FLUID INCLUSION PROCEDURES FOR EXPLORATION

A LITERATURE SURVEY

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INTRODUCTION

The purpose of this study is to review the extensive litera-
ture on Fluid Inclusions from the viewpoint of their use as
an aid to established techniques in the exploration for ore
deposits. As such it is not intended to be a complete review
of the literature, much of which deals strictly with research
or ore genesis and no apology is made for any resulting bias
towards methods which are considered or known to be directly
relevant to exploration.

In view of the vast amount of information reported on fluid
inclusions, and the importance of this data in studies of ore
genesis, the lack of application of fluid inclusions to explor-
ation is enigmatic. This is possibly due to the expense of
collecting fluid inclusion data by the slow techniques
commonly used in research institutions. Consequently
this study focuses on the possibility of using rapid, auto-
mated techniques with a view to their use in a manner analogous
to geochemical rock and soil surveys. Some loss of accuracy
is inherent in such procedures but there is reasonable justi-
fication from the existing literature to expect the resulting
information to be of substantial value to exploration if not
to ore genesis investigations.

In conjunction with this literature study an automated, computer
controlled apparatus has been constructed to obtain decrepi-
grams. Orientation surveys are now being carried out to assess
the use of these decrepigrams in exploration for various
types of ore deposits.

This project is being undertaken by Burlinson Geochemical
Services, Darwin.

WHAT ARE FLUID INCLUSIONS

Fluid inclusions are small volumes of fluid which are trapped within crystals by any of several mechanisms either during their growth or by later processes. They are generally representative of the fluids present during crystal growth or in which it was later bathed. They occur commonly in most minerals, are rarely greater than 1 mm and generally less than 10 microns in size. Small ones can be observed in ordinary petrological thin sections but in general doubly polished thick sections are preferred. The ordinary petrological microscope used at magnifications of X200 to X1000 is quite suitable for observing them.

Their abundance varies, but may be as many as a billion per cubic centimetre. Those trapped during host crystal growth are referred to as primary inclusions and contain a sample of the formation fluid. Later shearing and rehealing of fractures will cause trapping of large numbers of secondary inclusions containing samples of the fluids present at such time.

When trapped the ore forming fluids are most commonly (but not always) a single phase. During cooling to present temperatures these fluids may separate into several phases depending on their compositions. They may now contain any combination of solid phase (referred to as daughter crystals), liquid phase and gas (often as a bubble).

Materials which commonly occur in inclusions are water, water vapour, halite and carbon dioxide (either as a liquid or gas phase). An enormous variety of less common materials have been recorded, and their identification is frequently difficult due to the small amounts involved.

From the investigation of these fluid inclusions it is possible to deduce much about the environment in which the crystal grew. Such information includes:-

1) The temperature of formation;

2) The salinity of the formation fluids;

3) Presence of such constituents as carbondioxide, hydrocarbons, hydrogen sulphide;

4)   Occurrence of boiling during formation;

..... and much more.

This data is very commonly used in developing models for
ore genesis and to a lesser extent has been used to define
targets for exploration programmes.

MEASUREMENT OF FLUID INCLUSION PARAMATERS

The most commonly made measurements on fluid inclusions are the temperatures at which various phase changes occur. These measurements are made by observing a single inclusion (or a few inclusions within the one field of view) under a microscope while either heating or cooling the sample. The temperatures of various phase changes within the inclusion can be accurately measured, generally within a degree or two. Temperatures of interest are:-

1) Homogenisation temperature (T_H) - the temperature at which the several phases in the inclusion become a single homogenous phase when the sample is heated;

2) The temperature of freezing of the aqueous phase can provide information on the salinity and occasionally an indication of the salt composition (K, Ca, Na). The presence of CO_2 can be determined in some cases as it can form clathrates, which are recognizable during cooling;

3) Filling temperature. In some cases when an inclusion containing a daughter crystal (S) is heated, the liquid may expand to fill the inclusion without totally dissolving the daughter crystal. As 2 phases (solid and liquid) remain, this is not the same as the homogenisation temperature, and is referred to as the temperature of filling.

Less commonly made measurements include:-

1) Heat the sample until expansion of the fluids in the inclusion causes the mineral to physically burst. This is referred to as the temperature of decrepitation (T_D). A microscope is not necessary for this technique;

2) Opening the inclusion within a pool of oil by using a sharp point while observing it under the microscope. This gives an estimate of internal pressure by estimating the expansion of the gas phase;

3) Various chemical, microprobe or mass spectrometer analyses. These usually require opened inclusions and are without exception long, involved and demanding processes which are beyond the scope of this study.

Data from these measurements is used to deduce the chemical composition, nature and temperature of the fluid during crystal formation. The temperature of formation (T_F) is greater than or equal to T_H depending on corrections necessary to allow for the fluid pressure and salinity. Note that the pressure is not usually discernable from fluid inclusion measurements alone and is estimated from geological considerations.

Most of these measurements require a skilled operator and take a considerable amount of time as the sample must be heated or cooled slowly (usually less than $5^{o}C$ per minute). As only a very few inclusions can be measured simultaneously many days of work may be involved in obtaining a statistically meaningful result for a single sample.

In contrast, measurement of the decrepitation temperature (T_D) can be made quite quickly and is amenable to automation. It is for this reason that this study concentrates on the measurement of T_D, despite some limitations which are outlined later.

BRIEF HISTORY

Sorby first proposed the use of fluid inclusions to estimate crystal formation temperatures in 1858. There was little interest in inclusions until the late 1940's when Smith, Little and Peach became involved with measurements of T_D. Their apparatus is best described by Peach (1949). Some controversy arose between the schools of thought favouring T_H and T_D and by about 1955 the homogenisation method had superseded the decrepitation method in the western world because of the inherent limitations of the decrepitation method.

The Russians however, took to using T_D measurements and used this technique extensively in mineral exploration programmes. Their use of the T_D method has continued to the present day, although, perhaps declining slightly in favour of T_H measurements in recent years.

In the western world there has been no significant use of T_D measurements by the exploration community, and the academic community has preferred the more precise T_H method.

While several decrepitation instruments are manufactured in Russia there are no commercial instruments available in the western world and only a few individually constructed instruments seem to be in existence.

Although the major use of fluid inclusion measurements in the western world is in research on ore genesis, several studies have looked at fluid inclusions from an exploration viewpoint. (Nash 1972, 1975, 1976; Bradshaw, 1968; Roedder 1977). These studies have used the T_H method and have shown some potential for the further use of fluid inclusion data in mineral exploration programmes.

FLUID INCLUSIONS IN EXPLORATION

Many models of ore formation involve circulating fluids
driven by a heat source. Such models range from the generation
of quartz vein systems around intrusives to large scale
convection cells either responsible for or associated with
porphyry copper deposits. Samples of such fluids will be
trapped in both the ore and gangue minerals during formation and
the study of these trapped fluids can assist in determining
the conditions of ore formation. However, in contrast to the
various ore minerals which may be concentrated at only a few
points in the fluid system, fluid inclusions will be more widely
dispersed throughout the fluid system. The resulting pattern
of fluid inclusions can be likened to a primary geochemical
dispersion halo of trace elements. However, this fluid inclusion
halo has several important advantages over conventional
primary geochemical haloes, such as:-

1) It is generally much more extensive as inclusions
   can still form after the fluid composition or tempera-
   ture is no longer favourable for the transport of
   the ore elements or their associated indicator
   elements;

2) The fluid inclusion halo is little (if at all)
   affected by subsequent weathering processes;

3) In addition to the frequency of occurrence of fluid
   inclusions other paramaters such as salinity, T_H or
   T_D can indicate the direction towards the fluid
   system centre;

4) Fluid inclusion formation is relatively independent
   of pH, EH, pO_2 etc and therefore less subject to
   complications which can adversely affect trace metal
   transport.

The use of fluid inclusion haloes in exploration would there-
fore form a useful adjunct to conventional geochemical, geolog-
ical and geophysical procedures.

Because the formation of a fluid inclusion halo presupposes
little more than the existence of heated fluids a great
variety of ore types should be amenable to exploration by
fluid inclusion techniques. Such ore types include:-

1) Late stage magmatic deposits;
2) Hydrothermal/Pneumatolitic deposits;
3) High level acid intrusive associations;
4) Deposits formed by country rock scavenging
    in convection cell systems;
5) Possibly even deposits formed due to dewatering
    during diagenesis or metamorphic dewatering;
6) Replacements and skarns (?)

This variety of ore types includes ores of a great many elements
including Au, Ag, Bi, Sn, W, Mo, Cu, Pb, Zn, U etc as well
as such commodities as fluorite.

In view of the wide variety of ore types and ore metals to
which exploration by fluid inclusion techniques could be
applied, the almost total lack of use of fluid inclusions in
exploration (in the western world) is enigmatic!

EXPLORATION EXAMPLES

Although there is a great deal of fluid inclusion data in the literature, most of this is concerned primarily with ore genesis rather than exploration. Most of the exploration examples are in the Russian literature and the data is sometimes less than complete. Nash, at the U.S. Geological Survey, has however carried out much work which is directly relevant to the use of fluid inclusion data in exploration.

Porphyry Copper Deposits

Extensive zoned haloes of fluid inclusions have been observed around many porphyry copper deposits by Nash. (Nash, 1976.) He found the most useful measurement to be the salinities of the inclusions, and in most cases the salinity decreased away from the ore zone. The size of the anomalous salinity area was generally somewhat smaller than the pyritic alteration zone. He concludes that the fluid inclusion halo is a more satisfactory target than either minor element or alteration haloes as these latter are poorly developed in siliceous rocks. Nash has found evidence of vertical zonation of fluid inclusions in some but not all of the orebodies he studied and a change from boiling to non-boiling fluids seems to occur at the base of the system. Base and precious metal ores tend to occur at these lower levels. Similar effects were noted at Bingham by Roedder, 1971.

Although the porphyry copper deposits typically form at temperatures of $400 \pm 100^{\circ}C$, zonation of fluid inclusion filling temperatures around the orebodies is often subject to complications such as high temperature pulses and late stage activity and temperature zonation alone is a less reliable target than salinity zonation. Some studies have drawn attention to the zonation of the abundance of fluid inclusions (Nash, 1976; Chivas and Wilkins 1977). Simple counting techniques could be used to determine such zonation rather than the slow and involved heating/cooling stage procedures. Decrepitation measurements can also provide this information even more rapidly.

Massive Sulphides

Franklin, at the 1980 Archaean Symposium, outlined a model
for massive sulphide deposits of the Timmins type in which
large convection cells driven by a deep heat source are
involved. He considers this model to be relevant to a number
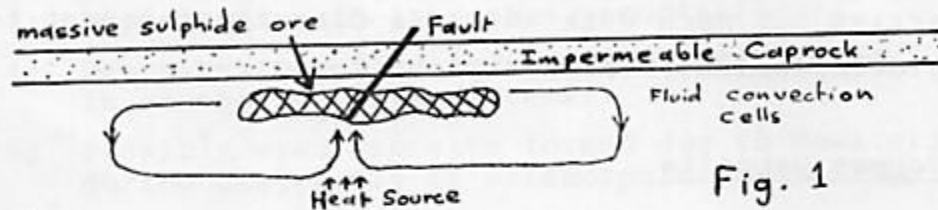of Canadian massive sulphides.

Fig. 1

This model is similar to the convection cells set up around
porphyry copper stocks and by analogy fluid inclusions
should be a useful exploration tool, although no such
studies seem to have been done to date.

Sulphide Veins and Pipes

Vein and pipe-type base metal deposits have been well
studied from an exploration viewpoint, particularly by the
Russians. (Ermakov 1966; Ermakov and Gromov 1971; Ermakov
and Kuznetsov 1972; Nash 1975). The Russians frequently
report decrepigrams showing good contrast anomalies near
such mineralisations. (Figs. 2,3,4,5). The extent of
these anomalies seems to be quite variable and would seem to
be very dependent on the sampling medium (rarely specified
in the Russian papers). Nash's work at the Argentine vein,
Colorado, found no systematic variation in filling temperatures
which could be related to mineral zoning in an extensive
vertical and lateral region of mineralised veins around the
Silverton caldera. Unfortunately his sampling pattern is very
irregular due to mine inaccessibility and the study stopped
short of comparing barren and mineralised areas. Post sulphide
stage veins were shown to have distinctly different filling
temperatures (153° - $188^{\circ}C$) to the ore veins (220° - $315^{\circ}C$)
and so there may be some value in using fluid inclusions to
discriminate between the various vein systems. In contrast,
Bradshaw, 1968, studied the filling temperatures of vein materials
in south-west England and suggested that filling temperatures
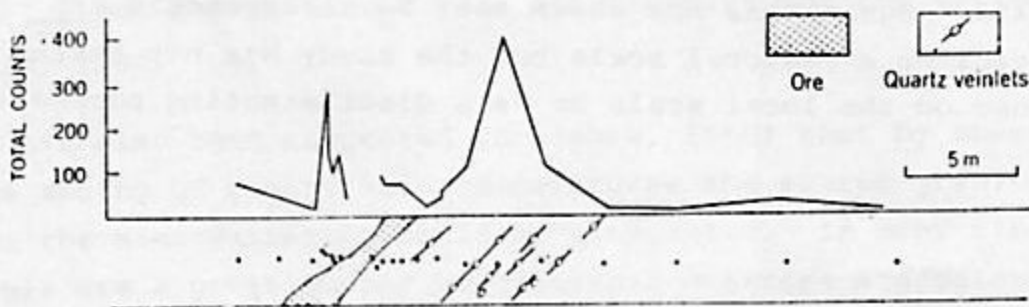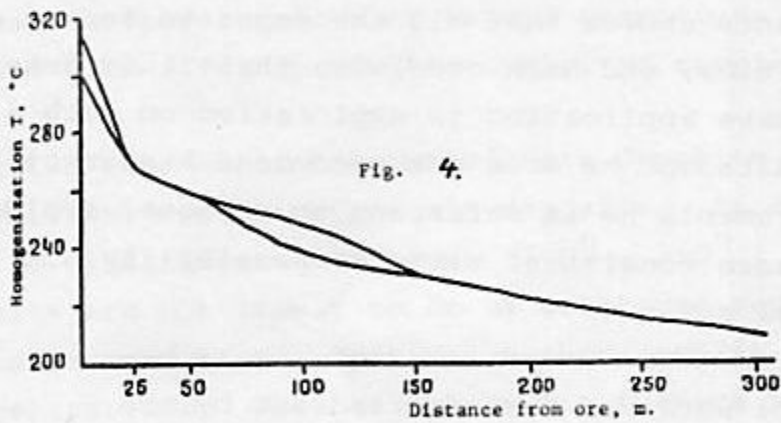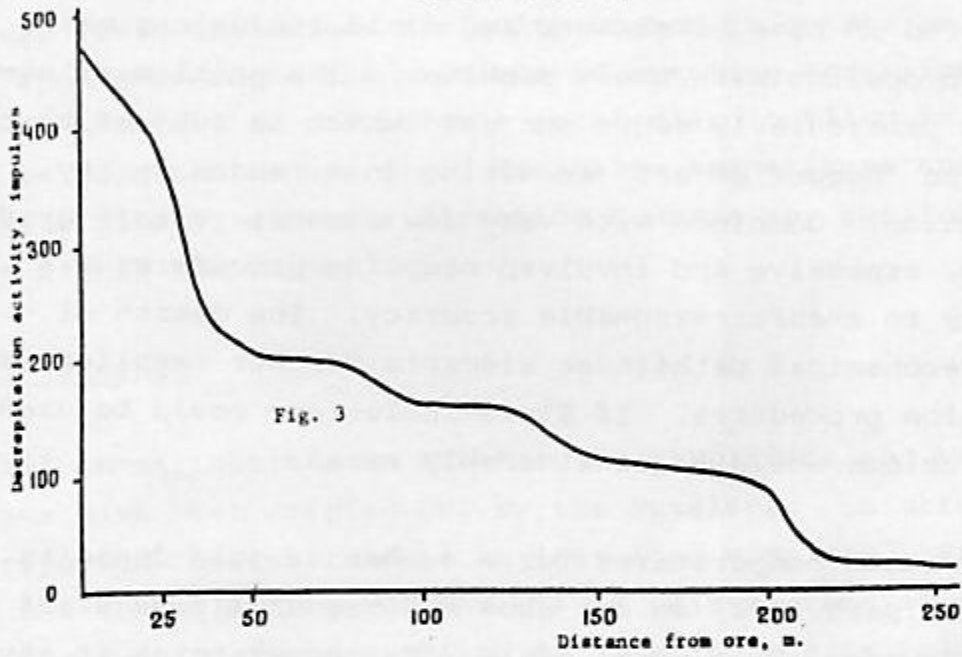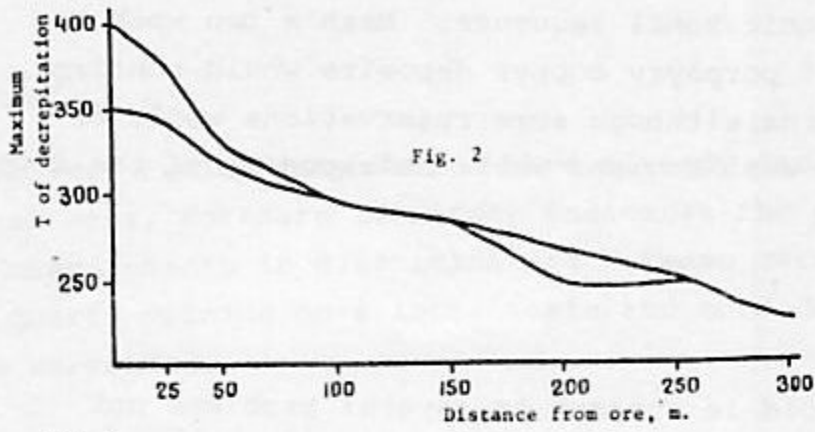can be used to determine the relationship between a particular

Fig. 2

Fig. 3

Fig. 4

FIG. **5.** Graph of decrepitometric activity of limestone from a drift in the Brichmull deposit, Uzbekistan (Polykovskii, 1971, p. 143).

vein and the economic zonal sequence. Nash's own work on
the lower zones of porphyry copper deposits would confirm
such zoning patterns although some reservations would be
in order in south-west England where telescoping of the deposits
is common.

Gold Deposits

Exploration for gold is subject to several problems not
encountered in base metal work and fluid inclusions may
assist in dealing with these problems. The problem of sampling
error is particularly acute for gold which is subject to the
oft quoted "nugget effect" resulting in a random spotty
distribution. Combined with very low economic cutoff grades
for gold, expensive and involved sampling procedures are
necessary to ensure reasonable accuracy. The dearth of
useful geochemical pathfinder elements further complicates
exploration procedures. If fluid inclusions could be used,
these problems would be considerably eased.

Homogenisation temperatures for a number of gold deposits
in Nevada (Nash 1972) do not show any regionally constant
value. However, on a local scale the temperatures in any
one deposit tend to be restricted to a range of about 30°C.
Salinity measurements showed that all the deposits formed at
similar low salinities, and Nash concludes that fluid density
measurements may have application in exploration on such a
regional scale. Although he does not recommend exploration
based on T_H measurements he is referring to regional explor-
ation and his data are consistent with the possibility of
using T_H on a local scale.

A limited amount of work has been carried out by the
S.A. Department of Mines and Energy on gold areas in South
Australia. Again this has shown that T_H measurements are
not useful on a regional scale but the study has not tested
their use on the local scale or as a discriminating paramater.

Some very rudimentary work I have already done in the Pine
Creek area, Northern Territory indicates the potential of
T_D measurements in discriminating between various stages
of quartz veining on a local scale and more detailed studies
are warrented.

Because fluid inclusions are quite common in quartz veins, using
them should overcome the problems of sampling error for gold.
Once familiarity is gained in a particular locality it may
also be possible to use fluid inclusion temperature and
salinity data to deduce a direction towards any auriferous
zones within the veins.

Tin - Tungsten

Several investigations on tin-bearing granitoids and vein
systems have been carried out by the Russians. Unfortunately
the reported results tend to be less than complete. Bradshaw,
1968 has looked at some of the quartz vein systems in south-
west England and found a zoning of T_H measurements related
to the mineralisation zoning of Sn, Pb, Zn, Cu. He also
shows a temperature zoning around granitoids (Fig. 6),
albeit from a fairly limited number of sample points.

Existing studies of base metal vein deposits should also
be relevant for vein-type tin deposits. As cassiterite forms
over a wide temperature range (200° - $350^{\circ}C$) fluid inclusion
results are not likely to be of great use regionally, but
could be used as an empirical method locally to pinpoint ore
concentrations. Most vein-type tin systems have a confusing
array of quartz veins, both barren and mineralised, and fluid
inclusions may be of use as a discriminant for the various
vein types.

It has also been suggested (Bradshaw, 1968) that by observing
the zoning of quartz vein temperatures the source granitoid
for the mineralization could be pinpointed. In many tin areas
there are a great number of granitoid outcrops and often a great

number of different granitoid phases occur (eg some 20 odd in the Blue Tier Batholith, N.E. Tasmania). Pinpointing the source granitoid is usually not a trivial matter. This same technique may be of use as a guide in exploration for non-outcropping granitoids or cusps. Such unexposed areas are of interest in the search for high volume low grade greisen deposits.
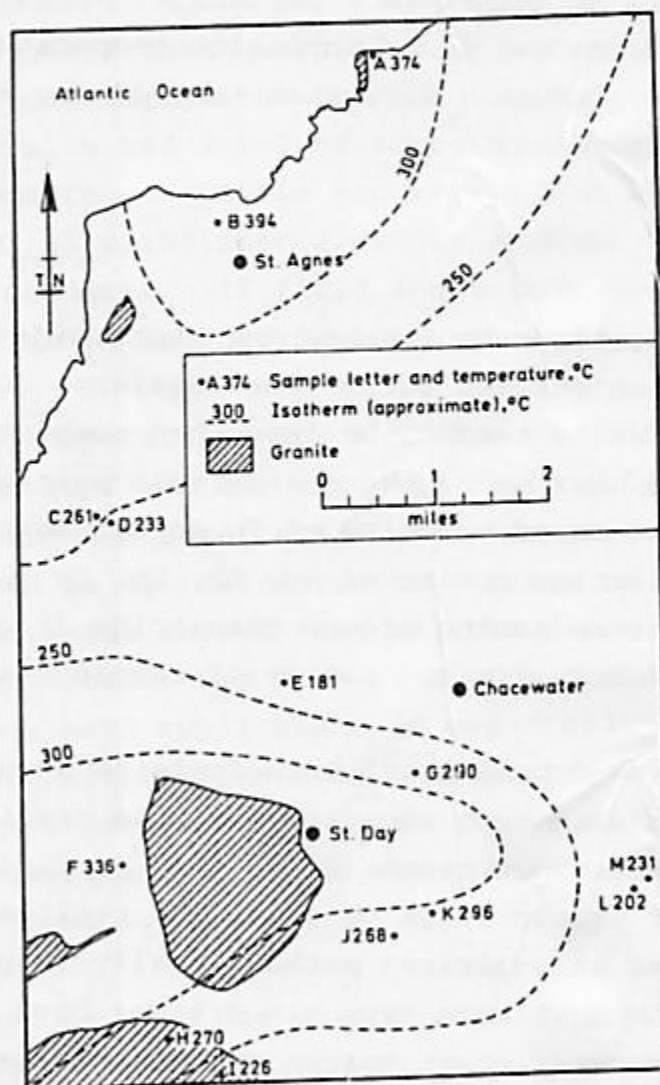
Fig. 6 Upper limit of filling temperatures recorded from individual deposits in St. Agnes—St. Day area

Little has been reported on exploration for quartz vein-type
tungsten deposits, but they are so closely associated with tin
that the same procedures should apply.

Although little data is available in the literature about
tin/tungsten replacement or skarn deposits by analogy with
other replacement and skarn deposits fluid inclusion data
should be of use in exploration.

The problems of sampling for tin and tungsten are similar
to those of sampling for gold and similarly there are few
reliable geochemical pathfinder elements. Fluid inclusion
methods may be of use in overcoming these limitations.

Replacement/Skarn Deposits

Much of the work which has been done on these deposits is
concerned with ore genesis rather than exploration and it is
difficult to deduce how useful fluid inclusion measurements
might be for exploration.

Nash, 1975, presents much data on the replacement Cu-Pb-Zn
mineralisation at Idarado, Colorado, and shows the relation-
ship between the replacement ore and the nearby crosscutting
veins. However, no data is available from which to deduce any
possible zoning.

Tan Teong Hing and Kwak 1979, have shown a T_F zoning in
garnets at the King Island tungsten skarn (Fig. 7). This shows
a consistent temperature drop along a section extending 500 m
from the igneous contact. This diagram also shows the complica-
tions due to zoning of the individual crystals. Other skarn
deposits have been studied by the Russians and Fig. 8 shows
a decrepitometric traverse across a small skarn (Ermakov and
Gromov, 1971; diagram from Roedder, 1977). This type
of data presentation is common in the Russian literature.

Although previous studies of these deposit types from an
exploration viewpoint are rare, there is justification to
think that fluid inclusion data could aid in their exploration.
More investigations seem to be warranted.
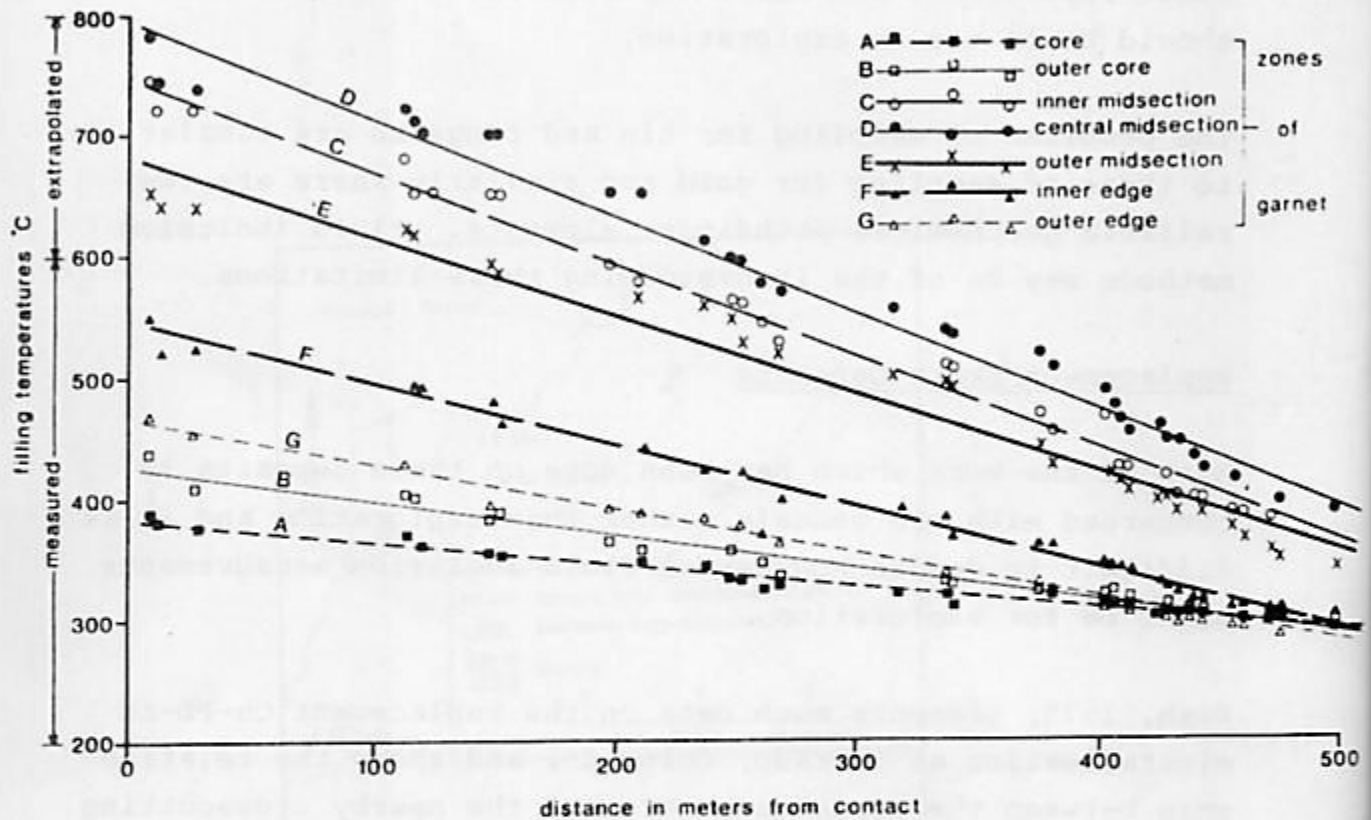
FIG. 7.—Measured temperature vs. distance curves from different parts of the garnets displayed in figure 2

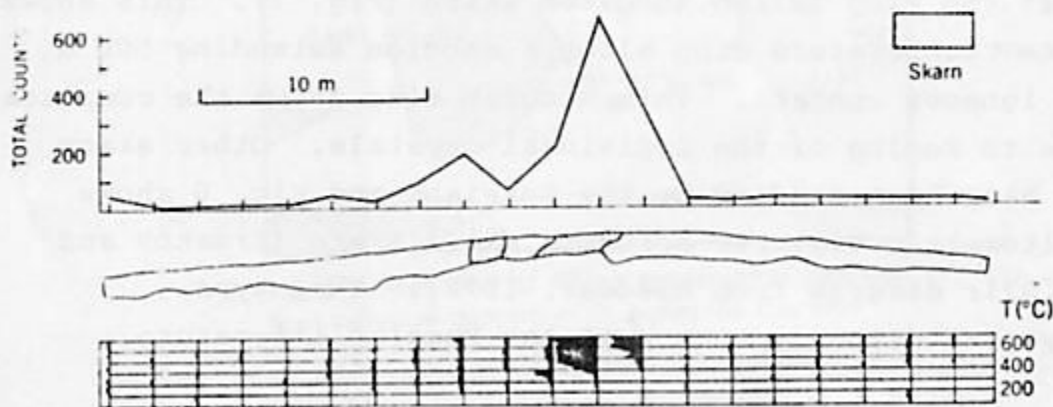FIG. 8. Decrepitometric activity adjacent to garnet-pyroxene skarn in granite and tuffs in the Slushoky area, Central Kazakhstan (Ermakov and Gromov, 1971, p. 136). The individual decrepigraphs for samples every 2 m are given below the section, and the integrated (total) decrepitometric activity is shown by the graph above the section.

Hydrothermal/Pneumatolitic Deposits

The close relationship between these deposits and fluid
processes should make them good candidates for exploration
by fluid inclusion techniques. The Russian literature contains
numerous examples of studies of these deposits, but all too
often the data is incomplete.

Fig. 9 shows the change in decrepitation activity (directly
related to abundance of inclusions) away from an unspecified
ore vein. This type of measurement can be quite simply made
in comparison to T_H or salinity measurements and is frequently
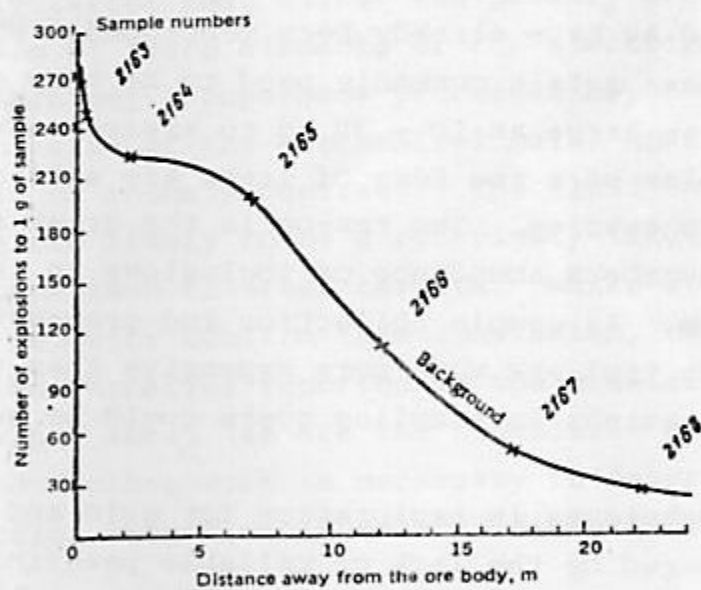used in exploration programmes in Russia.

FIGURE 9. Decrepitation activity curve for sands tones,
going away from the vertical hydrothermal vein

ADVANTAGES OF FLUID INCLUSION METHODS

The use of fluid inclusion techniques in exploration would lead to a number of advantages over conventional geochemical techniques.

Foremost among these advantages is the persistence of inclusions in the resistent gangue minerals despite intense weathering. In fact many studies have been done on detrital grains and even on laterites, using fluid inclusions in quartz grains to determine the source of the host grains. (Roedder 1977, Ermakov 1966.) Few other exploration techniques can claim such immunity to weathering processes. Given the intense and deep weathering in many areas of Australia this advantage is of major significance.

The ability to overcome some of the sampling problems in exploration for Sn and Au have already been mentioned. While assay samples for these metals commonly need to be very carefully collected and as large as 10 - 30 kg to assure reasonable accuracy, samples of a few tens of grams are sufficient for fluid inclusion studies. The reason is the great and relatively homogenous abundance of inclusions in the quartz sampling medium. As sample collection and preparation for gold (and often tin) are much more expensive than the actual analysis, the savings in sampling costs could be substantial.

Geochemical techniques in exploration for gold and tin in particular are hampered by the lack of reliable pathfinder elements. Fluid inclusion measurements could help fill this void. Measurements of T_H or T_D are potentially of use on a local scale as an empirical exploration procedure in the same sense that geochemical and many geophysical techniques are now used.

Further potential for the use of fluid inclusion procedures is as a method of discriminating between potentially ore-bearing and ore barren veins or areas. Because the fluid inclusion characteristics are more intimately related to the actual ore forming processes than is the presence of associated elements (pathfinder elements) these paramaters should be

more reliable discriminators than the concentrations of associated elements.

The problem of determining the direction towards the ore centre frequently occurs in exploration. Measurements of T_H, T_D or salinities provide a means of determining the palaeothermal gradients and hence of providing a direction towards the source of the original ore fluids. While this can be done using geochemical pathfinder techniques the fluid inclusion measurements are a much more direct method as they do not rely on assumptions about the relative mobilities of the various elements under the conditions prevailing during ore formation.

The target size is of major importance in any exploration procedures. Fluid inclusion haloes have the potential to be as large as the fluid system from which the ore formed. This is most likely larger than either the primary geochemical dispersion halo of trace elements or the electrical/magnetic target of an orebody. Supergene processes may then serve to enlarge the size of the geochemical halo, however, this is at the expense of anomaly contrast. The fluid inclusion halo is therefore likely to be a relatively large, high contrast anomaly in comparison to other targets. While studies of porphyry copper deposits confirm this conclusion, many of the fluid inclusion anomalies reported in the Russian literature seem to be rather small (as are the"orebodies" on many occasions) and further work is necessary to determine whether a fluid inclusion target would be significantly larger than other targets.

LIMITATIONS OF THE METHODS

Despite the great number of proven and potential applications outlined in the previous pages fluid inclusions are nct the universal panacea to exploration problems.

The most important problem is that of the cost of many fluid inclusion procedures. Measurements of T_H, salinity or fluid compositions require relatively uncommon apparatus, a skilled petrologist, a doubly polished rock slice and considerable time and patience. Some measurements also require a supply of liquid nitrogen. Considerable operator skill is required in order to decide between the primary and secondary inclusions in a sample. The sample is then slowly heated and/or cooled while observing the inclusions. Because only a very few inclusions can be measured simultaneously the acquisition of a statistically meaningful amount of data can easily take weeks. These factors probably account for the lack of orientation surveys relevant to exploration.

Subsequent metamorphic events generally cause decrepitation of the inclusions and in effect erase the pre-existing inclusion patterns. While this has been used to advantage to determine the age relations of cross-cutting dykes, it is more likely to be a nuisance during exploration usage.

The applicability of fluid inclusion techniques to exploration will also depend on the type of deposit concerned. They are unlikely to be of much use for magmatic ores, stratiform sedimentary ores or other ores which are not associated with hot fluid systems. Such ores as the Mississippi valley type and submarine exhalative deposits are unlikely candidates but orientation surveys need to be done on these deposit types. The limitation of their use to only certain deposit types is a relatively minor limitation as all other exploration techniques are similarly restricted in the types of deposit to which they are relevant.

PRACTICAL EXPLORATION PROCEDURES

While many fluid inclusion measurements are difficult and costly to make, the measurement of decrepitation temperature can be more readily made. In this procedure the sample can be more rapidly heated, the measurements can be made by unskilled personnel, simultaneous measurements can be made on a statistically meaningful number of inclusions and the procedure is amenable to automation.

In Russia several decrepitometers are manufactured some of which are field operable. Using these instruments the Russians are able to produce decrepigrams on up to 12 samples simultaneously in the field and up to 90 samples per day. (Ermakov, 1966.)

A further advantage of this technique is that opaque minerals are just as easily studied as the transparent minerals. No other satisfactory method of investigating opaques is available. Conventional microscopic methods cannot deal with very small inclusions because it is too difficult to observe the phase changes within them during heating/cooling. Such small inclusions are less of a problem to the decrepitation method. Friable samples or detrital grains require more involved sample preparation for the microscopic methods while these materials present no problem at all to the decrepitation method.

These significant advantages are not, however, obtained without cost and considerable information is sacrificed to attain them.

While the homogenisation temperature is subject only to corrections due to the pressure at the time of formation, the decrepitation temperature is affected by many additional factors:-

1) Degree of fill of the inclusions - varying degrees of fill will result in different expansion behaviour of the fluids leading to variations in decrepitation measurements;

2) Mineral strength - Different host minerals will require different overpressures before the inclusions will actually burst;

3) Salinity - Varying salinities can result in different expansion behaviour of the fluids, hence influencing T_D;

4) Partial pressure of CO_2 - Gas rich inclusions may build up pressure only slowly and decrepitation will be delayed and may not even occur at all;

5) Homogenisation in the vapour phase - This effect is similar to (4);

6) Secondary inclusions - In microscopic techniques these are identified and avoided. They cannot be avoided in the T_D method and the effect they cause on the resulting decrepigram can vary from beneficial to disastrous. Where the secondary inclusions decrepitate at a significantly different temperature to the primary inclusions they can actually provide useful additional data. In the absence of such a differential however, they may completely mask the primary inclusions. As secondary inclusions are most often lower temperature, and liquid filled there is some hope that the temperature differential between them and the primary inclusions will generally be sufficient to avoid swamping the primary inclusions.

A further consequence of using the decrepitation method is that no salinity data can be obtained.

Despite these limitations there is a considerable body of decrepitation data (almost all in the Russian literature) which attests to the usefulness of this technique in exploration. The resulting data must be interpreted empirically, in contrast to T_H data, but such practices are not new to exploration personnel, particularly geochemists and geophysicists.

By combining surveys using these rapid methods with a limited number of control measurements made by microscopic methods an effective and economic exploration technique could result.

CONCLUSIONS

Fluid inclusions have long provided valuable information on
the genesis of ore deposits. This same information has been
shown by a great number of studies to be of practical
importance to exploration, not only by improving our geologi-
cal understanding and modelling, but also as a means of pin-
pointing ore environments and deposits.

While the commonly measured paramaters of fluid inclusions
require considerable skill and time for their determination
and interpretation, some of the more readily measured paramaters
such as decrepitation temperature, decrepitation activity
and abundance of inclusions can be used as a refinement of
existing exploration techniques. Exploration procedures
based on these methods have been shown to be both useful and
practical and are in use in Russia today.

The simplifications involved in these exploration procedures
can be compared to those made in the adoption of geochemical
surveys by Atomic Absorption analyses of patterns of samples.
To obtain rapid and cheap analyses the approximations of
incomplete sample digestions, restricted measurement accuracy,
tolerance of some inter-element interference and empirical
interpretation procedures have been accepted. The resulting
techniques, despite the approximations, have often played a
significant role in exploration.

The absence of commercial instrumentation to make these rapid
fluid inclusion measurements has mitigated against the adoption
of these techniques in exploration. It has also resulted in a
lack of well-controlled orientation surveys, many of the Russian
surveys being only poorly described in the literature.

It is considered that fluid inclusion techniques do have an
important role to play in exploration. They are already play-
ing an important role in developing more accurate geological
models. Simplifications of these high precision techniques
could also directly aid in exploration procedures. The

decrepitation temperature/activity method has potential as a
rapid and cheap technique which can provide an exploration
tool which is uniquely immune to disturbance by weathering
processes.

A microprocessor controlled instrument to obtain this
decrepitometric data has already been constructed. A
programme of orientation surveys is now underway to further
test the applicability of this data to exploration and to
develop useful exploration procedures.

GLOSSARY

Decrepigram : A histogram of the number of decrepitations versus temperature. Most often used by the Russians.

Decrepitation : The bursting of a fluid inclusion due to fluid expansion generating a pressure sufficient to fracture the host grain.

Decrepitation Activity : A count of the total number of inclusions which decrepitate when the sample is heated through a certain temperature interval. Equivalent to cumulatively summing the decrepigram.

Decrepitation Temperature: Variably defined as either the temperature at which the greatest number of inclusions burst or the temperature of onset of massive bursting. The latter definition is preferred for comparions with homogenisation temperature, and is taken as the point of inflection preceding the main decrepitation peak of the decrepigram.

Decrepitometer : An instrument to produce decrepigrams by counting the frequency of bursting while the sample is heated.

Formation Temperature : The temperature at which the mineral is considered to have crystallized. Generally deduced from the Homogenisation temperature by making the necessary pressure corrections.

Freezing Stage : A microscope attachment which allows the sample to be cooled while being observed. The cooling rate needs to be well-controlled to allow accurate determination of the temperatures at which the phases of the fluid inclusions freeze. Generally operate using liquid nitrogen and require an ancillary regulator and temperature measurement system. Usually have a heating system incorporated for both heating and cooling measurements.

Heating Stage :	A microscope attachment which allows the sample to be heated while being observed. Require an external power supply and a temperature measurement and control system. May or may not be combined with a freezing stage. Generally limited to maximum temperatures around $500^{\circ}C$.
Homogenisation Temperature :	The temperature at which the phases in the inclusion become a single homogenous fluid. Generally considered to be an accurate estimator upon which to base determination of the Formation Temperature.
Primary inclusion :	A fluid inclusion trapped during the original crystallisation of the host grain. These are generally recognised by their close relationships to lines showing crystal growth.
Secondary inclusion :	Any inclusion trapped subsequent to original crystallisation. These may arise during metamorphic recrystallization or shearing after formation. They are generally recognised by their relationships to fractures, grain boundaries etc. Frequently they are liquid filled, low temperature inclusions. Although they may supply useful information about post mineral crystallisation processes they are usually only of nuisance value.
T_D :	Decrepitation Temperature - see above.
T_F :	Formation Temperature - see above.
T_H :	Homognisation Temperature - see above.

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