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PETROLOGIC STUDIES IN THE FAIRBANKS DISTRICT: I MOLYBDENUM MINERALIZATION AT THE SILVER FOX MINE

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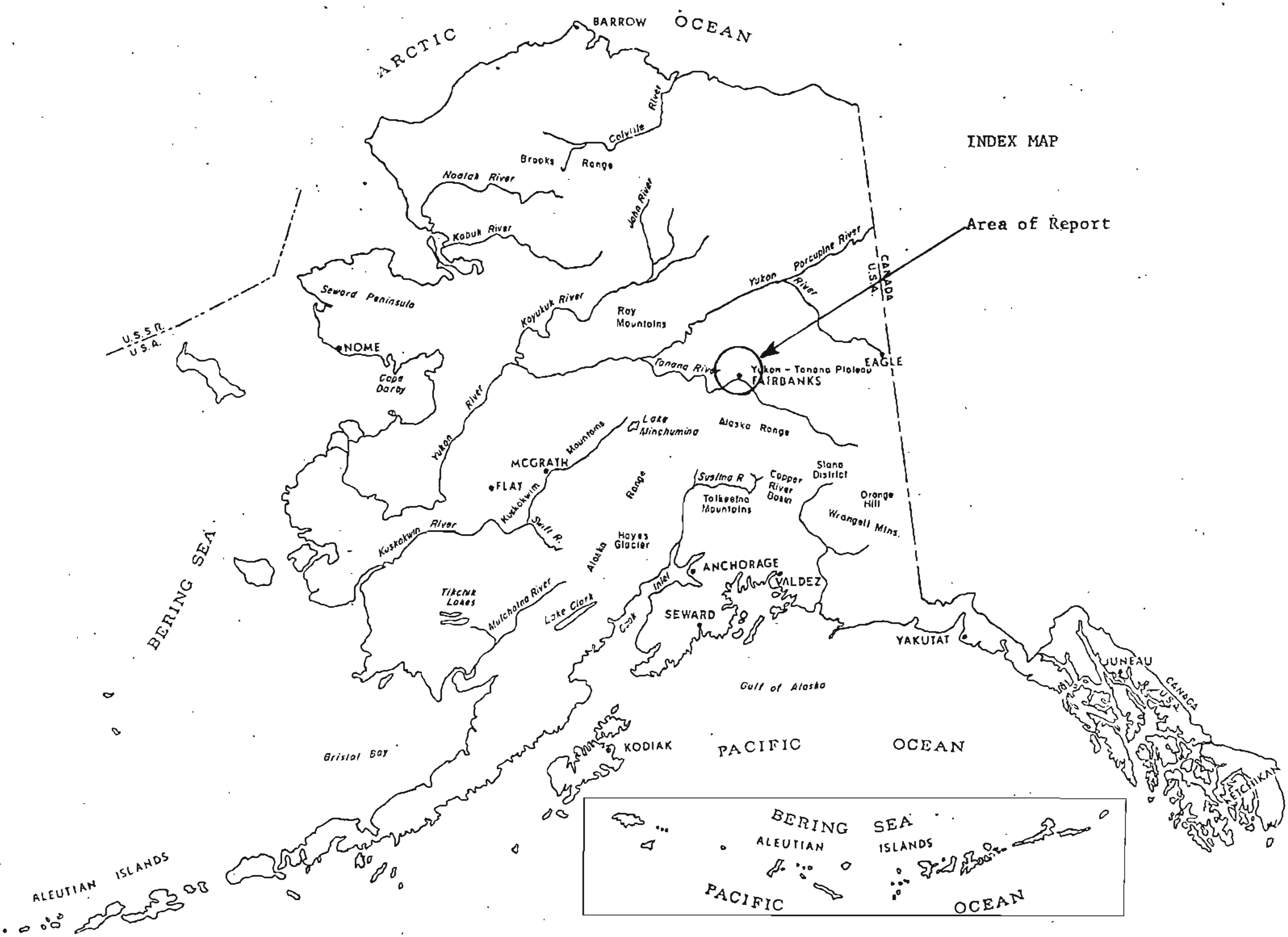
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ABSTRACT

During the course of petrologic studies of granitic and associated metamorphic rocks in the Pedro Dome-Gilmore Dome area, Fairbanks District, Alaska, a noteworthy occurrence of molybdenite was encountered near the settlement of Fox. The molybdenite is found in tonalitic rocks which are associated with granodioritic and granitic variants. It appears to have been introduced along a system of fractures in the tonalites, during a silicification alteration stage. This stage was preceded by a potassium silicate (potassium feldspar ± sericite) alteration stage which penetrated the tonalites along the same fracture system. Further dislocation subsequent to the silicification stage developed along a different system of fractures, and this enabled penetration of a mobile phase which resulted in a deposition/alteration stage of calcite-pyrite ± chalcopyrite ± chlorite. Each of these alteration episodes affected the country rocks to varying extents, apparently depending to a considerable degree upon the density of spacing of the fractures within the host rocks. Dominating the locality are more widely - spaced fissure veins containing gold-silver-lead ± zinc, and some tungsten also occurs elsewhere in the area.

Laboratory studies concerning various aspects of the mineralogy and geochemistry of the country rocks and associated alteration/mineralization phases are currently in progress. Additionally, the area would seem to warrant further investigation of an exploration nature, in order to more fully evaluate the possibilities of economic mineralization.

INTRODUCTION

In an effort to further assess the potential for hitherto unrecognized mineralization of economic interest in the Fairbanks, Alaska area, the authors have been investigating selected aspects of the bedrock petrologic-geochemical relationships in this region. Initial emphasis has been on endeavoring to relate known occurrences of ore minerals with lithologic-geochemical characteristics of rocks of granitic aspect, as well as related metamorphic rocks. It was felt that in this way an increased knowledge of the geologic framework would encourage more systematic exploration in the district. The present report represents a rathor cursory appraisal of an occurrence of molybdenite in a quartz-vein context, associated with tonalitic (quartz dioritic) rocks in the Pedro Dome-Fox area. This appears to represent the first documented occurrence of significant amounts of molybdenite in the district (B. Thomas, U. S. Bureau of Mines, personal communication, 1974) in a lode setting of this type. It was encountered during the course of petrologic studies of a tonalite-granodiorite-granite plutonic assemblage associated with known deposits of pyritiferous lead (argentiferous)-zinc ± antimony-gold fissure veins, and was deemed to be of sufficient interest to warrant a preliminary report at this time. More detailed geochemical and mineralogical studies are in progress concerning the sulphide minerals, as well as the primary and alteration phases which were found in this locality.

GEOLOGIC SETTING

The Fairbanks area is located in interior Alaska, in the Yukon-Tanana upland (Figure 1, from Foster, et al, 1973). This upland is defined by Foster, et al (1973) as "primarily a region of complexly deformed metamorphic rocks which have been intruded by Mesozoic batholiths and smaller Mesozoic and Tertiary plutons". Foster, et al further subdivide the upland into two general

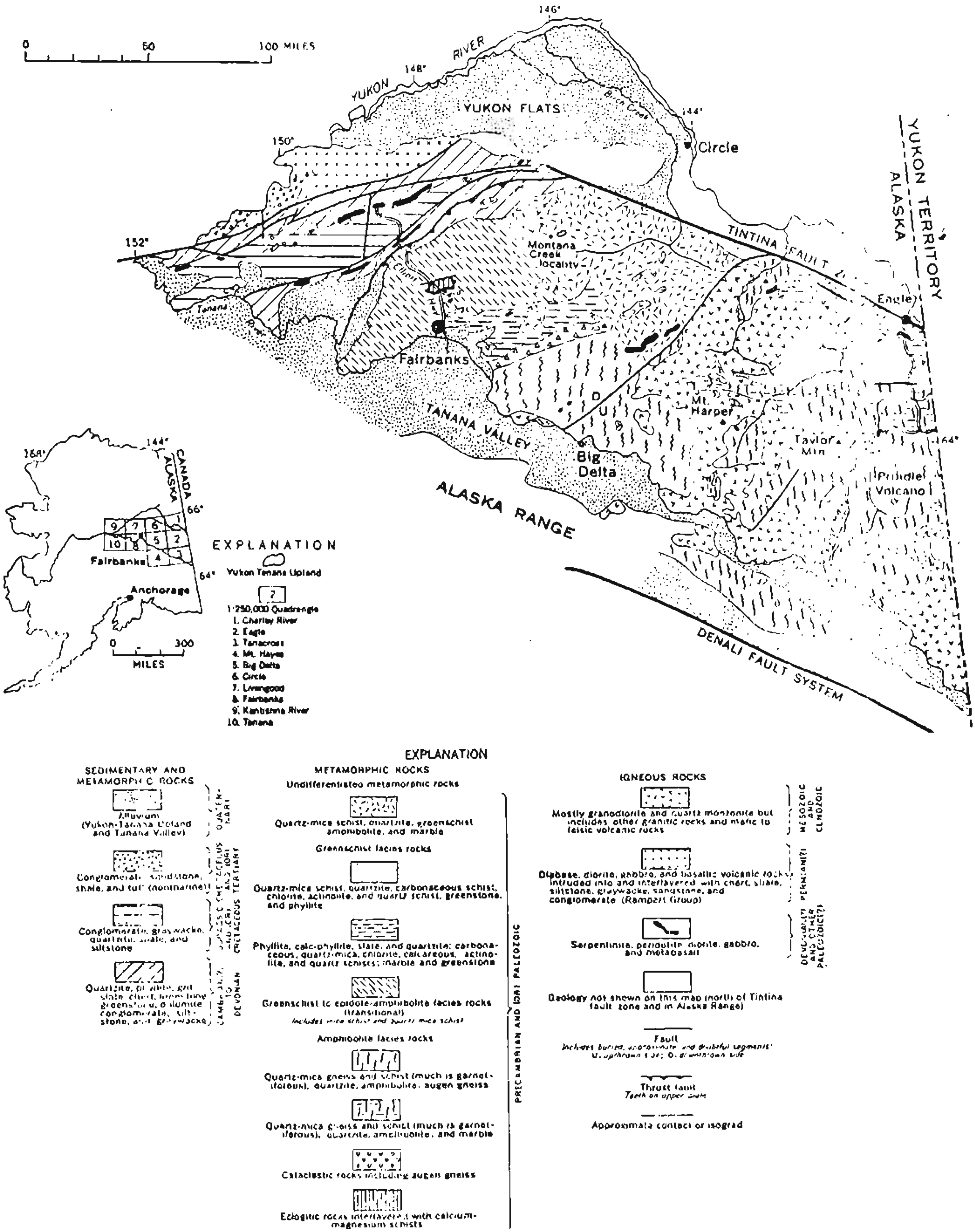
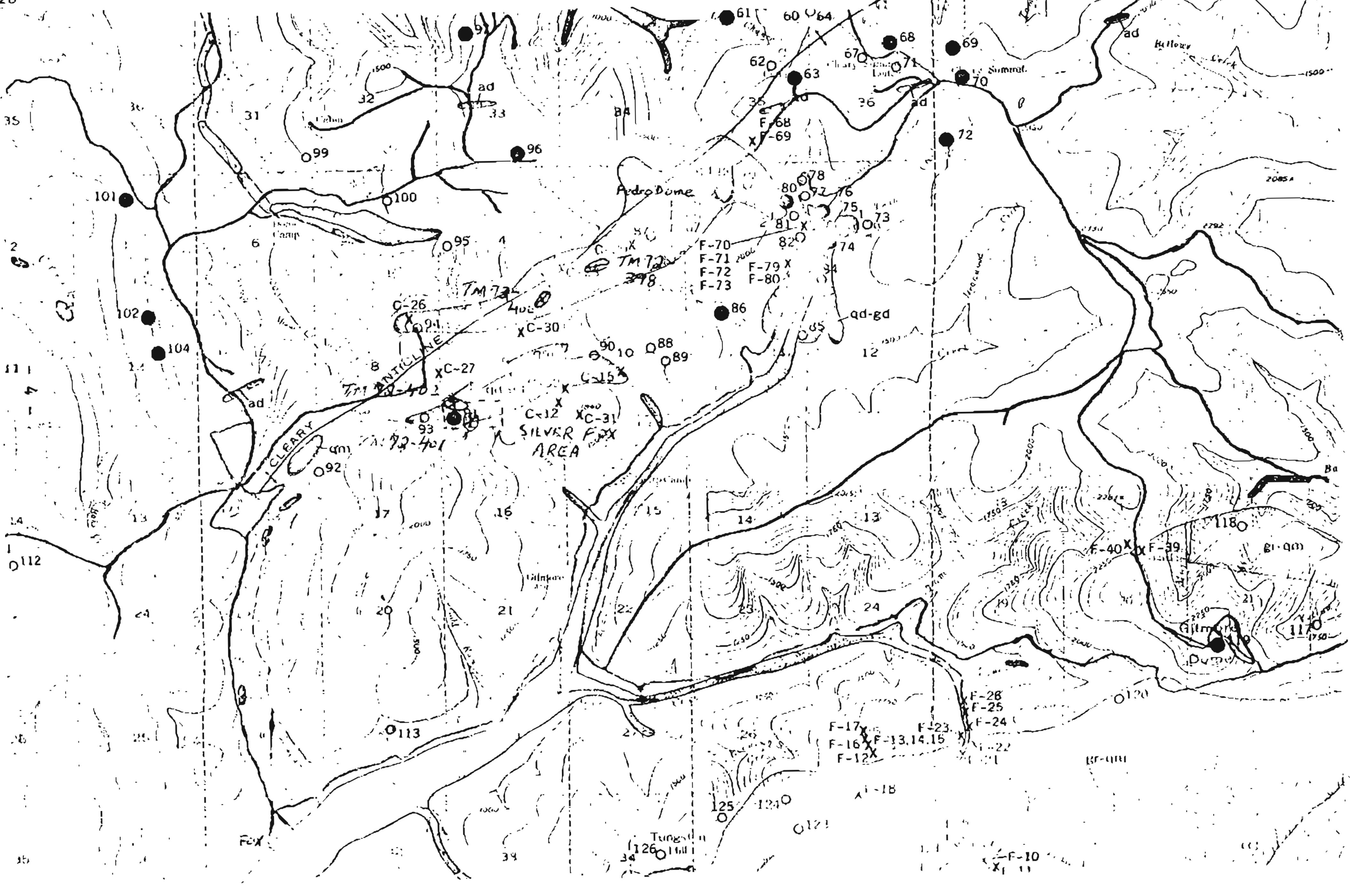


Figure 1. Geology of Yukon - Tanana Upland (from Foster, et al, 1973)

areas; the one of interest in the present study has been termed the "Fairbanks-Big Delta region," containing belts of metamorphic rocks of greenschist/epidote-amphibolite/amphibolite facies. Plutonic rocks which range in composition from granite through gabbro also occur in this region, although the largest plutons are exposed in the other ("Eagle-Fortymile") region to the east. The plutonic rocks in the area proximal to Fairbanks, (the "Fairbanks District" of earlier times when mining operations were more active) which we have been studying include two main localities, in the general areas of the two major topographic prominences termed "Pedro Dome" and "Gilmore Dome," north of the city of Fairbanks. Of these, the Pedro Dome locality, north of the settlement (intersection of the Steese and Elliott Highways) of Fox, includes the site of the materials discussed in the present report (cf. Figure 2, based on map from Chapman and Foster, 1969).

The Fairbanks District has been the locale for considerable mining activity in the past, primarily from the rich gold placers which were exploited extensively. In addition, bedrock lode mineralization is known in the district, comprising hydrothermal vein associations containing a variety of metals, notably gold, lead, silver, zinc and antimony, as well as skarn associations with tungsten. However, the lode deposits discovered to date have not proved to be truly major producers, although their presence and types, together with the regional geologic setting of the district, would seem to suggest considerable potential for economic mineralization. Viewed in toto, the general geologic framework, in particular the bedrock petrology, the character and spatial associations of the known lode mineralization, and the possible implications of the significant placer production of the past suggest that the Fairbanks District merits further more detailed and systematic exploration efforts. To date, much of such exploration as has been done has been either rather superficial, or, on the other hand, in some instances

Figure 2. Location map, based on Plate 1, U.S. Geological Survey Professional Paper G25-D (Chapman and Foster, 1969) geology by R.M. Chapman and R.L. Foster, 1966-67.



has been done in a very detailed but somewhat restricted fashion, for a particular area and/or mineralization type of particularly compelling interest (eg. the "tungsten programs" of World Wars I and II; cf. Byers, 1957). Thus, without intending to deprecate the quality or extent of exploration endeavors to date in the district, one retains a distinct feeling of uneasiness with regard to the thoroughness of the search overall, in such an interesting area. Essentially, much that has been done might better be considered as "prospecting", rather than minerals exploration on the scale which seems merited.

Admittedly, much of this is the result of the obvious economic disadvantages of the Fairbanks area in terms of climate, geographic location and distance to markets, etc., but it should be pointed out that some of these factors are becoming less significant as time passes, and as the world resources situation continues to change. Additionally, the proximity to a population and transportation (road, rail, air) center, together with the likelihood of increased regional development resulting from construction of the Alyeska pipeline must be considered as favorable factors.

Previous published work on aspects of district geology relevant to the present study includes, in addition to the papers cited above, contributions by Brown, 1962; Forbes and Brown, 1961; Forbes, et al, 1968; Mertie, 1937; Pewe, et al, 1966; Prindle, 1913; Sandvik, 1964 and Wasserburg, et al, 1963.

SILVER FOX CLAIMS

As shown on Figure 2, a plutonic body approximately three and one-half miles long and up to one mile wide is exposed trending in a generally southwesterly direction from the topographic prominence of Pedro Dome. South-southeast and sub-parallel to this another, somewhat smaller (less than two miles long by one-half mile wide in outcrop) body of plutonic rocks is exposed. As is the general case throughout the region, natural surface exposures of bedrock are rather scattered, due to the dense cover of vegetal material, hence the bedrock relationships are often difficult to discern with any degree of confidence.

However, these two plutonic bodies are petrologically similar, and presumably are connected at some as yet undetermined depth. The larger body consists of tonalitic-granodioritic rocks, similar to those found in the smaller body. In addition, a belt of granitic (quartz monzonitic) rocks occurs along the north-western margin of the smaller body, apparently with intrusive relations to the more mafic rocks. Toward the southwestern end of the smaller body, near its southern margin, mineralization in the form of fissure-veins of pyrite, with associated galena (argentiferous) ± sphalerite and gold has been prospected, with minor production sporadically. One locality in particular, the "Silver Fox" claims, has shown sufficient apparent promise to merit several periods of such activity. Although presently being operated primarily as a tourist attraction, the underground workings on this site continue to be gradually extended and it was during the course of such work in 1973 that the molybdenite vein mineralization was first encountered. Although molybdenum in various forms has been observed elsewhere in the Fairbanks District upon occasion, the present occurrence appears to be the first documented showing of amounts of significant interest, in the quartz-vein association context.

During the summer of 1973, drilling and blasting was done intermittently at the present working face area of the Silver Fox mine, at the end of a 50 foot long drift (approximately 85 feet below the present land surface), which runs off from a 375 foot long main adit. In the course of this work, it was noted that a narrow fault zone apparently representing a significant (but as yet undetermined) amount of movement and offset of the country rock was encountered. The character of the country rock was somewhat different beyond this zone, in that increased minor fracturing and pervasive veining on a small scale was observed. Scrutiny of the veinlets resulted in the recognition of molybdenite, scattered in flattened, ovoid to irregular pods ranging up to one-half inch in maximum dimension. These were always associated with quartz on the vein surfaces, in rocks which megascopically resembled the tonalitic country rocks prevalent elsewhere within the mine workings, except for the pervasive appearance of "alteration/fracturing" in the molybdenum-bearing materials.

Several dominant orientations of fracture surfaces were discernible upon closer study. It was noted that one of these sets of fractures showed pronounced slickensides on the gently undulating fracture surfaces, together with "smeared-out" patches of pyrite ± chalcopyrite elongated parallel to the apparent sense of movement along the slickensided surfaces. Additionally, a moderate degree of staining was discernible on these surfaces, apparently ferruginous as well as at least in part cupriferous, on the basis of coloration. This was of considerable interest, since reported occurrences of copper mineralization have not been common heretofore in the Fairbanks District, although it has been noted upon occasion, particularly in carbonate-rock replacement settings adjacent to granitoid intrusives. It should also be stressed that the veins carrying the molybdenite are different in spatial orientation and temporally, as well as in mineralogy, from the slickensided-pyritiferous-stained fracture set. The former appear to be earlier, and are offset (slightly, up to an inch or so) where intersected by the latter. Preliminary structural attitude studies of these fracture sets and their relationships to larger-scale structural trends within the area were made, but remain proprietary information at this time.

Petrographic investigation, supplemented by X-ray diffraction analysis and chemical analysis of "acid extractable" metals were carried out on a number of specimens collected from the working area of the mine, as well as on samples obtained previously during the course of surface examination of the bedrock geology of the Silver Fox claims and surrounding areas. The results of these studies are summarized by, and tabulated for, a few representative specimens in Appendices 1 and 2. Petrologic nomenclature follows Streckeisen, 1967. Samples TM 73-51-A, 51-B and 55 are from the roof, walls, and face of the working area of the mine as of September, 1973; TM 72-401, 402, 400, and 398 are representative surface samples whose locations are shown on Figure 2.

Although the chemical analyses do not show concentrations of economic interest in the materials analyzed, the associations are of fundamental interest. The samples assayed consisted of materials deliberately selected to avoid megascopically obvious quartz-vein molybdenite, with the intent of rather evaluating the country rocks for their contents of disseminated metals of interest. Thus, at present, no really quantitative assessment has been made of the grade of the molybdenite occurrence, in terms of relative concentrations of quartz-vein associated molybdenite within the overall deposit. The patches of molybdenite on the fracture surfaces are sufficiently large that a considerable volume of country rock plus veins would have to be considered in estimating potential grade of ore. However, measurements made on several quartz-vein fracture surfaces, parallel to the plane of fracture, indicate that the area of these surfaces occupied by molybdenite is on the order of 10-15%, giving some crude estimate of the "grade".

On the basis of our present data, it would appear that the Silver Fox mine specimens represent the products of a sequence of alteration/mineralization events which have superimposed characteristic assemblages of mineral phases upon pre-existing moderately porphyritic rocks of tonalitic/granodioritic aspect. The amount of variation within the tonalite-granodiorite compositional spectrum attributable to original compositional differences in the magma, as opposed to subsequent alteration (metasomatism, ie.) processes is difficult to assess, and due consideration must also be given to possible modifications resulting from contamination (hybridization) of magma during the course of its intrusion and crystallization. However, certain relationships appear to be clearly discernible.

With some temerity we thus advance the following suggested sequence of events which seem to be implied from our observations to date, with the realization that few if any such schemes tend to survive the test of time and/or new data. It is felt that these speculations may at least serve to be thought-provoking in terms of mineralization in this locality, and may also be more broadly applicable, at least within the Fairbanks District.

SUGGESTED PETROLOGIC/MINERALOGIC GENETIC RELATIONSHIPS

1. Existence of magma from which medium-coarse crystals of plagioclase (andesine), hornblende, and magnetite/ilmenite, ± biotite, began to crystallize; ie. presence of phenocrysts plus residual melt phases.
2. Action of some mechanism(s), such as loss of volatiles, rise of magma, etc., by which a decrease in temperature and/or pressure was effected within the petrogenetic system. The result was rapid crystallization of fine-grained (matrix) plagioclase, quartz, and biotite, ± hornblende, magnetite/ilmenite, and perhaps some primary potassium feldspar. With subsequent "deuteric" alteration effects (eg. varying degrees of chloritization of biotite, sericitization of plagioclase, and bleaching/chloritization of hornblende), the result would be a "normal" tonalitic/granodioritic rock, such as TM 72-401, 400, 398. The specimens from the present working area of the mine show additional effects, however.
3. A mobile phase rich in potassium was introduced along fractures developed within the crystallized "hood" rocks of stages 1 and 2, above. Presumably the fractures resulted from deformational stresses attendant upon continued movement of the magma and its solidified margins as cooling continued with time. Similarly, the source of the potassium-rich phase is most likely to have been the subjacent magmatic material. The effect of this introduction of potassium is very nicely shown in specimens such as TM 73-51-A and 55. Potassium feldspar (orthoclase, optically) metasomatism occurred from the veins into the country rock, with preferential replacement of matrix (fairly complete) and phenocryst (less complete) plagioclase. There are some indications of a sericitization stage having affected the plagioclases prior to the

potassium feldspar replacement stage, which presumably reflects changing (increasing) intensity of potassium metasomatism (or changing $[K^+/H^+]$, or P_{H_2O}, etc.). Such sericitization as persists (rather pervasive, especially in phenocryst cores) in plagioclase is probably the result of this episode, although a separate and later stage of sericitization is not precluded by our data. It is likely that some secondary biotite was formed, and that at least some of the biotitization of amphibole observed also occurred during the stage of "potassium silicate alteration". A rock of granodioritic aspect would be one result of this process, if carried sufficiently far. In fact, the "normal" granodiorites observed in the present study may well have been formed in this manner, elsewhere in the magma system, as products of a more normal course of igneous differentiation, perhaps contemporaneously with the introduction of the potassium-rich phase along the fractures in the more marginal facies rocks. The observed vein relationships in the rocks from the mine clearly delineate the effects of the metasomatic process, although some of the rocks from the mine do contain sufficient amounts of this alteration potassium feldspar that, on the basis of gross mineralogic composition, they are granodioritic. The specimens which have been less intensely affected illustrate the process of replacement of pre-existing tonalitic rocks quite well, however.

4. Continued movement of crystallized rocks and subjacent magma, with further fracturing within the solid rocks, particularly along the zones of weakness represented by the fractures (now filled with potassium feldspar) of stage 3, above.

5. Introduction of a mobile phase rich in silica, which crystallized along the fractures as quartz, often engulfing potassium feldspar previously deposited along these veins. Concurrent with this, deposition of molybdenite occurred along the margins of these quartz veins. Demonstrable replacement of other

mineral phases by quartz is not obvious in the specimens studied, although some of the quartz in the tonalites may well be of such secondary origin.

6. Continued deformational stresses within the crystallized rocks, with further fracturing transverse to the orientations of the earlier veins. Coincidental with this activity, a carbonate-rich mobile phase was introduced along the active fractures, followed by some iron (± copper) and sulphur-bearing phase(s). This resulted in the crystallization of calcite along the veins, as well as in the form of replacements of some pre-existing silicate minerals, followed by deposition of traces of pyrite ± chalcopyrite as seams and thin pods bordered by the calcite vein-filling material. Minor alteration of wall rocks to a melange of chlorite/serpentine materials was observed in several specimens.

7. Further movement along the surfaces developed in stage 6, with smearing-out of pyrite ± chalcopyrite, and the formation of slickensided surfaces.

Indeterminate in this sequence is the stage at which the chloritization of biotite took place. It might have been as early as the "deuteric" alteration stage of the "normal" tonalite, and/or perhaps during the waning stages of the alteration processes.

In any event, the sequence of events as outlined above seems fairly well defined. The implications with respect to mineralization prospects in the Fairbanks District depend to some extent on what one may or may not choose to read into the data, together with the general concepts of petrogenesis and ore deposition which may be preferred.

SPECULATIONS

The occurrence of significant molybdenite, with suggestions of the possibility of associated copper mineralization in the Fairbanks District is in itself noteworthy. Although admittedly the present study represents a very preliminary attempt at assessment of relationships, the situation seems worthy of further evaluation on broader as well as more detailed scales. As suggested by the demonstrated "potassium silicate alteration" grade seen underground in a faulted (amount of movement presently not well defined) block in the Silver Fox mine, the possibility is certainly raised of the existence of similar materials elsewhere in the general area. It might be suggested that the assemblages studied to date merely represent the first recognizable examples of alteration/mineralization which may well exist peripheral to this occurrence, and may be similar or different in character. The mere manifestation of this type of mineralization is the important point at this stage in the elucidation of the framework; further exploration work must be done to more fully evaluate the situation, locally as well as over broader areas within the district.

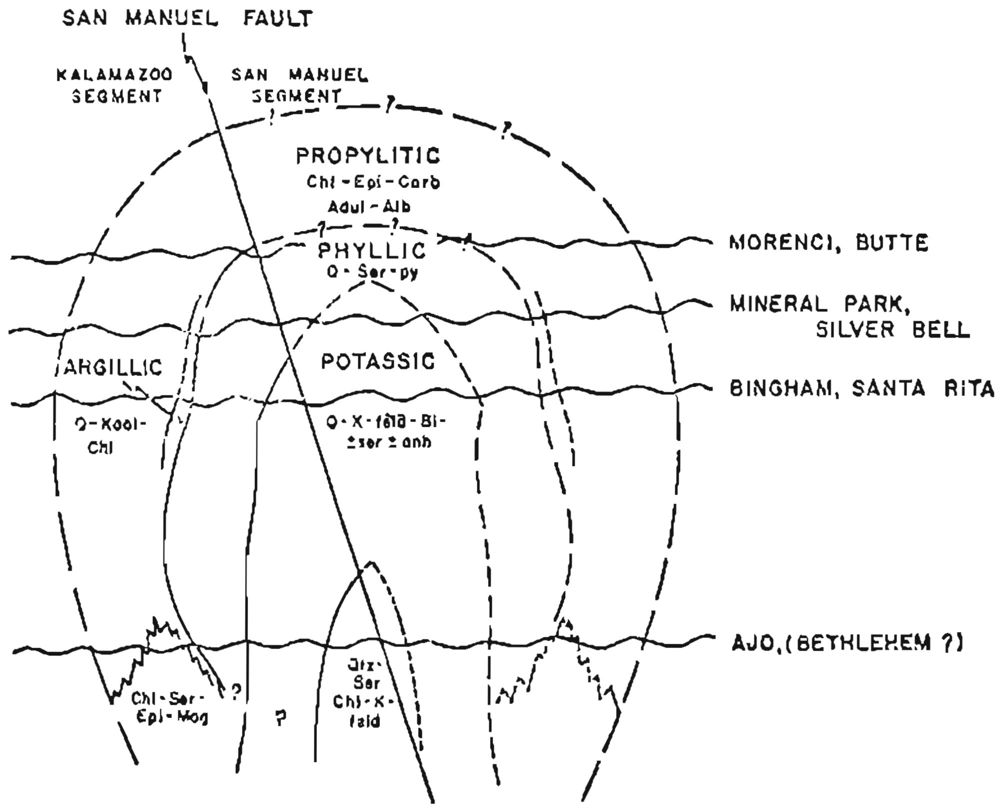
Thus, perhaps at the Silver Fox area we see a higher (or more marginal) facies (a cupola?) of a larger subjacent plutonic body. Certainly the increasingly acidic nature (granodiorites) of some of the granitoids in the Pedro Dome area suggest areal variability in fundamental accord with this suggestion, and the presence of the granitic rocks intrusive into the more mafic ones on and adjacent to the Silver Fox claims further substantiates this. The occurrence of a somewhat larger plutonic body, comprised primarily of granitic rocks, in the Gilmore Dome area nearby also seems to indicate an extended sequence of igneous events which, when better understood, ought to offer enhanced prospects for exploration for economic mineralization. Of interest in the Silver Fox setting is the fact that, prior to encountering the faulted block containing the molybdenite-bearing veins, the mining operation had been following a fissure vein pattern predominantly made up of pyrite, with associated galena (argentiferous) and some sphalerite, and scheelite $\pm$ powellite has also been found in the area. A marked zoning of this vein system had been observed, from gold-silver-lead ores, through gold-silver-lead $\pm$ zinc, into the present gold-silver-lead-zinc $\pm$ molybdenum association, over a depth of some 85 feet in the mine workings. Thus, the newly encountered mineralization seems to represent a continuation of this zonation pattern of increased maximum temperature of formation as a function of depth.

As mentioned earlier, depending upon one's predilections for any particular theories or models of ore genesis, various interpretations might be made of the presently available information. Thus, for example, it does perhaps appear likely that the molybdenite occurrence in the Silver Fox mine represents a typical quartz-vein molybdenite stockwork association. On the other hand, the suggestion of associated copper mineralization might imply some further thoughts regarding the possibility of a "porphyry" deposit situation of some sort, perhaps similar to the many others elsewhere. Deposits of the latter type have been extensively and intensively studied, and reported on by authors far too numerous to cite here. Among summary papers, the contributions of Sillitoe (1973) and of Lowell and Guilbert (1970) might be deemed representative of the more widely accepted models, and thus be useful in the present context in endeavoring to place the Silver Fox occurrence in some perspective. The cited papers should be consulted for details, we have merely selected one figure from each, and presented them as Figures 3 and 4, for purposes of the present report. These figures show that the mineral assemblages which we have observed in the present study can be assigned to the "Q - K-feld-Bi±ser±anh" field of Lowell and Guilbert, or the analogous "potassium silicate-sericite" fields of Sillitoe. Further discussion of the relationships at this time seems somewhat premature, given the preliminary nature of the present paper, but certainly it would appear that the possibilities are intriguing, to say the least.

CONCLUSIONS

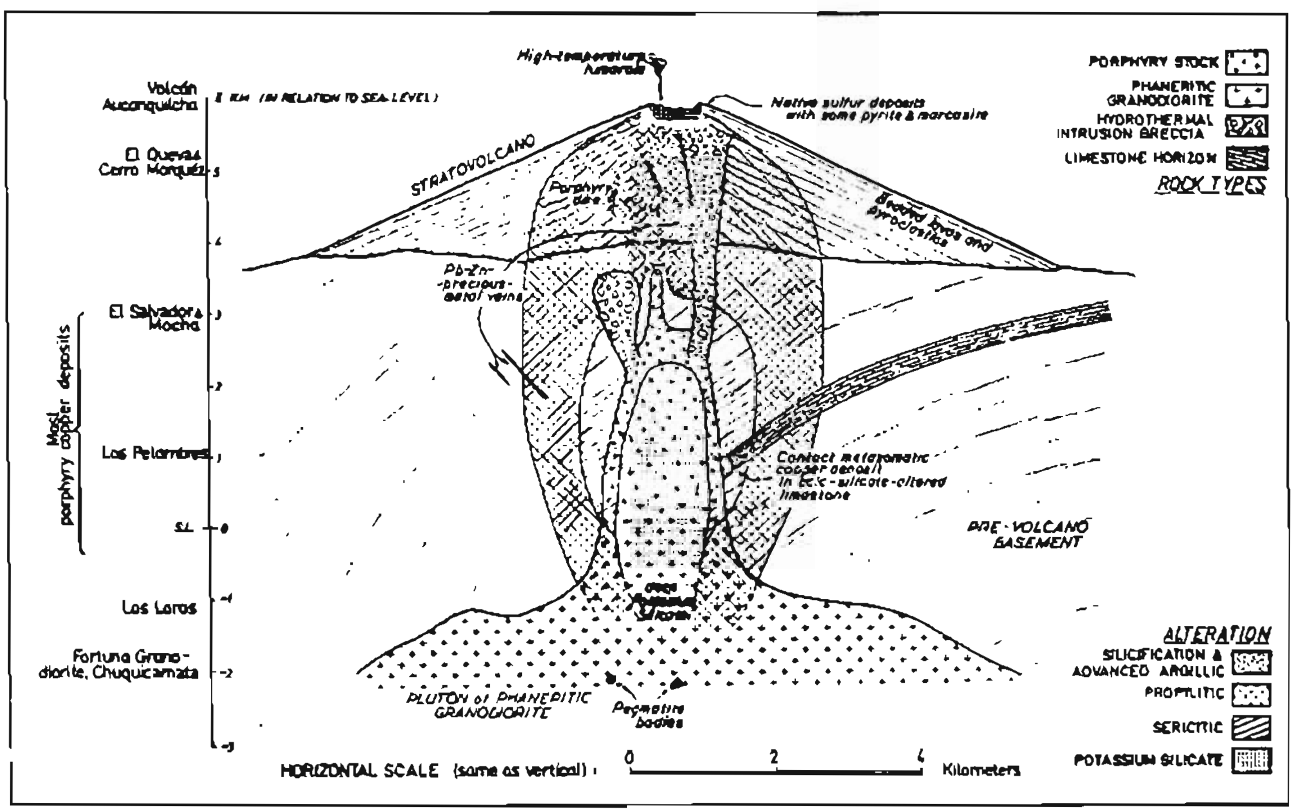
Depending upon the credence one places in models of this sort, it would thus appear that the observed relationships in the Silver Fox area are suggestive of a situation warranting further study, as well as possibly indicating the nature and direction that future exploration efforts might most profitably consider.

The present authors are currently involved in investigating various geochemical and mineralogic aspects of the sulphide, silicate, and other alteration phases, and



Schematic drawing of San Manuel-Kalamazoo showing exposure levels of several porphyry copper deposits. Other deposits could be added, but these few serve to show a vertically developed dimension.

Figure 3. From Lowell and Guilbert, 1970.



Idealized cross section of a typical, simple porphyry copper deposit showing its position at the boundary between plutonic and volcanic environments. Vertical and horizontal dimensions are meant to be only approximate.

Figure 4. from Sillitoe, 1973.

we plan to report on this work in the near future.

ACKNOWLEDGMENTS

We wish to acknowledge with sincere thanks the courtesy, hospitality, and cooperation extended us by Mr. and Mrs. Tury Anderson, holders of the Silver Fox claims and present operators of the Silver Fox Mine. The sagacity and insights manifested by these long-time residents of interior Alaska were most impressive, and quite helpful during the course of the present study. Very few observational relationships appear to have escaped their attention with regard to natural associations, be they geologic, floral, faunal, etc. It was a rare and most memorably pleasant experience to have shared their company in the field, mine, and elsewhere.

Discussions with Mr. Bruce Thomas, U.S. Bureau of Mines, Fairbanks were quite informative with respect to various aspects of geology and mineralization, based on his extensive Alaskan experience.

Comments by Dr. S.M. Aleksandrov, Vernadsky Institute for Geochemistry and Analytical Chemistry, Moscow, U.S.S.R. while visiting and working with us at the Alaska Geological and Geophysical Surveys during the summer of 1973 were most helpful. In particular, his thoughts regarding various theories of petrogenesis and ore genesis, as well as his petrographic observations were quite illuminating.

Dr. D. Grybeck, Department of Geology, University of Alaska has had a continuing interest in mineralization in the Fairbanks District, and his views and comments, much of it based on his unpublished data, are appreciated.

Additionally, discussions with numerous exploration and research geologists employed by several American and Canadian mining and minerals exploration organizations were most beneficial, in that they provided forums for comparison of models, hypotheses (and worse) with the sometimes harsh realities of the rocks themselves, from a somewhat more pragmatic point of view than that which often seems all too prevalent in the more erudite circles of academia. These gentlemen cannot be acknowledged individually here, but their cooperation and interest are greatly appreciated.

The support of Mr. W. Fackler, then State Geologist and presently Assistant Commissioner for Mineral Resources, State of Alaska, during the early stages of this work is also acknowledged with thanks.

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APPENDIX A.

Petrographic Analyses

PETROGRAPHIC ANALYSIS

Specimen Number: TM 73-51-A **Location:** Silver Fox mine, Sept. 1973

Texture: Porphyritic **Structure:** Veined

Misc.: Tonalite (altered)

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.3 & > 8.0	30 - -		rock matrix & in veins
Plagioclase	sub-euhedral	~ 1.2 & < 0.3	38	strongly to sericite and to K-feldspar	zoned and twinned, An $47 \rightarrow 38$; & An 40
Biotite	subhedral	< 0.5	15	moderately to chlorite	some primary, some secondary
Amphibole (Hornblende)	sub-anhedral	1.2+<	17	some fresh, some moderately to biotite to chlorite(±)	greenish-blue-green, pale
K-feldspar	irregular	variable	- -		marginal to quartz vein, and replacing plagioclase
Calcite	irregular	variable	- -		latest stage
Sphene	sub-euhedral	< 0.4	trace		
Magnetite/ Ilmenite	irregular	< 0.3	trace		early, and assoc. with biotite
Molybdenite	irregular	variable	trace		with quartz veins

Commentary:

This specimen shows the alteration sequence K-feldspar, silification, calcite quite well, superimposed on a porphyritic tonalite. The stages observed are:

1. crystallization of phenocryst of plagioclase, amphibole, ± biotite, magnetite/ilmenite

2. crystallization of matrix quartz, biotite, plagioclase, minor K-feldspar

3. Potassium introduction along fractures, with K-feldspar replacement of plagioclase and sericite, as well as crystallization of K-feldspar in veins

4. Silica introduction along the same fractures, broadening of the veins, engulfment of vein-marginal K-feldspar, crystallization of quartz and minor molybdenite in veins.

5. Introduction of calcite depositing phase along a new set of fractures oriented transversely to the earlier ones. Calcite crystallizes in veins, and also replaces pre-existing mafic minerals proximal to vein, ± formation of chlorite/serpentine phases. In hand specimen, this sample shows slickensided surfaces along this set of fractures, along with traces of smeared-out pyrite, copper-staining and possible galena on these surfaces.

PETROGRAPHIC ANALYSIS

Specimen Number: TM 73-51-B **Location:** Silver Fox mine, Sept. 1973

Texture: Porphyritic **Structure:** Veined

Misc.: Tonalite (strongly altered)

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.3 & 2.5+ <	30 - -		matrix; & veins
Plagioclase	euhedral	2.2+ < & < 0.3	43 (19)	strongly to sericite ± K-feldspar; & strongly to K-feldspar	phenocrysts, zoned and twinned, An_{40-30}; & matrix
Biotite	subhedral	< 0.7	18	moderately to chlorite	mostly primary
K-feldspar	sub-anhedral	< 0.3	(24)		some (?) primary mostly replacing plagioclase
Amphibole	sub-anhedral	< 1.0	10	moderately to biotite ± chlorite	
Calcite	irregular	variable	- -		last stage, along fractures
Magnetite/ Ilmenite ± Molybdenite	sub-anhedral	1.0+ <	trace		assoc. with biotite, and with quartz veins

Commentary:

Sequence of events discernible:

1. Crystallization of phenocrysts of plagioclase, amphibole, biotite, ± magnetite/ilmenite(?)

2. Crystallization of matrix quartz, plagioclase, mafics, some(?) K-feldspar

3. Potassium metasomatism along fractures, with replacement of matrix plagioclase (fairly complete) and phenocryst plagioclase (less complete).

4. Silica (and molybdenite) introduction and deposition, along the same fractures as above; some(?) silica metasomatic replacement activity of matrix phases as well(?).

5. Deposition of calcite along newly formed fractures transverse to earlier ones, as well as minor replacement of earlier phases by calcite.

PETROGRAPHIC ANALYSIS

Specimen Number: TM 73-55 **Location:** Silver Fox mine, Sept. 1973

Texture: Porphyritic **Structure:** Veined

Misc.: Tonalite (moderately altered)

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.5	30		matrix
Plagioclase	euhedral-subhedral	1.0+ < & < 0.4	47 (35)	strongly to sericite ± K-feldspar	phenocrysts, zoned and twinned, rims fresh; & matrix
Biotite	subhedral	< 0.6	10	moderately to chlorite ± opaques	mostly primary
Amphibole	sub-anhedral	3.0+ <	13	slightly to biotite ± opaques	somewhat glomeroporphyritic; colorless to light green-blue
K-feldspar	anhedral	variable	(12)		all(?) replacement, especially of plagioclase, and concentrated along veins
Calcite	irregular	variable	- -		in late veinlets
Magnetite/ ilmenite	irregular	variable	trace	to leucoxene (some with opaque cores)	associated with biotite
Pyrite/ chalcopyrite	irregular	variable	trace		associated with calcite veinlets, as pods and lenses

Commentary:

This specimen shows the genetic relationships particularly well:

1. Crystallization of phenocrysts of plagioclase, amphibole, perhaps some biotite.

2. Crystallization of matrix of plagioclase, quartz, biotite, perhaps some primary K-feldspar.

3. Sericitization of plagioclase (especially the cores); ± amphibole altering somewhat to biotite ± opaques(?).

4. K-feldspar metasomatism along fractures due to deformational stress (occur at same times as step 3, perhaps?)

5. Feldspathization from the veins into the country rock, with preferential replacement of matrix plagioclase (and also to a lesser degree of phenocryst plagioclase)

6. See just a hint of silicafication in this specimen (cf. other samples from mine area)

7. Crystallization of calcite along stage 4 fractures, as well along fractures oriented transversely to these earlier ones.

8. Deposition of minor sulphides (pyrite/chalcopyrite ± galena(?) along both sets of fractures).

NOTE: The chloritization of biotite stage is undetermined; it could be as early as the "normal" deuteric process prior to stage 3, or during any of the later stages.

PETROGRAPHIC ANALYSIS

Specimen Number: TM 72-401

Location: U.S.B.M. trench on Silver Fox claim to west of Silver Fox mine "72-7-30-5"

Texture: Porphyritic

Structure:

Misc.: Granodiorite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.5	27		matrix only
Plagioclase	euhedral-subhedral	1.3+ < & < 0.5	38	strongly to sericite; & fresh, with sericite cores	phenocrysts (few), zoned and twinned; & matrix; zoned and twinned, An_{40+}
Biotite	sub-anhedral	< 1.0	24	moderately to chlorite	some fresh, some completely altered
K-feldspar	anhedral	variable, patchy	10		apparently primary, and late-stage
Amphibole	subhedral	3.0+ <	< 2	moderately to chlorite	phenocrysts, primarily

Commentary:

A medium-fine grained porphyritic granodiorite.

PETROGRAPHIC ANALYSIS

Specimen Number: TM 72-402

Location: Prospect pit on Silver Fox claim, west of Silver Fox mine

Texture: Granitoid - cataclastic

Structure:

Misc.: Granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	±6.0(?)	35	moderately broken up	
Plagioclase	euhedral-subhedral	±3.0(?)	31	strongly to sericite, etc. and moderately broken up	
Orthoclase microperthite	subhedral-euhedral	±6.0(?)	34	moderately broken	
Magnetite	sub-euhedral	<0.5	trace	to hematite	

Commentary:

Coarse-medium grained granite

PETROGRAPHIC ANALYSIS

Specimen Number: TM 72-400

Location: Outcrop north of Silver Fox claims, toward Pedro Dome

Texture: Seriate-scattered phenocrysts

Structure:

Misc.: Tonalite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.3	32		matrix, wide crystal-lization range
Plagioclase	euhedral & eu-subhedral	3.0-1.0 & <1.0	39	moderately to sericite	(very few) phenocrysts & matrix, $An_{45 \rightarrow 32}$; both zoned and twinned
Biotite	subhedral	< 2.0	17	moderately to chlorite	
Amphibole	subhedral	1.0+ <	12	rimmed with biotite often	colorless - blue-green
K-feldspar	irregular	variable, patchy	trace		primary, late, interstitial
Magnetite/ ilmenite	anhedral	< 0.2	trace		associated with (often preceding) biotite

Commentary:

Medium-fine grained tonalite.

PETROGRAPHIC ANALYSIS

Specimen Number: TM 72-398

Location: North of Silver Fox claims, towards Pedro Dome

Texture: Porphyritic-seriate

Structure: Veined

Misc.: Quartz monzodiorite/granodiorite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 0.4	16		late, interstitial; and in veins (<0.7mm)
Plagioclase	euhedral-subhedral	1.3 and <;+ 0.7 and <	41	moderately strongly to sericite; & fairly fresh	phenocrysts; & matrix, $An_{46 \rightarrow 26}$; both zoned and twinned
K-feldspar	anhedral	< 0.4	8		late, interstitial, and apparently primary
Biotite	subhedral	1.0+ <	21	slightly to chlorite	crystallizes with and after amphibole
Amphibole	subhedral	1.2 and < & < 0.5	14	moderately to biotite ± chlorite	phenocrysts, sub-zoned; & matrix
Magnetite/ Ilmenite	sub-anhedral	<0.2	trace	moderately to hematite	associated (often precedes) biotite

APPENDIX B.

Chemical Analyses

DM-11
Rev. 10/67

Report No. ____

Date of Report November 5, 1973

STATE OF ALASKA
Department of Natural Resources
DIVISION OF MINES AND GEOLOGY
Box C, College, Alaska 99701

LABORATORY ANALYSIS REPORT

For Thomas C. Mowatt Address ____

Number of Samples ____ Date Sample Received ____

Work Done: (for Analyst see below)
A. X-ray flourescence quant. ☐ semi-quant. ☐
B. X-ray diffraction ☐
C. Spectrographic quant. ☐ semi-quant. ☐
D. Spectroscopic ☐
E. Atomic absorption quant. ☐ semi-quant. ☐
F. Fire assay ☐
G. Microscopic examination ☐
H. Other (Specify) ☐
I. Ultraviolet light ☐

LABORATORY NUMBER	SAMPLE MARKED	ANALYSIS OR IDENTIFICATION							
		E. Ounces Per Ton		Parts Per Million				AR Sol. Wt. per Cent	
		Gold	Silver	Copper	Lead	Zinc	Molybdenum	Calcium	Iron
	TM 73-51	Nil	0.049	60	67	32	40.0	5.30	1.7
	TM 73-52	Nil	0.064	43	60	95	3.0	2.10	4.1
	TM 73-53	Nil	0.043	46	40	47	2.8	2.05	2.8
	TM 73-54	Nil	0.058	43	71	73	2.4	2.10	3.3
	TM 73-55	Nil	0.069	40	120	75	8.7	3.20	2.8
	TM 73-56	Nil	0.064	36	66	65	2.1	1.80	4.2
	TM 73-57	Nil	0.061	55	110	68	1.3	2.80	3.3
	TM 73-58	Nil	0.064	50	72	75	3.4	1.45	3.6

E. Donald R. Stein
ANALYST & WORK DONE

ANALYST & WORK DONE

ANALYST & WORK DONE

APPROVED ____
LABORATORY SUPERVISOR

NOTE: Samples discarded after 60 days and pulps after 6 months unless instructed otherwise.