MEMOIRS GEOLOGICAL SOCIETY OF INDIA
No. 11, pp. 67–78.

The recognition of variations in sample suites using fluid inclusion decrepitation—applications in mineral exploration.

KINGSLEY BURLINSON
Burlinson Geochemical Services Pty. Ltd. P.O. Box 37134, Winnellie 5789, N.T.Australia

Abstract

Mineral samples often look identical in hand specimen but contain completely different fluid inclusion populations. The decrepitation method provides a rapid and cheap method of observing the variations in the fluid inclusion populations as a means of discriminating between such similar looking samples. It is possible to use decrepitation on samples of pervasive silicification as well as on quartz veins and comparison of such samples shows the relationship between coexisting veins and silicification. Decrepitation responses from vein quartz and chert at gold mines in the Northern Territory, Australia, are quite different and aid in the geological mapping of the area. Opal samples give a particularly characteristic, narrow decrepitation peak while variations between carbonate samples can aid in the discrimination between sedimentary carbonate horizons. Decrepitation differences in magnetite samples at Tennant Creek, N.T., Australia, could not be correlated with the known gold distribution, but do indicate that the ore bodies are quite complex and significantly different from normal sedimentary banded iron formations. Although the method is best used to compare suites of similar samples, in some cases it can also provide an insight into the genesis of the deposits.

INTRODUCTION

The decrepitation method has been used intermittently since its introduction in Canada by Scott (Scott, 1948). The method entails the measuring of acoustic emissions from a sample while it is heated at a controlled rate and plotting the data as a histogram of counts against temperature (a decrepigram). The technique was initially proposed as a means of obtaining mineral formation temperatures, but because of inherent inaccuracies the microthermometric technique was adopted and decrepitation fell into disfavour in the Western countries. It was however used extensively in Russia, where it was applied as an exploration tool. In recent years further research on the technique has been done in the Western countries and it is being recognized as a valid exploration method to examine variations across suites of samples, in which application the accuracy limitations are less critical. In order to provide cost effective and reliable analyses a microprocessor controlled decrepitometer was constructed and used to analyse some 4000 samples. The data presented here were analysed on this decrepitometer, the BGS model 04. (Burlinson, 1988).

The analytical sample used is 0.5g of crushed, sieved, monomineralic grains, which is easily and cheaply prepared. This is heated to a maximum of 800°C. Audible pulses occur as the fluid inclusions build up sufficient internal pressure to exceed the strength of the host mineral grain. In quartz, this usually requires excess pressures of about 700 bars (Leroy, 1979). Aqueous inclusions which homogenise to the aqueous phase develop such excess pressures quite close to their homogenization temperatures and the decrepitation temperatures can then be used to infer the homogenization temperatures with reasonable accuracy. Hladky and Wilkins (1987) have shown that under these circumstances the decrepitation peak temperature is about 70±20°C above the homogenization temperature of the inclusions. Complications arise when dealing with other mineral phases, very small inclusions (<3 microns), inclusions which homogenize to the vapour phase or gas rich inclusions. Leroy (1979) has shown that small inclusions may not decrepitate at all, whereas in gas rich inclusions, decrepitation is often observed to precede homogenization during microthermometric studies. In these cases it is not possible to use the decrepitation data to infer homogenization temperatures.

Although decrepitation has most commonly been applied to vein quartz samples, it is also applicable to other forms of silica such as zones of pervasive silicification of host rocks and to opaline silica from secondary and hot spring deposits. It is also useful in discriminating between quartz formed in hydrothermal events and cherts of low temperature sedimentary origin. The method is not restricted to transparent minerals and has also been used on magnetite, pyrite, carbonates and many other minerals. On these minerals the technique has been used to empirically compare suites of samples, as there is little understanding of the nature of fluid inclusions and decrepitation activity in opaque minerals.

DECREPITATION OF QUARTZ SAMPLES

Decrepigrams on quartz samples can often be used as a guide in determining the formation temperature of the minerals. Smith (1950) used the temperature at the "onset of massive decrepitation" for this purpose and it often provides acceptable temperatures. Alternatively, subtraction of 70°C from the temperature of the decrepitation maximum gives good agreement with microthermometrically determined homogenization temperatures in some cases (Hladky and Wilkins, 1987). Decrepigrams of quartz typically have a peak near 580°C, being caused by the weakening of quartz at the alpha-beta phase transition temperature, which facilitates the decrepitation of any inclusions still present (Hladky, 1982, personal communication). Quartz gives no decrepitation response above this temperature and so such samples are normally only heated to 620°C during their analysis. Most emphasis in decrepitation interpretation of quartz samples is therefore, placed on the other peaks, which are independant of crystallographic effects.

Gas-rich inclusions commonly decrepitate below their homogenization temperatures and such samples give decrepigrams with distinctive low temperature peaks. This has been applied as an exploration method to locate samples rich in CO_2 (Burlinson, 1988; Burlinson, 1984), as an aid in exploration for gold deposits.

Coeur d'Alene Ag-Pb-Zn district, Idaho, USA

At the Sunshine mine, near Kellogg, replacement veins are mined for Ag, Pb and Zn. These veins commonly lie within numerous intersecting fault zones (Fryklund, 1964) and the genetic relationships between the veins are complex and difficult to discern reliably. A decrepitation study of 47 samples from various veins and levels in the mine was performed to examine the application of decrepitation in discerning between the various spatially overlapping veins. Structural features and vein continuity are used in the mapping of the mine workings to distinguish different vein systems and samples from 16 different systems were collected for comparison. The objective of distinguishing between veins requires that the variations between different veins be greater than the variation within individual veins, both across the thickness and along strike. The samples collected therefore, included 4 cross sections of various veins and many along strike samples from the same vein to check the uniformity of decrepitation within individual veins. These results show that there are marked variations across the thickness of the veins, indicating the presence of significant growth zoning (Fig. 1). In addition, significant variations along strike were observed within individual veins. These within-vein variations indicate that individual vein deposition was a complex event involving fluids of various compositions and temperatures. The variations between different vein sets (Fig. 2) were often quite marked and greater than that expected within individual veins. Hence, the decrepitation data can be used to ascertain which vein system a sample has come from, but the amount of variation within individual veins does lead to ambiguity in some cases.

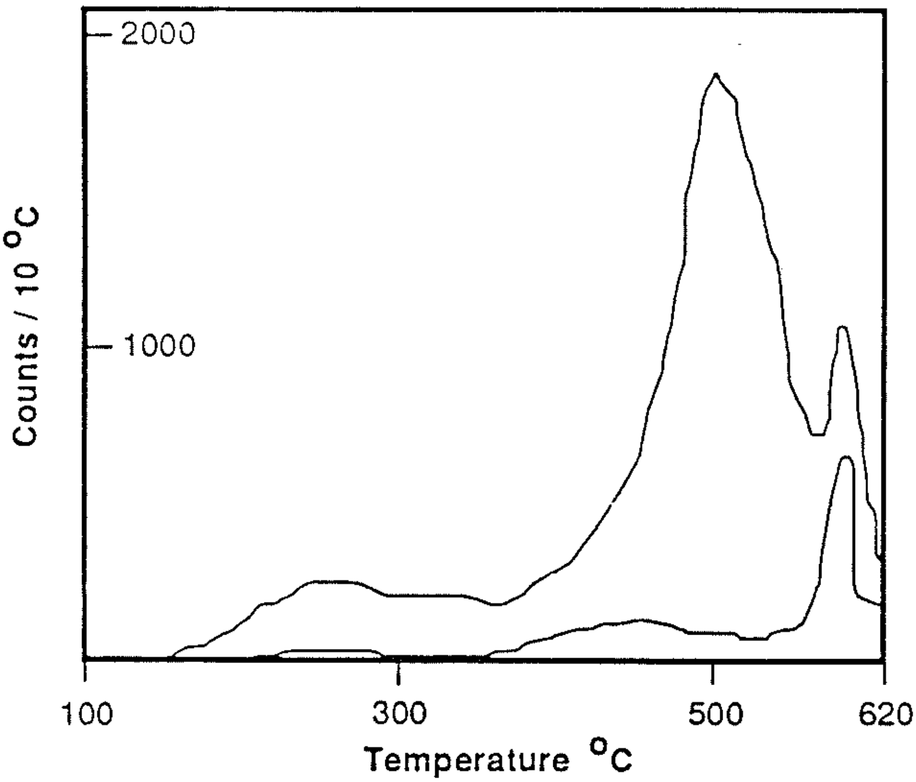

Figure 1. Variation across the thickness of the Cu vein, 5000' level, Sunshine mine, Idaho.

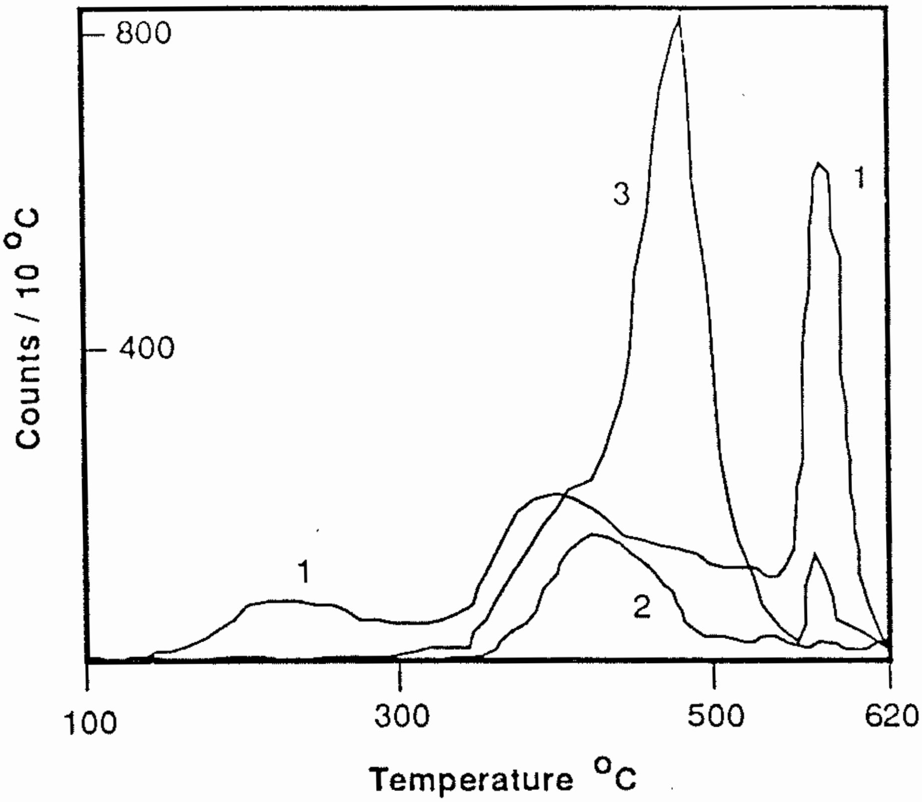

Figure 2. Variation between the D vein (1), Syndicate vein (2) and 37R02 vein (3) at the Sunshine mine, Idaho.

A similar study was conducted at the Lucky Friday mine, located some 21 Km to the east of the Sunshine mine. Here, in contrast to the complexity of veining at the Sunshine mine, there is essentially a single quartz vein of considerable extent (some 1000 m lateral and 2000 m vertical), which has been dislocated by many later crosscutting faults. Twenty one quartz samples were collected over a vertical range of 1000 m and a lateral extent of 700 m (on the 1500 m level) to test for fluid inclusion zonation within the vein. Only minor variations in decrepitation behaviour of the quartz were observed (Fig. 3) and it is inferred that this deposit was formed as a single genetic event in distinct contrast to the complex genesis inferred at the Sunshine mine. These studies were not intended to provide absolute formation temperatures of the veins or details of the vein's geneses, however, the decrepitation data has shown the complexity of the multiple stages of formation at the Sunshine mine in contrast to the Lucky Friday mine, where much more uniform depositional conditions prevailed.

Quartz veining and adjacent pervasive silicification

In addition to being useful on ordinary vein quartz, it is frequently possible to

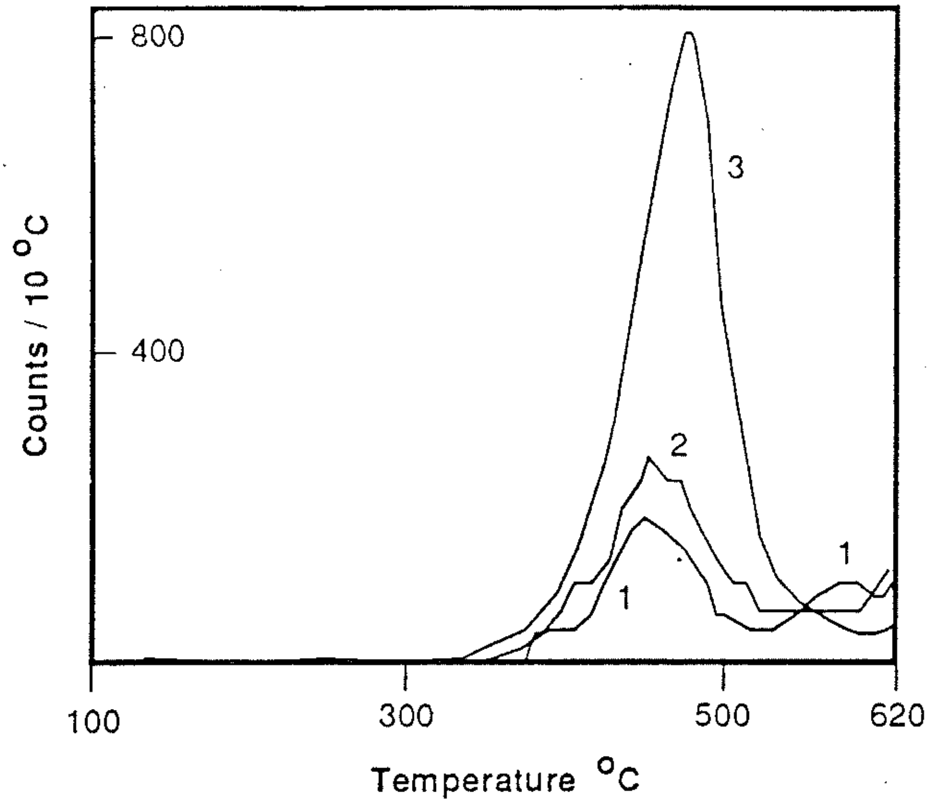

Figure 3. Similarity throughout the Lucky Friday mine, Idaho. 1800' level (1), 93 crosscut on the 4900' level (2) and 107 crosscut on the 4900' level (3).

use the decrepitation method on zones of pervasive silicification, such materials rarely being suitable for microthermometric study. The Northumberland Au mine, Nevada, USA is a sediment-hosted deposit, the gold occuring within pervasive silicification of the porous host rock (Motter and Chapman, 1984). The altered and silicified host rocks give low level, but quite distinct, decrepigrams while the unaltered massive host rock argillites give no decrepitation response. This provides a rapid means of discrimination between unmineralised and potentially mineralised silicified host rocks, which can be used on difficult samples such as percussion drilling chips. In Fig. 4 the decrepitation temperature of the pervasive silicification (as measured at the onset of massive decrepitation) is 40°C less than the temperature of the adjacent quartz vein, which suggests that the quartz veining is a different genetic event from silicification and its associated gold mineralisation.

Similar studies on coexisting quartz and silicification have been done at the Elan vein in the Cassiar gold camp, British Columbia, Canada. In this area, gold occurs in quartz lenses which occupy a shear zone within andesite and tuff host rocks (Diakow and Panteleyev, 1981). Fig. 5 shows the decrepitation response from both the vein quartz itself and the immediately adjacent silicification of the wallrock. The silicifi-

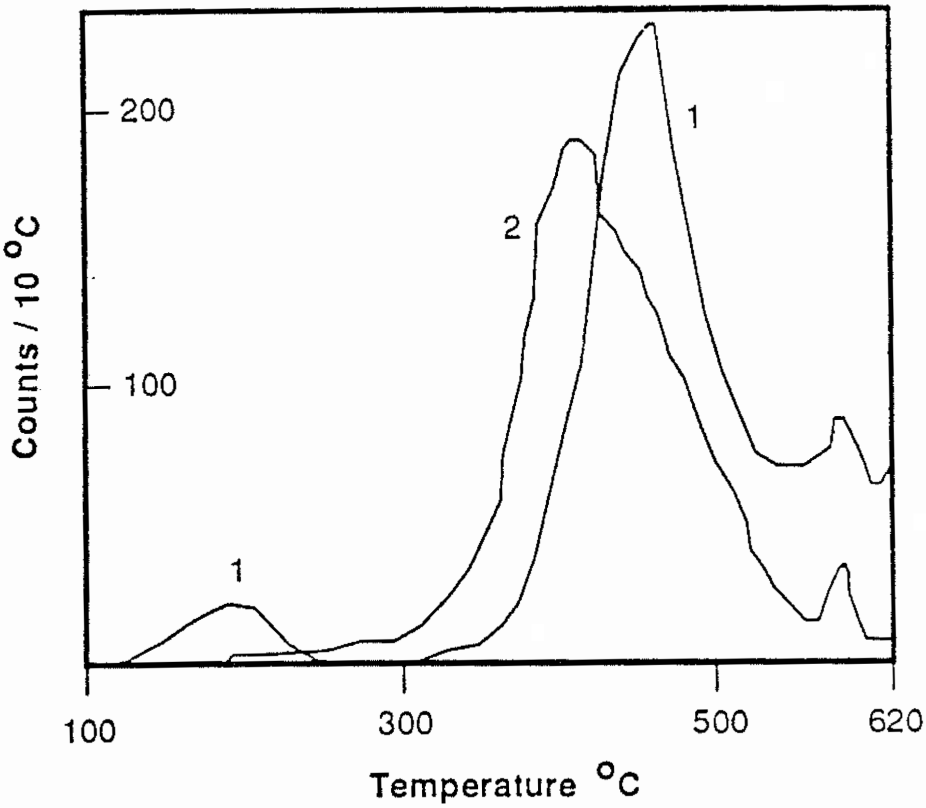

Figure 4. Temperature difference of 40°C between vein quartz (1) and adjacent silicification (2) at the Northumberland mine, Nevada.

cation material responds almost as well as the vein quartz and the temperature of both samples is the same, indicating that, in this area, the silicification and quartz veining are part of the same event.

Opaline Silica

The method has also been applied on opaline silica, which is readily distinguished from ordinary silica and quartz. The regular close packing of equidimensional spheres of silica in opaline materials results in the presence of numerous intersticies which are of exceptionally uniform size. This regularity gives rise to particularly narrow and intense decrepitation patterns in contrast to the broader decrepitation patterns of ordinary quartz (Fig. 6). At Coober Pedy, South Australia, the term potch is used for silica which does not display the colouring of precious opal. Decrepitation offers the potential of discriminating between various types of potch. Some potch gives decrepigrams similar to precious opal and may thus have potential for opalization nearby, while other potch lacks the distinctive narrow decrepitation peak and is inferred to be of low opalisation potential. Decrepigrams of opalite from the Amalgam area, Nevada, USA, show the same sharp response as the

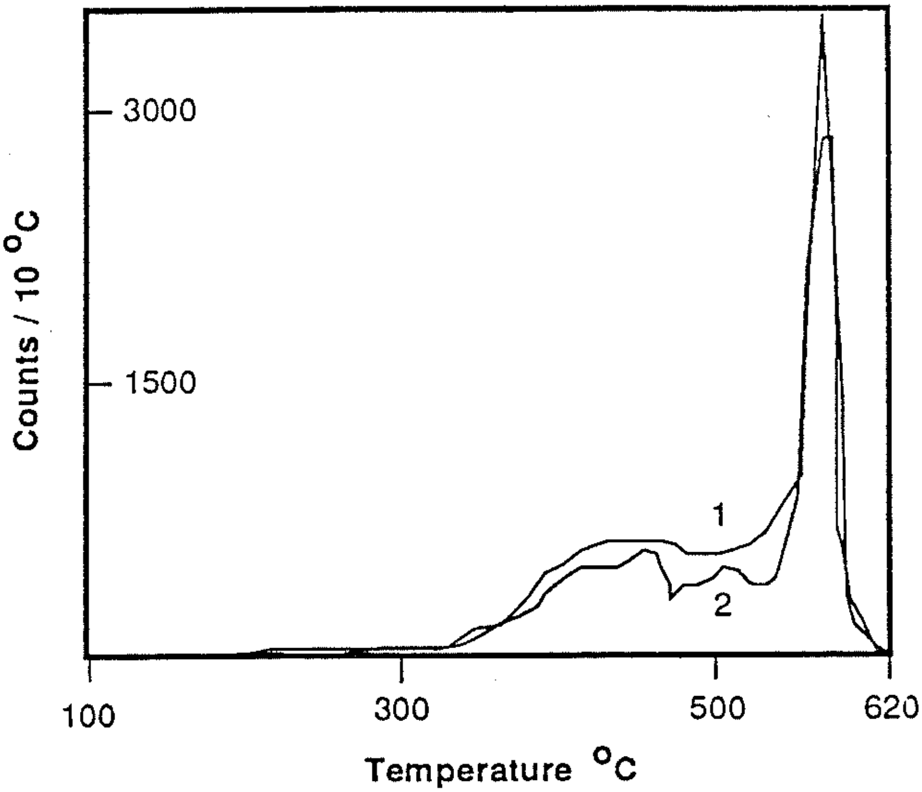

Figure 5. No temperature difference between the vein quartz (1) and adjacent silicification (2) at the Elan vein, Cassiar camp, British Columbia.

opal at Coober Pedy, despite the different geneses of these samples, the Coober Pedy opal being a secondary deposit formed during weathering, whereas the Nevada samples are from the rims of ancient thermal springs and are of hot spring origin.

Chert

The decrepitation method can also be used as an aid in distinguishing between chert and hydrothermal quartz because chert samples either do not decrepitate or give only very weak responses, whereas quartz usually gives a more definite response. At the Cosmo Howley gold mine, 150 Km south of Darwin, N. T., Australia, the gold occurs in association with a banded iron formation unit which is folded and cut by discordant quartz veins. The vein quartz can be clearly distinguished from the cherts using decrepitation (Fig. 7), although current mapping at the mine interprets both these samples to be chert. The Enterprise mine at Pine Creek, N.T. is some 100 Km south of the Cosmo Howley mine, where again both cherts and discordant quartz veins occur together, the gold being associated with the discordant quartz. Here the decrepitation data again provides a clear discrimination between the quartz and chert.

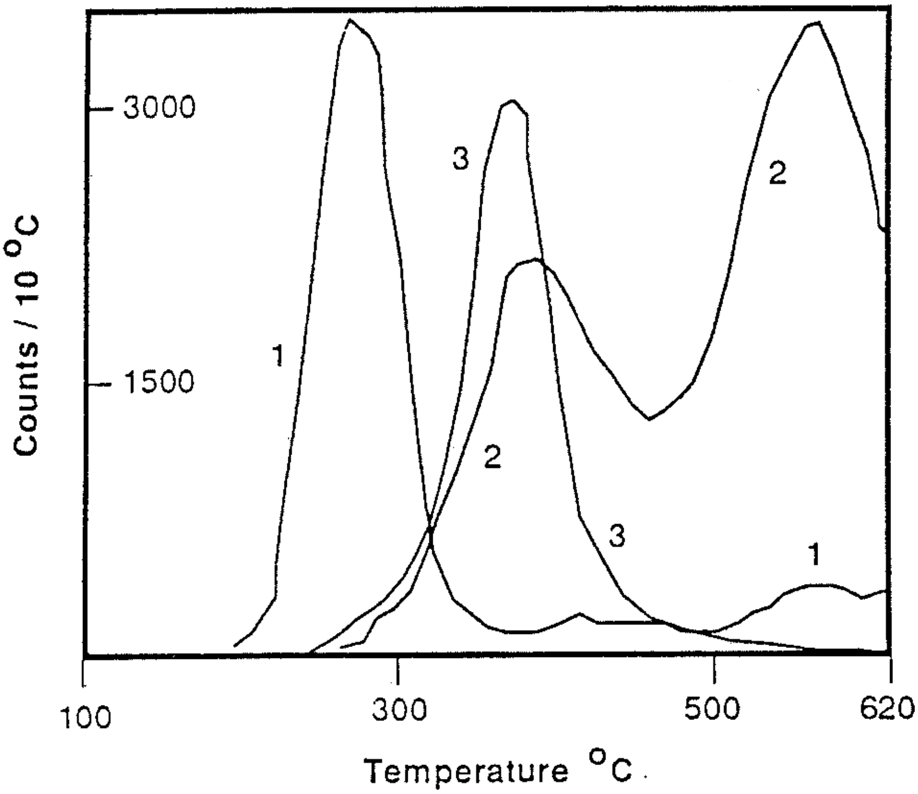

Figure 6. Contrasting response of precious opal (1) and potch (2) at Coober Pedy, South Australia and comparison with opalite (3) from Amalgam, Nevada.

The distinction between quartz and chert in areas where both occur together is frequently difficult and decrepitation provides a reliable means of discriminating between these materials.

DECREPITATION OF CARBONATE MINERALS

Carbonate samples generally give rise to very intense decrepitation responses extending to 800°C. The decrepitation temperatures are usually much higher than the expected formation temperatures, due to the ductility of the carbonates which permits considerable stretching of the fluid inclusions before decrepitation occurs. Considerable differences between samples can often be observed, such as between samples supposedly of the same carbonate horizon in two drillholes 90 m apart at the Ranger uranium mine, N.T., Australia (Fig. 8). The prominent change in decrepitation temperatures between these samples has not been explained, but implies that the samples are not from the same horizon and the method clearly has potential in exploration as an aid in discriminating between carbonate samples.

Some carbonate samples undergo thermal decomposition at temperatures below the 800°C maximum of the instrument and this is observed as a sudden cessation of

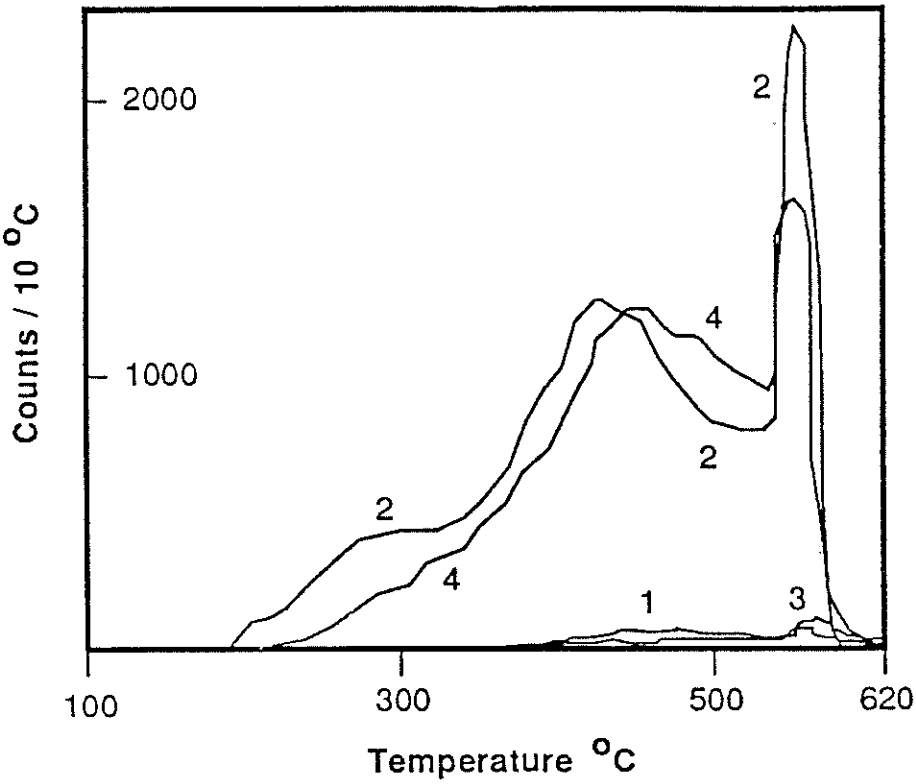

Figure 7. Lack of response in chert compared with vein quartz, Northern Territory. At the Cosmo Howley mine, chert (1) and vein quartz (2). At the Enterprise mine, chert (3) and vein quartz (4).

decrepitation when the carbonate decomposes. The temperature of decomposition can vary according to the Fe^{++} content of the carbonate (Burlinson, 1988) and observation of the decomposition temperature using decrepitation provides another means of discriminating between carbonate samples.

DECREPITATION OF MAGNETITE

At Tennant Creek, N.T., Australia, copper and gold mineralisation occurs within magnetite-haematite-chlorite pods within greywackes and siltstones of lower Proterozoic age (Large, 1975). Magnetite samples from the various pods almost always show intense decrepitation and there are marked differences between samples (Fig. 9). An attempt was made to outline decrepitation zonation within individual pods to see if this could be related to the known gold distribution, but this was unsuccessful due to excessive and unexplained decrepitation variations between similarly mineralised samples. However, it is clear that the magnetite pods are more complex than is indicated by the existing geological mapping. For comparison, a sample of magnetite from banded iron formation of similar age from Aritunga, some 500 Km south of

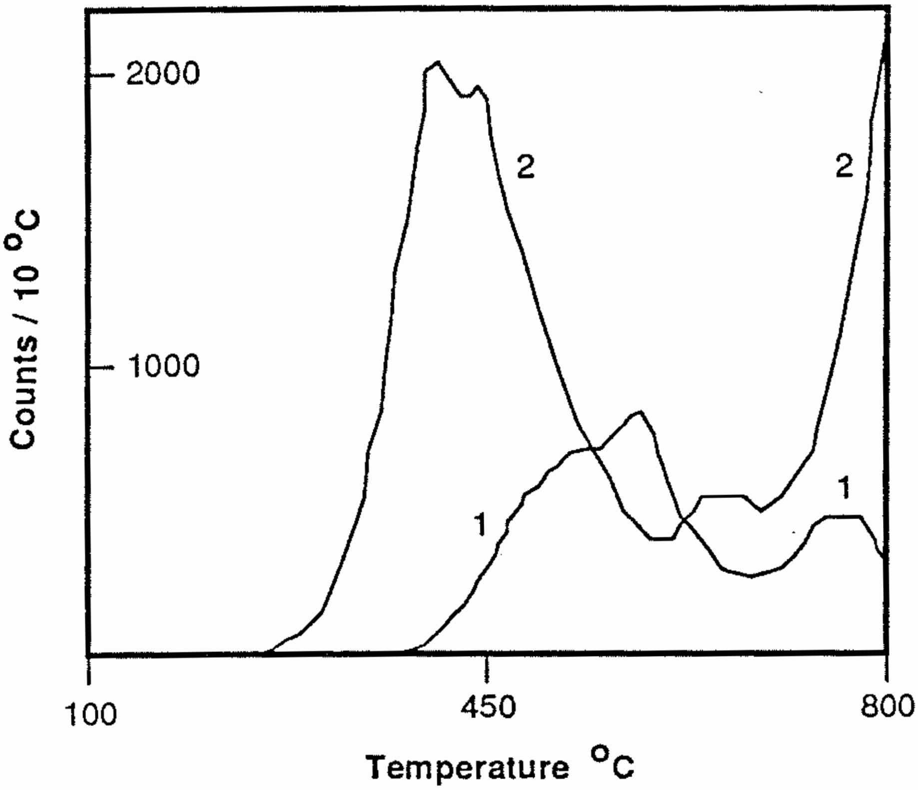

Figure 8. Carbonates from drillholes 90 m apart at the Ranger uranium mine, Northern Territory. Hole P88 (1) and hole P90 (2).

Tennant Creek was also analysed. This sample, despite having undergone a very similar metamorphic history, gave no decrepitation response at all and suggests that the magnetite bodies at Tennant Creek are not sedimentary, as proposed in some geological models, but are of hydrothermal origin. A further comparison was undertaken with the No Name mine at Iron Creek, near Salmon, Idaho, USA. This is a magnetite rich pod with minor associated Cu mineralisation but no gold, which was thought to be similar to the Tennant Creek ores. However, the magnetite from the No Name mine gave no decrepitation response and it is inferred that this deposit is not analogous to the Tennant Creek deposits.

Although we have no clear understanding of the cause of decrepitation in magnetite, the significant differences observed have been very useful in comparing different deposits and have potential as a means of detailed mapping of the internal structure of magnetite bodies such as those at Tennant Creek.

SUMMARY

Decrepitation analysis of suites of carefully chosen samples can be of particular benefit in exploration and, in some cases, the study of ore deposit genesis. The

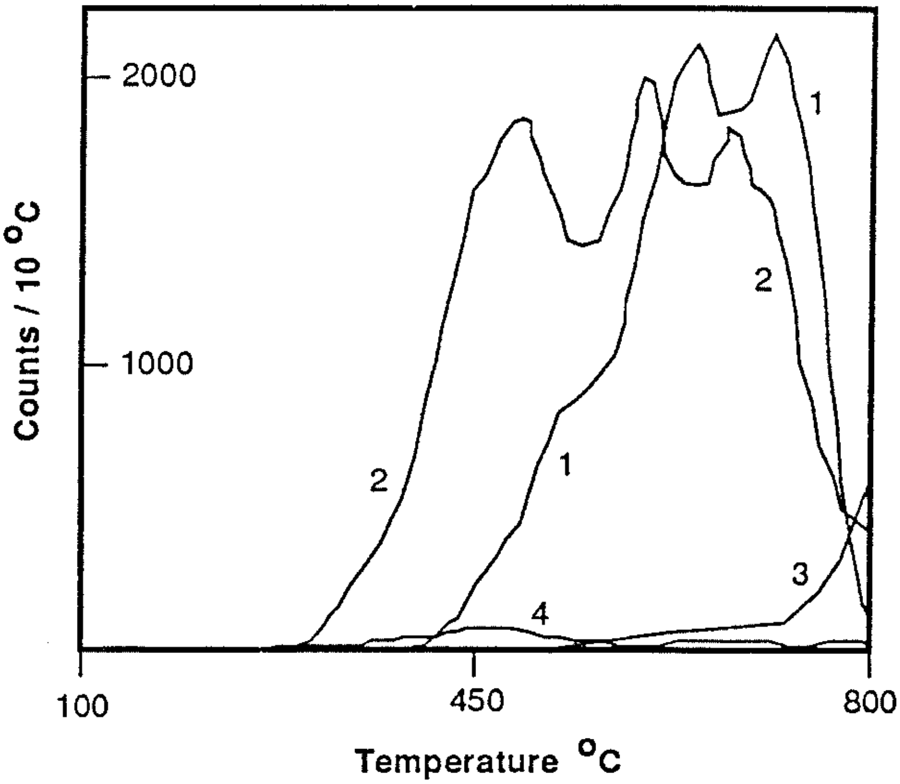

Figure 9. Variation between magnetite samples at Tennant Creek, Northern Territory (1) & (2) compared with magnetite from unmineralised banded iron formation (3) at Arltunga, N.T. and copper mineralised magnetite (4) at Iron Creek, Idaho.

method is applicable on a wide range of minerals, not only those which are transparent, and provides a statistically meaningful result from the decrepitation of many inclusions (typically 10^4 to 10^5) per sample.

The complex zoning of thermal systems, as seen at Tennant Creek and Sunshine has been observed in many deposits which were previously assumed to be simple. The recognition that such mineralised systems are zoned is surely important in exploration for and development of ore bodies, and should not be ignored as is currently the case in many mineral exploration programmes.

One problem faced by the decrepitation method is the effect of recrystallisation events which can modify the decrepitation signature subsequent to mineral deposition. In some cases this can completely destroy all the inclusions in a sample, resulting in no decrepitation response. In the past, secondary inclusions have often been thought to invalidate the decrepitation method, but they do not cause noticeable interference, as these examples demonstrate. This is thought to be because low temperature secondary inclusions do not release sufficient energy to be detectable by the instrument when they decrepitate (Hladky, 1987, personal communication).

The interpretations to date have focused on the observation of temperature differences between samples and place little emphasis on the intensity of decrepitation at the various temperatures. In this way the effects of recrystallisation, which changes the inclusion abundances but has little effect on the inclusion decrepitation temperatures, are minimised. In addition, the decrepitation intensities are difficult to interpret because of the current lack of understanding of the controls on the abundance, size and shape of fluid inclusions during mineral growth.

CONCLUSIONS

The discrimination between samples of identical appearence based on their decrepitation character has a useful part to play in the exploration of most hydrothermal and some sedimentary mineral deposits. It is particularly useful on opaque minerals which cannot be studied by microthermometric methods. The application of this data can facilitate a better understanding of the relationships between geological samples in complex areas as well as contributing towards an understanding of the geneses of deposits. Because the technique is rapid and cheap it is feasible to undertake far more extensive surveys than was previously possible and with microthermometric control of selected samples, reasonable accuracy can still be achieved.

References

BURLINSON, K.. (1984) Exploration for gold at Pine Creek and Tennant Creek, N.T. and at Halls Creek, W. A. using the fluid inclusion decrepitation technique. *The Aus. I.M.M. Conference, Darwin, 1984*. pp. 373–375.

BURLINSON, K., (1988) An Instrument for fluid inclusion decrepitometry and examples of its application. *Bull. Minéral.* v. 111, pp. 267–278

DIAKOW, L. J. and PANTELEYEV, A., (1981) Cassiar gold deposits, McDame map area. *B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1980, paper 1981–1*. pp. 55–62.

FRYKLUND, V. C. Jr., (1964) Ore deposits of the Coeur d'Alene district, Shoshone county, Idaho. *U.S. Geol. Survey Prof. Paper 445*. 103p.

HLADKY, G. and WILKINS, R. W. T., (1987) A new approach to fluid inclusion decrepitometry. Practice. *Chem. Geol.* v. 61, pp. 37–45.

LARGE, R. R., (1975) Zonation of hydrothermal minerals at the Juno mine, Tennant Creek goldfield, Central Australia. *Econ. Geol.* v. 70, pp. 1387–1413.

LEROY, J., (1979) Contribution a l'etalonnage de la pression interne des inclusions fluides lors de leur décrépitation. *Bull. Minéral.* v. 102, pp. 584–593.

MOTTER, J. W. and CHAPMAN, P. E., (1984) Northumberland gold deposit, Nye county, NV. *Symposium of the Association of Exploration Geochemists, Reno, Nevada, 1984, Field Trip Guidebook*. pp. FT2 9–26.

SCOTT, H. S., (1948) The decrepitation method applied to minerals with fluid inclusions. *Econ. Geol.* v. 44, pp. 449–454.

SMITH, F. G., (1950) A method of determining the direction of flow of hydrothermal solutions. *Econ. Geol.* v. 45, pp. 62–69.