crop/rubble(?) here.

[TM-04-6-9-3] (Map# 3)

....

Might these so-called dikes actually represent marginal portions/offshoots/border zones/"chills"/rapidly-cooled variants of the (contaminated/"basification" by assimilation/reaction with intruded rocks/carbonates) [cf. TM-04-6-9-3(?)-2, an apparent "plagioclase - pyroxene" rock of interesting "salt-and-pepper" aspect/possibly igneous texture??] "main (granodioritic/granitic?) magma" responsible (thermally and geochemically) for the bulk of the metamorphism/metasomatism at the AC??

Are these "dike" rocks and/or the/any other "skarn" rocks here at this sample site/locality at least in part "endoskarn", at least in a certain sense/one sense or another?? Fine grained/porphyritic, rapidly-cooled/quenched variants of a "dioritic"/more mafic magmatic type (with plagioclase[?] phenocrysts having formed initially during "basification" of the main magma, at the periphery of the main intrusive body, and "quenching" of the matrix subsequently during injection into country rocks as "basified" magma at elevated temperatures?? With perhaps some, or perhaps relatively little/none metamorphic/metasomatic effects [even at the relatively high temperatures likely extant, due to the relatively small volume of these melt materials as well as perhaps the physical conditions leading to/permitting their migration/intrusion into the country rocks] on adjacent surrounding country rocks into which this partially crystallized mafic melt was intruded??) ?? [Ie. relatively rapid intrusion, perhaps due to tectonic activity/fracturing of country rocks, with attendant pressure drop/release, cooling, etc. ??]

Perhaps aided and abetted in their distribution, emplacement, cooling and solidification by structural/tectonic events/features, in particular fractures/fracture zones, perhaps related to the "contraction phenomenon" associated with the evolution of the main magma body(ies), as discussed/espoused by Aleksandrov?? [Ie. perhaps representatives of the "main magma" extant at depth subsequent to the metamorphic and metasomatic events/conditions attendant to the formation of the skarns and related mineralization??]. "Long-lived" (or perhaps only relatively short-lived) tectonic "crush zones", ie. Featuring/affording porous and permeable zones, reduced pressures, locally and/or for relatively brief periods of time, perhaps facilitating migration/ "flight"/escape of more basic/less silicic, higher temperature, lower viscosity melt materials as "fugitives", in a sense, from the bulk heat source of the main magma body?? With or without assistance from tectonic manifestations related to physical differences in main magma body versus surrounding rocks, in addition to heat differentials/gradients.

Is the somewhat casual/summary treatment/dismissal of these "dikes", especially in terms of their influence/relevance/significance with regard to the metamorphism-metasomatism-mineralization, as mentioned/indicated/suggested in previous reports, perhaps mis-guided/inappropriate/short-sighted/premature???

A NOTION/THREAD PERHAPS WORTH LOOKING INTO FURTHER.

Cf. (below, locality #4) photos from opposite ("south") rim of pit, featuring views of locality #3.

[TM-04-6-9-3] (Map #3)

....

4- Just across the AC (west) pit entrance from locality #3, to the south-"ish". Samples and photos looking northward at locality #3, and around the pit to the west. Samples of carbonate rocks ("marbles", and "calciphyres"), "skarn " materials, "ores"; in-place/rubble-crop. Note some "brownish specks" (perhaps brucite, after perclase?) in some of the carbonate rocks? Note interesting structures in the carbonate rocks and associated skarn materials (across pit entrance) as shown in these photos.

[TM-04-6-9-4] (Map #4)

5- Just "east" of locality #3, on northeast side of AC (west) pit. Outcrop and subcrop carbonate rock samples ("marbles", and "calciphyres"); rubble-crop?/rubble samples of "skarn" materials, "ores", "endoskarn/diorite" material(?). Note some "brownish specks" (perhaps brucite, after perclase?) in some of the carbonate rocks?

[TM-04-6-9-5] (Map #5)

6- Today also collected grab/character samples of rubble from along the road downhill east of the AC (west) pit. Samples likely came from the "AC (<u>east</u>)" pit. Samples taken at easternmost end of the smaller pit area, along a shoulder on the north side at the open end of the cut (ie. the end distal from the pit "headwall") into the pit proper. Several photos into pit, with "granitics",+/- (?), at the far end/headwall of the AC (east) pit.

[TM-04-6-9-6](Map #6)

....

FIELD NOTES, 10 JUNE 2004---

Photos of Arctic Chief (east) pit. From about the TM-04-6-9-6 locale.

Photos of AC (west) pit. From both the TM-04-6-9-1 and 3 locales, as well as the TM-04-6-9-4 locale.

10 June 04-

1- Below locale 9 June 04-3 [TM-04-6-9-3], rim of AC (west) pit. Samples of "skarn" materials, carbonate rocks ("marbles", and "calciphyres"; brownish specks, perhaps brucite after periclase, noted in many of these), as well as "dike rocks"(??). Rubble immediately below the semi-intact outcrop/exposure hanging overhead, as well as jutting out over the edge of the pit wall (a "dicey" sampling spot --- "not a place to spend the night"). Cf. remarks under entry "9 June 04-3", above. Cf. numerous photos.

[TM-04-6-10-1](Map #3)

2- A variety of "character" samples from rubble near entrance to AC (west) pit. Most not far from their apparent in-place sources just uphill; others more likely are appreciably out-of-place, from elsewhere inside the pit, moved and deposited here by activities during the course of developing the pit, etc.

[TM-04-6-10-2](Map #12)

3- Additional samples from near 9 June 04-5 locality (which cf.).

[TM-04-6-10-3](Map #13)

Next opted to search for carbonate rocks of more "original" nature/character, ie. (hopefully) outside the sphere of influence of the intrusives, rocks at least of "less-than-marble-grade". Drove on up the road beyond the north side of the top of the AC (west) pit; went a couple of miles, with fair but intermittent rock exposures, apparently of igneous/"granitic-dioritic"/metamorphic? character.

(Perhaps/likely it would be more fruitful to pursue "unbesmirched/untainted", hopefully stratigraphically at least somewhat "equivalent" carbonate rocks along strike to the "north-northwest" {or, perhaps, across the entrance to the AC (west) pit, into and beyond the carbonate rocks exposed at the rim of the pit on that /"south" side; ie. at the 04-6-9-4 locale and along its trend}. Cf. the striking mountainside (cf. photo #"36") exposures some distance to the north of the AC. Need to check with Mike Burke on this. Although the exposures along the entrance cut of the "east" pit at AC might well have the sorts of "precursorial" carbonate rocks I'm looking for[?].).

4- Outcrop ("4a" sample locality; "skarn" materials) along the road at odometer reading 184.7, on uphill beyond the top of the AC (west) pit. Other samples here include a piece of float/subcrop/rubblecrop (perhaps even road-building/bulldozer-relocated -- if so, from uphill, presumably/most likely??-- and redeposited material?) of "skarn"/"dioritic"? (hornblende-bearing?) rock taken from the "southern" side of the road, displaying appreciable amounts of moybdenite on fracture surfaces of broken sample {cf. HAT "new-type" mineralization??}. The outcrop at this locality crosses the road, with evident "skarn" featuring calcite, red-brown garnet, etc.

[TM-04-6-10-4](Map# Z/14)

5- Odometer = 184.7+++. Outcrop; featuring appreciable amount of sulphide(s?) - "pyrite?/pyrrhotite??/arsenopyrite"??? on fracture surfaces of broken "diorite" specimen {cf. HAT "new-type" mineralization??}. Outcrop on the "northern" side of the road.

[TM-04-6-10-5](Map# Z/15)

6- Odometer reading 184.9. Outcrop at dip in the road, just N/W of the top of the AC (west) pit. Rocks are "dioritic"?; "endoskarn"??. Darker sample is from outcrop, lighter one is "float"/not actually in place.

[TM-04-6-10-6](Map# Z/16)

7- Odometer reading 185.0. Outcrop at the junction with the road out to the top edge of the north rim of the AC (west) pit. Sample of "skarn" (endo?/exo?) materials, with garnet veinlets, etc.

[TM-04-6-10-7](Map# Z/17)

8- Same locality as 9 June 04-3 (which cf.). Photos of pit. Samples of carbonate rocks, skarn(s). [TM-04-6-10-8](Map# Z/18)

9- Same locality as 9 June 04-5 (which cf.). Photos of pit. Samples of carbonate rocks, skarn(s). [TM-04-6-10-9](Map# Z/19)

X- Ended the day's efforts at the Arctic Chief by taking a number of "serendipitous" grab/rubble/character/"doorstop"/"exploration" samples from here and there ("targets of opportunity") along/beside the road from the north/east(?) edge of the AC (west) pit, which extends "northward" to its junction with the road leading up the hill.

[TM-04-6-10-X](Map# "Z")

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(End field notes, June 2004)

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FIELD NOTES, 9 August 2004---

Arctic Chief (west)

Photos from"NE" rim of pit, into pit. "Sunrise" shots all around. View from TM-04-6-9-1&3 localities. (Map #s 1&3).

<u>9 August 04-</u>

1- Samples from TM-04-6-9-3 locale. "Dike" rocks, etc. , vs. "hard" carbonate rocks. "Contact" between "skarn"/"carbonate" rocks? "Dikes" = "plagioclase-pyroxene" rocks of SMA? Cf. photos across pit mouth looking toward locale "5". These "dikes" appear possibly (in photos taken from TM-04-6-9-4 locale) to be associated with (?) "tongues" of "skarn/intrusive rocks" (?) into the carbonates (?).

[TM-04-8-9-1](Map #3)

2 - Collected (as rubble/rubble-crop) four large bags of "typical" (?!) garnet-pyroxene +/- skarn "specimens" along the road from the north rim of the pit ---> road leading up the hill.

[TM-04-8-9-2] (Map # "Z")

Traversed/toured the "southeast<-->southwest" rims/upper benches of the AC (west). Many photos from there, and from the pit entrance, as well as from the "north-northeast" rim "carbonate" rocks locales.

Did some "sketch mapping", via pacing and Brunton compass.

Noted no "granitics" at the "east<--->south" and "south<--->west" rims of the AC (west) pit during my approximately "3/4 of the way around" traverse/tour of the accessible portion of that area. Seems to be all garnet-pyroxene, +/- , "skarn" rocks thereabouts (?). [[PLAN TO REVISIT]]

Collected a number of samples (probably/likely as rubble-crop) of "typical" (?!) pyroxene-garnet, +/-, "skarn", from the top/"bench" and edge of the "southwest" **(Map# E)**, and "southeast" rims **(Map #21)** of the AC (west) pit. Also collected samples of "ores" - some banded, from the "easternmost" part of the "southeast" rim).

This traverse/"tour" also included the "south" ("headwall") rim of the AC (east) pit area, including photos. Note "granitics" (porphyritic--very fine grain--fine grain--coarser-grained; some containing -- mostly "mafic" -- xenoliths) in rubble above this rim. [[PLAN TO REVISIT]]
(Map# F, & #23[part]).

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12 October 2004-

Arctic Chief area. Windy and a bit chilly this morning up on the AC. Ice on the windshield, etc., down in the valley at Whitehorse this morning.

[TM-04-10-12-1-1 --->] :

Collected "ores" (ie. magnetite +/- bornite +/- chalcopyrite +/- ?) from the AC (west) pit entrance, and on inside pit **(Map #22B)**, as well as uphill **(Map #22A)** on south side of the pit entrance (in approximately the TM-6-9-4 area). Rubble/float samples. Some samples frozen in place. Several "non-ore" specimens of "skarn"-materials, etc. (from below the TM-04-6-9-3 area; **Map #22**).

[TM-04-10-12-2-1 --->]:

Below, approximately east-northeast, of the TM-04-6-9-4 locale, in the area peripheral to the "head" of the AC (east) pit. Rubble/float samples of "granitics", "ores". **(Map #23).**

Left the rather impressive molybdenite-laden "foot specimen" of TM-04-6-10-4 "B" **(Map#Z)** with Jim Coyne for his continued edification/amusement, +/-possible slabbing to look at vein-alteration-host rock characteristics. As R. Zuran put it, examining a piece, "that's a lot of moly"......

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END OF 2004 FIELD SEASON

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FIELD NOTES, May & June 2005 -1

25 May 2005-

Arctic Chief (west)

Photos from "NE" corner **(Map#s "O", "C")** of rim of pit. Views from, in, at and around the TM-04-6-9-1, &3, &5 localities.

TM-05-5-25-1:

In-place and "recognizably-displaced" samples from TM-04-6-9-3 locale **(Map area #C/Map area #3)**. "Dike" rocks, etc., vs. "hard" carbonate rocks. "Contact" between "dike"/"skarn"(?)/"carbonate" rocks.

"Speculatively": These "dikes" appear (cf. photos from TM-04-6-9-4 locale) to perhaps (???) be"tongues" related to/of "skarn/intrusive rocks" (??) into the carbonates (?). Or, rather,"merely" dikes from magma intruded either/or/all (??) prior/during/subsequent to the "main magma" event(s?) which were responsible for the formation (viz. metamorphism and metasomatism) of the skarns and ore mineralization. [Or, rather, both/all of these (???)].

Samples represent outcrop/"in-place"/rubble-crop materials, either in-place or not at all far from being actually in-place. Many of these specimens were obtained in-place, at some varying degrees of hazard, from the very "brink" of the (overhanging) pit rim.

Specimens of carbonate rocks ("marbles", and "calciphyres"; brownish specks, perhaps brucite after periclase, noted in many of these); porphyritic as well as more equigranular ("dioritic"?) igneous (?) rocks (this locality is at the "massive" exposure, *not* the "bird"exposure; cf. photos and legends, 2004); "skarn" materials (with some magnetite (?), +/-). Some examples of "lenses/zones" featuring garnet, pyroxene, magnetite (?), +/-, adjacent to carbonate host rocks. (Some photos of latter occurrences).

These rocks occur in a three-part (or more) sequence, from (from "left to right"/"southish" to "northish"; cf. photos): the "igneous"/"dike" rocks, through a "black" material interval, and thence into whitish/light grey carbonate rocks.

As can be discerned on some of the photos taken, the site of TM-05-5-25-1 shows an interesting relationship between the darkish-light grey-light grey-greenish "dike" (?) rocks exposed in the "massive exposure" atop this locality and the adjoining carbonate rocks. At least in places, a "zone"/"lenses" (?) of very dark green/black material(s?) occurs between these "porphyritic and more-equigranular igneous" rocks and the light grey/whitish carbonate rocks.

There is some/a fair amount of smaller-scale "intermingling" between adjacent "zones" of this sequence (cf. samples). Some interesting structures/textures are manifest in some of these specimens. The "black" interval appears megascopically/from a distance to perhaps represent at least in part a "sheared" interval (with apparent slickensides, etc. noted on closer examination, in places). The "blackish" material appears at least in part to be chlorite (?); (+/-).

Speculative "scenarios" for this particular locality might include:

1. "Black" material/zone = a zone of shear/cataclastic materials/gouge, resulting from structural movement and attendant deformation along the dike/carbonate rocks contact zone subsequent to solidification of the dike rocks (with similar possible scenarios as suggested in #2, below, as to the nature/timing/sequence of metamorphic and/or metasomatic effects/events (?).

2. "Black" material/zone = contact metamorphic/metasomatic product(s) of dike magma intrusive into the carbonate rocks (the carbonates either previously unmetamorphosed/metamorphosed-metasomatized/affected by "skarning" event(s)/processes, prior to intrusion of dike magma (?).

3. "Dike" magma coeval with, or an apophysis of, the "main magma" which was responsible for the overall contact metamorphism/metasomatism of this deposit/locality. Or subsequent to this? Or prior to this? Perhaps, as a guess/impression/"interpretation", the dike magma is (?) an offshoot of the main magma, from the relationships observed at this locale in particular.

Some other observations at this locale (**"Map #C"**) seem worthy of note as well:

A. Some distance from this vantage point, in an approximately northwest direction, apparent grey-green rocks/materials can be observed to occur at and near the top of the "steeply-dipping" sheer-faced "North" wall of the pit. These grey-green rocks/materials might well be "on trend" with the "massive exposure" (ie. at locale "Map #C") and/or "the bird" dike rock (also grey-green in aspect) exposures (at the "NE" pit corner rim area, on the "N" side of the pit entrance, respectively [cf. 2004 photos, as well as photos taken this date]).

Or, these grey-green rocks near and at the top of the "N" pit wall might (?), alternatively, be a continuation (across the pit, ie.) of a possible (?) dike/intrusion exposed in the the "S-SE" wall of the pit, adjacent to the carbonate rocks +/- of locale Map #4. (This possible [?] dike/intrusion in the "S-SE" wall of the pit is the "V-shaped" feature, with reddish margins, shown in photographs [2004, 2005] from the "N-NE" rim of the pit, looking approximately South.)

B. Also note photos of the above-described "V-shaped" feature in the "S-SE" wall, as taken from the "NE" corner area on 25 May 2005. Note especially those featuring the carbonate rocks of Map #5, with the "on-trend"/equivalent (?) carbonate rocks of Map #4 in the distance across the pit entrance, with the "V-shaped" feature to the west of the carbonates, in the "S-SE" wall of the pit.

C. Need to revisit/check/sample the rim above this "V-shaped" feature, as well as the pit below it. Unfortunately the steep/essentially vertical pit wall itself, further threatened/endangered by its overhanging rim, is not readily accessible/sampled in-place.

Also took other photos from site "Map #C" (and of the site itself as well).

TM-05-5-25-2:
Samples (two) from outcrop/in-place of the "steeply-dipping" sheer-faced "northeast" pit wall near **Map# "O"** locale. "Pyritic siltstone" unit (?), or ??.

Also several photos from this site.

TM-05-5-25-3:
Also collected a number of garnet-pyroxene +/- samples from the road from the north rim of the pit <---> road up the hill (the areas of **Map#s "O" <--> "Z"**). "Float-rubble" materials/"character samples". "Exploration samples". One never knows what might be lurking inside these (or any) types of rocks. As I learned way back when......

Other photographs taken from Map # 5, #1, etc., from this general area of the "NE" corner of the pit rim.

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26 June 2005-

ARCTIC CHIEF (west)---

- 1 Character samples ("-A") from "Map #3" locale- : magnetite +/-. Character samples ("-B") from the northwest side of the pit entrance: magnetite, +/-.

[TM-05-6-26-1-A, B]

NOTES: View of AC (east) pit, from AC (west) pit entrance : Sketch in notebook. Accompanied by D. Hogarth.

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END OF 2005 FIELD SEASON.

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FIELD NOTES, August 2006 -1

22 August 2006-

Arctic Chief (west), Whitehorse Copper Belt, Yukon Territory, Canada

Refer to enclosed sketch maps, above, for locations of the samples described in the following notes of this date.

TM-06-8-22-1:
Atop the veneer of carbonate rock rubble/"rubble-crop" which overlies the "massive" exposure of a/the dike at this site (**Cf. Map#C**). Portions of this exposure of dike rocks were sampled. Samples of the carbonate rocks were also taken. All samples were of "loose" material. However, the dike rock samples, in particular, are "sub-crop" of adjacent in-place portions of the dike. Samples feature "banded" and "dioritic" (?) rocks, among other types. [Refer to work of previous years at this locale for additional comments, details, etc.]

TM-06-8-22-2:
Locality shown on above map (**"Page 3 of 3"**) is in the AC pit, up on the side of the wall of the northern corner of the pit entrance, where it adjoins/meets the wall of the main portion of the pit.

The geologic relationships displayed at this locality are shown, variously, in the numerous photographs taken of this site in previous years (see "photo index" files). A rough sketch, (**"Attachment TM-06-8-22-2-"**), cf. below, made in the field shows the general spatial relationships of the materials comprising the "tongue" of darker materials into the host carbonate rocks. This sketch/"geo-cartoon" is not to scale, since direct measurements were not readily feasible due to difficulty of access. Approximate dimensions were estimated in the field, as well as by comparisons, from photographs, to the dimension of the exposure of sill-rock above this location which was pace-measured previously.

This is a very interesting, perhaps "key", locality. It is the location of a copper-bearing "tongue" of dark materials ("skarn", +/-, presumably[?]) projecting into carbonate rocks at/near/along the apparent crest of a structural fold in the host carbonate rock sequence. This is the "gaudy" feature shown in many photographs, taken from various sites, during field work of previous years (2004-2005).

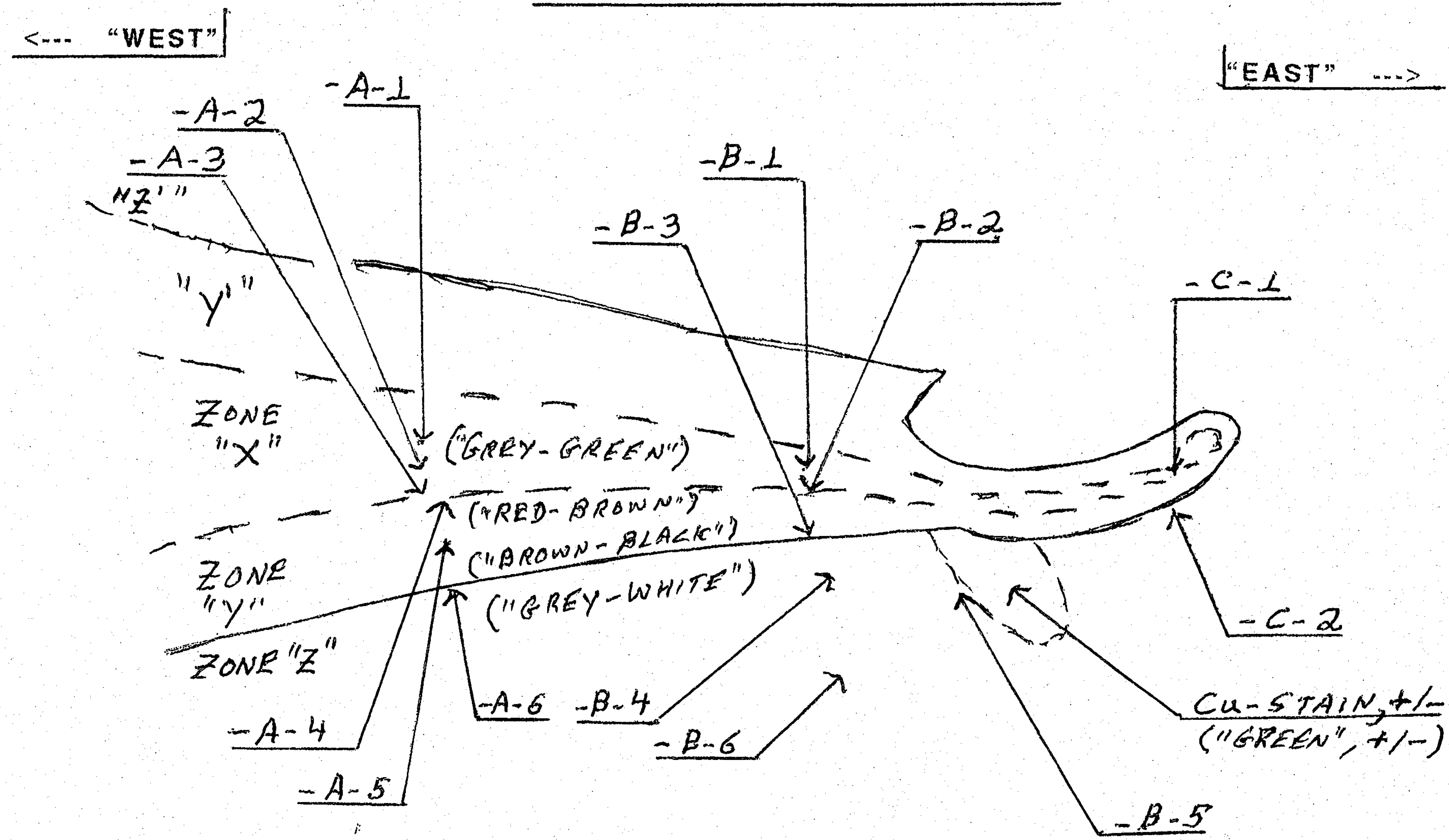
Samples were taken of all principal lithologies/zones/etc.
Represented were "host/country" carbonate rocks (the predominant carbonate rocks in the sequence exposed here are light grey, with subordinate proportions of discrete interbedded sedimentary (presumably [?]) horizons of darker grey carbonate rocks [cf. photographs]).
Also sampled were a variety of darker rocks, representative of "skarn-like" and "igneous(?)" materials. Samples included in-place materials, as well as some "sub-crop" and "rubble-crop/float"; the latter samples were obtained immediately below those portions of this location not readily accessible. (Essentially vertical, or overhanging, walls in places.)

SUPPLEMENTAL NOTES REGARDING SAMPLE LOCATION "TM-06-8-22-2-A-, B-, C-":
(Cf. "Attachment TM-06-8-22-2-")

TM-06-8-22-2-A-:
Specimen "-1": from the central/medial portion of the medial zone ("X") of the greyish-greenish rocks.
Specimen "-2": from zone "X", intermediate between specimen "-1" and specimen "-3".
Specimen "-3": from zone "X", adjacent to the upper part of zone "Y".
Specimen "-4": from zone "Y", near/adjacent to the lower part of zone "X".
Specimen "-5": from zone "Y" <---> zone "Z" border area.
Specimen "-6": from zone "Y" <---> zone "Z" border area; more distal from zone "X" than specimen "-5".

TM-06-8-22-2-B-:
Specimen "-1": from zone "X".
Specimen "-2": from zone "X" <---> zone "Y" "contact".
Specimen "-3": from zone "Y" <---> zone "Z" "contact".
Specimen "-4": from zone "Z".
Specimen "-5": from zone "Z", somewhat more distal from zone "Y" than specimen "-4". Note Cu-staining/mineralization in/on this specimen, taken at the edge of the prominent

ATTACHMENT "TM-06-8-22-2-....."



ARCTIC CHIEF (WEST), WHITEHORSE COPPER BELT
YUKON TERRITORY, CANADA

green area shown on photograph #5 (and other photographs which show this "tongue-like" geological feature).

Specimen "-6": from zone "Z", more distal from zone "Y" than specimens "-4" and "-5".

TM-06-8-22-2-C-:

Specimen "1": from zone "X" <---> zone "Y".

Specimen "2": from zone "Z".

The two specimens from TM-06-8-22-2-C represent materials from the (easternmost) "tip" of the "tongue-like" feature, at the "end" of this structure where it terminates (in this exposure) against country/host/wall rocks.

The six specimens from TM-06-8-22-2-B represent a "cross-section" of this feature, further to the west from the "-2-C-" location. This section was taken from the medial "core" to the lower edge of this "tongue", into the wall rocks.

The six specimens from TM-06-8-22-2-A represent another "cross-section", further to the west from the "2-B-" location, toward the western end of the exposure of this tongue-like feature. This cross-section also was taken from the medial "core" to the lower edge of this "tongue", into the wall rocks.

The attached sketch (("**Attachment TM-06-8-22-2-**") roughly depicts the relationships of the samples taken to the "tongue"-like" body overall.

Some comments on the character of the "zones" as adopted for purposes of field sampling are as follows:

Zone "X": Made up of grey-greenish rocks of apparent (?) igneous aspect. Grain size of the specimens shows a general decrease from the central/medial portion of the zone outward towards zone "Y" (specimens "-2-A-1" ---> "-2-A-2" ---> "-2-A-3"). Specimen "-2-A-3" is adjacent to zone "Y", and features porphyritic texture, with an aphanitic groundmass, perhaps suggestive of a "chill zone" of sorts. Specimen TM-06-8-22-2-C-1 is somewhat more complex in character, having formed out at the "tip" of the "tongue".

Zone "Y": Comprised of reddish-brown/black rocks of apparent "skarn" aspect, featuring apparent garnet, pyroxene, magnetite, +/- copper minerals, +/-?.

Zone "Z": Consists of wall/host/country rocks of carbonate composition, variously affected by metamorphism/metasomatism +/- "veining" (magnetite?/+/-??).

Zones "Y' " and "Z' ", which were not sampled due to appreciably greater difficulty of access, appear to be essentially similar ("mirror-images", so to speak), in general, to zones "Y" and "Z", respectively, "peripheral" to zone "X".

Further musings on the TM-06-8-22-2- location are as follows:

This geologic feature apparently represents a "tongue" of skarn and skarn-related materials, projecting into adjacent carbonate rocks. This location is apparently marginal to the previously present principal mineralization/"ore-body" of magnetite-bornite-chalcopyrite, +/- , now "mined-out" from the AC (west) pit.

Perhaps it is not atypical, thus, of the conditions/situation extant during/responsible for the more extensive mineralization of the main ore zones. Hopefully providing an example, though at a smaller scale/"in miniature", perhaps, of the processes and results/products at this deposit.

Possibly a vestige of more substantial skarn formation related to a portion of the ore body. This feature/location *is* on the margin/peripheral to the mined-out pit. And there *is* magnetite, copper staining, +/-? at this site. Copper staining reflect bornite, and/or chalcopyrite, and/or......... ??

Apparent(?) presence of certain silicate minerals (viz. forsterite?, serpentine?, phlogopite??) indicative of a magnesian skarn situation? The carbonate country/wall rocks *are* "on trend" with the periclase (brucite) marbles just to the north of this site.

The nature of the zone "X" apparently igneous (?) rocks (ie. "dioritic", "porphyritic andesitic [?]") is of interest, as are the grain size/textural relationships/"intrusive" characteristics noted.

Are these "igneous" rocks representative(?)/indicative of the character/composition of the "main magma" responsible for the the metamorphism/metasomatism at the AC (west), +/- elsewhere in the area? And/or "modified" by assimilation/contamination/reaction etc. etc. (?). Cf. other samples taken on August 8, 2006 elsewhere in the AC (west) pit, especially those of "dioritic" (??) aspect collected in the vicinity of the sump/pond/"glory-hole" near the southwest corner of the pit floor (?).

What is the relationship of these rocks with those of the "dikes" in the neighborhood? The porphyritic specimen collected from the "tongue" has a fair degree of similarity in (megascopic) aspect to some of those dike rocks. Though presumably/supposedly these dikes were "later" than the metamorphism, metasomatism, ore deposition. The apparent lack of significant "contact" metamorphic effects between dike rocks (for example at the "bird-like" dike exposure [cf. TM-06-8-22-2-5-], or its [likely] extension at the nearby "massive sill" exposure) and immediately adjacent carbonate wall rocks is suggestive/informative. As are the observed relationships in this "tongue".

<u>TM-06-8-22-3:</u>
See above map (**"Page 3 of 3"**) for location. Samples of "rubble-crop/float" materials collected along a traverse from the south wall of the pit entrance, where it meets the main wall of the pit, to the south corner of the pit. The traverse proceeding along the foot/lower flanks of the southeast wall of the pit, just below the near-vertical/vertical/overhanging wall.

"Character" samples were taken, from the pit entrance (carbonates), thence southwestward. Collecting, sequentially, dark "ore/s", +/-, followed by "skarn"-materials (pyroxene/garnet, +/-) to the southern corner of the pit. Some white materials (carbonate?/??) were collected beneath exposures observed higher above in the pit wall.

Photographs of the AC (west) pit show general relationships/features. Faults/fault zones, some with associated alteration (vis. green/greenish-yellow, rusty/reddish-brown, esp.), were noted with moderate frequency in the pit wall along the course of this traverse. One such zone occurs at the south corner of the pit where the southeast and southwest walls of the pit meet.

<u>TM-06-8-22-4:</u>
See above map (**"Page 3 of 3"**) for location. Numerous photographs (over the years) feature some views of this location. Traverse was along the foot/lowermost flanks of the southwest pit wall, at/near the base of the vertical/near-vertical/overhanging wall.

Samples of rubble-crop/float character. Rocks predominantly "skarn"-materials (minor exceptions being several "white patches" in this southwest wall, reminiscent of similar features observed in the southeast wall of the pit). This "skarn" comprised principally of pyroxene and/or garnet, with associated "pockets" of eu/subhedral calcite, garnet, minor chalcopyrite, +/-....). No "granitic/granitoid" rocks were noted along this wall of the pit.

However, distal from the wall proper, toward the center of the pit, there is a relatively small depression at the deepest part of the floor. A "sump"/"glory-hole", of sorts, presumably. As noted over the three years of this study, subject to flooding, and formation of a small "pond". Though this "pond" was appreciably "smaller/drier" on the present date.

At this location, a pile ("float?/rubble?/subcrop"?) of dark ("dioritic"?) rocks was noted (and sampled). Perhaps representative of rocks occurring in/near/below this location? Indicative of similar/"dioritic" (?) rocks in place below? Perhaps representing "exoskarn" (??), or/and "endoskarn" (??). A portion of a phase/carapace/shell/border zone of the "main magmatic mass" related to/responsible for the AC metamorphism, metasomatism, skarn and ore formation??

<u>TM-06-8-22-5:</u>

See above map (**"Page 3 of 3"**) for location. Numerous photographs feature some views of this location. Locality is toward the top of the north wall of the AC (west) pit entrance. At the contact between the "bird-shaped" exposure of the dike and the adjacent/transected carbonate rocks. Samples were obtained from the area of, and near, the "chin/throat" part of the "bird". Cf. TCM photographs from previous years (2004, 2005) and this date.

In-place/outcrop samples of carbonate rocks and adjacent dike rock. Also some samples as "float" from this area. Also other samples of rocks as "float/rubble" in the immediate area. No specimens containing both carbonate rock and adjoining dike rock together in one sample were obtained, as all attempts to obtain such a sample succumbed to the blows of a hammer, and the two lithologies "parted company". The bond between these carbonate host rocks and the intruded dike materials is not physically strong; apparently a "sharp" contact indeed, here.

Only relatively minor alteration (vis. some slight/moderate shearing/gouge, "serpentinization"//+/- (?), of the igneous rocks was noted. The white-buff-very light grey carbonate rocks give off a "ringing/tinkling/bell-banging" sound under the hammer or when pieces are struck against one another. Specks of light-brownish brucite-after-periclase apparent in these marbles. The igneous rocks are dark greenish-grey, aphanitic/very fine-grained at the immediate dike/host rock contact, with larger grain size (in places porphyritic, with apparent plagioclase, +/-?, phenocrysts) developing with distance from the contact.

It appears (from the nature of this contact, and/or the lack of skarn or ore formation [?]) unlikely (?) that appreciable (additional) contact metamorphic (+/- metasomatic) effects occurred in the host carbonates, due to thermal or other effects related to these adjacent igneous "dike" rocks. The carbonate rocks presumably having been previously subjected to the periclase marble level of metamorphism, in more pervasive/areal fashion, preceding the formation of this dike here [?]. While these "dike" rocks themselves lack obvious features attributable to such a level of metamorphism, hence appear to have been emplaced "post" periclase marble formation.

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END OF 2006 FIELD SEASON

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COMMENTS ON PRELIMINARY ANALYSIS/"TRIAGING" OF ARCTIC CHIEF SAMPLES (TCM):

All field samples were subsequently examined further, in preliminary fashion ("triaged"), by TCM in Haines, utilizing hammer, chisel, hand lens, acid bottle, and a 30x/60x stereo microscope on rock surfaces (freshly-broken and otherwise). In some select cases, also examining grains-in-oil materials using a personally-owned petrographic microscope. Deferring to S. M. Aleksandrov ("SMA") for decisions as to thin-/polished-section petrographic analysis, etc., as he might see fit. In any case, the "low-budget" circumstances precluding appreciable petrographic thin-/polished-section preparation and analysis by TCM.

A substantial amount of detailed analytical/laboratory notes accumulated as the result of this preliminary examination/"triage" stage. Including observations, commentary, sketches, and photographs. The stereo microscope can be a valuable tool indeed. Due to the accumulation represented, they are not included en toto - nor even in any great detail- in the present report. TCM can be contacted regarding specific interests, questions, etc.

Selected materials (about one hundred specimens, in all) were then mailed to Dr. Aleksandrov, at the V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow, for examination, evaluation, and further analysis as he deemed appropriate to his own ongoing research. This latter work included hand specimen, petrographic microscope, microprobe analysis, etc. of representative materials of particular interest.

The following are some selected comments, as culled from the analytical notes (TCM) mentioned above. Of particular interest were observations dealing with samples which -- the entire specimen, or portions thereof -- were subsequently sent to SMA. Especially the periclase (brucite) marbles, calciphyres, banded rocks and "ores", etc. Descriptions, and sketch maps, of field/sampling localities are presented elsewhere (above) in the "Data Supplement" section of the present report.

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The sample labeling scheme used is exemplified as follows: TM = the sampler's initials; "04" = the year, 2004; "6" = the sixth month, June; "9" = the ninth day of that month; "3" = the sample locality/site for that day, per my field notes; the final number ("N") is that assigned to a/this particular specimen.

Ie., in this instance : [TM-04-6-9-3-N].

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1981 Samples-

TM-81-7-30-1:

"Skarn". Garnet, pyroxene major minerals. Subordinate to minor amounts of "calcite/carbonate"(?), magnetite, quartz, epidote, actinolite (w/chlorite?), idocrase, chalcopyrite, serpentine(?). And/or perhaps some bornite (?), tremolite(?), wollastonite(?).

Garnet: Eu/subhedral, to anhedral, massive; reddish-brown; often enclosed/surrounded by pyroxene, calcite.

Pyroxene: Euhedral-subhedral, to anhedral, massive; dark green-blackish.

Calcite: Euhedral-subhedral, to anhedral, granular, patchy massive; pink-salmon-orange-white-clear colorless.

Quartz: Anhedral to (some) subhedral; colorless, clear, glassy.

Magnetite: Octahedral and cubic euhedral crystals; black. Some apparent magnetite might actually be bornite(?).

Epidote: Euhedral, and also less-well-developed; lemon-lime to pistachio color.

"Actinolite/chlorite/tremolite"; "serpentine", in part(?): Sheaf-like crystals, eu-subhedral, and anhedral granular/massive; pale/light green to green.

Serpentine: Fibrous; light greenish-whitish-colorless.

Chalcopyrite: Eu-subhedral, and as less-well-developed crystals.

Assemblages/relationships:

Magnetite occurs within quartz, epidote, calcite, and adjacent to chalcopyrite.
Epidote occurs on/after black pyroxene, some of which is eu-subhedral.
Garnet occurs within calcite, as well as intergrown with pyroxene.
Serpentine occurs with "tremolite/actinolite".
Quartz encloses magnetite, epidote; is noted "adjacent to" chalcopyrite.
Quartz-epidote-garnet-calcite-pyroxene-magnetite.
White granular wollastonite (??) adjacent to/on calcite; in veins/fracture fillings, adjacent to garnet. Some (at least) of the apparent "wollastonite" might actually be ("weathered" ?) calcite (??, +/-?).

"Vug-like" patches (maximum dimension observed about10 cm.) of "calcite/carbonate" (euhedral and less-well developed), garnet (euhedral and less-well developed), pyroxene (euhedral and less-well developed), quartz (anhedral), chalcopyrite. Grains range from +/- 2mm to substantially larger, and are well-developed crystals, for the most part. These "patches/vugs" are disseminated/scattered throughout the specimen, the remainder of which consists principally of pyroxene and garnet, coarser-grained/more massively-developed. This latter type of intergrown garnet and pyroxene, +/- minor amounts of "alteration products" and scattered "dark/black opaques" comprise the bulk of this "skarn material/rock".

These "vugs/patches" are suggestive, in terms of general petrologic aspect, as well as geochemical, mineralogic, and textural characteristics, of some form of "late-stage/last gasp" crystallization related to relatively "volatiles-rich" fluid(s). There is a "pegmatoid" aspect to them. Their mode of occurrence, as often vaguely-defined features within a varied-size mosaic principally composed of "massive" garnet and pyroxene, is striking. Typically, somewhat "vaguely-defined", yet generally readily discernible boundaries/borders between "patches/vugs" and surroundings are observed.

The carbonate seems a key - the "typical" - feature, the essentially omnipresent mineral of these "patches". Together with the quartz, and sulphides, +/- "epidote, serpentine, etc., suggesting concentration of CO2, Si, some form(s) of S, and, likely, H2O, +/-, presumably in a "fluid" phase(es?), within a surrounding environment of Ca-Fe-Mg-rich materials.

TM-81-7-30-2:

"Skarn". Garnet, pyroxene major minerals. Subordinate amount of "calcite/carbonate"; minor/trace amounts of magnetite, quartz, epidote, actinolite, serpentine(?) chalcopyrite, malachite, bornite. "Possible" (?) pyrite/pyrrhotite/arsenoprite; and/or (??) some tremolite, wollastonite, talc. Traces of several fractures noted, with calcite and/or quartz on fracture surfaces.

Garnet: Eu/subhedral, to anhedral, massive; reddish-brown; often enclosed/surrounded by pyroxene, calcite.

Pyroxene: Euhedral-subhedral, to anhedral, massive; black to dark green-blackish. Intergrown with, often enclosed by, garnet.

Calcite: Euhedral-subhedral, to anhedral, granular, patchy massive; pink-salmon-orange-white-clear colorless.

Quartz: Anhedral to (some) subhedral; colorless, clear, glassy.

Magnetite: Octahedral and cubic euhedral crystals, and as less-well-developed grains; black. Some apparent magnetite might actually be bornite(?); or other mineral(s). As well, some of the magnetite might represent -perhaps pseudomorphically - replacements of pre-existing minerals (viz. esp. "borates"?).

Epidote: Euhedral, and also less-well-developed; lemon-lime to pistachio color.

"Actinolite/chlorite/tremolite"; "serpentine", in part(?): Sheaf-like crystals, eu-subhedral, and anhedral granular/massive; pale/light green to green.

Serpentine: Fibrous; light greenish-whitish-colorless.

Chalcopyrite: Eu-subhedral, and as less-well-developed crystals.

Bornite: Subhedral and less-well-developed grains; black-purplish/bluish.

Assemblages/relationships:

Garnet after pyroxene.

Massive pyroxene with the appearance of "being engulfed/altered by/to" garnet.

Calcite after pyroxene, garnet.

Minor/traces of epidote, +/-, on pyroxene.

This specimen also features "vug-like patches" similar to those described above (cf. TM-81-7-30-1).

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2004 Samples-

TM-04-6-9-3-1:

Calciphyre. Calcite, with marble texture. Disseminated brownish spinel(?), as well as apparent brucite pseudomorphous after periclase. (Cf. remarks on similar appearing periclase [brucite] marble under TM-04-6-9-3-9, below). Other minerals noted are forsterite; phlogopite//+/- serpentine?, talc? (after/adjacent to forsterite), talc(?); magnetite (?), or perhaps other black mineral(s). Magnetite might (?) be pseudomorphous after Mg-Fe borates(?), +/-.

TM-04-6-9-3-2:

A "granitic"-aspect rock. Featuring fractures filled with epidote, calcite, quartz(?), magnetite(?). Rock also features black eu-subhedral pyroxene(?)/amphibole(???) [shows some apparent "approx. 90-degrees" cleavage]; plagioclase (note [subhedral] crystal morphology, cleavages); quartz(?); some magnetite(?) +/- associated pyrite(?)/chalcopyrite(??), all altering to "limonite". Also some epidote, on fractures, and in "vugs(?)" (after calcite?, etc.?), as well as marginal to - as alteration of(?) - plagioclase.

A "quartz dioritic" -- perhaps a "quartz gabbro"(?) -- rock (now). "Altered" rock(?)/"endoskarn"(?). Or representative of a "plagioclase-pyroxene zone", per SMA.

TM-04-6-9-3-3:

Zoned magnesian-skarn material. An excellent example of its type.

Five distinct zones/portions occur in this specimen (the specimen is approximately 11 cm in maximum dimension).

A zone (on the order of 3 cm, as exposed) of periclase (brucite) marble occurs at one edge of the specimen. (Cf. remarks on similar-appearing periclase [brucite] marble under TM-04-6-9-3-9, below).

Next to this is a zone approximately 3-5 mm in width, comprised principally of reddish-brownish garnet (?), with associated quartz?, chlorite??.

Next to this is a zone (on the order of 2 cm wide) consisting principally of dark greenish/black pyroxene.

Followed in turn by a zone, about 4 cm wide, made up principally of phlogopite, +/-.

Next to this is a zone of calciphyre, occupying the remaining approximately 2 cm of the specimen, along this "traverse" across its surface parallel to the maximum dimension of the specimen.

Perhaps representing a "vein-like" development of skarn? With similarities to sample "-1", above. Portions of the specimen consisting of marble are principally calcite, with disseminated brownish material(s?), some/most of which appears to be brucite after periclase, while some perhaps is more likely spinel(?). The "calciphyre" lithology features major calcite, subordinate forsterite(?)/related alteration products (viz. "serpentine?/ phlogopite?, +/-?), as well as -- perhaps -- trace amounts of magnetite (?) and/or spinel (?), +/-?.

(Compare this specimen with specimens TM-04-6-9-3-10; -11; -12).

TM-04-6-9-3-4:

Periclase (brucite) marble; calcitic, white-light grey. Containing sets of darker-coloured/greyish cross-fractures. The fractures "filled/healed" with clear -- hence the "darker, greyish" effect -- carbonate/calcite(?). Ie. "self-healed/recrystallized". "Crush zones(??)". Rock otherwise rather homogeneous, mineralogically and texturally. Though small disseminated brownish specks occur, some such being brucite after periclase(?), as well as (some) spinel(?) , and/or......... ??

(Cf. remarks on similar appearing periclase [brucite] marble under TM-04-6-9-3-9, below).

Specimen is a hard,"bell-banging" rock, which rings/clangs/tinkles nicely under hammer blows; or, especially, when thin slivers of the rock are struck together. "Chattering rocks": which chatter on -- amiably..... or irritably......, according to one's mood of the moment -- ; as one makes his way -- or, more frequently, stumbles along, slipping and sliding, -- over accumulations of rubble/float fragments of this lithology. The sort of rocks perhaps one might be able to map "by ear", or even in the dark (?). Sharp edges, pointy corners, too.......

TM-04-6-9-3-5:

Carbonate rocks. Periclase (brucite) marbles.

Two "varieties" (sedimentary layering, apparently[?]) manifest in this specimen; one essentially white, the other "greyer"("carbonaceous/graphitic"?), with rather abrupt/sharp contacts between these "varieties".

Set(s) of intersecting fractures transect both of these varieties of rocks, cutting across both similarly without interruption. These fractures are similar to those mentioned in sample TM-04-6-9-4 (above), perhaps/likely as "self-healed"/recrystallized crush/shear zones.

Minerals present feature a "glassy" clear "quartzy"-looking crystalline material, intergrown with a duller, white, crystalline material which shows subhedral crystals (as "stubbyish forms/laths") when in lesser proportion to surrounding "quartzy" material. The latter also exhibits some eu-subhedral aspects here and there, possibly of "quartz aspect" (?). The "lighter" portion of the specimen consists of predominant "white" carbonate (calcite) material; the "greyer" portion of the specimen, as well as the transecting fractures/zones, contain carbonate/calcite, as well appreciable "quartzy-looking" mineral.

A "siliceous"/"quartzose"(?) periclase (brucite) marble. (Cf. remarks on periclase [brucite] marble under TM-04-6-9-3-9, below).

Trace/minor amounts of fine-/very-fine-grained black crystalline material(s?) occur here and there, including within fracture zones. These perhaps consist of graphite(?)/magnetite(?)/+/- ??. Also disseminated in this specimen are many somewhat obscure "brownish specks", which perhaps/likely (somewhat "unclear" in this particular specimen) are brucite, after periclase.

TM-04-6-9-3-6:

Carbonate rock(s). Periclase (brucite) marble.

Two variants in this specimen. One a dark grey, the other a lighter grey-white, apparently interbedded (?). Some fractures, especially apparent/only present(?) in the darker variety of rock here, with lighter material (carbonate/calcite, +/-?) along the fracture surfaces.

Might(??) the lighter "beds"/"layers" of carbonate rock actually be "wider"/"mega" shear zones, with recrystallized carbonate, +/-?, along/within these zones (??). One edge of one of the white "zones"/"layers" exhibits a distinct "ringing"/"bell-banging" character when struck sharply.

The darker grey material features greyish vitreous-looking mineral(s); carbonate/quartz(?)/+/-?), and (appreciable) associated dark/black disseminated material(s?). The latter possibly graphite?/magnetite?/?"borates"?/or ??. Note, in this darker material, brownish subequant (on weathered surface) grains of apparent brucite after periclase. And/or spinel(??).

In the lighter material, there appear to be at least two "predominant" minerals: one "dull whitish", the other a light grey, and perhaps "more vitreous"-looking. Likely periclase/ brucite, and calcite.

(Cf. specimens TM-04-6-9-3, 4, 5).

(Cf. remarks on similar appearing periclase [brucite] marble under TM-04-6-9-3-9, below).

In the darker material in this specimen, these two "predominant" minerals also occur, but with a more substantial amount of black materials(s?); viz.graphite? /magnetite?/ "borates"?/+/-??.

These "whitish" versus "light-greyish" minerals are present in approximately coequal proportions in both the lighter and darker portions; ie., the "lighter" and the "darker" carbonate(?) rocks/layers comprising this specimen. Hence likely (?) represent periclase/brucite and calcite.

((Might at least some of the "grey" material be fluorite(???); note an optical impression of sort of a "greasy" appearance, here and there. Though perhaps more likely this is also periclase/brucite.))

TM-04-6-9-3-7:

White carbonate rock. Periclase (brucite) marble.

With at least two sets of intersecting fractures. The earlier set features greyish ("quartzy-looking") material (cf. specimens TM-04-6-9-3, -4, -5, -6, per above). The later set features some similar material, though containing appreciably more black material/mineral(s) - (graphite?/magnetite?/Mg-Fe borates??/tourmaline???/+/-?).

The white carbonate material appears to consist of approximately coequal amounts of a white, "dullish-appearing" mineral, and a more "vitreous-appearing", clearer ("quartzy-looking") mineral (which latter, however, is not as greyish as the "quartzy-looking" mineral in/associated with the fractures.

(Cf. remarks on similar appearing periclase [brucite] marble under TM-04-6-9-3-9, below).

In the "later" fracture-fillings/"veins", the black mineral(s) are the principal constituent, with apparent "spreading"/"diffusion" laterally into the country rock surrounding these "veins". Much of the "vein-filling" is also a darkish-grey "quartzy-looking"/[rather, carbonate(?)] material (cf. the phases noted in samples TM-04-6-9-3, -4, -5, -6, as above).

This specimen presents the aspect of "vein-filling" material, perhaps along "crushed" and "recrystallized" zones/fractures. Featuring a "self-healing" situation, in this particular case in concert with deposition of the black mineral(s)/material(s). The dark veins offset the lighter grey veins, slightly but noticeably. These darker veins are somewhat remindful of similar features observed at the magnesian skarn-related localities of Lost River/Brooks Mountain/+/-Tin Creek, western Seward Peninsula, Alaska.

Some buff/tan/"rusty" weathering (presumably) effects noted on older/"pre-hammering" surfaces of this specimen. Also noted on these surfaces are a number of apparently "residual" periclase --> brucite "holes"/depressions, displaying euhedral outlines typical of the genre.

TM-04-6-9-3-8:

White carbonate rock. Periclase (brucite) marble. Displaying two sets/orientations of intersecting fractures.

The earlier set/orientation attitude contains a darker subset, with the aspect of a "crushed zone" (as per specimens TM-04-6-9-3-3, -4, -5-, -6, -7, above), and a relatively lighter subset. These two subsets are subparallel to one another.

This set is terminated abruptly by the second set/orientation attitude, which latter is manifest as an only-vaguely-discernible zone/fracture oriented at an angle of approximately 90 degrees to the trend of the earlier set. This later fracture/termination vaguely shows some apparent recrystallization features along its trend.

This sample, otherwise, is a fairly "homogeneous" rock.

(Cf. remarks on similar appearing periclase [brucite] marble under TM-04-6-9-3-9, below).

TM-04-6-9-3-9:

This specimen is a KEY one. Consisting as it does of an excellent ("splendid", according to SMA's subsequent more complete analysis) example of a periclase (brucite) marble.

Principal features (often clearly displayed, in superb fashion) include:

"Original" periclase; as residual cores of periclase, featuring well-developed euhedral crystal forms.

Subsequent partial to apparently complete pseudomorphous replacement of periclase by brucite.

Brucite occurs as radiating masses of eu-subhedral crystals (a "radial fibrous" texture /aspect). The long dimensions of the fibres are oriented essentially perpendicularly to the original outline/faces of the periclase crystal replaced/being replaced.

Various "facets/degrees/extents" of this are displayed throughout the entirety of this specimen. Apparently without any (recognized) preferred location(s) for the "occurrence /degree/extent" of the process(es).

These features texturally and mineralogically manifesting -- affording clear evidence of -- the petrogenetically-key chemical reaction for the formation of periclase marble from precursorial dolomite: $CaMg(CO_3)_2 \longrightarrow CaCO_3+MgO+CO_2$. (Cf. H. G. F. Winkler, 1979, esp.).

The specimen overall is a white/very light grey carbonate rock (marble). It features a somewhat rectilinear system of fractures/ "recrystallized/healed crush zones", with two predominant sets recognized, intersecting with one another at relatively high angles (ca. 60 degrees +/-).

One set consists of fractures on the order of 1-3 mm in apparent width, as viewed on the largest specimen face; the other set consisting of fracture zones on the order of 4-5 mm in apparent width, as viewed on the same specimen face. This specimen face is essentially rectangular in outline, with dimensions of approximately 6.5 x 4.5 cm. The fracture fillings/"veins" are vaguely "zoned", with "darker/greyer" borders, and medial portions lighter, more similar in color to the surrounding host rock marble.

Associated with both the white translucent-clear material (calcite, texturally present as a crystalline mosaic) comprising the bulk of the carbonate rock/marble, and the greyish-clear phase(s) of carbonate(?)/+/-?? in the "veins/veinlets/crush/healed zones", are dullish-white "blobs/patches". Such a blob/patch displays (variously) a black-brownish-greenish-yellowish central "core" of apparent ("residual/relict") periclase, surrounded peripherally by white-brownish-grey-greenish, "waxy"/semi-vitreous, generally fibrous, brucite. In many cases the spatial relationships represent, essentially, brucite "caught-in-the-act" of replacing previously-formed periclase. (Mineralogically and texturally manifesting the petrogenetically key reaction:

CaMg(CO3)2 ---> CaCO3 + MgO + CO2).

Numerous examples, variously-well-developed/displayed, are apparent throughout this specimen. Many are, indeed, truly "exemplary". Typically, (Cf. the somewhat voluminous original detailed laboratory notes, and accompanying drawings, of the specimen examinations by TCM, not presented in this report.)

In most places throughout this specimen, the ratio (by visual estimation under the stereomicroscope) of carbonate (calcite):periclase/brucite is on the order of 60:40. The latter abounds, as areas of filled/partially-filled voids, "patches", "blebs", throughout the specimen, within the "white carbonate" as well as the "greyer", "veinlet" portions of the specimen.

The fractures, the relationships among them, and between them and the calcite and the periclase(brucite) occurrences, afford indications as to the geological history, timing, course of events, as related to the geochemical/petrogenetic episodes represented in this specimen, and the Arctic Chief locality overall. (Cf. as well, in this context, similarities to other periclase (brucite) marble specimens from this, and other nearby/stratigraphically equivalent locations sampled [as described above and below].)

The fractures/crushed zones, with their associated recrystallized carbonate, +/-, material(s), appear to have formed prior to (?) the formation of the periclase. This seems likely, since the periclase crystals (and, significantly, their subsequently-replacing brucite) are apparently unaffected by these fractures/crushed zones, and also occur with essentially the same/equal concentrations/frequency within as well as outside these zones. And the likely relatively fragile//readily-deformed/obliterated radiating crystal habits/habitats of brucite, as well as the often well-developed euhedral outlines/shapes of the original periclase crystals, are similar/the same/identical within as well as outside these zones of apparent structural disturbance/deformation and related/associated recrystallization. Likely they would have been distorted/damaged/obliterated had they existed prior to, or during, this fracturing.

TM-04-6-9-3-10:

Specimen features a number of readily discernible metasomatic/metamorphic "zones".

These all occur in the relatively small volume of this specimen. The dimension measured at a right angle to the attitudes of the "zones" as displayed on the "best" specimen surface is 8.5 cm. This zoning seems to perhaps exemplify the "primitive" type in a magnesian skarn (cf. Aleksandrov,1998 & etc., on zoning "in pipes and stockworks in tectonically crushed zones in the envelope of dolomitic rocks around granitic contacts"). The zoning is manifest mineralogically, geochemically, texturally, as well as visually.

Note some indications/evidence (viz. offsets, trends of mineral occurrences) of fracturing/faulting within this specimen, which suggest (per SMA; see "references") perhaps a situation of "long-lived" tectonic/"crushed zone" setting? Ie. during the magmatic and post-magmatic stages. Although (per SMA, esp. p. 4 in the 1998 book) the nature and scale of the zoning in this particular specimen actually seem to suggest a situation of pre-skarn fracturing/crushed zone formation, which features became sealed during the formation of the primary metasomatic zoning (seemingly as exemplified in this specimen (?).

The "zones" featured in this specimen are here-labeled (solely for purposes of description) and here-described, from "left to right" across the particular orientation and face of this specimen selected for description.

The first zone ("A") consists of a white-light grey periclase (brucite) marble. The major mineral constituents of this marble are calcite and periclase (brucite), occurring as a crystalline mosaic. The periclase (brucite) occurrences are often rather well-developed (some "classic"), nicely displaying the periclase "core"-brucite "rim" relationships, etc., as noted in other marble specimens collected/observed at this sample location, as well as at other sites at the Arctic Chief. [Cf. remarks on similar-appearing periclase [brucite] marble under TM-04-6-9-3-9, above. See also observations, comments, sketches, in detailed laboratory notes (TCM), which are not included in this report.].

Trace amounts of subequant sub-euhedral crystals of a greenish-black semi-transparent mineral(s) are noted which might (?) be spinel, or pyroxene (?). One such observed is associated with a small grain of a black crystalline material which might be magnetite (?), or pyroxene (?), or (??).

The "best" such euhedral crystal of a black mineral noted shows vaguely-defined striae/cleavage (?) subparallel to its long dimension, suggestive of a pyroxene. This crystal may well be twinned, as an apparently similar crystal lurks beneath, vaguely defined within the surrounding crystalline mosaic of calcite, periclase (brucite), etc., comprising the bulk of the marble. This crystalline mosaic also features disseminated "very-very"-fine-grained black "platy" (graphite?/magnetite?/phlogopite?/??) specks/grains, some associated with apparent "rusty" (hence iron-bearing?) material(s).

Zone "B" is a "forsterite, +/-?, calciphyre". It consists principally of predominant calcite (as a crystalline mosaic), and, generally (except where present in some concentrations, as "layers/bands/lenses/patches/streaks"), substantially subordinate forsterite/forsteritic olivine. The zone is "somewhat banded" overall, and features darker grey, lighter grey, and yellowish-greenish "subzones"/portions, as well as varying grain sizes (some discernible megascopically).

Compared to zone "A", zone "B" features a greater amount of black vitreous crystals/aggregates, some of which are associated with patches/margins of yellow-brown material similar to that observed in zone "A" in association with black crystals of (?). Also note some crystals (some apparently 6-sided) of clear vitreous aspect, with patchy distribution of internal disseminations/"dustings" of a "very-very"-fine-grained chocloate brown material. All set in the crystalline mosaic "matrix" of the predominant calcite.

The concentrations of greenish, black, and brown-dusted materials are most apparent as occurring in ill-defined but discernible "bands", which define the "banding" within this zone, occurring in subparallel aspect/orientation to the major "boundaries" between "zones" (ie. marble, then calciphyre, then forsterite, serpentine, pyroxene, garnet) in this specimen. These "bands" are often more like wispy patches, lenses, actually, within this zone "B". "Interbands" containing more, or less, marble/calcite crystalline mosaic material occur as well, essentially by varying degrees of absence/lack -- default, as it were -- of other constituents.

The zone "B" vs. zone "C" boundary, if indeed a "B-C boundary" actually exists as such, is "vague"; perhaps illusory(?). Though the concentration of green mineral(s) increases from "B"-->"C"-->"D".

Zone "C" consists of a forsterite calciphyre, similar to "B" except for a greater proportion of "yellow-green" mineral constituent(s), principally forsterite.

Zone "D" is light green in color, with a yellow tinge, due to its increasingly forsterite-rich (yellow-green mineral) content, becoming an essentially "monomineralic" zone (though with scattered black sub-euhedral opaque grains -- magnetite?) distally from "C".

At the distal-from-"C"/proximal-to-zone "F" portion of this zone (ie. "D"), is a relatively thin subzone ("E"), consisting of serpentine (+/- some forsterite), developed essentially continuously along this "border/boundary". This is probably the "bottom" of zone "D", if, as seems not unlikely, the presumed source of the metasomatizing fluids was toward zone "F". (???) **A "monomineralic forsterite" zone, per SMA(?).**

Subzone "E" is light green, "waxy" in appearance, comprised principally of crystalline serpentine, with preferred orientations of the long dimensions of the prismatic-appearing crystals -- chrysotile, or perhaps antigorite (?) -- in growth positions (apparently), essentially perpendicular to the boundary with zone "F". It is highly fractured, with some white fibrous crystals (talc?/+/-?) also present, lining the fractures/seams. At the distal-from-"F" margin of subzone "E", a thin interval of "darker/denser"-appearing material of undetermined nature (representing depositional conditions more conducive to a "massive" form of crystallization of a serpentine mineral, perhaps antigorite?), occurs, separating "E" from zone "D".

Immediately adjacent to/"below" this "basal" serpentine-rich subzone ("E") is a relatively thin layer of red-brown garnet, which has invaded through the black pyroxene zone ("F") adjacent to zone "D". This type of red-brown garnet -- comprising the predominant mineral of zone "G" -- is seen in zone "F", engulfing black pyroxene euhedra/masses. Zone "F" is dark grey to blackish, with a reddish cast. It is comprised principally of very fine grained, to massive, pyroxene, +/-, as a "skarn". The pyroxene euhedra occur as black stubby prisms, with good cleavage displayed.

Somewhat intermittently developed between zones "E" and "F" is subzone "P", comprised principally of phlogopite, +/- perhaps subordinate amounts of other material(s). Developed "below/subeven" with the serpentine horizon of subzone "E", "P" manifests itself as pods/lenses of phlogopite. These pods/lenses occur immediately adjacent to serpentine on one side, and to pyroxene (+/- garnet) of zone "F" on the other side. In some places, observed clear micaceous materials may -- at least in part -- actually be talc (?), while in other (most) places the micaceous mineral is darker/greenish, and most likely phlogopite.

An additional, rather intriguing, situation seems to present itself in this particular portion of the specimen:

Other minerals present in this general "horizon" include opaque phases (in minor/trace amounts). These include euhedra/"octahedra"(?) of "brassy"-appearing opaque material(s);

perhaps chalcopyrite (?), or chalcopyrite after magnetite (?). Possibly (??) valleriite, tochilinite, etc. (???).

Some opaque masses feature a yellow-brown/"bronzy" material of pyrrhotite "aspect", but in direct contact with black material which may be/include magnetite (?!?). Some of this bronzy material apparently has a "prismatic" crystal habit, variously developed. The opaques seem to be transected by garnet, +/- quartz(?), +/-carbonate(?), at least locally.

Elsewhere in this same general "horizon", some apparently prismatic (or, perhaps, actually an "end-on" view of "layers"??) crystals of "bronzy" opaque material(s) are present, in direct contact with (apparent) pyroxene (magnetite??). In this particular occurrence, the "prismatic" aspect of the bronzy opaque material might, alternatively, actually represent manifestation of cleavage on subjacent pyroxene crystals (perhaps undergoing alteration/replacment??).

This "horizon" is essentially within the zone "F" vs. zone "G" transition/border, with boundaries irregular, vague. As noted above, zone "F" contains appreciable/principally pyroxene, occurring as black stubby prismatic sub-euhedral crystals, showing good cleavage.

Might (??), per an observation by Ramdohr, the "bronzy opaque" material occur as an "encrustation" on pyroxene?. As a "preferred" (for valleriite/etc.) mode of occurrence "as encrustations....... associated with serpentine, etc......." (Ramdohr).

Pursuing this thread further, is the black "pyroxene" in contact with the bronzy opaque/valleriite(???) actually pyroxene? Or, perhaps, magnetite? [In an association of garnet+/-quartz(?)+/-calcite+/-magnetite+/-valleriite/tochilinite+/-pyrrhotite ??]

Zone "F" becomes decreasingly a discrete entity as admixture with/replacement by garnet, opaque minerals, +/-, is shown/represented through zone "G" to the distal edge/tip of the specimen. Zone "G" features a dark brown-reddish cast overall, due to the predominant garnet. This zone is, essentially, representative of "garnetiferous skarn". Pyroxene, magnetite, other opaque minerals, including sulphides, occur, variously, in subordinate/minor/trace amounts. Some '"rusty" patches occur. Copper "staining", apparently as malachite, +/-, occurs at the extreme tip of the specimen.

Thus, in summary, a <u>very</u> interesting specimen. Essentially a "microcosm"of the sequence:

Periclase (brucite) marble -- calciphyre(s) -- forsterite(+/-) -- pyroxene -- garnet+/-opaque minerals "zonation".

With calciphyres, forsterite, phlogopite, serpentine, opaques (perhaps including valleriite/tochilinite??). Each in its "proper"/appropriate "position", spatially and genetically, petrologically and geochemically. (See Aleksandrov, 1998, & etc.).

This specimen displays:

- Periclase (brucite) marble
- Calciphyres, with forsterite, +/-
- Metasomatic zoning of the magmatic stage
- Subsequent (partial, at least) effects of post-magmatic "alterations", through at least the "acid stage"
- Minerals such as spinel, phlogopite, serpentine; magnetite, chalcopyrite, garnet, pyroxene

TM-04-6-9-3-11:

This is a specimen with a number of aspects of magnesian skarn displayed in "microcosm":

Blocks/fragments of apparent periclase (brucite) marble, with rims of garnet, adjacent to pyroxene skarn material; then phlogopite +/- serpentine, then forsterite, then once again back into pyroxene skarn, followed in turn by another garnet rim, around another block/fragment of marble.

Phlogopite is very-well-developed, serpentine well-developed. Spinel, +/- magnetite, +/-?, occurs scattered throughout the specimen. Note periclase and brucite, with character and relationships as noted in other calcitic marbles/ calciphyres, from this, and other localities at the Arctic Chief.

Interpretation of the observed overall relationships in this specimen remains somewhat "uncertain".

Do these blocks/fragments represent "nodules" of marble/calciphyre, rimmed by "reaction zones" (??) of garnet, as remnants within pyroxene skarn?

Or might they be related to "apophyses" of "granitic"/? melt, as "tongue-like" features intrusive into host rocks of carbonate (or previously-formed skarn material?) nature. With the pyroxene, garnet, phlogopite, serpentine, etc. observed being ancillary to this sort of situation.

(Cf. TM-04-6-9-3-1, and -3, specimens with similarities to this one.)

TM-04-6-9-3-12:

Specimen (maximum dimension = 8.5 cm) contains a number of "zones", especially well-displayed across one of its faces. In order, along a distance of 5.0 cm across this face, in a direction ("left to right") perpendicular to the trends of these zones, the relationships observed are as follows:

From the leftmost edge of the specimen, a zone of reddish-brownish garnet, with minor calcite, 1.5 cm wide.

A zone of pyroxene skarn. Predominantly consisting of a relatively light green pyroxene, with minor/trace spinel, +/-?. This zone is on the order of 2.0 cm wide.

A zone featuring predominant phlogopite, with lesser calcite, spinel(?), "rusty" magnetite(?), talc (??). This zone is on the order of 1.3 cm wide.

A thin zone (approximately 2-3 mm wide) along the rightmost edge of the specimen. It consists principally of serpentine, some clearly fibrous, and minor "rusty" opaque material, presumably magnetite, +/- ?.

Additional observations:

Black "very-very"-fine-grained, black ("flaky", at least in part) crystals/materials occur disseminated throughout the "pyroxene skarn" zone.

The garnet zone has an aspect suggestive of an "apophysis"/tongue. (As discussed by Aleksandrov, 1998, & etc. Especially note a diagram depicting the development of zoning around an "apophysis"....... Also, on a larger scale, the similarity to known relationships at the Holton/Hol-Kol, North Korea, locality/deposit.)

[As a further observation, it should be noted that there actually appear to be a number of similarities between this Korean deposit and the Arctic Chief].

The shape/orientation of the adjacent pyroxene skarn, as well as that of its adjoining neighbor, the phlogopite, +/-, zone, mimicking as they do the shape/outline of the garnet zone, add to this "suggestiveness".

Similarly, though not as well-displayed due to its location on the edge of the specimen, the shape/orientation of the serpentine, +/-, zone further substantiates this "apophysis-like" impression.

The serpentine occurs intergrown with, and likely from, adjacent phlogopite of the phlogopite +/- zone.

Phlogopite occurs as well-developed euhedral crystals, light olive green to dark olive green in color, often with physically interleaved/interlayered other minerals (viz. calcite?, +/-?).

Given the nature, and "position", of these "zones", it might be speculated that a zone featuring forsterite, +/-, might well have existed "beyond"/adjacent to the serpentine/"phlogopite-serpentine"(?) zone observed in this specimen.

TM-04-6-9-3-13:

Specimen is on the order of 5.0 x 5.5 cm. It features several "zones", especially well-displayed on one of its relatively flat surfaces.

In order, along a distance of approximately 5.2 cm across this face, in a direction ("left to right") perpendicular to the trends of these zones, the relationships observed are as follows:

A zone of "calciphyre", on the order of 3.7 cm wide, from the left edge of the specimen to the adjoining zone to its right.

A zone on the order of 0.9 cm wide, consisting of pyroxene skarn, with minor associated spinel(?), +/-?.

A zone consisting of serpentine, +/- forsterite, +/-?. It is discontinuously developed, with a maximum observed width of about 1 - 2 mm.

A zone approximately 5.0 mm in maximum observed width, extending to the right edge of the specimen. This zone consists predominantly of phlogopite, +/- associated talc(?), +/-?.

The calciphyre zone presents some indications of additional "subzoning"/banding within it, but this is rather "subtle", at best (especially under the stereomicroscope, on a rock surface).

The caliciphyre is made up predominantly of a crystalline calcite mosaic (ie. a "periclase[brucite] marble"), with lesser amounts of associated "light", and "dark" minerals. These include forsterite, pyroxene, vesuvianite/idocrase(?), spinel, +/-?. Trace quantities of opaque minerals, featuring magnetite, +/- valleriite?, +/- pyrrhotite?/pyrite?/arsenopyrite??-loellingite??, also are present, as lenslike/streaky occurrences.

The calciphyre also features some patches of garnet(??)/+/- magnetite(??) -- as "rusty" black crystalline sub-euhedral grains. In association with the surrounding calcite mosaic, some particular examples of this material(s) are also noted to be in close proximity to traces/specks/crystals(?) of a bright blue-green mineral(s).

The latter range from sub-euhedral, are tabular-prismatic, and appear/look "coppery". Ie., chrysocolla, +/- malachite, +/- azurite (?). Or, sometimes seemingly "emerald-turquoise colored". These "coppery" materials appear to be "vitreous-waxy" in aspect, and are concentrated in a "patch/lens/layer" of the "rusty" black minerals.

Additionally, disseminated sporadically throughout the serpentine zone and its environs, are some black-very dark brown vitreous crystals, not uncommonly as euhedra/subhedra with six-sided or eight-sided aspects. Some are "dendritic"/"snowflaky" in appearance, perhaps as crystal aggregates/skeletal crystals/growth forms. Remindful of manganese oxide "dendrites". Arborescent, overall. With many (variously) well-developed "six-rayed" branching forms displayed. Skeletal crystals/forms(?); possibly borates(?); graphite(?), +/- ?

TM-04-6-9-3-14:

Specimen is 6.5 cm in width, as measured across the face described here. Consists of a number of "zones", characterized for descriptive purposes principally by overall color, mineralogy, texture. As observed, from "left to right" across the face, these zones are as follows:

1. On the order of 6 mm and, variously, less in apparent width, at the leftmost edge of the specimen. Greenish, consisting principally of phlogopite, with minor calcite, talc(?).
2. Adjacent to zone 1. Approximately 1.1 cm in apparent width, variously, and

conforming to the shape of the adjacent zones on either side. Greyish, consisting principally of calcite/"carbonate", with some associated periclase (brucite), and minor/trace amounts of relatively finer-grained "dark" minerals (spinel?/magnetite?/+/-?). A "periclase (brucite) marble"/"calciphyre(?)".

3. Adjacent to zone 2. A "lens"/"tongue" of material comprising zone 5 occurs within zone 3, occupying an apparent width of 1.5 cm in the central portion of zone 3. The apparent width of zone 3 is 1.5 cm on the "left" side of this lens/tongue, and 1.0 cm on the other side of it. Zone 3 is comprised of "calciphyre", containing predominant calcite, with associated periclase (brucite), and minor forsterite, +/-pyroxene.

5. The above-described zone 5 is made up of principally of patches of reddish-brownish garnet, as well as some calcite, minor forsterite, epidote?/serpentine(?), and some blue-grey material which may be zoisite/clinozoisite/+/- (?).

4. Approximately 0.8 cm in width, adjacent to the "rightmost" portion of zone 3, and on to the "right" edge of the specimen. Features appreciable pink and green (epidote?) and pink (zoisite?) materials, as well as "other" minerals, all "dark", some opaque. Relatively fine grain size precludes definitive characterization (on a rock surface, with the stereomicroscope) of the materials comprising this zone. The overall "aspect" is suggestive of "epidotization"/ "alteration" of previously-existing material(s).

Might zones 2, 3, 4, 5 represent "marble/calciphyres" (2 and 3), associated with (4 and 5) "veins"/"apophysis-related" features? After having been broken into several smaller pieces, this specimen shows some interesting "zonal" -- "transitional" -- "banded" aspects/features. Especially as regards the "calc-skarn"-like(?) garnet-epidote-opaque /"other" dark mineral(s)-"blue-grey" zoisite/clinozoisite(?) association/"assemblage".

TM-04-6-9-3-15:

This specimen rather "complex". A "hodge-podge"/veritable "witches' brew". "Calciphyre"(?)/"marble"(?);"originally". Featuring (relict) "prograde"(?), as well as "retrograde" (ie. "magmatic stage", and "post-magmatic stage"), assemblages. Minerals recognized/perhaps present are pyroxene (diopside?), garnet, magnetite, calcite, phlogopite, spinel(?), forsterite(?), +/-?.

Patches/lenses/"apophyses"/"fingers" of pyroxene/diopside(?), +/- , occur. These rimmed with/outlined by reddish-brownish garnet, calcite, +/-?. The other minerals/assemblages occur between/among the several such "apophyses"(?) present.

Apparently (?) representing a portion of what was originally a magnesian skarn, with subsequent "retrograde" ("post-magmatic; late early-alkaline <---> acid stages", +/- --->?). Illustrative, thus, of the general trend/sequence of metamorphic and metasomatic events which were involved in the history of this specimen. And, thus, by extension, to the Arctic Chief deposit as a whole/overall (?).

This specimen one of several collected at this sampling site as representing the "skarn" material(s) -- the "darker rocks", ie. -- of the "apophysis(es)" into/ associated with the lighter surrounding carbonate (viz. marble/calciphyre) country/host rocks at this locale. ["Representing", though not necessarily -- though of course "hopefully" -- "representative" of such, ie.]

TM-04-6-9-3-16:

Specimen is made up of a number of "zones", manifested by color, mineralogy, texture. Illustrative of, "representing" (not necessarily "representative" of) the "skarn"-like darker material(s) occurring as apparent "finger/lens/apophysis" features into/associated with the lighter-colored "carbonate" country rocks at this locale.

In the direction perpendicular to the "zones", the distance is on the order of 3.0 cm, across the face of the specimen. From "left to right" along this direction, the zones/materials encountered are as follows:

1. Approximately 1.5 cm in apparent width. Principal constituents recognized in a texturally "complex" rock mass include calcite ("marble", ie.), scattered phlogopite, olivine/forsterite(?), +/-?. Or perhaps better termed a "calciphyre" (?). A dark "horizon"/"subzone" of pyroxene, +/-?, occurs in one portion of this zone, toward the side adjacent to the adjoining zone "3". At the edge of zone 1, immediately adjacent to zone 3, is a thin "layer"/"subzone" comprised of principally of olivine/forsterite(?), +/-?.

2. Occurring within the central area of zone ("1") is a "lens/patch" of "exotic/foreign" material, which is designated as "zone 2". It is "tinged" with/comprised at least in part of reddish-brownish garnet, and epidote(?), as -- apparently(?) -- some sort of "vein/replacement" material(s).

3. About 1.0 cm in apparent width, zone 3 is a light grey/whitish "band", consisting predominantly of calcite ("marble", ie.), with trace amounts of scattered "dark" material(s). A thin, discontinuously-developed "subzone" rich in phlogopite, +/-, occurs along the margin of zone 3, adjacent to zone 1.

4. On the order of 0.5 cm in apparent width, zone 4 is made up predominantly of phlogopite, some calcite, +/-?, as a "dark band/horizon" in the specimen.

5. Occurring along the "rightmost" edge of the specimen, zone 5 is essentially a thin "rind"/"skin" of either weathered specimen surface, or, perhaps, vein-related/alteration material(s). The material(s) have a bluish-greyish hue, with indications of vitreous aspect, perhaps also displaying some prismatic forms.

TM-04-6-9-3-17:

Specimen is a porphyritic igneous intrusive rock, apparently, of "intermediate" composition.

Representing a dike, perhaps "late"/"after" (?) the metamorphic/metasomatic activity responsible for the formation of the Arctic Chief deposit (??) [Cf. "References" section of this report.].

Or, alternatively, perhaps at some, likely "later", stage during the formation of this deposit. In either case, this rock perhaps -- likely? -- crystallized from a melt related to, or a part of, the "main magma/intrusion" responsible for the metamorphism/metasomatism at the Arctic Chief locality, with attendant formation of this ore deposit. [Cf. other remarks by the authors elsewhere in this report.].

This specimen features phenocrysts of zoned sub-euhedral plagioclase (with some included "iron-affected" [Viz. "magnetite/+/-?".] core and marginal areas. [Much "magnetite" began to crystallize late in the crystallization of plagioclase, as well as during subsequent matrix solidification.] Such plagioclase is the predominant phenocryst mineral present, with

subordinate amounts of quartz (eu-subhedral, and often somewhat broken up).
Also noted are a few scattered subrounded "lithic fragments"/"inclusions" ("cognate"?), containing, variously, plagioclase, pyroxene/amphibole(?), quartz, magnetite. Also present are trace amounts of "micaceous material" (likely "biotite")?/pyroxene, amphibole? subhedra, of similar size to the phenocrysts, which perhaps represent portions of "relict/disaggregated" lithic fragments.

The groundmass of this specimen is fine-grained, grey-green iin color, featuring plagioclase sub-euhedral crystals, set in a surrounding matrix of quartz(?), magnetite(?), +/- another silicate mineral which may be amphibole (??) and/or pyroxene(??). This matrix appears to be too light in color to contain appreciable amounts, if any, of such mafic silicates, however. Thus, rather, perhaps a matter of "dusty" quartz/+/-, with finely disseminated opaque(s) mineral(s) -- viz. magnetite, +/-.

Some potassium feldspar might also be present, as matrix material, and/or as "micro" phenocrysts (??). However, this is difficult to ascertain with confidence, using only a stereomicroscope on rock surfaces.

This specimen is moderately fractured, and "veined". The fracture-fillings/veins feature a thin medial zone, generally dark/black (magnetite?), with adjacent borders made up of white material(s), perhaps quartz?/carbonate?/feldspar(s)?.

TM-04-6-9-4-.........

The collected specimens from this locale include carbonate rocks and "skarn" material(s). Three of the latter "-17-A, B, C" feature "skarn" materials and "ores". These specimens are from outcrop/rubble-crop, at a high "bench" location, with -- at present -- not much directly above the sampling area except air, birds, aircraft, etc. to have contributed "significantly out-of-place" material to these samples. (Bulldozers, etc. excepted, of course.)

TM-04-6-9-4-1:

An example of periclase (brucite) marble. This is a somewhat weathered/altered(?) specimen. Rock contains predominant calcite, periclase (brucite), and a distinctly minor/trace amount of disseminated dark-black material(s), probably at least in part magnetite (note "rust"), though some might be graphite(?).

The "pock-marked" weathered surfaces are of interest as regards recognition/ identification of rock constituents. Much useful information to be gleaned from scrutiny of "rusty" surfaces.

Periclase (brucite) and calcite are present in essentially subequal amounts, intergrown throughout the specimen.

Comparisons with observations/comments regarding similar-appearing specimens elsewhere at the Arctic Chief suggest not at all dissimilar rocks. Of particular interest in this regard are comparisons with samples from TM-04-6-9-3, & -5, locations, which are just across the Arctic Chief (west) pit entrance cut, to the "northish" of this "-4" locality. Carbonate, and other, rocks, apparently/essentially "on-trend" across the pit entrance cut here.

TM-04-6-9-4-2:

Specimen is an "interesting" one. A combination of periclase (brucite) marble and "skarn" material portions.

With apparent chalcopyrite/+/-? disseminated -- in fair amount -- within the carbonate rock adjacent to the skarn material. The marble apparently having been invaded by sulphides, featuring chalcopyrite, +/- galena(??), +/-?. The marble is comprised predominantly of calcite and periclase (brucite), with some disseminated pinkish-light brownish euhedra which may be spinel(?), and/or "flourite"(???)/+/-?.

A "banded"/gradational contact/intercontact exists between marble and "skarn". In part at least along "seams/fractures/shear zones"?. Some evidence of "internal shears/slip surfaces/slickensides/seamlets" within/throughout "skarn" as well as marble.

"Skarn" consists of pinkish-brownish garnet, sulphide minerals (disseminated/semi-concentrated; chalcopyrite?/+/-?), calcite, quartz(?), +/- trace of "epidote-like" coloration here and there, +/-?. One "pod/lens" of "skarn" seemingly occurs as an "offshoot/tongue" from the banded portion, into the adjacent marble.

The weathered surfaces of this specimen afford supplementary information/evidence regarding mineralogies, textures, structures.

TM-04-6-9-4-3:

A specimen featuring "banded skarn" adjacent to/"invading" periclase (brucite) marble. Quite similar to specimen TM-04-6-9-4-2 (cf. above).

Marble predominantly comprised of calcite and periclase (brucite), with some disseminated sulphide (chalcopyrite, +/-?) mineral(s), +/-graphite?, +/-?. This marble is quite similar to that at other nearby localities elsewhere at the Arctic Chief (viz. TM-04-6-9-3, -5). "Skarn" consists of pinkish-brownish garnet, pyroxene, sulphide mineral(s) -- chalcopyrite(?), +/-? -- , calcite, black opaque material(s)/magnetite(?), +/-?.

TM-04-6-9-4-4:

A large (hand-size) specimen, broken into three pieces (which fit back together like pieces of a jigsaw puzzle). Displays "banding",overall, in varieties of greys, black,whitish, pinkish-brownish.

Piece #1. The largest piece. Comprised of a number of "layers/bands".

Layer "A": White-grey periclase (brucite) marble. Consisting of predominant calcite, and subequal (periclase (brucite). Compare with other similar marbles at nearby locations at the Arctic Chief (viz. TM-04-6-9-3, -5). There are trace amounts of black material(s) -- magnetite(?), graphite (??), +/-? -- disseminated throughout, often in "pockets" of concentrations, and/or along "seams" within the rock. Also scattered eu-subhedral crystals (tetrahedrons?, +/-?) of pinkish-greyish-brownish material (spinel?) disseminated in this layer as well. Trace amounts of sulphides (chalcopyrite?) are noted, "smeared out" along a "seam" (a "mini"-crushed zone) "healed" with recrystallized(?) calcite.

Layer "B": A band of "darker" materials, adjacent to "A". Comprised of black mineral(s) -- pyroxene?, magnetite??, +/-?, pinkish-brownish vitreous crystals/masses --garnet, +/-?, calcite/marble??. Some "hematite/limonite" like material(s) is/are associated with the black mineral(s), as well as along "mini-seams" across the rock, subparallel to the "banding".

Layer "C": A thinner band adjoining "B". Composed of somewhat more coarsely-crystalline calcite, perhaps due to recrystallization along a "seam"(?) Trace amounts of pinkish-brownish euhedral (tetrahedral?) crystals (spinel?/or??) occur sporadically within this band. There is also occasional sulphide(?) material(s), as well as, more commonly, some reddish very-fine-grained crystalline material which might be hematite(?)/+/-?.

Layer "D": Adjacent to "C", this is another "dark" band, similar in aspect and thickness to layer "B". It lies subparallel to the other bands in the specimen.

Layer "E": Adjacent to "D". This a lighter band, made up principally of a periclase (brucite) marble/"calciphyre"(?), similar texturally and mineralogically to "A", but with a somewhat greater proportion of "darker" constituents. These latter present as dark grey or black sub-euhedra (pyroxene?, magnetite?, traces of sulphides (chalcopyrite(?), perhaps galena?? and/or molybdenite(???), +/-?), disseminated throughout the surrounding calcite and periclase (brucite) principal constituents.

Piece #2: Adjacent to/continuing from Layer "E".

Layer "F": Essentially similar to the description of "E", above.

Layer "G": Next to "F". Is a whiter band, similar to the material described as Layer "C". above. Like it, "G" is a somewhat more-coarsely-drystalline interval than the "marble/ calciphyre" bands observed elsewhere in the specimen. Relatively "pure", preponderantly crystalline calcite, though with some concentrations of sulphides, +/-?, especially along the margins of this band/layer.

Layer "H": Adjacent to "G", this is another band of "intermediately-darker" (?!?) aspect, somewhat similar texturally and mineralogically to some of the other bands in this specimen, such as Layer "E" in particular.

Layer "I": Adjacent to "H", this is a lighter band, featuring much less in the way of "darker" minerals/materials. It resembles Layer "A" rather closely, and is the final "Layer" so-designated in this specimen. It is a periclase (brucite) marble/"calciphyre"?, consisting principally of a crystalline mosaic of calcite and associated periclase (brucite). Note especially features in evidence on the weathered surfaces of this specimen. Cf. other specimens from elsewhere at the Arctic Chief, especially TM-04-6-9-3, -5. Trace amounts of disseminated dark opaque grains are observed, likely magnetite (note accompanying "rusty" haloes. Also note some pinkish-brownish sub-euhedra (tetrahedra?; = spinel?), as well as perhaps some graphite(?), disseminated throughout this layer.

Piece #3: Comprised of some of the "bands/layers" described in the other two pieces of the original specimen. This Piece #3 contains Layers "E, F, G, H, I", per the foregoing observations.

The weathered surfaces of this specimen offer a wealth of evidence/effects/information as to textures, mineralogies present. Studied in conjunction with freshly-broken surfaces, collectively *much* is available to be gleaned from this specimen.

TM-04-6-9-4-5:

Specimen a white periclase (brucite) marble. Contains transecting greyish "veins"; linear features which apparently are "healed"/recrystallized "crush"-zones/fractures. These are made up of clearer, coarser-grained calcite than occurs within the crystalline mosaic of the marble per se. Cf. similar marbles, etc., from other nearby sample localities at the Arctic Chief -- viz. TM-04-6-9-3, -5, etc. The weathered surfaces are informative as to texture and mineralogy of this specimen. In particular, the presence and nature of the periclase (brucite) and the calcite, as well as the relationships among them, are well-displayed (as, in fact, they are within this specimen as well).

Trace amounts of fine-grained black material(s) -- magnetite(?), graphite(??), +/-? -- are disseminated throughout the specimen.

The"veins"/fractures in the specimen are essentially "linear", and intersect one another at various angles, in a relatively (to other observed specimens at the Arctic Chief) widely-spaced network.

TM-04-6-9-4-6:

This specimen is quite similar to TM-04-6-9-5 (which cf., above), but with a more closely-spaced network of "veins/fractures/healed crush-zones". A periclase (brucite) marble, with predominant calcite and periclase (brucite), as well as trace amounts of disseminated black material(s), which may be magnetite(?)/graphite(?)/+/-?.

The weathered surface of this specimen is not as well-developed as on some other similar specimens, hence the informative "hummocky topography" is not as prominently evident here.

TM-04-6-9-4-7:

This specimen, together with the nearby TM-04-6-9-4, -5, -6 specimens, essentially represent "minor variations on a common theme", as it were. All are rather similar in general appearance, aspect, composition. This ("-7") specimen, however, features a more-closely-spaced network of "veins/fractures/healed crush-zones" (ie., a greater/higher "fracture density" than any of the others).

Perhaps interestingly/informatively(?), in the context of the foregoing, this specimen also affords, perhaps most clearly of the four, a quite well-developed, most illustrative, example of the periclase/brucite, and associated calcite, typical of these periclase (brucite) marbles present at the Arctic Chief. The grain-sizes are relatively larger, here, in this specimen. The minerals are well(better)-developed, their inter-relationships (more)clearly-presented. All fairly evident, both on weathered, as well as freshly-broken, surfaces, while also displayed quite clearly within the specimen.

TM-04-6-9-4-8:

This specimen is a light grey periclase (brucite) marble. Consists predominantly of a crystalline mosaic of calcite and periclase (brucite), with trace amounts of black material(s) which may be magnetite(?), graphite(?), +/-?. This specimen is similar to others from nearby localities sampled at the Arctic Chief (cf. in particular TM-04-6-9-3, -4, -5).

Some relatively vague indications of "crushed"/"healed" zones throughout this specimen, manifest as somewhat well-defined linear features, although well-developed networks of intersecting "veins"/etc. are not readily apparent.

Moderately-developed weathered surfaces display textural, mineralogical, structural features, in complementary fashion to the freshly-broken surfaces elsewhere on this specimen. Not quite the sort of "hummocky topography" as developed on other specimens of similar character, but akin to it.

TM-04-6-9-4-9:

Light greyish periclase (brucite) marble. Featuring some especially noteworthy examples of the periclase-brucite relationship, evident in umistakeable fashion. With some fine examples, variously, of periclase crystals, remnant "cores", with fibrous crystalline brucite "rims/whorls" adjacent to/surrounding/pseudomorphous after/replacing the periclase. All within a "marble-textured" crystalline mosaic consisting of subequal/ predominant calcite as well. As per a comment of SMA, this is indeed a "splendid" example of the periclase (brucite) marble lithology. With all the implications -- petrogenetic, geochemical, geological -- pertaining thereto.

The general "greyish" cast of this specimen likely is due to the significant (though "trace" amount, overall) abundance of very-fine-grained black (graphite?/magnetite??/+/-?) material(s) disseminated throughout. Not in even a minor amount, or so it appears, yet quite evenly-distributed within the specimen.

There is at least one "pocket" of sulphide minerals (chalcopyrite?/pyrite???/+/-?), with some at least displaying aspects of eu-subhedral habit, within the "periclase (brucite) marble"/"rock-forming minerals" crystalline mosaic. Suggestive, perhaps, of an "early" formation, likely attendant to the metamorphism of the assemblage. Perhaps due to the presence, pre-metamorphism (cf. as well the apparent[?] presence of ubiquitous very-fine-grained "graphite"[?] throughout the entire specimen) of an isolated remnant of pre-existing, likely biologically derived, organic matter? Ie. "organic" material(s) in a precursorial carbonate sediment, etc., etc. ?

Several excellent examples of periclase-cored, brucite-rimmed, eu-subhedrally-outlined pseudomorphous "crystals" occur not far from this "pocket/patch" of sulphides. "Accident".......... "coincidence"...... ; or "incident"........ ?

Several subparallel semi-linear/planar "seams/veins" transect this specimen. These occur in a fairly-widely-spaced "network" of intersecting fractures/shears/"healed crush zones". Though compared to other similar samples from elsewhere at the Arctic Chief, the "fracture density" apparent in this specimen might best be termed "moderate".

On weathered surfaces, there tends to be a "greenish cast" associated with materials presently occupying "core" positions in/within periclase --> brucite "composite crystals". Perhaps a weathering phenomenon/product? Possibly related to a ferruginous componentof the original periclase....... and/or the replacive brucite? Or...... ?

All-in-all, <u>an exemplary specimen</u>, in a number of ways.

TM-04-6-9-4-10:

A largish specimen, comprised of two types/colors of periclase (brucite) marble, one a dark grey and the other a "whitish" color. The two varieties adjoin one another with a rather well-defined/sharp contact, of apparent sedimentary nature. There is the decided impression of original differences in composition (+/- texture) between these two variants (ie. a "bedding contact"). Although some sort of "front"-type contact related to metamorphism/ metasomatism is another (though unlikely, in my opinion) alternative interpretation.

The "white/lighter" lithology closely resembles similar-appearing periclase (brucite) marbles encountered at the Arctic Chief (cf. TM-04-6-9-3, -4, -5, etc.) Some fine examples of the mineralogies and textures, in terms of the predominant calcite and periclase (brucite) phases present, are evident herein. These relationships are also well-illustrated on weathered surfaces of this specimen.

A particularly illustrative "veinlet"/fracture of linear/planar aspect transects the darker lithological variant, abutting against/trending into the lighter adjoining "layer" at essentially 90 degrees. This feature appears to continue on through the lighter material, on to the "distal" weathered specimen surface, on which a "rusty" zone is manifest, associated with a series of dark fine-grained "specks" (presumably iron-rich; sulphides? and or magnetite?; or....?).

Such "vein/fracture"-associated zones at the distal (from the darker-colored rock variant) end of the specimen feature a "string-of-beads"-like array of black crystals (magnetite?/+/?), with "rusty" portions/subzones/margins/adjacent host rock-staining/ alteration effects manifested. One of these "effects" being apparent staining/alteration of nearby/adjacent minerals. This especially notably affecting "rims", and/or "cores" of the periclase --> brucite assemblage/materials, which appear to have been particularly susceptible to such "iron-staining". Perhaps essentially merely a matter of physical adsorption, etc., of iron-rich fluids by, especially, the generally-fibrous brucite. Though formation of "iron-rich brucites" due/related to to pre-weathering phenomena are also a possibility.

This "string-of-beads" occurrence is unique to the fracture/crushed-healed zone best developed at the distal end of the specimen, and best-displayed on the weathered surface there. The "white" rock variant being elsewhere/otherwise essentially free of other materials, containing only relatively little/trace amounts in the way of disseminated dark/black material(s) -- graphite?, +/-?. Appreciable similar-appearing very-fine-grained dark/ black material(s) occur(s) in association with the above-described fracture/healed-crush-zone. Other crystalline material(s) of "rusty" appearance also is/are found in this zone, though, again, this perhaps is actually representing "iron-staining"(?). Or another mineral/phase ???.

This "crushed zone" features more-coarsely-crystalline calcite, suggesting a "self-healing/recrystallization" genesis, attendant to fracturing and recrystallization during and/or subsequent to metamorphism (cf. analogs in similar lithologies at other nearby Arctic Chief locations).

This zone persists in linear-planar attitude across the "white" lithology, manifest, for the most part only vaguely, by a trend of sporadic "rusty" specks/material(s), until "emerging" at the "distal" end, clearly evident on the weathered rock surfaces there. This zone crosses the "border/contact" between the lighter and the darker lithologies, persisting across the latter to the edge of the specimen. More clearly evident in the darker lithology, due to the contrastingly white calcite of which this zone is presently comprised. It immediately/abruptly changes character upon entering the white lithology. Seemingly swallowed up/disappearing, as it were, within this new host rock of somewhat less-dissimilar nature to itself, as compared with the darker lithology.

The darker greyer lithology owes this aspect principally to the substantial (verging on being a "minor", rather than a "trace" constituent) amount of fine-grained black material(s) of "graphitic"(?) aspect disseminated/scattered throughout this rock type, along (principally, if not actually totally) the margins/boundaries of the rock-forming minerals (viz. calcite, and periclase [brucite]). There is also an impression of somewhat "greyer" crystals of calcite in this "darker" lithologic variant.

Though the amount, and widespread dissemination, of the discernible inter-crystalline "graphite"(?)/+/-? material(s) in itself seems sufficient/quite adequate to "explain" the relative darker color/cast of this lithology. Presumably representative of an original sediment/sedimentary rock with an appreciable carbonaceous component. [Perhaps less magnesium-rich as well? With possible implications with respect to "magnesian-skarn" development?? Is the periclase (brucite) component of this "darker" lithology less than, equal to, or greater, than in the "whiter" lithology? Good/interesting question....... (?!?). Though the "appearance" under the stereo- microscope suggests subequal proportions of the two principal rock-forming minerals in this darker lithology (in which the viewing constrast is perhaps no better or worse, essentially, than it is in the lighter lithology(?). [Perhaps a useful subject for some thin-section work?]

TM-04-6-9-4-11:

A white periclase (brucite) marble. A "foot"-specimen; ie. somewhat larger than merely the run-of-the-mill "hand" specimen. Chosen thus for purposes of serving as a "reserve" specimen, for possible future work. "Representative" of other "white marbles" of similar aspect in this portion of the Arctic Chief. Calcite and periclase (brucite) the principal rock-forming phases, with associated trace amounts of dark/black material(s) ["graphite"?/+/-?] somewhat irregularly disseminated throughout.

TM-04-6-9-4-12:

Another "foot" specimen. Mostly a light-grey periclase (brucite) marble, with one end of the specimen an apparently coarser-grained white periclase (brucite) marble. A relatively sharp contact exists between these two litholgic/color variants. Perhaps most likely representing a sedimentary/bedding contact (?). Or some sort of "front", due to metamorphic/metasomatic activities (???).

One obvious fracture/seam/crushed-zone (?) cuts the grey rock, at an other-than-subparallel angle to the white-versus-grey rock contact.

The grey rock has some lenses/pods/wisps of coarser-grained "carbonate" rock/material(s) in it, here and there. Not as white as the "white marble", but lighter, and coarser-grained, than the "grey" marble.

The white marble contains approximately subequal proportions of the two principal rock-forming minerals, calcite and (nicely-developed and displayed) periclase (brucite). Trace amounts of "very-very"-fine-grained black (graphite?/+?-?) and amber (spinel?) grains are disseminated throughout the white marble.

The grey marble shows even better-developed periclase (brucite) features, with excellent examples of brucite "cabbage head" rims/pseudomorphs, periclase cores, etc. Some especially nice examples occur on weathered surfaces of the specimen. This grey rock is also quite similar to numerous others from nearby localities examined at the Arctic Chief. The rock-forming calcite in this grey marble here is somewhat finer-grained than its counterpart in the associated white marble in this specimen. The amount of dark-black material(s) disseminated in this grey variant here is a bit/somewhat -- though not all that much -- greater than in the associated white marble.

TM-04-6-9-4-13:

A hand specimen. Featuring two variations on the theme of periclase (brucite) marble. One a "white", coarser-grained, more "massive" variant. The other a "less-white", finer-grained, less "massive"-- "bedded/layered" (structurally?) -- variant. The contact/border/inter-relationships between these two somewhat ambiguous in hand specimen.

The less-massive type contains/is cut by a relatively-closely-spaced network of (apparent) fractures(?), intersecting one another at various low-higher angles (cross-bedding??).

Both variants are well-developed periclase (brucite) marbles, similar to others from nearby localities at the Arctic Chief. Weathered surfaces show this best on the "white" variant here, while the similar relationships are even better-displayed by the other variant, both on weathered and "fresh" surfaces.

TM-04-6-9-4-14:

A large hand (a "semi-foot"?) specimen. Mostly weathered surfaces all around on this particular specimen. Rock a whitish periclase (brucite) marble/ "calciphyre"?, featuring a pod/lens/inclusion/(?) of dark grey-black material(s). [Possibly of organic composition, origin? Ie., perhaps "faunal/floral" remains?] The black material(s) might(???), alternatively, be "skarn" -- ie. garnet(?), +/-pyroxene(?), +/-?. The weathered surfaces of this whitish rock display, rather/fairly well, the usual features representative of the periclase (brucite) presence/relationship, similar to other specimens from nearby localities at the Arctic Chief.

TM-04-6-9-4-15:

A hand specimen. . A grey-whitish periclase (brucite) marble/"calciphyre"(??). All surfaces are moderately weathered. Some "hummocky topography" is developed. The weathered surfaces manifest quite well the relict cores of periclase, and the surrounding rinds/shells/rims of brucite pseudomophously replacing originally eu-subhedral crystals of periclase*. As noted commonly at this, and other nearby localities at the Arctic Chief.

[*Often featuring an "oolitic" aspect. Which ought to be kept in mind when studying features on weathered surfaces. While of course "true" oolitic forms do in fact occasionally/not infrequently occur in carbonate rocks!]

Note a set of intersecting fractures transecting the specimen, at/with a moderate spacing/density. Note also suggestions of banding/layering subparallel to the short dimensions of the specimen.

Some portions ("bands/layers", ie.) of the specimen are "whiter", others less so, ("greyish", or "pinkish"). A pinkish hue is not uncommon, and somewhat more apparent in calcite-rich portions of the rock, due to the darker-greyish material(s) associated with surrounding/adjacent network of fractures. Some of the "pinkishness" may be due to "rusty" effects of weathering/+/-?.

TM-04-6-9-4-16:

This is a "large" hand specimen. Features two varieties of periclase (brucite) marble. One a lighter grey, more massive type, the other a darker grey, more "layered/banded/bedded" variant. The contact between the two is fairly-well defined, and is in subparallel orientation/attitude with respect to "layering" in the darker variety. The specimen overall seems somewhat "heavy/dense" for its size/dimensions(?). A vague impression of a certain "unusual heft" to it (?).

The layering/etc.(?) of the darker variant reflects original bedding, apparently/probably. Perhaps(?) also a result of "less intense/less thorough" metamorphism (+/- metasomatism) of this portion/lithology of the specimen. This darker variety appears to contain a greater proportion of "carbonaceous/graphitic"(?) material.

Both variants are akin to periclase (brucite) marbles from other nearby areas at the Arctic Chief.

Specimen too large for much examination with the stereo-microscope, while further breaking might destroy some of its "mega" aspects. Thus "reserved as-is" for possible future work.

TM-04-6-9-4-17-A:

Specimen one of three (-"A, -B, -C") from the same sampling site at this "-17" locality. This "-A" specimen an example of "banded skarn". Featuring pyroxene (?), magnetite-bornite-phlogopite-chlorite?-talc?, calcite (pinkish white), garnet (pinkish-brown), +/?.

Pyroxene now strongly altered, with products including "amphibole" (actinolite/tremolite), "green micaceous" material, likely phlogopite (+/-?), +/-?. Some fibrous "serpentine" also noted. "Relict/actual" pyroxene is not readily apparent, but there might well be some remnants, masked by/associated with the alteration products ubiquitously present with "pyroxene-like" material.

Some of the "green micaceous material(s)" is/are a lovely bright to deep green (likely phlogopite [or "clintonite, "mariposite/fuchsite"??]). Not infrequently "fibrous" margins/edges of this material are variously well-developed ("serpentine/chlorite/talc" ??).

The calcite and garnet are intergrown (sub-euhedral) in "pockets", with surrounding "green micaceous material(s)", magnetite, bornite (some of which is also intergrown with calcite and garnet). Magnetite and bornite range sub-euhedral throughout the specimen. The "micaceous" minerals are generally well-developed sub-euhedra intergrown with magnetite, bornite, etc. Also possibly(??) some hematite(?), quartz, +/-?, associated in very minor amount with the calcite-garnet, +/-?, "pods/lenses/vugs(?)". Much of this specimen consists of intergrown "green micaceous"-magnetite+/-bornite.

<u>Note an unusual "dull brownish-blackish sub-euhedral opaque phase/material" in one place, associated with "green micaceous" mineral(s), calcite, magnetite (which is not "rusty/oxidized"). This "unusual/dull"-appearing material resembling, perhaps, an oxidized/weathered/altered magnetite (but, note the presence of the adjacent "fresh" magnetite). This material somewhat resembles/has some intriguing similarities to a specimen labelled "valleriite", presently on display in the Yukon Visitor Centre display of minerals found in the Territory. The site of this material in the present sample is on one edge, near one of the "tips" of the specimen. The "valleriite????" is intergrown with bright "green micaceous" mineral/material, for the most part, as well as in part intergrown with adjacent magnetite +/- bornite, in the one noted "occurrence".</u>

This specimen, TM-04-6-9-17-A, should be compared with the descriptions of its (complementary) "compatriots", "-17-B, -17-C". Especially with regard to the presence or absence of pyroxene in each, vis-a-vis magnetite. Also as regards the green micaceous mineral(s)/materials(s), etc.

TM-04-6-9-4-17-B:

Hand specimen of "ore". Made up of bornite-chalcopyrite-magnetite-"skarn"-, +/-?. Some "rusty" areas on specimen surfaces. Apparent relict black pyroxene (note cleavages) occurs, though in large part altered to "masking" green micaceous material(s), +/-. (Cf. sample "-A").

The larger, more "flamboyant" crystals of "green micaceous" mineral(s) seem to be associated with the "ore" minerals. While the smaller, somewhat less-"spectacular" mica-like materials tend to be found/occur in association with the "skarn"/pyroxene, where lesser amounts of "ore" minerals are in relatively close proximity (?). In this latter -- ie. the "pyroxene" - "skarn" areas --, the mica-like crystals are smaller, thus (?) appear "lighter" in "greenishness", with perhaps(?) an additional mineral (white, "very-very-fine-grained", perhaps calcite?/ amphibole?/ serpentine?/ diopside?/ talc??/ forsterite???/+/-?. Though this may merely represent an optical "illusion" due to smaller grain size(?). This grain size effect perhaps the result of "granulization" due to pulverization attendant upon tectonic/structural deformation? Using only the stereomicroscope, much of the foregoing remains somewhat "speculative", at best.

The "skarn" portion of this specimen grades into a zone of more coarsely-grained "mica-like" material(s) + relict pyroxene + magnetite + chalcopyrite + bornite, intimately intergrown, with some scattered small vug-like patches of very-very-fine-grained euhedra of calcite/"carbonate" of light buff colour (ankerite?/siderite?. Mica-like material is "retrograded/altered" to talc(?) and/or serpentine(?), +/- chlorite (??).

Minor amount of brownish-reddish garnet, eu-sub-anhedral in aspect, occurs sporadically distributed within the "skarn" material.

Brownish carbonate -- calcite?; siderite?; ankerite?) -- occurs, similarly, in the "skarn". Such carbonate also occurs, as more well-developed crystals, in association with "ore", especially magnetite.

How much apparent "pyroxene" is actually magnetite (with cleavage), at least in parts of this specimen?

The "green micaceous" looks more like "talc"(?), for the most part, in this "-B" specimen, than it did in specimen "-A". "Green" phlogopite --> talc and/or serpentine (note fibrous edges/margins of "mica-like" crystals), as "retrograde" and/or "alteration" effects/results?

Magnetite in this specimen is euhedral-subhedral, massive; bornite sub-euhedral; chalcopyrite is rarely better than anhedral. This specimen is "rustier" than "-17-A". The "rustiness" makes the search for "valleriite" rather difficult. Only the very occasional possibility was noted; -- all rather "dubious".

This specimen, TM-04-6-9-17-B, should be compared with the descriptions of its (complementary) "compatriots", "-17-A, -17-C". Especially with regard to the presence or absence of pyroxene in each, vis-a-vis magnetite. Also as regards the green micaceous mineral(s)/materials(s), etc.

TM-04-6-9-4-17-C:

A hand specimen. "Banded". with bands of "skarn" (pyroxene, +/-) and of "ore" (magnetite-bornite- +/-?). One surface of this specimen is "slickensided", with a "skin" of dark-green-black "smeared-out" mafic material(s), perhaps chlorite, +/-, etc.

Magnetite occurs as eu-subhedral crystals to anhedral masses, often in association with "green micaceous" mineral(s)/material(s), intergrown with lesser bornite, as well as, occasionally, trace amounts of chalcopyrite (sub-anhedral). The anhedral-subhedral-euhedral developments of each of these sulphide minerals varies from place-to-place within this specimen.

The "skarn" bands -- at least some -- appear to actually be "crushed zones/shear zones/seams" made up of very-fine-grained magnetite and "crushed/recrystallized" light "green micaceous" (viz. phlogopite?, talc?/serpentine?/chlorite?) material(s). [[Cf. descriptions of specimens TM-04-6-9-4-17-A, -B. Which, in light of the foregoing, may merit/require some "reinterpretation"(?).]]

Note occasional patches/pods of very-well-developed euhedra of magnetite (the "prismatic magnetite" of SMA?), "micas", and fairly-well-developed crystals of bornite, chalcopyrite. Affording an almost "pegmatitic" aspect, a "vuglike" appearance. One small pod has eu-subhedral chalcopyrite surrounded by subhedral, +/-, bornite, with magnetite eu-subhedra surrounding bornite and chalcopyrite. The adjacent "green micaceous" is very-fine-grained (perhaps pulverized/ recrystallized?), as part of apparent movement/structural deformation in this portion of the specimen (throughout the specimen, likely, with recrystallization of euhedral/+/- magnetite and sulphides post(?) these effects on previously-existing "green micaceous" (or, rather, pre-existing pyroxene/forsterite/+/- [?]). A trace amount of carbonate/calcite(?) is associated with this (and others) "pod".

Note some occurrences of chalcopyrite (as well as magnetite, bornite) interleaved/ intergrown with coarse-grained "green micaceous" material(s). [Where is the valleriite?!? Why not here? Perhaps because no clinohumite??] Where chalcopyrite occurs, the paragenesis consistently is: chalcopyrite, then bornite, then magnetite. Bornite occurring within magnetite sometimes displays a rounded outline (due to the bornite having been partially "resorbed"?).

Note some copper "staining" (light blue green, ie.), here and there, on weathered surfaces of this specimen. Perhaps also some blue (covellite?, chalcosite?, +/-?) on some bornite crystal masses/ surfaces (and also on the rims of some bornite crystals observed on "fresher" specimen surfaces).

Some "turquoise"-/green-blue- colored material(s) occurs in association with "green micaceous" material(s) in a few places (weathering?/or?). When viewed "end-on", quite a bit of the "green micaceous" material(s) has this appearance, even in perhaps "fresher" views afforded on fractured surfaces. Here and there, a talc/serpentine after/around "green micaceous" crystals relationship does seem apparent/manifest.

See some good examples of the "transition" between very-coarse-grained well-developed crystals of "green micaceous" material(s) and adjacent finer-grained materials. Generally appears to be "gradational", hence perhaps supportive(?) of the "structural deformation/ dislocation" premise/postulate for this state of affairs within this specimen (as well as in the "compatriot" specimens "-17-A, -17-B").

Patches of buff-light brown eu-anhedral carbonate mineral(s) occur here and there, more often associated with coarse-grained "zones"/areas of the specimen. Note a fair amount of apparent evidence (viz. contortion of "mica" plates/crystals, "smearing"/shearing?, etc.; perhaps also the coarse-grained pods/patches/zones as subsequent recrystallization effects?), supportive of this deformation/metamorphism(?).

Much (but not all) of the carbonate material(s) mentioned above appears to occur on/within one particular "shear surface/zone" within the specimen.

Some magnetite occurs as masses of perhaps "spheroidal" aspect (or is this appearance actually due, rather, to the "conchoidal" fracture aspect of this magnetite?), with seemingly "radial prismatic" textures on broken surfaces (ie. of "spheroidal" grains /pods/

"whatever"[?!?]). Note these especially in association with coarse-grained "green micaceous" crystals.

Difficult to recognize possible "valleriite" in this specimen, due to the weathering effects.

This specimen is important in terms of many aspects of all three "-17-" specimens. Especially so with regard to the suggested/postulated "structural /deformational/ metamorphic" aspects of the coarse-grained <--> fine-grained "green micaceous" material(s), as well as the presence/absence of "relict" pyroxene, and the paragenesis of the sulphide minerals and magnetite. Each of these three specimens affords unique manifestations, and should be considered in complementary fashion in any subsequent work.

TM-04-6-9-5-....

TM-04-6-9-5-1:

An originally large specimen, subsequently broken into "many" pieces. Periclase (brucite) marble. Two variants present in this specimen. One a lighter/whitish, somewhat coarser-grained rock, the other a greyer, denser (?), finer-grained lithology. A rather subtle, but apparent,"sharpish" border/contact separates the two. A vein/fracture zone(?)/? is subparallel to the latter, and trends along into the "border" between the two variants. This "border" likely(?) a sedimentary "contact", ie. "bedding plane".

The nature of the periclase and the brucite, as well as their genetic and textural relationships (brucite pseudomorphously replacing periclase), are well-displayed, both throughout the specimen, as well as on weathered surfaces. The predominant rock-forming minerals, calcite and periclase (brucite), occur in a crystalline mosaic of typical "marble" texture. Minor/trace amounts of greenish-greyish-brownish fine-grained material(s) disseminated throughout likely are spinel(+/-?). Some similarly disseminated very-fine-grained black material(s) may be graphite(?), and/or magnetite(??). A trace amount of quartz, some appprently as sub-euhedral grains, occurs similarly disseminated.

TM-04-6-9-5-2:

A "salt-and-pepper", "dioritic-looking" specimen.

Featuring pyroxene, plagioclase, quartz(?), carbonate(?) material(s), with lesser proportions of magnetite(?), pyrite, chalcopyrite(?), and associated epidote(?) veinlets.

Amphibole [tremolite/actinolite (?)], serpentine(?), chlorite(?), +/-?, are observed in association with pyroxene, presumably as alteration phases. The pyroxene tends to occur as stubby, sub-euhdral, prismatic crystals, exhibiting good cleavage, along with associated alteration minerals. The latter manifest themselves as rims, sheaths, coatings, etc., comprised, variously, of amphibole(tremolitic/actinolitic), chlorite, serpentine(?), talc(?), +/-?, adjacent to quartz+/-carbonate+/-epidote. Fresh/unaltered pyroxene is black-very dark greenish in color.

The sulphides often occur as crystalline masses, aggregates, surrounding, engulfing, and/or replacing pyroxene. Or as discrete eu-subhedral crystals adjacent to such occurrences. Some fine examples of striated pyrite euhedra (including pyritohedra, cubes) are noted, associated with pyroxene, quartz(?), carbonate, +/-epidote, +/-?. Examples of chalcopyrite tetrahedra occur as well.

At least two sets of epidote/+/- veinlets are apparent, transecting portions of the specimen.

Might this seemingly "dioritic" rock actually represent "endoskarn" material, in the sense of Aleksandrov (1998)? It appears to feature original "igneous" textural, mineralogical, and overall compositional characteristics. Perhaps a representative of "contaminated" magma, from a "carapace/shell" of dioritic character. Portions of which, presumably were potentially available to intrude into portions of the adjacent/surrounding country rocks as geological circumstances may have dictated/permitted/facilitated. Providing magmatic materials for "apophyses" which might serve as metamorphic/metasomatic "facilitators" vis-a-vis especially "susceptible" country rocks such as dolomites, resulting in formation of "skarns" and related materials. Per the concepts presented by Aleksandrov (1998, and etc.).

TM-04-6-9-5-3:

Specimen similar in aspect to TM-04-6-9-5-1, which cf. White-colored; a periclase (brucite) marble. Predominant rock-forming minerals occurring as a crystalline mosaic of calcite and periclase (brucite), with associated minor/trace amounts of spinel(?), graphite(??), +/-?, disseminated throughout the rock. The periclase (brucite) nature, and their genetic/textural relationships, are rather nicely exemplified in this specimen. (Cf. specimens of similar nature, from other nearby sample locations at the Arctic Chief.)

As in other similar lithologies from this general area of the Arctic Chief, there is evidence of at least a moderate (strong?) degree of structural deformation having affected these rocks. "Crushed/healed zones", fractures, as well as some "slickenside"-like features, occur, variously, within these specimens, as especially manifested by the carbonate grains/crystals. Perhaps not "pervasive", but "substantial".

TM-04-6-9-5-4:

Specimen represents part of a "skarn" zone. Under the stereo-microscope, restricted to working at 30x/60x, and only on specimen surfaces (fresh as well as weathered), this specimen is of the "challenging" sort. A "character sample", in the parlance.

"Skarn" material. Featuring pyroxene, +/-?. With seams of fibrous "serpentine", +/-?, on/along the fractures. Specimen is "fraught" with slickensides, epidote on fractures, etc. Carbonate (calcite?) is abundant in parts of the specimen (ie. the "marble/calciphyre" lithologies, +/-). The specimen representing a "pyroxene +/- skarn --- forsterite/forsterite-rich zone --- calciphyre" sequence, apparently. Evidence overall of a "magnesian skarn" situation, in all likelihood.

Note traces of sulphides (pyrite, +/-?) in the "calciphyre" zone. Also, as well, in the "forsterite/forsterite-rich" zone, near "seams/shears" featuring/with apparent "serpentine"(?) occurring as prismatic/fibrous eu-subhedra oriented sub-perpendicularly to "crush zone/fracture walls" of forsterite(?), etc., adjacent thereto. Epidote present here and there as well.

Similar "serpentine"/+/- occurs within fractures/zones which transect pyroxene and/or other black minerals in "calciphyre", along with associated forsterite, +/-. Pyrite occurs in trace amounts nearby, sometimes as (fresh) cubes.

<u>Specimen represents a "retrograde" situation/set of assemblages, apparently. Complex. As such, not insignificant in the greater scheme of things here.</u>

TM-04-6-9-5-5:

Specimen apparently presents a "diorite/endoskarn" to "garnet"(?) to "pyroxene" skarn contact(s) sequence [??].

Featuring a plagioclase-pyroxene- +/- "diorite" ("endoskarn"?), similar to TM-04-6-9-5-2, etc.

A thin layer/zone of pinkish-light brownish garnet(?) [rather, zoisite?/clinozoisite?/ epidote?/ ....??] separates the "diorite" from a less-well-defined "skarn"(?) of darker and lighter minerals (viz. pyroxene?, carbonate?, +/-?) A trace amount of sulphides (pyrite?, +/-?) occurs in this "skarn" zone.

Cf. Aleksandrov (1998, & etc.) on "diorite", "endoskarn", "HHP granitoids", etc.

TM-04-6-9-5-13:

A "banded" periclase (brucite) marble specimen.

Predominantly consisting of white/lighter-colored bands (most of the specimen) made up predominantly of a crystalline mosaic of the rock-forming minerals, calcite and periclase (brucite).

WIth some light grey, much thinner, bands/zones/horizons of more-coarsely-crystalline calcite, featuring evidence of deformation of crystals (ie. representing a "crushed// healed/ recrystallized" zone within a formerly/originally more "homogeneous"(?) marble/carbonate rock protolith(?).

Trace amounts of black/dark ("micaceous/mica-like"; ie. perhaps graphite?) mineral(s)/material(s) occur disseminated throughout, especially (more prominently?) within the "lighter" portions of the specimen. Such "dark" material(s) somewhat/ appreciably less-abundant in this specimen than is the case in otherwise quite similar rocks from nearby sampling sites at the Arctic Chief.

Perhaps the "two types" of marble in this specimen represent different "degrees" of metamorphism/metasomatism, or differing degrees of "susceptibility" thereto; and/or "locally" differing degrees of structural deformation having occurred -- for various reasons -- within this specimen; and/or actually a case of two originally different lithologies/ proportions of constituents/components(?). Viz. "dolostone" vs. "marble" (??), Etc.......... (?). And/or merely a case of original "sedimentary" bedding??.

TM-04-6-10-4......

TM-04-6-10-4-A-1:

Part of a "foot" (ie. appreciably larger than a "hand") specimen ("-4-A-"), subsequently broken with a hammer into several smaller ("-A-N........") pieces/sub-specimens.

This one a dark rock, with a vein(s) with attitude(s) subparallel to a dominant direction/ orientation of breakage of the specimen. Vein "fresh" <--> "weathered/altered", laterally, on broken specimen surface. Specimen is/seems relatively "dense", "heavy".

A dark rock. Made up of pyroxene sub-euhedra, black/dark green, with alteration to tremolitic/actinolitic amphibole marginally (+/-talc?, chlorite?, ??). Some manifestations (warping, bending, of crystals) of deformational stresses having been experienced within the rock.

A minor (+/-) amount of clear-whitish plagioclase(?) occurs intergranular to the predominant (altered) pyroxene. This plagioclase shows cleavage, and occasional subhedral crystal forms/outlines, with darker/smoky-brownish central cores (perhaps at least in part quartz?), and clear-whitish grain margins. (Cf. other specimens in the "TM-04-6-10-1 <--> 6" series). The latter presumably representing igneous zoning, though some sort of "secondary/overgrowth" phenomenon might also be invoked here (viz. with quartz, garnet, +/-?).

Note occurrences of vein(s) of quartz(?), +/- calcite/carbonate, +/- epidote, with vague to moderately-well-defined margins, adjacent to the "pyroxene" +/- rock. Iron-stained, as well as with traces of malachite, near a small "pod" of probable chalcopyrite(?) +/- magnetite, +/- ("green calcite"?). Some offshoots here and there of "epidote", +/- "cryptocrystalline" quartz" (??), into adjacent rock walls. The chalcopyrite crystals are eu-subhedral, "tarnished", and lie within the vein. There is evidence of shear parallel to the plane of the vein, with "unconformity" surfaces within the vein. Evidence of "altered"/ "silicified", +/- "carbonatized"(?)/"epidotized"(??) relict (euhedral, +/-) pyroxene grains within the vein. Two "generations" of carbonates, a darker brown ("earlier"?), and a clear whitish ("later"?), in the veins (??). [And/or magnetite(?), +/-?, with carbonate, quartz(?). Or quartz(brownish)?; then carbonate?].

Original pyroxene grains eu-subhedral, oriented variously ("randomly"?), with (quite) subordinate plagioclase, +/-? (including carbonate). Magnetite sub-euhedra disseminated amongst the pyroxene grains. Epidote, quartz, (chalcopyrite?), carbonate, (chalcopyrite?), the apparent(???) depositional sequence in veins, from margins inward. Pseudomorphs of carbonate?/quartz?/epidote?/+/-? after pyroxene, with retention of relict crystal outlines, cleavage noted(??).

Weathered specimen surfaces suggest "plagioclase", magnetite, +/-quartz, epidote, carbonate, pyroxene do in fact comprise portions of this specimen, per the above/foregoing "treatise"/"exposition". A sample of "pyroxene skarn"(?), rather than "igneous", ie. ??

TM-04-6-10-4-A-2:

Another, larger, broken piece of "-4-A-.....". The "other half", actually , of a piece broken from "-4-A-1...." originally. "Same as its mate".

TM-04-6-10-4-A-3:

A larger broken piece. Observe sub-euhedral outlines of "pyroxene"(?) crystals (12 mm, +/-, and smaller) here and there; "vein/seam" of carbonate(?), +/-. The large "pyroxene" grains show 87/93-degree cleavages (?), are black-dark green, could be altered to hornblende(??), and then to tremolitic/actinolitic amphibole, marginally (+/-talc?/+/-?). The eu-subhedra abut one another at various (--> 90 degrees) angles ("glomeroporphyritic"/"blasto-"), originally???. Sample is "seamed", with epidote, quartz(?), carbonate, +/- "opaques" (???).

TM-04-6-10-4-A-4:

Largest broken piece. Calcite euhedra in one location associated with a "vein". "Color index" of this sample = 60+ (to "++"). Calcite (cleavage remnants) =16 mm, +/-.

"Much" of the "late"-clear-whitish material in the specimen probably is calcite(?). Though some is likely plagioclase (?), +/-?. "Seam/vein" is quartz and calcite, +/- epidote, +/-....

Perhaps (?) most likely (??) an "altered/retrograded" "endoskarn"?? pyroxene and plagioclase rock ("exoskarn"?), with magnetite, veined/seamed with calcite+/-quartz+/-epidote+/-magnetite(??)+/-?.

Possibly (?) trace of very-fine-grained "opaques"; viz. "sulphides" (and/or "graphite" ?/ /+/-/or "disrupted" magnetite (??), disseminated throughout the specimen (??).

TM-04-6-10-4-B-1:

Once part of an original "foot" specimen, now broken into several pieces. These labelled "TM-04-6-10-4-B-1, -2, -3".

Note euhedral (well-developed) prismatic pyroxene (clinopyroxene?) "ghosts" on a (freshly-broken) fractured surface, which also contains sulphides. The "ghosts" now pseudomorphed --> hornblende(?) +/-?. Carbonate euhedra (and also some less-well-developed), on the opposite (also freshly-broken) specimen surface (pinkish-buff-whitish), with sulphides present as well. Note similar "ghost" features in other "dioritic" rocks in this general area. Are these originally igneous in origin, or metamorphic/metasomatic?

<u>Scattered eu-subhedra (and less-well-developed) of sulphides ("molybdenite"?, galena?, magnetite??) on specimen surfaces.</u> Specimen broke readily along these surfaces, thus they are "zones of weakness", +/- "zone(s)" of structural significance within this, as well as the original larger, specimen. Featuring mineralization/alteration associated with them.

Apparently featuring euhedral crystals/platelets of molybdenite(?) -- hexagonal, seemingly opaque, shiny, moderately "loosely-leaved". Or, alternatively (??), some sort of peculiarly "blackish/bluish", shiny to "dull-appearing" black mica (viz. biotite, phlogopite (??); or graphite(??). Or "smeared" galena, +/-?. A penknife point succeeded in "peeling" a curling "shaving" of a layer, from one or these hexagonal crystals; ie. "looks metallic"(?).

Host rock/specimen overall: Features eu-subhedral pyroxene(?) --> "amphibole" initially hornblende, then subsequently --> tremolitic/actinolitic variety. Plagioclase is another principal mineral present in this specimen, occurring as eu-sub-anhedral clear-whitish grains. Minor euhedral and less-well developed quartz(?) is also present. Thus the rock might be considered to be a quartz-bearing/quartz diorite, with an "igneous-like"(?) texture of intergrown crystals.

Evidence of a moderate(?) degree of structural deformation throughout the specimen, with some "veinlets" along semi-planar "shear/fracture" surfaces, which often feature very-fine-grained carbonate (calcite?) +/- quartz(?), +/-?. Molybdenite/? is essentially restricted, as far as can be discerned in this hand specimen, to one zone/fracture/shear (??).

Relative proportions of pyroxene/etc. vs. plagioclase seem to vary within the specimen ("banding"?). The larger-scale "ghosts" mentioned above are not readily evident as such at 30x magnification, likely due to the replacing/pseudomorphing materials ("amphiboles", +/-) "masking/confusing/obfuscating" aspects of the original pyroxene crystals.

Trace amounts of epidote occur here and there, especially in the "zone" which features the apparent molybdenite(?). These "molybdenite" euhedra are half-again or so as large as adjacent "pyroxene?" --> "amphiboles", +/-, grains. The "molybdenite" grains measure on the order of 3.0 mm in "width" of hexagonal plates.

The "other/whiter" side of this specimen features similar "molybdenite", more-widely-spaced/spread across the hammer-broken fracture surface, and they are of similar (ie. 3.0 mm, and smaller) "width" as their counterparts on the other "darker" surface of the specimen.

A penknife point drawn across a surface of one of these "platelets" readily leaves a groove (?). Though this material seems uncommonly "well-crystallized" for "graphite". Though in reflected oblique illumination at 30x magnification it also looks perhaps a "bit too black?" for molybdenite(??). These "enigmatic" opaques are intergrown/occur with "pyroxene" --> "amphiboles", +/-, and/or plagioclase, on this surface. Occasionally "interleaved" with "tremolitic/actinolitic amphibole"/+/-.

One massive accumulation of "molybdenite" crystals seems to have "reacted with/been altered to" a pale yellow-buff "box-work/network" of prismatic/lathlike crystalline aspect (with voids). Suggesting perhaps the "parent" material in this instance was not "graphite/carbon", but, rather, "something else"/a sulphide (viz. molydenite; and/or?). Ie. molybdenite/sulphide --> a sulfate, carbonate, +/- etc. (?). This occurrence lies within an area of plagioclase (+/- carbonate?), and "pyroxene" --> "amphiboles", +/-, not far from a "zone"/"veinlet" featuring rather well-crystallized epidote/+/-?.

White-pink materials on this specimen surface are carbonate (calcite?), quartz, plagioclase, +/-?.

The "ghosts" (1.2 mm and smaller) of "pyroxene" (?) euhedra mentioned above are apparently on the "darker" surface of this specimen. They are now comprised of a pseudomorphous assemblage of "amphiboles" (viz. hornblende, followed by "tremolitic/actinolitic" material). For the most part, these occur as fine prismatic crystals, more or less oriented in keeping with that of the "original" pyroxene crystals. There are, however, orientations at odds with this. This latter effect may be more apparent than real, however, since the "original" pyroxene(?) crystals occur in various orientations (even presently, within the "ghosts" -- ie. the "ghosts" perhaps not igneous in origin, but, rather "--blastic", due to "other-than-igneous" -- ie. metamorphic/metasomatic -- circumstances. "Growth/replacement" (???).

In places, such as shown on this surface/portion of the overall "-4-B-...." sample as a whole, the mineralogy, +/- the texture, appear to be more a "gabbroic"?/"skarnoid" type of affair (?!?). The "original" pyroxene(?) crystals (black, shiny) are often seen as representing "books"/"patches" of "platelets" -- ie. "mica-like"(?) -- (biotite/phlogopite/???). This appearance might(??) be the result of "alteration", and/or "breaking" with hammer, of traces of pyroxene cleavages on pyroxene "prism" faces (???). Cleavages, "ghost" morphology/outlines are, however, apparently indeed "pyroxene-like" (?). The "ghost" outlines are only apparent without magnification, and are not readily discerned at 30x.

It might be conceived that the rock originally was more akin to a "pyroxenite/gabbro" ("meladiorite"?) than a "diorite"; perhaps even more likely (?) a "pyroxene skarn", retrograded, fractured, mineralized, etc. (?).

<u>It does in fact seem that the apparent "molybdenite" is, most likely -- though requiring further confirmation -- , just that. Per its metallic luster and other characteristics, its color, its observed apparent "boxwork/network" alteration, and other attributes. Although "smeared-out" occurrences of sulphides such as galena, etc., remain possibilities yet to be dismissed. While "graphite" seems perhaps the least likely candidate.</u>

<u>All-in-all, a most interesting specimen. If perhaps remaining a bit "enigmatic", at the preliminary level of "triage/analysis" performed here. Petrographic scope time......!!!</u>

TM-04-6-10-4-B-2:

This sample ("-2") is from another (opposite) end of the larger specimen ("-4-B-.....") from the previously-discussed "TM-04-6-10-4-B-1" sample (which cf.).

Sample "-2" shows two rather distinct (in mega-appearance) apparent lithogies, one dark grey-black, with a color index of about 50+; the other one a lighter grey-green, though also with a color index of about 50+, if the "green" material(s) is/are considered "mafic". A moderately "sharp" border separates these two.

Note some "ghosts/mega-crystals-blasts-phenocrysts" (?), on the order of 1.2 cm and smaller. These appear to be somewhat akin to similar features observed in sample "-1". However those in the present sample have perhaps(?) a more "hornblende-like" aspect (?) than the apparent "pyroxene"(?) analogs in "-1".

There is actually a vague indication of "banding/layering", with "bands" of "black" versus "grey-green" alternating. Each band on the order of 1 to 3 cm in apparent thickness, as viewed on the specimen surface.

Two major broken specimen surfaces, one "fresh" ("F"), the other weathered ("W").

<u>"F":</u>

Presents some fine examples of euhedral pyroxene (with the distinctive cleavages), surrounded by rims of tremolitic/actinolitic amphibole, +/-, within/adjacent to sub-euhedral clear-whitish plagioclase. Some of the plagioclase is altered, variously, to (apparently) epidote, +/-, in places.

A "banded/layered" specimen, with darker ("pyroxene-rich") versus lighter-greenish-(plagioclase+/-epidote, +/-? - richer) "zones/bands".

A few thin planar "seams/veinlets" transect the specimen, with associated "more intense" development of epidote/epidotization of adjacent plagioclase, as well as some concentrations of FeO/OH (now, at present) material(s). Trace amounts of "magnetite"(?)/+/-"limonite" are scattered throughout the specimen as well.

A "plagioclase + pyroxene (now --> "amphiboles", +/-?) rock". "Diorite, mela-diorite, gabbro, etc. (?). "Igneous"? Or a "pyroxene-plagioclase "skarn/skarnoid"??

"W":

Suggestions (viz. cavities, "drusy surface") of carbonate on weathered surface of specimen. Trace of "molybdenite"(?)/"graphite"(??)/"smeared-out" sulphides, +/- ? // AND/ OR.......... ?, on surface. This surface is the extreme opposite end of the specimen from the specimen TM-04-6-10-4-B-1 (which cf.).

This (moderately) weathered surface features much "white" -- though with apparent "iron-staining" -- material ("crust"; and/or "fracture surface/seam/veinlet"?).

The "molybdenite"(?) occurs here and there, associated with white material(s) (ie. plagioclase +/- quartz(?) +/- carbonate? +/-?), as eu-subhedra, similar to that noted on the "-4-B-1" specimen. The "molybdenite"(?) is fresh, unweathered (?: perhaps, rather, "graphite", thus??).

Traces of eu-subhedral, "rusty", seemingly opaque (magnetite?; sulphide[s]?) grains occur on this surface of the specimen.

Some pyroxene crystals show slight/incipient weathering (?) --> "rusty" material(s). Note another "ghost" pyroxene, about 1.5 cm in maximum observed dimension, with euhedral crystal outline/shape, weathering/altering -->?.

[Note/Aside]--- Re/ "diorites", etc. Esp. in the Whitehorse Copper Belt, +/-.

"Igneous" diorites? Vs. "pyroxene-plagioclase" rocks; esp. as per Aleksandrov (1998, & other papers) ? Criteria for distinction?

Endoskarns....... Exoskarns....... Skarnoids..........

Contamination........ Reaction......... Assimilation......... Melting......... (esp. "of country/host rocks"; and/or "skarn"........)

"Mela-diorites"........... "Gabbroic rocks" -- compositionally (mineralogy, chemistry); texturally; modes/loci of occurence; etc. (?)

"Meta", "Meta'd", "Mela", -- "diorites".

"Granitics".........

"Super-heat".......... "High-heat-producing" (HHP) "granite/granitic" magmas/melts........ (Cf. Aleksandrov, esp. his "St. Austell"/HHP paper, and his1998 book).

TM-04-6-10-4-B-3:

Similar to "TM-04-6-10-4-B-1". of which the present specimen, "-3", is the larger "parent" portion, broken in turn from the largest (in "reserve") "foot" specimen ("-4-B-......."). While (as I mentioned to Jim Coyne) an even larger, "penultimate", parent resides(ed) along the "Mt. McIntyre"(?) road (on the "southish" side of the road), about 0.3 miles uphill from the junction of this road with the "road/two-track" to the top of the Arctic Chief (west) pit north rim (cf. field notes).

The present specimen ("B-3") features on the order of 3-5% "molybdenite" (?)/"graphite"(??)/"smeared" other material(s), viz. galena, other sulphides, etc. (??), located on the "fresh" fracture surface ("F") of the specimen, which surface is the "mate" to that/the similar one on specimen "-1" (which cf.).

This surface ("F") is intersected/transected by a number of moderately-spaced fractures cutting across it at high (---> 90 degrees) angles. These latter fractures are not obviously "mineralized". More akin to "cleavage" in aspect (?); "late", hence, presumably.

The opposite side of the specimen ("W") is moderately weathered, with appreciable whitish

+/- "rusty" material(s), as well as slightly-moderately weathered pyroxene, +/-.

These two surfaces, "W" and "F", are subparallel, with several variously-well-developed "seams/veinlets/fractures" subparallel to them, within the specimen. Also note several "veinlets", with associated "whitish" material(s), trending at high angles to both the "W" and "F" and the "cleavage-like" trends/fractures. In essence, more or less a "three-dimensional" network.

A "cross section" of a "weathering profile" at the larger butt end of the specimen has much to offer in terms of elucidation of mineralogies and textures of this specimen.

The "cleavage-like" fractures may have at least some associated quartz (ie. "silicified"), +/- traces of iron-bearing material(s).

The "molybdenite"(?) crystals/platelets seem to have a "coherency" as individual sub-platy flakes suggestive of a "metallic", rather than "graphitic/carbonaceous", character (?). Though, as well, there may well be some (smaller, disseminated) grains/platelets/etc. of graphite/carbonaceous material present on this fracture surface (??).

Some of the"molybdenite" (?) crystals/platelets are on the order of 4.0 mm (+/-) in maximum dimension of the hexagonal surfaces. The white/whitish (sometimes slightly "rusty/ferruginous"?) material(s) associated with these "molybdenite" (?) grains may be plagioclase/quartz(?)/carbonate(?)/+/-?. Epidote is not uncommon in proximity as well.

Also some copper-bearing sulphides (viz. chalcopyrite, +/ bornite, +/-?) occur sporadically on this fracture surface (associated with carbonate, quartz?, +/-?). Some green (malachite, +/-) material(s) associated as, presumably, alteration and/or weathering products. These sulphides are eu-subhedral, as well as less-well-developed. Seen best on one edge of the specimen, near the "wedge-end" of the specimen. Some very-well-developed "tetragonal-like" euhedra noted here.

Some "molybdenite"(?) is associated with/intergrown with "tremolitic-actinolitic" amphibole, +/-, and relict pyroxene.

There is a "chlorite-like green" cast to some of the "whitish-clear" mineral(s) (viz. quartz?, carbonate?, plagioclase?/+/-?), akin to an "internal dusting" of inclusions of "extremely fine-grained" green material(s) [??]. "Copper--"???.

"W":

Surface is moderately weathered.

Evidence of weathering of mafics (pyroxene --> "tremolitic/acinolitic" amphibole, +/- ....., with "drusy" very-fine-grained crystals of bright --"epidote"-- green eu-subhedra, seen on relict pyroxene crystals, etc. ---> surficial crust on weathered surface of specimen; more or less "ubiquitous").

Also weathering of carbonate, +/- plagioclase, is evident.

Numerous holes, cavities are noted, though there seems to be no (other)compelling evidence of "weathered-out" sulphides, or magnetite (?).

All-in all, an interesting specimen. Especially with regard to the chalcopyrite +/-bornite + malachite + "molybdenite"(?) associated on the "F" surface.

TM-04-6-10-5:

"Dioritic" (?) rock. Sulphides, and trace malachite, on a "readily broken" (with a hammer) surface ("fracture"?). Blebs/blobs/patches of black material(s) associated with these sulphides.

Specimen has a "granitic" aspect, overall, with vague "banding/layering" in places. A "salt and pepper" texture, megascopically.

"Rusty" weathered surfaces, staining near sulphides. Chalcopyrite, with associated white (carbonate?), red-brown (hematite?, garnet??), yellow-green (epidote?), clear-vitreous (quartz??/carbonate??/feldspar??) material(s). Chalcopyrite is eu-subhedral, with occasional weathered(?)/altered(?) associated malachite, hematite(?)/mercury-bearing mineral(s)[???].

This chalcopyrite, +/-, assemblage is essentially restricted to a planar zone of relatively small thickness, with evidence of structural movement within this zone (slickensided features, alteration). Essentially chalcopyrite; +/- pyrite(?), some bornite (? ; perhaps --> hematite?, +/- malachite, etc. ?, at least in part ?).

Note other "veinlets" of epidote(?), quartz(?), feldspar(?), +/-?, which transect this zone, here and there. Some such feature apparent very-fine-grained carbonate(?) of pinkish hue. Black hornblendic(?) amphibole, similar to that found less-intensely altered in the surrounding "country rock" of this specimen, is, in this zone, moderately/strongly altered, peripherally and along cleavages, to a light green prismatic "tremolitic/actinolitic" amphibole, +/-?.

The "host rock/diorite/endoskarn/exoskarn"(?) is made up principally of clear white plagioclase (?), and dark green to black amphibole (note cleavages)/+/- "pyroxene". The latter "mafic(s)" show(s) various degrees of "alteration" ---> "tremolitic/actinolitic" amphibole, but, for the most part, less intensely so than is the case within the sulphide-bearing zone. Eu-subhedral magnetite is an important third constituent mineral in this rock. Plagioclase, pyroxene(??)/amphibole (hornblende?, +/-?), are eu-subhedral, intergrown in an apparent (?) "igneous" texture ("granitoid/dioritic"), of medium-fine grain size, more or less equigranular constituent phases. Some epidote alteration of/marginal to/within plagioclase, and/or "amphibole(s)". Also +/- some "flakes/specks" of magnetite(?)/ galena(??)/molybdenite(???)/graphite(????) on "dioritic" rock proximal to the sulphide-bearing "zone". Some lozenge-shaped amber eu-subhedra within the rock might be sphene (?)/+/-?, in trace amount.

"Country rock" of "dioritic" aspect/flavour, mineralogically and texturally (?). [[However --- "genesis" is another matter. Especially given/in the context of the local-areal-regional geological setting/environment.]]

Perhaps/likely (?) an example here of the not unusual "dioritic" border/ margin/ carapace/shell associated with "granitic" intrusive suites in many places elsewhere. Apparent examples of such too numerous to do more than allude to here, in this report. Cf. also Aleksandrov, 1998, and other publications; especially his "HHP" paper at the St. Austell conclave.

Implications for the Arctic Chief? For the Whitehorse area/Copper Belt? Regionally?

Cf. also Moorhouse, 1959, regarding diorite, especially page 244 regarding hornblende after pyroxene morphology, etc.; also pp. 256-301. "A lot of lore", in Moorhouse (Hogarth, pers. comm.).

At a location on one edge/corner of this specimen, note one very-well-developed eight-sided, in part euhedral, crystal (pyroxene, originally). Replaced by epidote in the center , and by "malachite" at the crystal margin, with some relict "pyroxene" remaining in the central core.

Further, as regards the nature of the dark/black "blebs/blobs/patches" seen megascopically on the surface of the specimen, near the sulphides.

"Megasopically" they have a "blasto"-crystalline aspect, with seemingly a "metamorphic" equivalent of "poikilitic" texture (ie. "poikiloblastic"). Viz. the amphibole?/hornblende??/or.......... ?, with "inclusions" of "plagioclase", "pyroxene", +/-?. They seem to be, rather, "composites" of variously-oriented eu-subhedral pyroxene, which has been moderately "altered" --> "tremolitic/actinolitic" amphibole, (+/-).

Seemingly via an intermediate "hornblende" step/stage. The pyroxene having a decidedly "black, shiny, hornblende-like" appearance to it. Ie. (?) : pyroxene --> "hornblendic amphibole" ---> "tremolitic/actinolitic" amphibole, +/-.

Was the hornblende originally of igneous ("dioritic"?) parentage, initially? Subsequently pseudomorphed to pyroxene, via change (increase?) of temperature, and/or other effects related to changing pressure, composition conditions? With subsequent "retrograding/alteration" resulting in formation of tremolitic/actinolitic amphibole, +/-?

Some of the outlines of the "mega" crystals abut chalcopyrite +/- garnet? +/-?, as though they crystallized "side-by-side" (??).

Or, rather: sulphides, "quartz"?, epidote, carbonate, +/-, "replacive" of "pyroxene", +/- (?). [[Likely....... (??)]]

TM-04-6-10-6-1:

An outcrop specimen. A "salt and pepper" rock. "Dioritic"(?). Two variants noted in the specimen. The "contact/border" between them is relatively distinct/sharp.

One is a fine-grained equigranular rock, featuring apparent "pyroxene" (eu-subhedral) and plagioclase. "Pyroxene" features rims/borders of apparent "tremolitic/actinolitic" amphibole composition. These "pyroxene" grains occur intergrown with sub-anhedral plagioclase, +/- quartz(?), +/-?. Color index = 40+; ie. "diorite/meladiorite" (?).

Trace of molybdenite(?)/graphite(??)/magnetite(?). Molybdenite?/"smeared" galena or other sulphides?/"giant" magnetite? occur(s) associated with carbonate, at/near the margin/contact/boundary between the fine-grained and medium-grained variants of this specimen. Likely (?) magnetite, but might be "mica", viz. biotite, phlogopite (?). Persistent along this "contact", in trace amounts. Apparent magnetite euhedra noted. Note also some oxidation products ("rusty", +/- 4mm in size) associated with this "contact" zone (and elsewhere, too), where the fresh and weathered surfaces of the specimen meet. This material(s) persist(s) throughout the "medium-grained" portion of the specimen.

The other variant is a medium-grained rock,with large black eu-subhedral crystals of "pyroxene"(?), within lighter (plagioclase?) material(s). One (the largest noted) euhedral prismatic "pyroxene" crystal is 14 mm in maximum observed dimension; others are in the range of 7 mm and smaller.

The weathered surface of this medium-grained rock shows the major mineral constituents "in a different light", as it were.

Consisting of apparent quartz, plagioclase, carbonate, pyroxene (with "amphiboles"), magnetite, green euhedra of spinel(?)/??, and perhaps(?) some molybdenite(?). Some eu-subhedral clear amber crystals (spinel?/+/-??) occur in this rock type, associated with pyroxene, plagioclase, +/- quartz. Trace of garnet (??) noted, as very-fine-grained, red-amber, eu-subhedra, +/-, associated with pyroxene.

Might the pyroxene "euhedra" originally been "glomero-porphyritic/-phenocrystic" groups of crystals, now "altered"/whatever --> "uralite" (viz. hornblende? --> tremolitic/actinolitic amphibole/+/-epidote/+/-phlogopite or biotite in places? The "mega-euhdral" outlines now consist of a mass of variously-oriented eu-subhedral relict "pyroxene" crystals --> "amphibole(s)" --> +/-. Similar to relationships observed in "diorite-like" specimens from TM-04-6-10-4, & -5 (which cf.).

Two kinds/generations of plagioclase noted. An "earlier", often eu-subhedral, clear but "brownish" variety. This surrounded by a more abundant "whitish" variety (?). [The "brownish" could(?) actually be "later" than the "whitish" (???).] The "brownish" ranges from euhedral <--> "rounded". Perhaps these relationships, actually/merely representing a matter of zoning in plagioclase (?), from "dusty/smoky"/altered cores --> "whitish" rims (??). Likely (?), or so it appears, in some views. Ie. "zoned" plagioclase. [Perhaps "likely so"; but not "assuredly so". As is the case in most matters geologic -- and otherwise. Cf. Smith, Spry, etc.]

Does this suggest/indicate/establish/demonstrate/"prove" the "igneous" nature of this plagioclase? ....+/-the rock? At least during the crystallization of the plagioclase adjacent to/around the "pyroxene" eu-subhedra, etc. (?). Ie. crystallization from a melt, "contaminated" or otherwise (?). With attendant/presumed implications as to "d/deltaT", "HHP", etc., per Aleksandrov (1998, and other publications; especially his "St. Austell" paper). Ie. not a "plagioclase-pyroxene rock" as a metamorphic/metasomatic product. But, rather, a portion/variant (perhaps/likely "contaminated") of the /a "main magma" body (?).

[Aside/question: can/does a "contaminated", perhaps/likely(?) less-basic, melt crystallize medium-fine-grained eu-subhedral pyroxene, plagioclase, +/-, at lower temperatures than the experimentally-"demonstrated" phase relationships/mineral stabilities "regime" (at "thermodynamic equilibrium", ie. (??). Perhaps as a "non-equilibrium" "quench phase"/"over (or under) -shooting" sort of thing (??). "Reaction/assimilation" as a "type" of metamorphism? Cf. stabilities/assemblages per various PTC's.]

One freshly broken surface on the specimen shows some minor iron-staining at an edge where the surface adjoins one of the other, weathered, surfaces of the specimen.

TM-04-6-10-6-2:

A hand specimen now broken into six pieces. "Float" sample. One fracture noted cutting this specimen. Vaguely-defined "planar" seams occur subparallel to this, or at +/- 45 degrees to it.

Specimen displays a "salt and pepper" texture, megascopically. The lighter grains showing a "pinkish" cast, the darker ones a grey-green aspect. (Altered/metamorphosed-metasomatized?).

Light green material "diopside"? An "altered pyroxene", ---> "tremolitic/actinolitic" amphibole, +/-? Crystals displaying good outlines suggestive of "pyroxene". Now made up of crystalline material(s) with some apparent relict/vestigial "87-93 degrees" cleavages, but with overall color aspect of "diopside/tremolite-actinolite" (?). Some of these crystals are clearly eight-sided in outline; prismatic forms are displayed as well.

"Pinkish" material(s) originally/still(?) plagioclase (likely). Pink representing alteration --> clinozoisite/zoisite/Mn-epidote/+/-?. Now a subtle "rose quartz" color, in places (due to zoning, or to thickness of viewed crystal, etc.?). Though at least some of this pink material might actually be carbonate; some might be quartz(?). Traces of apparent zoning (?), with brownish cores and lighter rims. Could (?) be zoned garnet, rather than plagioclase (?).

Occasional scattered crystals/patches of dark brown-black "graphite-like-looking" material(s), especially associated with "plagioclase". Traces of light yellow-green epidote(?) are similarly associated, as eu-subhedral crystals. Also note some amber-brownish eu-subhedra of spinel(?)/garnet(??)/or?. Possibly (?) also some light red-pinkish garnet(?) here and there. Also (appreciable) eu-subhedral magnetite (?)/?, as well as phlogopite(?)/graphite(?)/sulphides, disseminated, here and there.

Note a few "prominent" internal fractures/shears, which intersect at various angles, in a moderately-spaced "network". Some "slickensided" features also noted in association with these.

Lithology(ies) now a pyroxene ("altered" --> "amphiboles", +/-) - plagioclase - garnet - magnetite (minor) - carbonate - +/- quartz? - +/-? "rock", with textural variants. An "altered/retrograded/(calc)-skarned" rock (?). Which could have had a "dioritic-gabbroic" protolith.

At least some of the "pinkish" material could be carbonate. There are some masses/pods of magnetite(?), here and there, as well as the disseminated eu-subhedra. Weathered specimen surfaces afford much useful information/perspective regarding this specimen.

The "light-green" material(s) does seem to be (altered) "pyroxene" (now diopside[?], and/or "tremolitic/actinolitic" amphibole(s), +/-), based on the nature of observed crystal shapes/outlines, and cleavages, especially when viewed on weathered (moderately+) specimen surfaces. The pinkish-whitish euhedra appear to be feldspar, presumably plagioclase, as similarly viewed on weathered specimen surfaces. Occasional bright green six-sided crystals are probably epidote. Also noted are variously rounded/weathered apparent euhedral crystals of "magnetite".

Weathered specimen surfaces are informative at 30x/60x viewing, especially with the stereomicroscope.

TM-04-6-10-8-A:

Hand specimen. "Ore". Massive specimen of magnetite, with scattered patches of serpentine(?) [greenish, to buffish-yellow on weathered surfaces]. Traces of copper-staining (light blue-green) on some fracture surfaces.

TM-04-8-9-2-Z:

Garnet (reddish-brownish) and pyroxene (dark green/black) "skarn", with crystalline calcite (orange-pink), +/-. (Cf. similar specimens TM-81-7-30-1 & -2.) "Typical skarn", sent to SMA January 2005. Cf. SMA comments.

TM-04-10-12-....

TM-04-10-12-22-A-101:

Massive chalcopyrite, magnetite, +/- bornite; with associated pyroxene, calcite(?), quartz(?), malachite (featuring some nice acicular crystals), serpentine(?), +/-?.

TM-04-10-12-22-A-102:

Massive magnetite-bornite-chalcopyrite, +/- calcite(?), serpentine(?), quartz(?).

TM-04-10-12-22-A-103:

Green "mica" (phlogopite, presumably); magnetite, bornite, pyroxene(?), serpentine(?), calcite, quartz(?), +/-?.

TM-04-10-12-22-A-107:

Massive magnetite, with coarser crystals of bornite(?) [with associated azurite/malachite on the weathered side of the specimen]. Also crystals of forsterite(?)/ --> serpentine(?). Also some calcite(?) and/or quartz(?). A small specimen, but one with some interesting textural relationships.

TM-04-10-12-22-A-112:

A "float" specimen from the "-22-A" area. Note some subtle "banding" in mega-view. Periclase (brucite) marble. Predominant rock-forming calcite and periclase (brucite). Trace amounts of black opaque mineral(s): magnetite(?), ludwigite/vonsenite(??), +/-?. Also some spinel(?), forsterite(?).

TM-04-10-12-22-A-113:

A carbonate rock specimen. "Float" from the "-22-A" area. Features two types of carbonate rocks, one white, the other grey. Both periclase (brucite) marble, lithologically. The periclase-brucite relationships are especially evident on the weathered specimen surface. Weathered surface also shows trace amounts of black opaque mineral(s), and some sulphides (pyrite?/and/or??. [Also perhaps?!?, molybdenite(??)].

TM-04-10-12-22-A-120:

Specimen from a LARGE chunk of ore material at locality "-22-A". Comprised of magnetite-bornite-phlogopite- ,+/-?. Note varying grain sizes of crystalline phlogopite.

TM-04-10-12-22-A-121:

Specimen from a LARGE "boulder"/chunk of ore material in the "-22" locale. On the "bench"/rim of the south side of, and above, the entrance cut at the Arctic Chief (west) pit. Specimen consists of magnetite-phlogopite-bornite, +/-?.

TM-04-10-12-22-A-122:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-bornite-chalcopyrite, with much associated phlogopite as well. (+/-?).

TM-04-10-12-22-A-123:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of pyroxene(?)-magnetite-bornite-chalcopyrite-phlogopite(?)- +/-?.

TM-04-10-12-22-A-124:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of pyroxene(?)-phlogopite-magnetite-bornite-chalcopyrite- +/-?.

TM-04-10-12-22-A-125:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of pyroxene(?)-phlogopite-magnetite-bornite-chalcopyrite- +/-?.

TM-04-10-12-22-A-126:

Specimen from the same general locality as the "-22-A-121" sample, above. Specimen is "banded", with opaques versus non-opaques: magnetite-bornite-chalcopyrite; forsterite(?)-calcite(??)- +/-?.

TM-04-10-12-22-A-127:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of phlogopite-magnetite-bornite- +/-?.

TM-04-10-12-22-A-128:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-chalcopyrite- +/-?.

TM-04-10-12-22-A-129:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-pyroxene --> phlogopite/tremolite-actinolite/? -chalcopyrite-bornite (trace amount). Features chalcopyrite and calcite on planar/vein-like surfaces as well.

TM-04-10-12-22-A-130:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-phlogopite-chalcopyrite- +/-?. Magnetite varies in crystalline/grain size.

TM-04-10-12-22-A-131:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-forsterite/serpentine/ +/-?.

TM-04-10-12-22-A-132:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-bornite (trace amount)-phlogopite-calcite- +/-?.

TM-04-10-12-22-A-133:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of phlogopite-serpentine-magnetite- +/-?.

TM-04-10-12-22-A-134:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-phlogopite-chalcopyrite-bornite- +/-?.

TM-04-10-12-22-A-135:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-phlogopite-calcite. A pod/lens of crystalline calcite was noted occuring within magnetite crystals in one location in the specimen.

TM-04-10-12-22-A-136:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-phlogopite-calcite- +/-?.

TM-04-10-12-22-A-137:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of pyroxene(?)-phlogopite-magnetite(?)-chalcopyrite-bornite-malachite-azurite-calcite- +/-?. Complex sample.

TM-04-10-12-22-A-138:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of magnetite-phlogopite-calcite(?)- +/-?.

TM-04-10-12-22-A-139:

Specimen from the same general locality as the "-22-A-121" sample, above. Consists of pyroxene(?)-magnetite-forsterite(?)/serpentine(?)/calcite(?)- +/-?.

TM-04-10-12-22-B-104:

A VERY NICE SPECIMEN. "Skarn"; "intrusive"/"front", "zoned". Collected in the vicinity of the skarn "apophysis"/"lens" at the north edge of the Arctic Chief (west) pit entrance. A "cognate float" sample, from below "map #3" (ie. TM-04-6-9-3) locality.

Specimen is approximately 16 cm in its maximum/"longest" dimension. Displaying six apparently recognizable individual/discrete "zones", as follows:

Zone 1. 3.7 cm in apparent width, as measured on the specimen surface selected for study. Periclase (brucite) marble, with minor/trace spinel(?), +/-?. Light grey, "banded".

Zone 2. About 2.0 mm "wide". Clear-grey. Coarse crystals of quartz(??), calcite(?), in a lens-like "border" region between zones 1 and 3.

Zone 3. On the order of 4.0 mm "wide". Dark grey-greenish-yellowish. Banded. Calcite(?), forsterite(?), pyroxene(?), +/-?.

Zone 4. About 5.0 mm "wide". A yellowish-greenish zone. Forsterite(?), +/-?; calcite(?).

Zone 5. On the order of 13.0 mm "wide". Dark greyish. Pyroxene(?), phlogopite(?), other "micaceous" mineral(s)(?), +/-?.

Zone 6. Approximately 16.0 mm in apparent width, as measured across this "tongue-like" feature which is surrounded by immediately-adjacent zone 5 material. Pinkish in color. Likely(?) altered igneous material -- ie. zoisite(?)/clinozoisite(?)/epidote(?)/+/-??; or garnet(??), calcite(??), +/-??.

This "illustrative" specimen is moderately-strongly fractured, with most of the evident fractures oriented more or less sub-perpendicularly to the "borders/margin" of the "apophysis/intrusive(?)/replacement zone ("6"), wherein the "skarn" material presently occurs. This latter perhaps/likely associated with a "long-lived" (or otherwise) fracture, oriented along the (apparently, in this view) long axis direction of the present mass of "skarn" and related zones surrounding the garnet, +/-, "core". (?).

This is the specimen described by S. M. Aleksandrov in his paper:
"Gold Behavior during Endogenic and Supergene Alteration of Sulfides in Magnesian Skarns" BY S. M. ALEKSANDROV, PUBLISHED IN GEOCHEMISTRY INTERNATIONAL, 2007, VOLUME 45, No. 2, pp. 152-169.

The following is taken from remarks of TCM, in his "review" of this paper, in the present report (above, pp. 7-9, which cf.):

.... Among others, one important point in particular seems worthy of special note here in this commentary. On page 154, Aleksandrov observes: "The magnesian skarns of the Arctic Chief deposit occur not only at contacts with the [main] intrusion but also around injections of diorite melts into dolomites (Fig. 2). The rocks preserve their zoning and inclusions of Mg-ludwigite in the forsterite calciphyres but contain no magnetite ore mineralization" [associated directly with the latter, smaller/minor 'injections', ie.].

Illustrative of this, his Figure 2, on his page 156, offers a drawing of a rock specimen.

This specimen happens to be the one designated "**TM-04-10-12-22-B-104**" when it was collected in the field at the Arctic Chief on October12, 2004, at sampling locale "22-B".

Described by TCM in his "triage" phase of analysis as a "VERY NICE SPECIMEN", among other comments. This specimen was subsequenty sent in its entirety to Aleksandrov. Studied, depicted and discussed, by him. Who also apparently found it a 'very nice specimen'.

Collected in the near vicinity of a larger skarn/apophysis/lens of tongue-like aspect, featuring zoned igneous and "skarn" materials within carbonate host rocks, with green, blue, +/-, "rusty"-/copper-staining present in places along its margins. This larger feature is a

rather "gaudy"/spectacular one; well-photographed, 2004 and later. As well as, subsequently, in 2006, collected in detail as samples "TM-06-8-22-2-........".
Cf. maps, descriptions, etc. by TCM in the "Data Supplement" of the present report.

Location is at the northern edge/margin of the entrance cut of the Arctic Chief (west) pit, exposed up on the side/wall of the cut. In the vicinity of the core/crest of a tight/overturned fold in the carbonate host rocks. Below map#3 (ie. TM-04-6-9-3 locality).

(From selected portions of earlier letters from SMA to TCM:

"Ludwigite is in serpentine-bearing marble **TM-[04]-10-12-22-B-104**, very little. May be in contact with marbles you can see kotoite Mg3(BO3)2???......."

"You can see rhythmically-banded textures, that inherit, and in magnetite ores. (The best you can see in **TM-04-10-12-22-b-104** --- [the sequence] around diorites' injection in marbles: exchanged ["altered"] diorite--clinozoisite rim--pyroxene skarn--banded ludwigite-bearing forsteritic calciphyre--banded periclase (brucite) marble.)

According to its caption, Aleksandrov's Figure 2 illustrates "diorite injection in dolomite and zoning in magnesian skarns"........... Recognized as such in the field, too. Collected with precisely this intent, this specimen is used as an example -- "in microcosm", as it were -- of the general relationships ("positions") typical of magnesian skarns, at various scales from hand specimen, as here, through "deposit scale". Per the "model" for the "geochemistry of skarn and ore formation in dolomites" as developed and set forth by Aleksandrov and his associates over a period of many years.

Providing further illustrative bonuses, as observed, and depicted, this informative specimen also features "rhythmically banded forsterite calciphyres", and "disseminated crystals of magnesioludwigite". In addition to the other compositional and textural features characteristic of magnesian skarns so nicely displayed in this one specimen.

Collectively, "Letting the rock speak for itself", as it were........

This Figure , this specimen, the evidence afforded, supplemented by Aleksandrov's comments, sufficiently informative to merit incorporation in the present report. A "key" item.

Thus his Figure 2 and caption are reproduced below, on page "Insert//SMA-156":

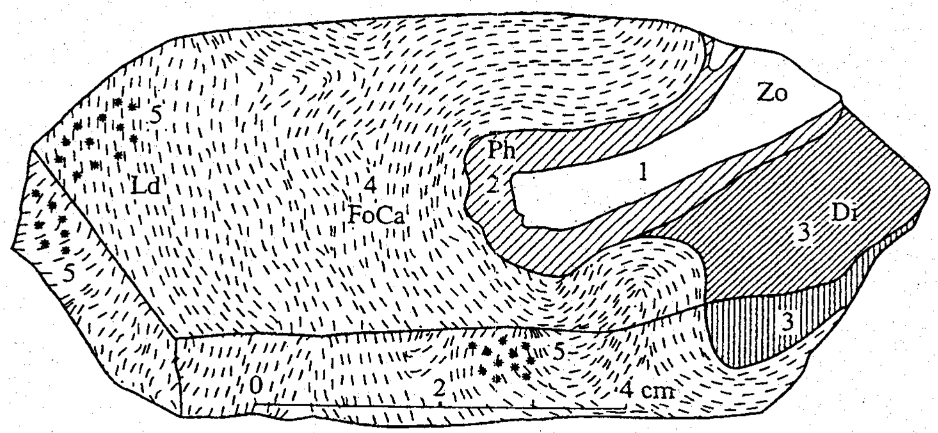

Fig. 2. Diorite injection in dolomite and zoning in magnesian skarns. Arctic Chief deposit (sample of T.C. Mowatt). (1) Diorite replaced by zoisite (Zo); (2) phlogopite–diopside skarn (Ph); (3) diopside skarn (Di); (4) rhythmlically banded forsterite calciphyre (FoCa); (5) disseminated crystals of magnesioludwigite (Ld). Magnification 2.5×.

((INSERT//SMA-156))

TM-04-10-12-22-B-114:

Specimen from the northwestern part of area "22-B", at the northwest side of the Arctic Chief (west) pit entrance. This is below map locale #3. A "float" sample.

Features a "plug-like" zone/lens/tongue of "skarn" into/surrounded by carbonate "host/country" rock. Presumably (?) fracture-related.

"Skarn" consists of a pinkish-brownish garnet "core", rimmed with a "calcite+magnetite(?)+pyrite+garnet" zone, featuring relative concetration of magnetite(?) pyrite(?)- +/-?.

The carbonate rock -- periclase (brucite) marble -- is white-light grey. It consists of the rock-forming assemblage of calcite and periclase (brucite), with minor-trace amounts of associated pyrite (euhedral, +/-), magnetite(?)/<u>molybdenite(???)</u>, +/- graphite(??).

Specimen contains some fractures, best observed on weathered surfaces.

TM-04-10-12-22-B-115:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

Features a "skarn" plug/lens/tongue into carbonate host rock. The larger of the two broken pieces was sent to SMA, the smaller piece, containing the "snout" of the plug/lens, was retained.

The carbonate host rock is a white periclase (brucite) marble, with trace amounts of associated graphite(?)/<u>molybdenite(???)</u>, pyrite, and spinel(?).

The "skarn" material(s) is/are dark grey-blackish; pyroxene(?)-magnetite(?)-sulphides (pyrite?, +/-?), as well as a minor-trace amount of reddish-pinkish-brownish garnet.

TM-04-10-12-22-B-116:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

Specimen features serpentine, with a seam/vein of white (calcite?) and dark grey/black material(s). Pyroxene(?), serpentine, forsterite(?), epidote(?), calcite, magnetite(?)/other black opaque mineral(s)(?); <u>trace of sulphides(??)</u>.

TM-04-10-12-22-B-117:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

An "alterered/retrograded" pyroxene skarn material(?): pyroxene --> tremolitic/ actinolitic apmphibole//talc(?)/+/-?. With some calcite(?) and <u>sulphides (pyrite?)</u>.

TM-04-10-12-22-B-118:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit. An "illustrative" specimen.

Specimen is about 11.0 cm in its "longest" dimension. "Banded/zoned", as follows:

Zone 1. 15 mm in apparent width, as measured on the face selected for study. A plagioclase-pyroxene rock; a "dioritic", or "endoskarn" material(?).

Zone 2. 4.3 cm "wide". Pinkish garnet.

Zone 3. 3.5 cm "wide". Pyroxene, moderately altered to tremolitic/actinolitic amphibole(?), +/-?.

Zone 4. 1.5 cm "wide". Phlogopite.

Zone 5. 1.5 cm "wide". Forsterite(?)/serpentine(?)/+/-?; spinel(?), maroon-red-brown "magnetite/hematite(?)", black opaques.

TM-04-10-12-22-B-119:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

Periclase (brucite) marble. With associated "black-smoky" spinel(?)/or some other more or less opaque mineral(?), occurring as eu-subhedra (tetrahedra?/cubes?/+/-?). ["Borates"??]. This "spinel/opaques/?" material(s) comprises an appreciable (+/-30% ?) component of this specimen.

TM-04-10-12-22-B-140:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

Pyroxene --> tremolitic/actinolitic amphibole - serpentine(?) - forsterite(?) - spinel(?) - trace garnet(?) - trace magnetite(?) - trace plagioclase(?). Pyroxene and plagioclase sub-euhedral.

"Exo-/endo-skarn"(?) - ie. "plagioclase-pyroxene rock"(?). Or....... ?

Note a concentration of chalcopyrite at one end of the specimen, intergrown with pyroxene (within pyroxene crystals, too), and disseminated among pyroxene and plagioclase. Specimen appears to perhaps be "silicified" (?).

TM-04-10-12-22-B-141:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit. Copper mineralization at one end of the specimen. Pyroxene(?)/magnetite- phlogopite-chalcopyrite-bornite(trace)-malachite-azurite-calcite.

TM-04-10-12-22-B-142:

A "float" sample, from locality "22-B", below locality "3" at the northwest side of the entrance to the Arctic Chief (west) pit.

Magnetite-serpentine?/forsterite?/+/-?.

TM-04-10-12-23-105:

A fractured, banded/layered/sheeted specimen. Weathered, but with some interesting structures and mineral textures/intergrowths.

Calcite-magnetite-chalcopyrite-malachite-/hematite(?)- +/-?.

TM-04-10-12-23-106:

Massive crystalline magnetite, with subordinate ("yellow-green") crystalline forsterite(?)-serpentine(?)- +/-?. Yellow-green, +/- some white, crystals are intergrown among magnetite crystals, as well as along fractures in specimen.

TM-04-10-12-23-108:

A "granitic" rock. Float/excavated/"cast" material from the southern end of the Arctic Chief (east) pit. A few fractures; three sets/directions/attitudes noted. Some apparent(?) inclusions(?), dark as well as light. [Or, perhaps, "phenocrysts"?].

Plagioclase-pyroxene/hornblende(?)-some calcite(?)-some "rosy" quartz(?)-trace chalcopyrite; magnetite(?).

A few fractures -- some with chalcoprite, +/-. Others with dark green crystalline material, +/-. Fractures bordered by "leuco"/light-colored zones ("bleached"?) - mostly plagioclase and/or?.

"Intrusive"......... , or "endoskarn"........ (?). Appears "dioritic", on cursory examination with the stereo-microscope (?).

TM-04-10-12-23-109:

Specimen represents float/excavated/"cast" material from the southern end of the Arctic Chief (east) pit. A "granitic" ("dioritic") rock. Texture igneous, or recrystallized/ metamorphic, or "contaminated" more leucocratic intrusive magma(?). Intrusive, or endoskarn, or...... (?).

Fractured, with "bleached" border zones, greenish vein-filling epidote.

Plagioclase(twinned)-pyroxene/hornblende(?)-quartz(???)-calcite(??), magnetite (??). Trace chalcopyrite. A "plagioclase-pyroxene" rock, apparently; of one sort or another.

Apparent(?) igneous crystallization textures, with plagioclase and pyroxene(?) eu-subhedra intergrown. Some retrograde(?) chlorite/serpentine(?)-- (after pyroxene?). Some plagioclase crystals feature "cores" of greenish crystalline (epidote?/+/-?) material(s) (altered anorthite-rich cores, or ??).

TM-04-10-12-23-110:

Specimen represents float/excavated/"cast" material from the southern end of the Arctic Chief (east) pit.

"Dioritic" rock. Plagioclase (sub-euhedra, twinned), pyroxene (sub-euhedra), epidote (especially as alteration product in central/core locations in plagioclase crystals). Some "rosy" pinkish quartz(?) here and there.

Trace pyrite(?), with a few crystals of apparent cube-pyritohedron aspect, adjacent to plagioclase and pyroxene, as individual grains (some noticeably striated).

A few fractures cross the specimen, with associated dark green-black (chlorite?, +/-?) material(s) as "fillings".

Some interesting textures, with apparent igneous character of intergrown plagioclase and pyroxene rock-forming minerals.

TM-04-10-12-23-111:

Specimen represents float/excavated/"cast" material from the southern end of the Arctic Chief (east) pit.

An altered "granitic" rock. Actually "dioritic", featuring pyroxene (altering/ed to chlorite, +/-), and plagioclase (altering/ed to clinozoisite/zoisite/epidote, +/-). Trace molybdenite(??), magnetite(?). A few fractures, with associated epidote, +/-.

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OTHER OBSERVATIONS ON SPECIFIC SPECIMENS (S. M. ALEKSANDROV) :

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"First commentaries for your samples: Common look - as also in Brooks Mountain and Tin Creek [Seward Peninsula, Alaska] in Arctic Chief rocks. [Emphasis by TCM]

...... in **TM-04-10-12-22-a-134 and -131 and -102** --- banded phlogopite--magnetite ores, in -126 --- serpentine/forsterite rhythm in magnetite; in **TM-04-6-9-4-2** --- is forsterite--calcite rhythm, etc....).

These textures have origin on progressive stage of metasomatic exchange of dolomites and reflected in ores-- see book [SMA, 1998], pages 77-87. It is non-equilibrium process."

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"**In your collection is splendid periclase marbles,** but in literature are not this **information.**

In many samples in marbles and forsterite-calcite environment are a bit to big black crystals of LUDWIGITE (see TM-04-10-12-22-b-115; -23-110, -23-108, etc. See Brooks Mountain! This fully are not in literature about Whitehorse copper belt!

[Underlining in above is original in letter from SMA; bold emphasis added by TCM.]

About typical lime skarn (**TM-04-08-09-2**) [of] pyroxene-garnet composition: What is its position with magnesian skarns? I believe that it has postmagmatic origin from Si-bearing marbles. What, how much, are sulfides in this type skarns?? Or absent?

In forsterite marble (**TM-04-6-9-5-1**) is spinel. The part of pyroxenes is Al-bearing. In this situation is formed late phlogopites in rocks and ores. ....

About dykes and its composition. In last letter I note about leucocratic hornblende quartz monzonite dyke. It is possible that monzonite from massif will be more basic! If this so /well then/ you can think that monzonite magma of massif is result of assimilation of host rocks and primary melt was more close to granitic composition and was superheated. Last dykes from deepest magmatic camera must be leucocratic. **In book [SMA, 1998] (Fig. 13) is illustrated this, and similar with Arctic Chief locality.** [Emphasis by TCM]. (In text, epidote = clinozoisite). Plus, see green amphibole with plagioclase in quartz-monzonite dyke- **TM-04-10-12-23-108, 110** with pyroxenes and quartz."

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TM-05-5-25-1-Q:

"Probably in this specimen is ludwigite in the marble part near contact with forsterite-magnetite ore. ...."

"Marble with ludwigite (??????) as black needles. ...."

"I will be send you new [[microprobe]] analytical data for sample #TM-05-5-25-1-Q (marble with Ldw?????? and + magnetite ore...........)"

[An excerpt from a letter from SMA to TCM, May 11, 2006 states: "All black needles are pseudomorphoses magnetite after borates............"]

" Other minerals in this specimen:
Mg-bearing magnetite- (>90% FeO, and 1.5% MgO)
Dolomite- (22% MgO, 30% CaO)
Serpentine- (36% MgO, 3% FeO, 45% SiO2)
Phlogopite, altered to clinochlore- (with MgO, SiO2, and Al2O3)
Talc- (MgO, SiO2)
Are [also] Fe-Mn species dolomite/ankerite."

"Near monzonite plag and prx -- transformed into zoisite and calcite; and prx -- into Mg phlogopite.

All periclase in marbles fully transformed to brucite, with calcite; its form is pseudomorphic after periclase. In these rocks are a few grains of forsterite and clinohumite.

In magnetite ores forsterite is transformed into serpentine near calciphyres, or into other silicates --- into Mg-phlogopites (after diopside). Mg-pyroxene is in **TM-04-10-12-22-A-137** and actinolite........ **22-B-117**, amphiboles........ **22-A-101**.

Green amphibole with plagioclase in quartz-monzonite dyke- TM-----**23-108**, **110** with pyroxenes."

"**TM-04-8-9-2-Z**:
Vesuvianite (idocrase)-pyroxenic typical barren skarn.

TM-04-10-12-22-A-101:
Actinolite in magnetite ore.

TM-04-10-12-22-A-113:
Brucite-periclase marble, with forsterite and clinohumite.
Microprobe analysis: P-68-2. Brucite and periclase, some dolomite.

TM-04-10-12-22-A-121:
Phlogopite in magnetite ore.

TM-04-10-12-22-A-126:
Rhythmically-banded serpentine-magnetite ore.

TM-04-10-12-22-A-130:
Magnetite ore with phlogopite.

TM-04-10-12-22-A-131:
Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-132:
Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-133:
Phlogopite-magnetite ore.

TM-04-10-12-22-A-134:
Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-135:
Magnetite ore with phlogopite; magnetite is prismatic.

TM-04-10-12-22-A-137:
Diopsidic skarn with prismatic magnetite.

TM-04-10-12-22-B-104:
Forsterite-bearing brucite (after periclase) marble, with calcite, serpentine and phlogopite.
Microprobe analysis: P-67-2. Forsterite, serpentine, brucite, phlogopite.

TM-04-10-12-22-B-114:
Rhythmically-banded serpentine-magnetite ore. Serpentine after forsterite.

TM-04-10-12-22-B-117:
Actinolite after diopside, in magnetite ore.

TM-04-10-12-22-B-119:
Brucite-periclase marble.
Microprobe analysis: P-68-1. Brucite with relicts of periclase, and dolomite + spinel + hydrotalcite (after spinel) and magnesite.

TM-04-10-12-22-B-141:
Magnetite ore with serpentine.

TM-04-10-12-23-106:
Rhythmically-banded serpentine-magnetite ore. Serpentine after forsterite.

TM-04-10-12-23-108:
Plagioclase rock with amphibole (dike???).

TM-04-10-12-23-109:
Clinohumite calciphyre with magnetite.

TM-04-10-12-23-110:
Plagioclase rock with hornblende and pyroxene (dike?).

TM-04-10-12-23-111:
Skarned zone on contact with dike. Content anorthite, pyroxenes (fassaites) and garnet. The typical in contact magnesian skarn plagioclase-pyroxene composition and secondary [-ily] transformed in [into] salite-garnet bearing associations.
Microprobe analysis: P-67-1. Salite, plagioclase (anorthite), garnet (grossularite 70%, andradite 30%), pyroxene.

TM-04-10-12-23-B-115:
Brucite (after periclase) marble with forsterite.

TM-05-10-13:
Rhythmic-banded marble with sulphides."