Characterisation of mineralised quartz at the Mount Boppy gold deposit and environs, Canbelego, NSW: A reconnaissance survey

K.G. McQueen

GeoInq

Report to James Lalley
(Mining Associates)
Manuka Resources Limited

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Summary

Samples of quartz collected from the Mount Boppy gold deposit and from the nearby Mount Boppy Conglomerate were examined and analysed by the baro-acoustic decrepitation technique to ascertain if they showed similarities or differences that could be useful in distinguishing different quartz-vein sets in the gold deposit and establishing if pebbles of mineralised quartz derived from erosion of the deposit are present in the Mount Boppy Conglomerate. The results show that there are differences between the decrepitation signatures for some of the quartz veins in the deposit and features of some quartz pebbles in the conglomerate consistent with mineralised quartz. It is recommended that these preliminary results be followed up and confirmed by trace element analysis of the quartz samples.

Introduction

The Mount Boppy gold mine is an historic and currently operating gold mine located at Canbelego, 45 km east of Cobar in western NSW. Historic gold production (1901-1922) is 13.5 t of gold from approximately 1 million tonnes of mined ore. Reprocessing of old tailings and mining of remnant ore since 1976 has produced additional gold in excess of 2.5 t (McQueen. 2005). The Mount Boppy deposit appears to be a mesothermal/epithermal lode style deposit containing free gold and gold in disseminated pyrite within microcrystalline to finely crystalline quartz veins and silica alteration zones.

Quartz is the mineral most commonly associated with gold deposits and identifying mineralised quartz is an important approach in exploration for quartz hosted gold deposits. Simply assaying quartz samples for gold is not always effective in locating gold-bearing quartz due to the ‘nugget effect’ of gold (i.e. the very uneven distribution of gold concentrations). There are several techniques that can be used to identify or characterise different types of quartz, including quartz associated with gold mineralisation. These techniques include: examining the nature and composition of fluid inclusions (small bubbles of fluid) trapped in the quartz either as it formed or introduced later; analysing the trace element chemistry of the quartz; isotopic analysis, particularly using oxygen isotopes; and electron paramagnetic resonance analysis (EPR) of the quartz (e.g. Ackerson *et al*., 2015; Chen *et al*., 2019; Mavrogenes *et al*., 1995; McQueen *et al*., 2001).

Aims

A key aim of this preliminary investigation is to determine the nature of some of the mineralised quartz in different vein styles in the Mount Boppy deposit to assist with understanding and locating gold mineralisation. Another objective is to examine the nature of quartz clasts in the nearby Mount Boppy Conglomerate to test whether any of this quartz could have derived by erosion of the Mount Boppy gold deposit. The latter could establish the age of the Mount Boppy deposit relative to the conglomerate and hence their correct stratigraphic relationship, with important implications for regional exploration and discovery of further Mount Boppy style mineralisation. As the study is reconnaissance in nature it was decided to initially examine the nature of fluid inclusions in quarts samples by baro-acoustic decrepitation. This is a rapid and relatively inexpensive technique used to characterise quartz in relation to mineral exploration (e.g. Burlinson) https://www.appliedminex.com/decrep/decrep.htm

Methods

Samples for the investigation include: samples of mined remnant ore collected by the author from the mine ROM pad in May 2004 (Figure 1); samples of three different quartz vein sets collected by James Lally (Mining Associates) from the Mount Boppy open pit in October 2020; a sample of ore from the historic tube mill at the former Mount Boppy mine plant collected by Reg Pretty; and samples of quartz clasts from the Mount Boppy Conglomerate also collected by Reg Pretty in 2020. A quartz clast resembling Mount

Boppy ore was collected by Hugh Paterson from the Mount Boppy Conglomerate in 2008 (Figure 3). Sample locations are listed in Appendix 1.

Figure 1. Sample (MB3/MBO) and sectioned surface of ore quartz collected from the ROM pad at the Mount Boppy gold mine.

Figure 2. Grinding 'pebble' of Mount Boppy gold ore from tube mill at historic processing plant Mount Boppy Mine.

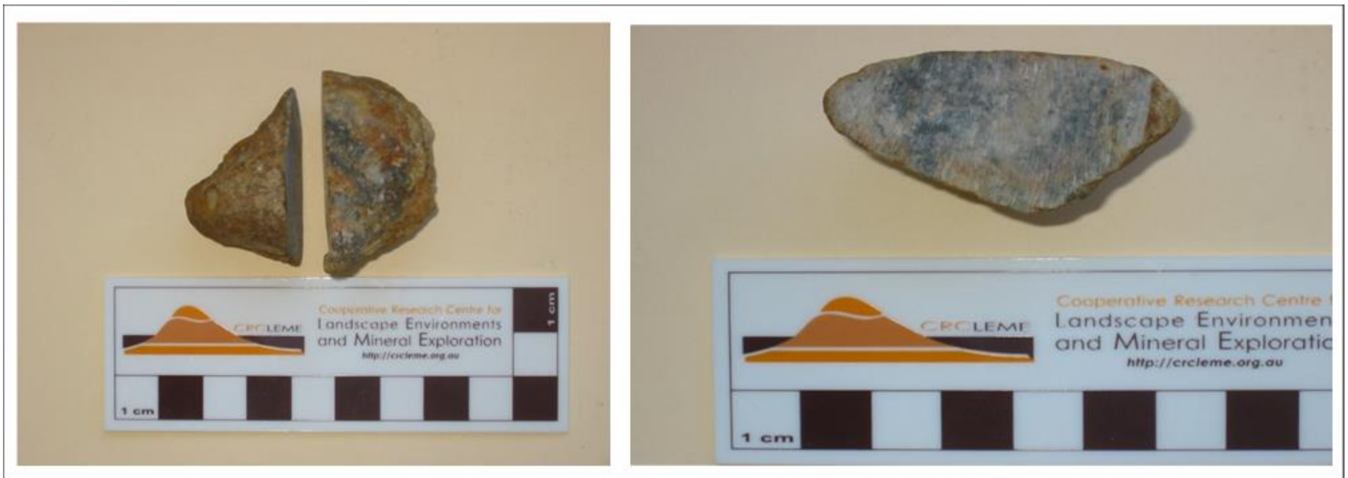


Figure 3. Pebble (clast) from the Mount Boppye Conglomerate and view of sectioned surface (sample MBC).

Prior to analysis, the various quartz samples were examined optically using a binocular microscope, described and then sectioned by diamond saw. Thin and polished sections of some ore-quartz (previously prepared for samples MB3 (MBO), MB4 and MBC) were examined by optical microscopy.

Samples were prepared for fluid inclusion baro-acoustic decrepitation analysis by selective breaking in a hydraulic tungsten-carbide press and hand picking of different quartz types. These samples were sent to Kingsley Burlinson (Burlinson Geochemical Services Pty. Ltd.) for decrepitation analysis. This analysis involved coarse crushing of the samples in a steel mortar and pestle and selection of the 200-420 µm size fraction by sieving. For each of these sub-samples either 0.5 or 1g (depending on the inclusion density) was then analysed in a BGS Model 216 decrepitometer. For quality control reproducibility the decrepitometer was routinely checked against a machine calibration standard of quartz from the Howley gold deposit NT. Decrepigram reproducibility is one histogram interval (10`C) and 10% in amplitude of the peaks.

Results

Mesoscopic descriptions of the quartz samples examined are presented in Appendix 2.

Microscopic observations

Thin section and polished section observations of mineralised and gold-bearing quartz from the Mount Boppy gold mine indicate that this material contains at least two different types of quartz and possibly multiple generations of silicification and quartz veining (Figures 4 and 5).

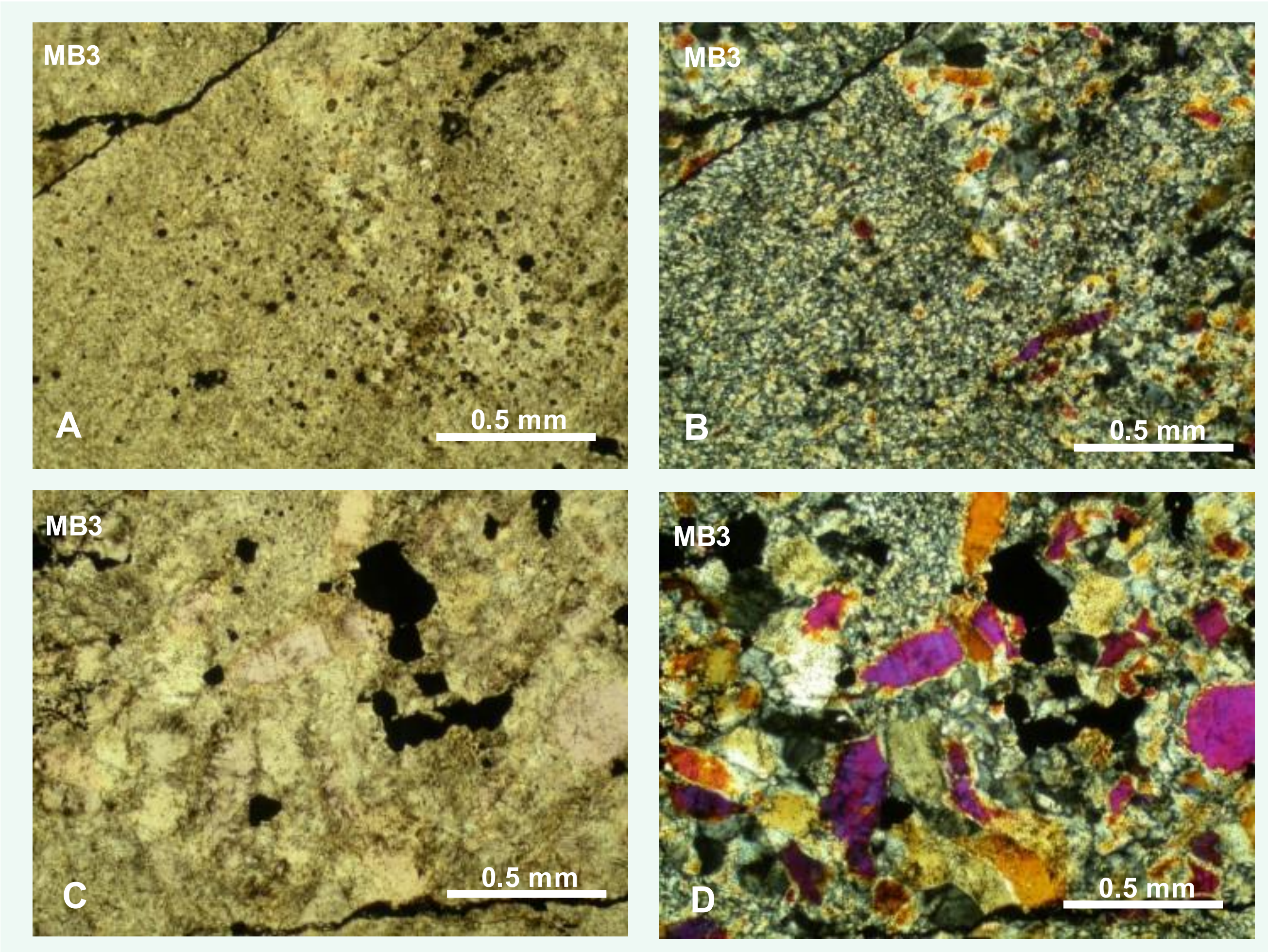
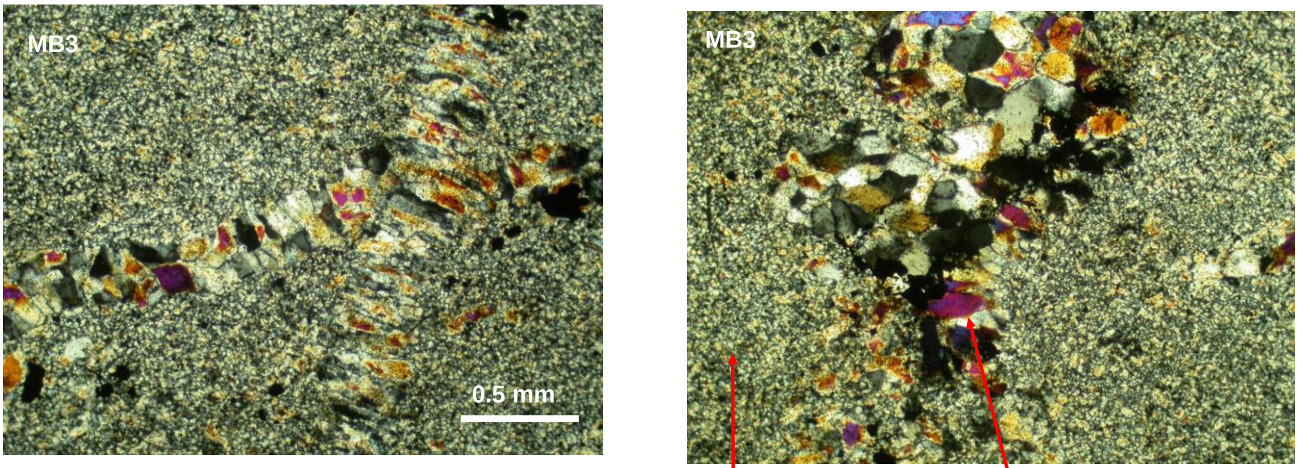


Figure 4. Thin section photomicrographs of sample MB3 (MBO). A. Microcrystalline greyish quartz with finely dispersed opaque minerals (mostly pyrite and goethite after pyrite (transmitted light). B. Same field of view as A in cross polarised light. C. Coarser grained polygonal quartz with large aggregate of pyrite (black opaque) and enclosing microcrystalline quartz (transmitted light). D. Same field of view as C in cross polarised light highlighting the coarser quartz grains.



Multiple quartz generations with late quartz veinlets in microcrystalline quartz

Microcrystalline replacement quartz

Later polygonal quartz veining

Figure 5. Thin section photomicrographs of mineralised quartz from sample MB3 showing two distinct generations of quartz, a pervasive, greyish microcrystalline quartz and later white, coarser grained quartz veinlets. (cross polarised light). The image on the left shows two cross-cutting veinlets with the near vertical veinlet being later. The alignment of quartz crystals normal to the veinlet walls suggests that these veinlets formed by extensional fracturing of the host microcrystalline quartz.

Microscopic observation of polished samples of Mount Boppy ore (from sample MB4) indicate that gold occurs as particles of free gold in both microcrystalline and later white quartz and as inclusions in pyrite and associated with pyrite in late-stage sulfide veinlets (Figure 6). In the oxidised ore, pyrite in veinlets and larger aggregates have typically been weathered to goethite leaving any gold inclusions intact. Small pyrite grains embedded and enclosed in the microcrystalline quartz have escaped weathering and oxidation (Figure 6C). Given the pyrite content of the ore it is possible that some secondary supergene gold was deposited in the upper part of the Mount Boppy deposit during extended chemical weathering during the Miocene. The later could partly account for the higher grade of near surface ore during early mining. ..

Observed gold particles ranged from 5-25 µm in diameter.

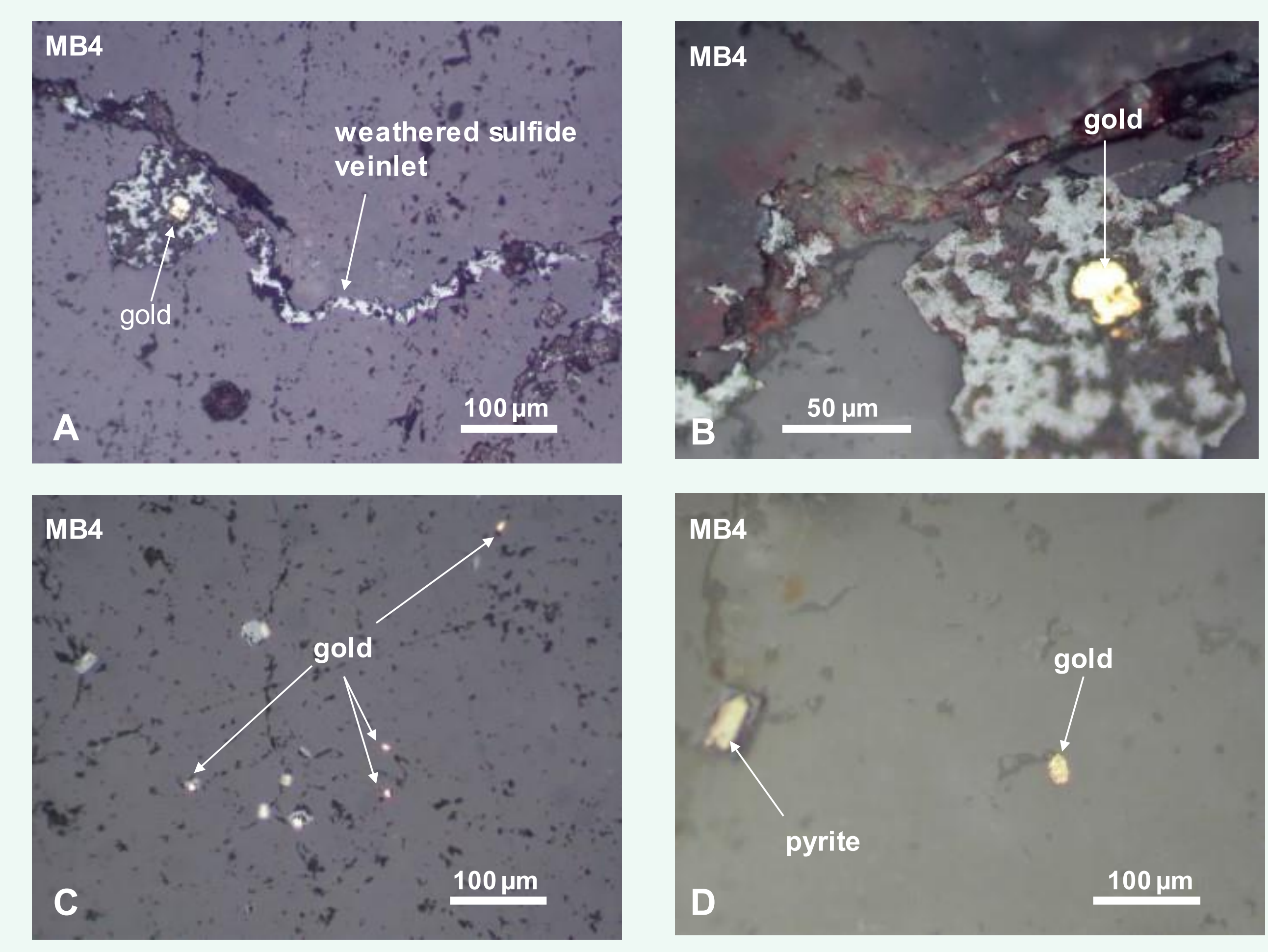


Figure 6. Polished section photomicrographs of remnant ore (Sample MB4) from the Mount Boppy gold mine.
A. Weathered sulfide veinlet in quartz, large goethite aggregate after pyrite at left contains a gold inclusion.
B. Enlarged view of gold inclusion in goethite aggregate.
C. Small grains of free gold and goethite grains after pyrite in microcrystalline quartz.
D. Grain of unweathered pyrite and free gold grain in quartz.
All images in plane polarised reflected light.

Decrepitation results

Baro-acoustic decrepitation of fluid inclusions is a rapid, inexpensive method of assessing fluid inclusions in quartz, relative to the time consuming and expensive method of visual observation of inclusion behaviour on a cooling-heating microscope stage (e.g. determining homogenisation temperature). Progressive heating of a quartz sample causes the fluid inclusions (typically containing liquid and gas phases at room temperature) to homogenise and expand. When the pressure inside an inclusion exceeds the strength of containment the inclusion bursts or decrepitates. These decrepitations can be detected by a very sensitive microphone. By progressively heating the sample and detecting the number of decrepitations at the different temperatures a plot or decrepigram can be constructed. Different types of inclusions in the quartz have their own particular temperatures of decrepitation such that decrepigrams can act like a type of 'fingerprint' of the quartz. Features of the inclusions that affect the decrepitation pattern include:

- Homogenization temperature of the inclusion, which is related to formation temperature (decrepitation usually occurs above the homogenisation of the inclusion often by up to 100º C);
- Physical size of the inclusion (very small ones may not decrepitate at all);

- Fluid composition, particularly presence of CO_2, degree of salinity;
- Host mineral strength and ductility;
- The degree of fill of the inclusion - vapour rich inclusions probably never decrepitate;
- Physical shape - angular inclusions stress at corners and decrepitate more easily.

Decripigrams for the analysed samples from this study are presented in Figures 8-13.

Discussion
Well defined and distinctive decrepitation patterns were obtained for most of the samples analysed. The samples from the Mount Boppy ore and vein systems show clear differences. For three of these samples, separate sub-samples of the grey microcrystalline quartz and later generation of white quartz were analysed. It was not possible to obtain complete separation of the white quartz veinlets from the surrounding microcrystalline quartz so there is some overlap between the two, but the dominant quartz type in the B sub-sample would be white quartz.

Sample K1 (bulk sample of a 30 cm wide silica-pyrite lode, Figure 11) has a relatively low abundance (density) of decrepitating inclusions which show decrepitation gradually increasing during heating to around 480º C before the pattern rises to 573º C where there is a peak in decrepitation facilitated by the alpha/beta transition in the quartz. An assay of this sample indicated 41.6 g/t gold (J. Lally pers. com.)

Sample K2 (from a broad zone of silicification, pyritization, brecciation, Figure 8) has a relatively high abundance of decrepitating inclusions and both the A and B sub-samples have a similar decrepitation pattern of a relatively rapid increase in decrepitation from 350º C to around 420º C, then a slightly decreased rate to around 480º C. The white quartz (B sub-sample) has lower decrease in decrepitation frequency after 480º C, before the pattern rises to the peak around 573º C related to the alpha/beta quartz transition. An assay of this sample indicated 6.6 g/t Au (J. Lally pers. com.).

Sample K3 (from 20 cm wide cherty grey quartz-pyrite vein, Figure 9) has a very different decrepitation pattern and the A and B sub-samples although broadly similar show some differences. The abundance of decrepitating inclusions is similar to that of K1 and much lower than K2. The key feature is a marked increase in decrepitation to around 300º C, particularly in the white quartz (B sub-sample). This feature is indicative of CO_2 rich fluid inclusions and the pattern suggests these are very abundant, particularly in the later generation white quartz veinlets. The B sub-sample shows a progressive increase in decrepitation with some changes in rate to around 510º C and then a decrease. The decrepigram for the A sub-sample (microcrystalline quartz) shows a sharp peak around 470º C which may relate to the abrupt oxidation of contained sulfides (pyrite) at this temperature. Sample K3 is particularly interesting as it indicates the presence of CO_2 rich fluids at Mount Boppy during development of the deposit. Such fluids are commonly associated with gold mineralisation. An example of a decrepigram for quartz associated with gold mineralisation is shown in Figure 7. This quartz contains a modest number of CO_2 rich fluid inclusions typical of many mesothermal gold mineralising fluids. The rising decrepitation pattern up to around 300° C reflects these CO_2 rich inclusions.

Sample MBO (MB3) (ore from the ROM pad, Figures 12 and 13) was separated into A and B fractions. The abundance of decrepitating inclusions is similar to that of K1 and K3. The decrepigrams for both quartz sub-samples show a pattern of progressive increase in decrepitation between 370º and 490 ºC then a decreasing rate to around 560º C, similar to that shown by samples K1 and K2. The decrpigram for sub-sample B (white quartz separate) shows a sharp, prominent peak at 470º C, probably related to sulfide oxidation in the sample (similar to K3).

Sample K4 (ore sample from tube mill, Figure 11) has a very low abundance of decrepitating inclusions, to the point where the decrepitation pattern is not useable. It might be worth re-running this sample with a large sample size to increase the number of recorded decrepitations. The reason for such a low abundance of decrepitating inclusions could be related to the history of intense percussive shocking of the quartz during milling.

Sample MBC (pebble from Mount Boppy Conglomerate with similar appearance to Mount Boppy ore, Figure 11) has a low abundance of decrepitating inclusions. The decrepigram shows a pattern of progressive increase in decrepitation from around 350º to 490º C, very similar to that exhibited by K2 and K1. However, this pattern alone is not sufficiently definitive to prove that the clast is of Mount Boppy ore quartz.

Samples K5, K7 and K8 (quartz pebbles from the Mount Boppy Conglomerate, Figure 10) show a very high abundance of decrepitating inclusions, with progressively increasing decrepitation between 400º and 520º C. This is generally a different pattern to that of the quartz from the Mount Boppy gold deposit. These samples are probably derived from high temperature metamorphic vein quartz from basement rocks.

Sample K6 (quartz pebble from the Mount Boppy Conglomerate, Figure 10) has a very high abundance of decrepitating inclusions. The decrepitation pattern shows a peak around 300º C, indicating the presence of CO_2 rich inclusions, then progressively increasing decrepitation from 380º to 480º C (similar to samples K1 and K2). This is an interesting sample as the decrepitation results indicate the presence of CO_2 rich fluid inclusions and suggesting the sample is derived from mineralised quartz deposited from CO_2 bearing fluids.

The key discriminating features apparent in the decrepitation patterns of the mineralised quartz from the Mount Boppy deposit are:

- A rapid and progressive increase in decrepitation frequency in the temperature range 350º to 480ºC followed by a levelling off or decrease in rate.
- In one sample a decrepitation frequency peak at around 300 C reflecting the presence of abundant CO_2 rich fluid inclusions.
- A marked peak in decrepitation frequency at 470º C related to the sudden oxidation of contained sulfide (pyrite) inclusions.

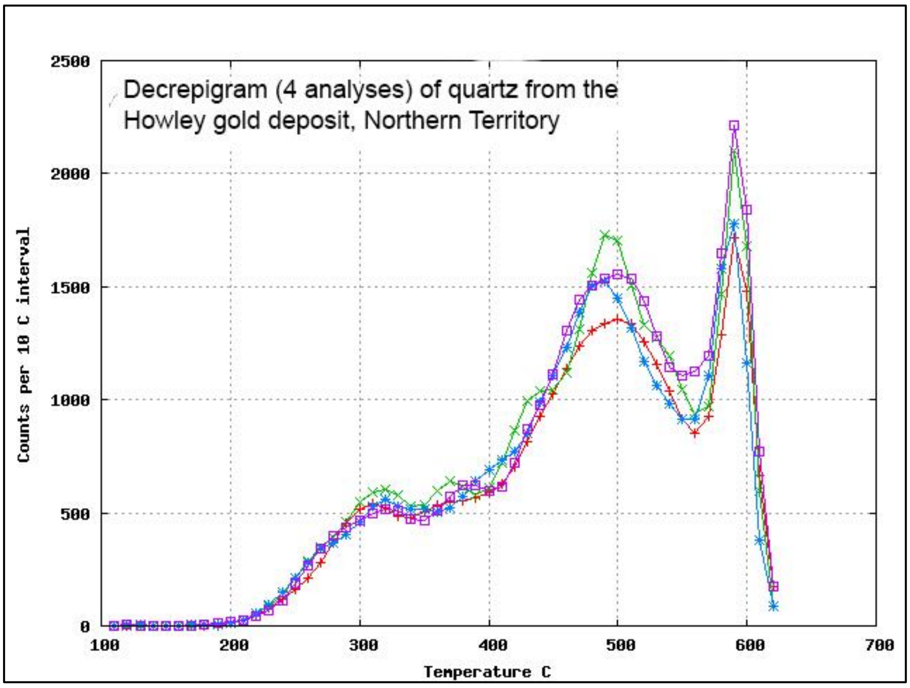


Figure 7. Decrepigrams of quartz from the Howley gold deposit, Northern Territory (standard). The pattern shows the peak around 300º C related to the presence if CO_2 rich inclusions, and a progressive increase in decrepitation to 490º C.
From Burlinson: https://www.appliedminex.com/decrep/decrep.htm

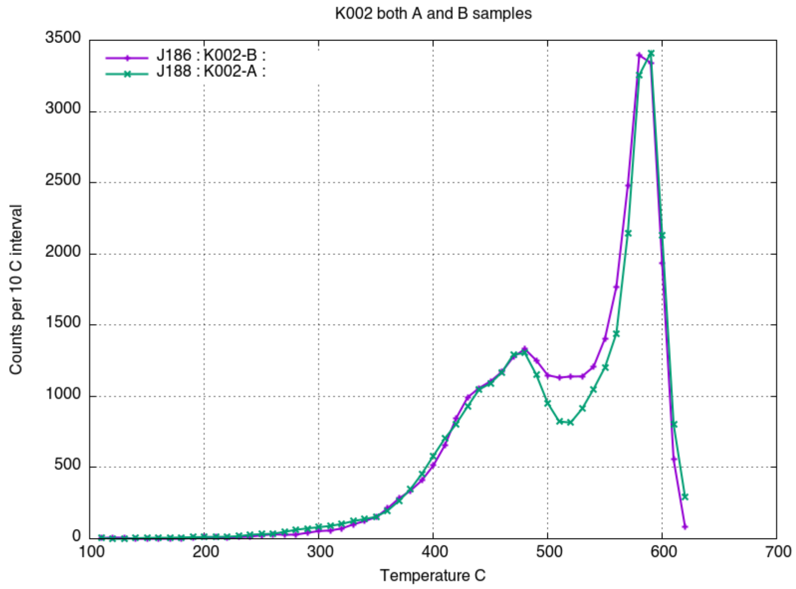


Figure 8.
Sample K002: microcrystalline grey quartz from broad silica lode.
A. bulk sample
B. white quartz separate.
Both sub-samples have a similar high density of decrepitating inclusions. Strong feature at 480°C. Major peak around 573°C corresponds to the facilitation of decrepitation by the alpha/beta quartz and is common in many patterns.

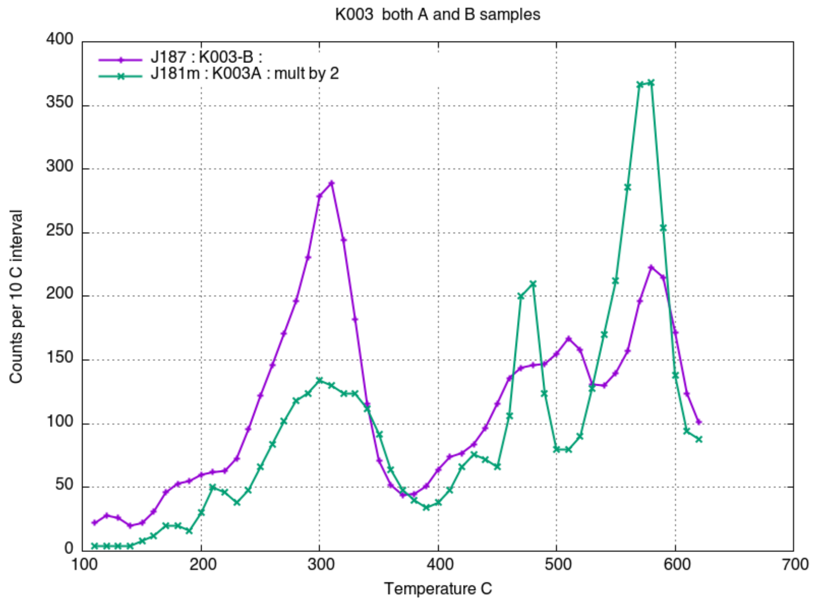


Figure 9.
Sample K003: microcrystalline grey quartz from 20 cm vein with white quartz veinlets and patches.
A. grey microcrystalline quartz.
B. white quartz separate.
Distinctive and prominent CO_2 signature at 300°C.
A. has a strong feature at 470ºC possibly related to sulfide oxidation event.

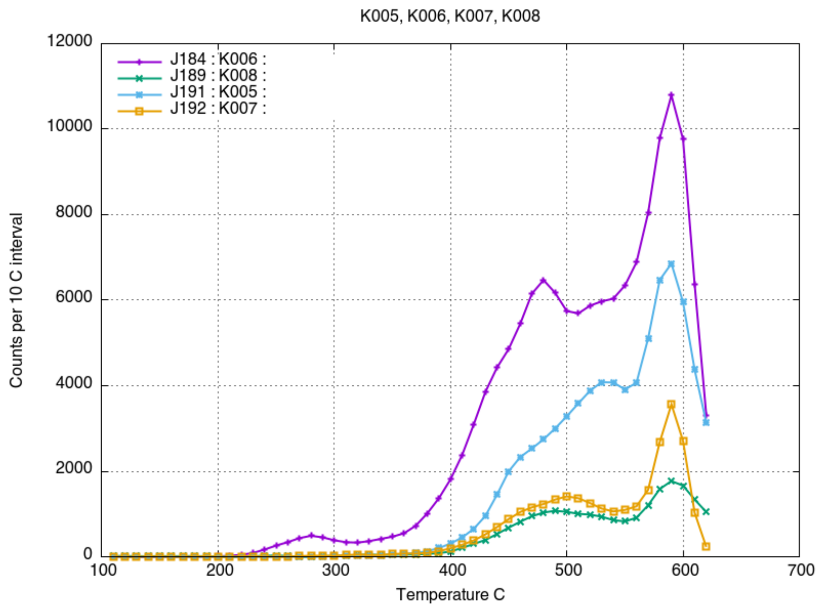


Figure 10.
Samples K005-008: Quartz clasts from Mount Boppy Conglomerate.
Sample K006 has weak CO_2 signature at 300ºC and sharp feature at 480°C similar to Mt Boppy quartz e.g. K003. Also has high density of decrepitating inclusions.

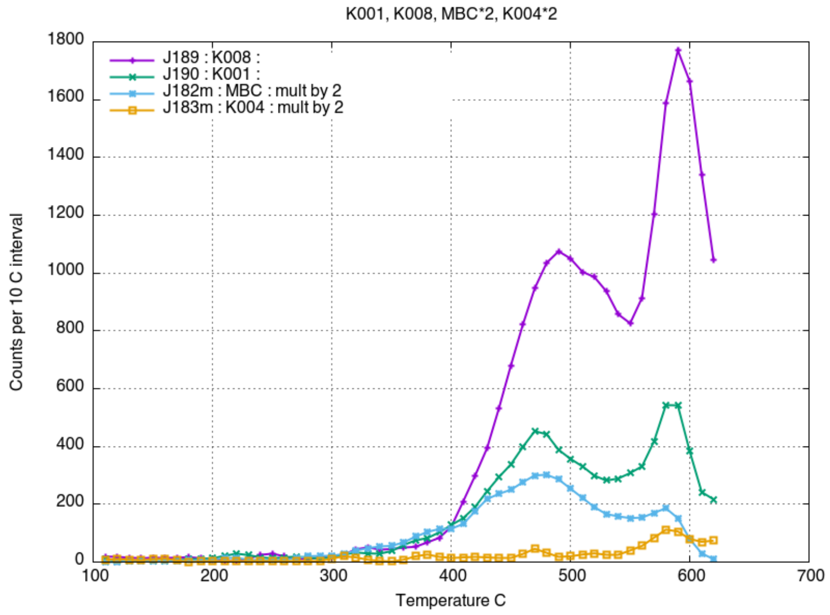


Figure 11.
Sample K001 bulk from 30 cm wide silica-pyrite lode.
Sample K004 is a pebble of ore quartz used in the tube mill for grinding ore and has a very low density of decrepitating inclusions (possibly due to history of intense percussion?).
Samples K008 and MBC are quartz clasts from the Mount Boppy Conglomerate.

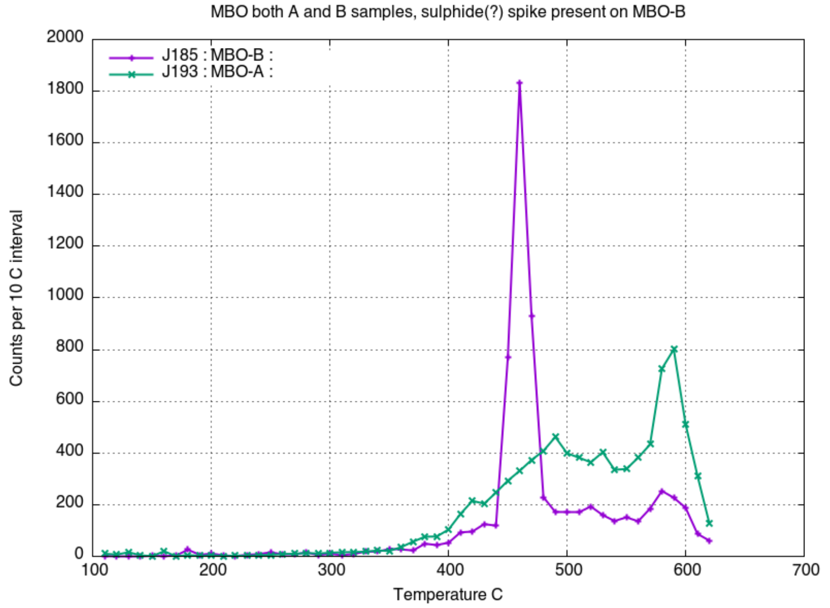


Figure 12.
Sample MBO remnant ore collected in 2004 from stockpile:
A. bulk quartz sample.
B. white quartz concentrate.
Prominent spike in the decrepigram at 470ºC for sub-sample B is probably due to sudden oxidation of contained sulfide inclusions.

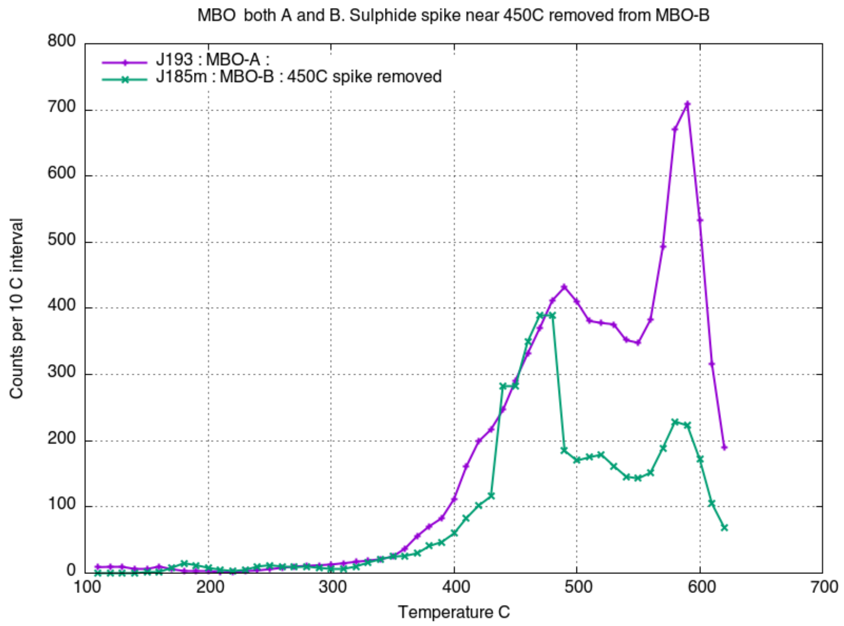


Figure 13.
Sample MBO remnant ore collected in 2004 from stockpile:
A. bulk quartz sample.
B. white quartz concentrate.
Decrepigrams are shown with sulfide oxidation peak removed for sub-sample B (note change of colour code from previous plot).

Conclusions and Recommendations

- Microscopic observation and baro-acoustic decrepitation analysis of a small number of samples from the Mount Boppy gold deposit indicates the presence of at least two different types of quartz and multiple generations of silicification and quartz veining.

- Importantly this reconnaissance study has shown that it is possible to identify differences in the quartz types using the decrepitation technique and to distinguish these from non-mineralised quartz. The analysis has also identified the presence of CO_2 rich fluid inclusions, in one of the vein sets, typical of mesothermal gold mineralisation. Thus baro-acoustic decrepitation analysis is a potential method for quickly and inexpensively identifying the different types of quartz veining at the Mount Boppy mine and in the surrounding area. For example, this approach could be used to identify extensions to the Mount Boppy deposit or identify accumulations of quartz ore eroded and transported from the top of the deposit into the surrounding drainage. The Mount Boppy deposit was originally discovered by tracing blocks of gold-bearing ore back up the present drainage and there are old gravels in a channel overlying the western edge of the mine pit.

- The study has also shown that two quartz samples collected from the Mount Boppy Conglomerate have fluid inclusion decrepitation patterns suggestive of mineralised quartz, possibly derived from erosion of the Mount Boppy or similar deposit.

- It is recommended that follow-up trace element analysis of the samples be conducted to confirm the characteristics of the different quartz types. It would also be worthwhile analysing some additional quartz veins from the Mount Boppy deposit to fully test the suitability of the decrepitation technique for identifying mineralised quartz at the mine and surrounds.

References

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Appendix 1
Sample Locations
(see also Figure 14)

Sample K1: 30 cm wide silica-pyrite lode cross-cutting foliation in possible Girilambone Group pelitic rocks faulted against Baledmund Formation. Lode margin dip/dip direction 62/275. 205 RL Boppy pit, approximately 435104 mE, 6508092 mN. A gold assay of this sample indicated 41.6 g/t Au.

Sample K2: part of broad, at least 5 m wide zone of silicification, pyritization, brecciation and quartz veining within Baledmund Formation siltstone approximately 3 m west of margin of back-filled East Lode. Narrow white flat-lying extension veins overprint earlier grey cherty quartz. Lode overprints cleavage in siltstone with a dip/dip direction 87/293. 200 RL Boppy pit, south end, approx. 435134 mE, 6507908 mN. A gold assay of this sample indicated 6.6 g/t Au.

Sample K3: 20 cm wide cherty grey quartz-pyrite vein extending 2m up face in Baledmund Formation siltstone/fine sandstone. Unusually, vein orientation dip/dip direction is 77/170, cut by a small fault 77/286 and by clay-filled fractures/joints 14/323. Traces of bright green possible copper oxides on joints cutting vein. Approx. location 200RL, 435118 mE, 6507906 mN.

Sample K4: Pebble from historic tube mill. Collected at site of old processing plant near viewing platform Approx. location 435260 mE, 6508220 mN.

Sample K5: Pebble from Mount Boppy Conglomerate. Collected near access road to telecommunication tower on Mount Boppy western peak.

Sample K6: Pebble from Mount Boppy Conglomerate. Collected near access road to telecommunication tower on Mount Boppy western peak.

Sample K7: Pebble from Mount Boppy Conglomerate. Collected near access road to telecommunication tower on Mount Boppy western peak.

Sample K8: Pebble from Mount Boppy Conglomerate. Collected near access road to telecommunication tower on Mount Boppy western peak.

Sample MBC: Quartz clast from Mount Boppy Conglomerate with some resemblance to Mount Boppy ore. From near trig station Mount Bobby approx. location 431738 mE, 6510180 mN.

Sample MB3 (MBO): Sample of ore from the ROM pad collected 27 May 2004.

Sample MB4: Sample of ore from the ROM pad collected 27 May 2004.

All locations and orientations are referenced to true north, coordinates MGA zone 55, GDA94.

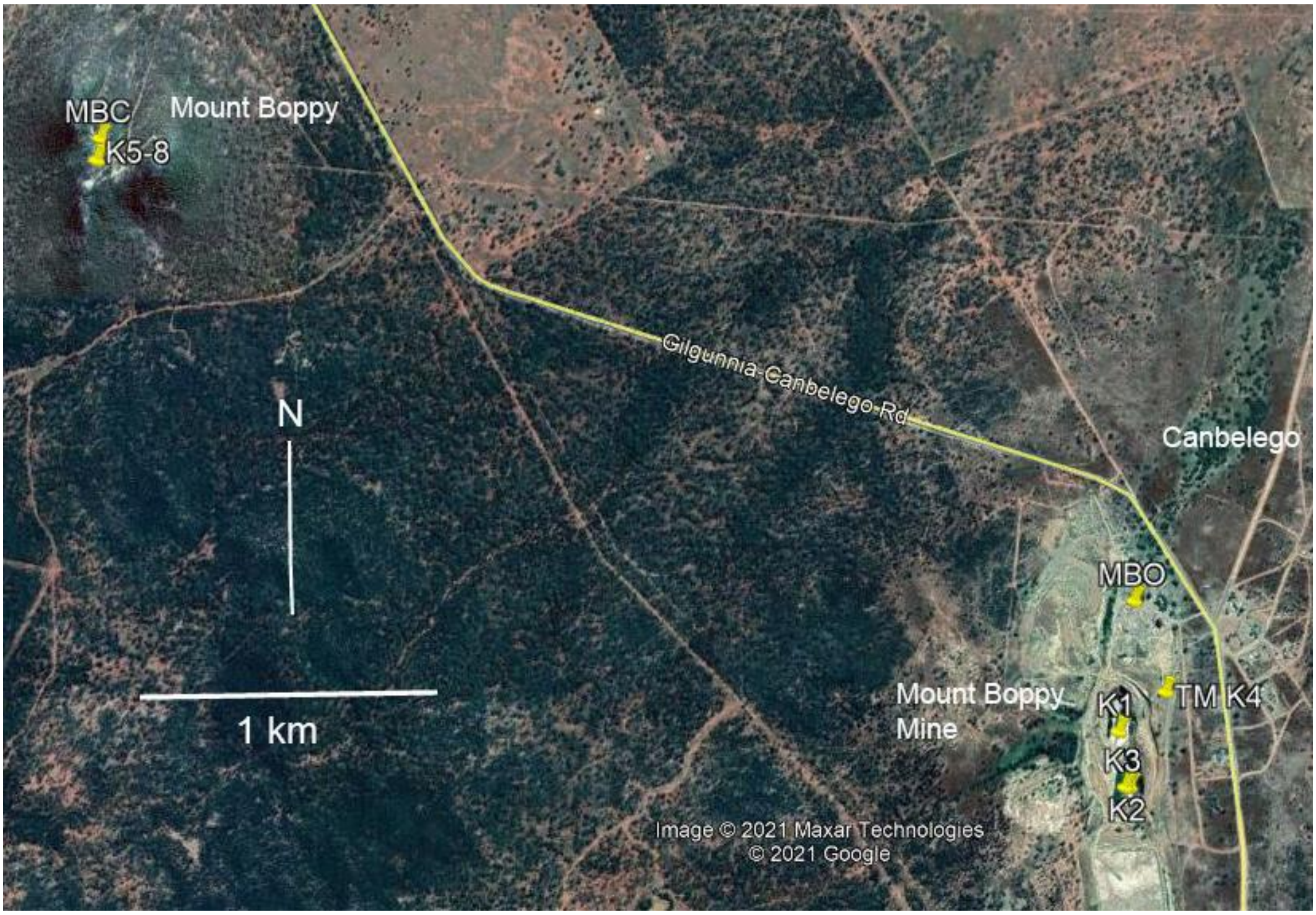

Figure 14: Locations of quartz samples collected at the Mount Boppy gold mine and from the Mount Boppy Conglomerate.

Appendix 2
Mesoscopic Sample Descriptions

Sample K1
Light grey, ‘waxy’ microcrystalline quartz with thin (0.5-1 mm wide) veinlets and irregular, scattered aggregates of white quartz. The white quartz veinlets appear to be along fractures and their crosscutting suggests this quartz is a later generation. There are some small open crystalline cavities with linings of tiny quartz crystals. The sample also has small ‘rusty’ patches and aggregates of oxidised pyrite as well as scattered, very fine pyrite grains.
Sample oxidised.

Sample K2
Light grey, ‘waxy’ microcrystalline quartz with vein-like zones of mottled white quartz. The white quartz appears to be veining or infilling around brecciated fragments of the grey microcrystalline quarts and contains some dark material, possibly chlorite.
Rusty oxidised surfaces.

Sample K3
Grey microcrystalline quartz with veinlets (1-3 mm wide) and patches of white quartz that contains abundant small (   ) cavities that appear to have formed by the oxidation and weathering out of pyrite aggregates and grains.
Sample oxidised. Very hard to cut with diamond saw.

Sample K4
Well rounded elongate pebble of historic ore from old tube mill. Dimensions 9 x 5 x 3.5 cm.
Mottled white and reddish quartz (original oxidised ore). The white quartz appears to have formed as irregular replacement or infilling around the reddish quart. The white quartz contains small cubic cavities (up to 1 mm) after original pyrite and small irregular fractures containing tiny cavities (<0.5 mm across) formed by the weathering oxidation of the original ore. There is an irregular layer of grey microcrystalline quartz on one edge containing irregular area of white and reddish quartz.

Two other similar grinding pebbles contain mixed grey and white quartz in a type of breccia relationship. Similar small cubic cavities after pyrite are present in the white quartz in these specimens.

Sample K5
Well rounded quartz pebble 4 cm in diameter. The sample has some faint brownish surface coloration and adhering material from the pebble matric/cement of the original conglomerate. The quartz is a translucent milky white variety with a mosaic pattern of micro fractures. The fractures have a filling (<0.3mm across) of a buff white quartz. On the surface of the pebble and in section there are some small cubic cavities possibly after pyrite.

Sample K6
Angular to subrounded quartz pebble 3 x 3 x 2.5 cm. The quartz is whitish grey and slightly translucent. On the outer and a broken surface, the quartz appears granular crystalline (i.e. with clearly visible grains). There is some fracturing of the quartz and small cavities on outer surfaces.

Sample K 7
A rough angular slightly rounded and partly broken white quartz pebble. Dimensions 4.5 x 3.5 x 2.5 cm. The outer surface has some brownish coating. On the sectioned surface the quartz is milk white, slightly translucent, with some invasive mottled vein-like areas of a more pinkish quartz. There is a brownish lined

cavity (ca. 1 mm in size) at one point in this pinkish quartz. Close to one edge of the pebble there is a fracture which appears to separate two different types of quartz. This fracture contains minute cavities.

Sample K8
Angular to sub-rounded, milk white quartz pebble. Dimensions 4.5 x 3.5 x 2.5 cm. The pebble shows one broken edge. On the sectioned surface the quartz appears mottled with a slightly more greyish quartz irregularly veining the milky quartz, which is slightly translucent. There is some fracturing of the quartz with associated minor cavities.

Sample MBC
Sub-rounded pebble composed of mottled greyish and white quartz (see Figure 3). Dimensions 6 x 5 x 3 cm, The outer surface of the pebble has a reddish brown oxidised coating.

Sample MB3 (MBO)
Broken block of remnant ore composed of grey, ‘cherty’ microcrystalline quartz with white quartz veinlets and irregular mottling (see Figure 1). There are some cubic and elongate, brownish cavities after weathered and oxidised sulfide grains and vein-like aggregates (up to 1 cm long.).

Sample MB4
See above