MINERALISATION, GREISENISATION AND KAOLINISATION
AT GOONBARROW CHINA CLAY PIT, CORNWALL, U.K.

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China Clay Pits
1. Wheal Remfry
2. Melbur
3. Treviso
4. Trethosa
5. Hendra
6. Dorothy
7. Dubbers
8. Littlejohns
9. Great Longstone
10. Longstone
11. Blackpool
12. Wheal Martyn
13. Gunheath
14. Goonbarrow
15. Rocks
16. West Carclaze
17. Carclaze Bal
18. Bodelva

Granite Types
A. Biotite-muscovite
B. Early Lithionite
C. Late Lithionite
D. Fluorite

Pegmatites
Elvans
Figure 4. Position of old mines and china clay pits in relation to the present Goonbarrow pit.
Figure 5. Cross-section showing veins in the Old Beam area

All this area intensely kaolinised
Figure 6. Cross-section showing veins on the island opposite Old Beam (now removed)

A 51m
B 72m
C 12.3m
D 4m
E 3m
F 5m

Aplite

Amethystine
Figure 7. Cross-section showing veins in Imperial Goonbarrow (western end of north face)
Figure 9. Cross-section showing veins in Imperial Goonbarrow (eastern end of north face)

All veins strike at ~43°.
Figure 10. Cross-section showing veins in Imperial Goonbarrow (south face)

A 0.5m
B 0.9m
C 0.7m
Figure 11. Cross-section showing veins on the island opposite Old Beam (south face, now removed)
Figure 12. Cross-section showing veins in the area near Martins Goonbarrow

Intensely Kaolinised area
Figure 13. Equal area projection of the poles to the veins at Goonbarrow.

All quartz/tourmaline veins.

Imperial-North face

Imperial-South face

Island facing south

Near Martins Goonbarrow
Figure 14. Equal area projection of the poles to the veins at Goonbarrow.

All quartz/tourmaline veins unless otherwise stated.

Old Beam

Opposite Old Beam

Island facing south (amethyst veins)

Multimineral veins
The St. Austell granite showing elvan localities.

Key
- Pegmatite
- Elvan
- Approximate lower level of pit
- Sample localities

0 50 100 150 metres
Figure 16. The China Clay refining process.

Samples from points A and B were used in the K/Ar age study

A = Hydroclone residue

B = No. 2 underflow

(Reproduced by kind permission of ECLP)
Figure 17. The overall sequence of geological events at Goonbarrow.

- Rb/Sr intrusion age: ~309 my.
- K/Ar cooling age: ~270 my.
- Temperature (°C):
  - ~700
  - ~300

Events include:
- Biotite muscovite granite
- Pegmatite
- Lithomixte granite
- Mineralisation
- Elvan intrusion
- Recrystallised elvan
- Mineralisation
- Kaolinisation

Time:
- 309 my.
- 270 my.
Figure 18. Necking down of an inclusion with time from its original state.

The resultant necked inclusions have varying vapour/liquid ratios which would produce erroneous filling temperatures. Only some of the necked inclusions may contain daughters. (adapted from Roedder, 1967)

\[ a = \text{NaCl}, \quad b = \text{KCl}. \]
Figure 19. An example of a CO\textsubscript{2} inclusion.

![Diagram](image)

\(v\) = vapour (a mixture of water and CO\textsubscript{2}

\(lw\) = liquid water solution

\(lc\) = liquid CO\textsubscript{2}

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Figure 20. A "Boiling" assemblage

Vapour rich and liquid rich phases have been trapped simultaneously. Inclusions A will homogenise into the liquid phase and inclusions B into the vapour phase.

![Diagram](image)

\(v\) = vapour

\(l\) = liquid
Figure 21. The vertical relationships of the ore-mineral zones in south-west England (after Edmonds et al., 1975)

<table>
<thead>
<tr>
<th>Zone (Hosking)</th>
<th>Approx. temp. of formation (°C)</th>
<th>Range and distribution of elements of economic importance</th>
<th>Major ore minerals</th>
<th>Approx. thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&amp;7</td>
<td>50-200</td>
<td>Fe, Sb</td>
<td>Hematite, Siderite, Jamesonite, Stibnite, Bournonite, Tetrahedrite.</td>
<td>400</td>
</tr>
<tr>
<td>5b</td>
<td>200-300</td>
<td>Ag, Pb, Zn</td>
<td>Argentite, Galena, Sphalerite</td>
<td>200</td>
</tr>
<tr>
<td>5a</td>
<td>200-300</td>
<td>U, Ni, Co</td>
<td>Pitchblende, Niccolite, Smaltite, Cobaltite</td>
<td>1800</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>Chalcopyrite, Arsenopyrite, Sphalerite, Pyrite, Wolframite, Scheelite.</td>
<td>2500</td>
</tr>
<tr>
<td>3</td>
<td>300-500</td>
<td>Cu</td>
<td>Chalcopyrite, Arsenopyrite, Wolframite, Scheelite, Cassiterite.</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>As</td>
<td>Cassiterite, Wolframite, Scheelite, Arsenopyrite.</td>
<td>2500</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Sn, W</td>
<td>Cassiterite, Specularite, Molybdenite.</td>
<td>2500</td>
</tr>
</tbody>
</table>
Figure 22.
Histogram of fluid inclusion filling temperatures from Goonbarrow.
Figure 23. Histogram of salinities of fluid inclusions from Goonbarrow.

Salinity (wt. % NaCl equivalent)
Figure 24. Graphical plot of filling temperature against salinity for inclusions in Goonbarrow vein samples.

Key to vein samples:
- 62
- 73
- 76
- 123
- GB2
- GB9

Tf - Filling Temperature (°C)
Salinity [% NaCl]
Figure 25. Boiling point curves for 10, 25, 40 wt% NaCl.
(Based on and extrapolated from Haas, 1971)
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Figure 27. \( \log_e(\text{specific volume}) \) against temperature for pure water at various pressures (data from Burnham et al. 1969).

\[
\begin{align*}
\log_e(\text{specific volume}) &
\begin{array}{c}
\text{Temperature (°C)} \\
300 & 400 & 500 & 600
\end{array} \\
200 \text{ Bars} &
\begin{array}{c}
2.5 \\
2.0
\end{array} \\
300 \text{ Bars} &
\begin{array}{c}
2.5 \\
2.0
\end{array} \\
400 \text{ Bars} &
\begin{array}{c}
2.5 \\
2.0
\end{array} \\
450 \text{ Bars (extrapolated)} &
\begin{array}{c}
2.5 \\
2.0
\end{array} \\
500 \text{ Bars} &
\begin{array}{c}
2.5 \\
2.0
\end{array}
\end{align*}
\]

\( \alpha \) (coefficient of expansivity of water) at 450°C, 450 Bars was calculated from the slope of the tangent at this point.
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Accelerating voltage = 40 Kv

Accelerating voltage = 10 Kv
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Figure 32. X-ray spectra obtained from two daughter minerals within a fluid inclusion from a quartz-tourmaline vein (sample no. 152v)

Daughter mineral C (see plate 89)

Daughter mineral F (see plate 89)
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- Kaolinite
- Sericite
- Kaolinite sericite
- Muscovite
- Biotite
- Whole Rock
- Water

† For explanation see text.
Figure 34. Plot of $\delta D$ vs $\delta^{18}O$ for calculated isotopic composition of the waters that would be in equilibrium with the unaltered granites at magmatic temperatures, and the alteration minerals at the stated temperatures (adapted from Sheppard, 1977).

Note: waters in equilibrium with alteration micas calculated using fractionation curve for hydrogen of (a) Friedman and O'Neil, 1977 (b) Taylor, 1974.

A = Alteration micas. B = Primary magmatic water. C = Cornubian magmatic waters.
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Calculated waters in equilibrium with greisen muscovites.
Calculated waters in equilibrium with vein quartz.

Goonbarrow quartz veins ($\delta^{18}$O quartz, $\delta^1$D inclusion fluid)

6D only inclusion fluids from other vein quartz
Water in equilibrium with Geevor kaolinite ($^\circ$C)
Geevor kaolinite
Water in equilibrium with kaolinite SPS ($^\circ$C)
Cornish kaolinites (including two from Goonbarrow)

Present meteoric waters
SMOW
Goonbarrow greisen muscovites (assumed $\delta^{18}$O)
Primary Cornubian magmatic water
Cornubian magmatic water

$\delta^1$D(‰)

$\delta^{18}$O(‰)
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(b) Magmatic water (V) mixing with sea water (S).

(c) Magmatic water (V) mixing with derived sea water (DS).
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(a) Hydrogen fractionation factor is positive at $T > 221^\circ C$

Composition of liquid and vapour produced on boiling.

(b) Hydrogen fractionation factor is negative at $T > 221^\circ C$

Composition of liquid and vapour produced on boiling.

(c) Hydrogen fractionation factor is negative at $T > 221^\circ C$

Composition of liquid and vapour, on condensation of extracted vapour produced on boiling.

O Initial starting composition.
Figure 41. Overall model to explain the observed isotopic compositions of vein quartz, greisen muscovites and kaolinites from Goonbarrow.

\[ \delta D(\%o) \]

- Liquid fraction, produced by intermittent boiling, trapped in inclusions within vein quartz.

- Derived magmatic water (DM) boils by throttling and irreversible adiabatic expansion at 450°C.

- Initial liquid fraction alters granite wallrock to form greisen muscovites.

- Water in equilibrium with kaolinite SPS.

- Overall Cornish kaolinites.

- Vapour fraction kaolinises granite feldspars. This condensed water is in equilibrium with Cornish kaolinites formed at \(-125°C\).

- Initial starting composition of cornubian magmatic water (M) moves to composition DM by mixing with meteoric water.

- Cornish kaolinites (including two from Goonbarrow).
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Calibration line

Read temperature (°C)

Temperature determined May 1976

Temperature determined May 1978
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Plate 32. A sample of the SFG-pegmatite contact. Feldspars can be seen growing in cross-sectional area and branching towards the SFG. The protruding feldspars are surrounded and overgrown by a fine grained aplitic matrix which blends gradationally into the SFG. Two thin tourmaline rich bands can be seen within the aplitite, one of which grows around the protruding feldspars.
Plate 33. Thin section of the Goonbarrow elvan, X200, crossed nicols. A large quartz megacryst is surrounded by a fine grained matrix of sericite-quartz. A small flake of relic primary muscovite is seen to the right hand corner of the quartz megacryst.

Plate 34. Thin section of the Goonbarrow elvan, X80, crossed nicols. Quartz megacrysts are surrounded by a fine grained matrix of sericite-quartz. A tourmaline "star" if seen at the upper left of the photograph.
Plate 35. Thin section of the Goonbarrow elvan, X800, crossed nicols. Fine grained kaolinite/sericite intergrowth pseudomorphing feldspar in a quartz/muscovite matrix.
Plate 36. The Goonbarrow elvan exposed at the south face of Imperial Goonbarrow. The quartz/tourmaline vein swarm surrounded by kaolinised granite is crosscut by the elvan.
Plate 37. Apophysis of the Goonbarrow elvan showing laminated flow banding (Location P).

Plate 38. The western end of Old Peam looking towards North Goonbarrow. Unkaolinised granite is exposed on the extreme left cut by a few small veins. As the vein swarm on the right if approached the granite becomes progressively more kaolinised.
Plate 39. The western end of Old Beam, the steep walls of the old North Goonbarrow pit in the background. Grey unkaolinised granite is clearly seen at the extreme right and left of the photograph crosscut by a few quartz/tourmaline veins. The large vein swarms in the centre are surrounded by kaolinised granite clearly discerned by its whiteness.

Plate 40. A vein swarm exposed in the area near Martins Goonbarrow. The granite is extremely kaolinised (see cross-section in Figure 12).
Plate 41. A sample of a cassiterite bearing vein from Old Beam. Tourmaline is found in the centre of the vein surrounded on either side by zoned cassiterite. A band of fine grained white topaz is found at the interface between the cassiterite and greisen. The scale is in one centimetre blocks.

Plate 42. Thin section of a cassiterite bearing vein (G00 76/55 from Old Beam, 100X, crossed nicols. The cassiterite on the left is zoned. A matrix of intergrown quartz and tourmaline is shown on the right.
Plate 43. A typical cassiterite bearing lode in the Old Beam area, with the old mine workings in the background. A white topaz rich greisen in the foreground alters gradationally to a "normal" greisen in the background. Cassiterite was found associated with the topaz greisen.

Plate 44. Close up of the topaz rich greisen shown in plate 43. Cassiterite is found throughout the greisen.
Plate 45. Close up of the "normal" greisen shown in plate 43. Cassiterite was not found associated with this greisen.

Plate 46. Old Seam. The stockwork of veins, many tin and tungsten bearing, is surrounded by intensely kaolinised granite. The remains of the old nineteenth century mine workings can be clearly seen. At the top of the photograph is the conveyor used to transport coarse grained quartz and unkaolinised granite, previously separated by a rotary classifier, to the top of the waste heap. A water monitor can be seen in the foreground, used to wash out the china clay.
Plate 47. Thin section of "pale mica" granite, X200, crossed nicols. The plagioclase in the centre of the field has been preferentially altered in the core. This is the first stage of kaolinisation.

Plate 48. Thin section of kaolinised "pale mica" granite, X200, crossed nicols. Highly corroded quartz megacrysts and relic muscovite are surrounded by a fine grained kaolinite/sericite matrix.
Plate 49. Thin section of kaolinised "pale mica" granite, X800, crossed nicols. Highly corroded quartz megacrysts and relic muscovite are surrounded by a fine grained kaolinised/sericite matrix.
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Plate 50 A typical two phase fluid inclusion. A trail of secondary inclusions lies above it. (Sample No. 147V).

Plate 51 A plane of secondary two phase inclusions. (Sample No. 10V).

Plate 52 A "necked" inclusion probably produced by tectonic movement or reheating. On heating an erroneous filling temperature would almost certainly be obtained. (Sample No. 187).

Plate 53 An inclusion formed before the process of "necking" has been completed. Had the process gone to completion it is probably that the majority of the water vapour would have been trapped in the upper right hand part of the inclusion and the daughter crystals on the lower left. Subsequent heating/freezing studies would have produced very anomalous results. (Sample No. 32V).
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10µm.

Examples of vapour or "boiling" inclusions. Unlike normal fluid inclusions these will homogenise into the vapour phase. When occurring in close proximity to normal fluid inclusions (Plate 55) this suggests that both vapour rich and fluid rich phases were trapped simultaneously from a boiling solution and that the aqueous fluid lies on the critical curve for that particular solution. If the salinity and temperature of the fluid is known from other inclusion evidence then the pressure may be easily obtained from the appropriate critical curve.

Plate 54 Sample No. 167
Plate 55 Sample No. 75V
Plate 56 Sample No. 75V
Plate 57 Sample No. 167
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Plate 58 An example of a fluid inclusion containing several rod-like daughter minerals. The vapour bubble is deformed as it has insufficient room to assume its normal spherical shape. The outline of this inclusion suggests it has been distorted since formation. (Sample No. 827).

Plate 59 Another example of a fluid inclusion containing a deformed vapour bubble and several daughter minerals including a cubic mineral - probably halite or sylvite. (Sample No. 243).

Plate 60 (plain light) and Plate 61 (crossed nicols). An irregular, deformed inclusion containing several daughters. The cubic mineral is halite or sylvite and the rod-like birefringent mineral (in plate 60b) is probably a mica viewed perpendicular to its c-axis.
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10µm.

Examples of cubic daughter minerals in fluid inclusions.

Plate 61 Sample No. 243
Plate 62 Sample No. 62V
Plate 63 Sample No. 243
Plate 64 Sample No. 632V
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Plate 65 An inclusion containing a cubic mineral - halite or sylvite. (Sample No. GB27).

Plate 66 An inclusion containing a cubic mineral and an hexagonal plate - almost certainly a mica. (Sample No. 243).

Plate 67 An inclusion containing several daughters including a cubic mineral. (Sample No. 243).

Plate 68 An inclusion containing several daughters including a cubic mineral and a rod - possibly a mica viewed perpendicular to its c-axis. (Sample No. 243).
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10 µm.

Plate 69 Two inclusions containing several daughters, some cubic. The inclusion on the right also contains a fibrous mineral (Sample No. 243).

Plate 70a (plain light) and Plate 70b (crossed nicols). A fluid inclusion containing a birefringent rod. (Sample No. 827).
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10 μm.

Plates 71a and 72a (plain light) and 71b and 72b (crossed nicols). Inclusions containing birefringent rods possibly a mica plate viewed perpendicular to the c-axis.

Plate 71 Sample No. 243
Plate 72 Sample No. 827
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Examples of inclusions containing hexagonal platelike daughters – almost certainly micas.

Plate 73 Sample No. 82V
Plate 74 Sample No. 187
Plate 75 Sample No. 82V
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10 µm.

Examples of fluid inclusions containing birefringent sub-spherical daughters.

Plates 76a and 77a - plain light and Plates 76b and 77b (crossed nicols).

Plate 76 Sample No. 62V.

Plate 77 Sample No. 137.
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10 μm.

Plate 78. An inclusion containing several sub-spherical daughters and a small vapour bubble. (Sample No. 243).

Plate 79. An inclusion containing a sub-spherical daughter. (Sample No. 143V).

Plate 80. An inclusion containing several sub-spherical daughters and another containing a deformed vapour bubble. (Sample No. 110V).

Plate 81. An inclusion containing a large blocky birefringent daughter. (Sample No. 243).
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Plates 82a (plain light) and 82b (crossed nicols). An inclusion containing a large blocky birefringent daughter.
(Sample No. 143V).

Plates 83a (plain light) and 83b (crossed nicols). An inclusion containing a birefringent fibrous mineral — rarely observed. (Sample No. 145V).
Fluid inclusions in quartz from Goonbarrow. Scale bars = 10μm.

Plates 84a (plain light) and 84b (crossed nicols). An inclusion containing a birefringent fibrous mineral. (Sample No. 143V).

Plate 85 An inclusion containing black opaque crystals. (Sample No. 10V).
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1 μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz).

a. Inclusion cavities containing cubes of halite (Sample No. 152V).

b. Close up of central inclusion in a.

c. Close up of inclusion in extreme left of a. Note small spots on halite cube which have been produced during analysis by the electron beam. Area analysed is therefore around 0.1 μm.

d. Needle-like daughter containing Al, Fe, Mn and Zn. (Sample No. 152V).

e. Platey mineral containing Si(?), Al and K. (Sample No. 152V). Identified as muscovite.

f. Amorphous daughter probably deposited from inclusion fluid during opening of inclusion (Sample No. 152V). Contains, Al, Cl, K and Na.

g. Cubic mineral containing Na and Cl (Sample No. 152V). Identified as halite.

h. Amorphous mineral containing Fe and Mn. (Sample from lensoid perlitite).
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1 μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz).

a. All crystals gave the same spectra containing Cl, Fe, Mn and S. (Sample No. 143G).

b. All crystals gave the same spectra containing Al and Na. (Sample No. 143G). Their platey habit suggests they are micaceous.

c. Platey mineral containing Al, Cl, K and Na. (Sample No. 53V).

d. Platey mineral containing Al, Cl, Fe and K. (Sample No. 53V).

e. Platey mineral containing Al, Cl, K and Na. (Sample No. 73V).

f. Crystal contains Na and Cl. Probably halite but does not have cubic morphology. (Sample No. 73V).

g. Platey hexagonal mineral containing Al, Cl and K. (Sample No. 165V).

h. Mineral probably of cubic morphology containing Cl, probably halite. (Sample No. 152V).
Scanning electron micrographs of daughter crystals in fluid inclusions cavities. Scale bars = 1 µm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz).

c. and d. Mineral contains Fe and Mn. (Sample No. 111).
e. and f. Mineral contains Fe and Mn. (Sample No. 142A).
g. Platey mineral containing Al and K. (Sample No. 142A).
h. Both crystals have identical spectra containing Cl, K and Na. (Sample No. 171IV).
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagram for easy reference.

a. Inclusion cavity containing several daughter crystals (Sample No. 152).

b. View of crystals E, C, D and F. X-ray analysis revealed the following analyses:
   - E: Fe, Mn and Zn
   - C: Al, Fe and K
   - D: No spectra peaks
   - E: K

c. Close up of crystals E and C.

d. Crystal A containing Al, S and Zn.
e. Crystal F containing Al and K.
f. Crystal C containing Cl.
g. Crystals H and I neither producing any spectral peaks.
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing two daughters (Sample No. 1527).

b. Close up of daughters A and B from a.
   1. contained Fe and K
   2. contained Fe and Mn

c. Inclusion containing a rhombohedral daughter (Sample No. 171W).

d. Close up of daughter A from c. Note ropey sides possibly produced by cleavage of crystal. Analysis indicated the presence of Fe and Mn.
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1 μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing several daughters (Sample No. 737V).
   A. contained Al and Fe
   B. contained Al, Cl and Fe, rod like.
   C. contained Cl, Fe and K, rod like.

b. Inclusion cavity containing several daughters (Sample No. 737V).
   A. contained Cl and K
   B. contained Al and Cl
   C. no spectral peaks obtained
   D. contained Cl, K and Na

c. Inclusion cavity containing two daughters (Sample No. 137V).
   A. Cubic (?) mineral containing Ca, Cl, Fe and Mn
   B. No spectral peaks obtained

d. Inclusion cavity containing three daughters (Sample No. 147V).
   A. Amorphous mineral containing Fe
   B. Platey mineral containing Al, Ca, Cl, K and S
   C. No spectral peaks obtained
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1 μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing two daughters (Sample No. 165V).
   A. Platey mineral containing Al and K
   B. Amorphous crystals containing Cl and K - probably deposited from fluid on opening the inclusion. Identified as sylvite.

b. Inclusion cavity containing several daughters (Sample No. 97V). Individual crystals were difficult to define hence several spot and raster analyses were made.
   Raster A revealed Cl, Fe, S and Zn
   Spot B, which was in the centre of raster A, revealed Fe, S and Zn.
   Spot C contained Cl, Fe, S and Zn
   Spot D contained Fe, S and Zn
   Spot E gave no spectral peaks

At least two daughters were identified, one containing Fe, S and Zn. The other Cl, Fe, S and Zn.

c. Inclusion containing three platey minerals (Sample No. 152V).
   A. contained Al and K
   B. contained Al, Cl and K
   C. contained Al and K

d. Inclusion containing two daughters (Sample No. 124V).
   A. contained Ca, Cl, Fe and Mn
   B. contained Ca(?) and Sn
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing several daughters (Sample No. 82G).

- A. contained As and Fe
- B. contained Fe
- C. contained Fe, Mn and Zn
- D. no spectral peaks obtained
- E. no spectral peaks obtained
- F. contained Fe
- G. contained Fe

b. Inclusion cavity containing two daughters (Sample No. 152V).

The daughter to the left of the platey mineral is very difficult to see in the photograph.

- A. contained Al, Fe and K
- B. contained Al and Cl

c. Inclusion cavity containing several daughters (Sample No. 82G).

- A. contained Fe, Mn and Zn
- B. contained Al and K, platey mineral
- C. no spectral peaks obtained
- D. contained Al and K
- E. no spectral peaks obtained
- F. crystals that were probably deposited from the fluid when the inclusion was opened. Contained Al, Cl, Fe, K, Mn and Zn.

d. Inclusion cavity containing two daughters (Sample No. 262).

- A. contained Al, Fe and K
- B. Flat like daughter crystal, no spectral peaks obtained.
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1 \mu m. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing several daughters (Sample No. 152V).
   - A. contained Cl, Fe and Mn
   - B. contained Al and Fe
   - C. contained Al, Cl and Fe
   - D. contained Cl, Fe and Mn
   - E. contained Cl
   - F. contained Cl, Fe and K

b. Inclusion cavity containing three daughters (Sample No. 137V).
   - A. contained Cl, Cu, Fe and Mn
   - B. no spectral peaks obtained
   - C. no spectral peaks obtained

c. Inclusion cavity containing several daughters (Sample No. 73V).
   - A. Platey mineral containing Fe and K
   - B. contained Fe and Mn

d. Inclusion cavity containing several daughters (Sample No. 53V).
   - A. Cubic mineral containing Fe and Mn
   - B. no spectral peaks obtained
   - C. no spectral peaks obtained
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1µm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing two daughters (Sample No. 152V).
b. Close up of crystal A from a. X-ray analysis identified the presence of Al and K. Its platey habit suggests that the mineral is muscovite.
c. Close up of crystal B from a. X-ray analysis identified the presence of Al and K. Its platey habit suggests the mineral is muscovite.
d. Inclusion cavity containing two daughters (Sample No. 152V).
e. Close up of crystals from d. X-ray analysis gave the following result:
   A. As, Cu, Fe and S. Identified as arsenopyrite.
   B. Cu, Fe and S. Identified as chalcopryite.
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing two daughter crystals. (Sample No. 152V).

b. Close up of crystal B. from a. X-ray analysis indicated the presence of Al and K. Its platey habit suggests the mineral is muscovite.

c. Close up of crystal A. from a. X-ray analysis indicated the presence of Fe and Mn. Its rhombohedral habit suggests the mineral is ferroan-rhodochrosite.

d. Inclusion cavity containing three daughter crystals. (Sample No. 152V).

e. Close up of crystal A. from d.

f. Close up of crystal B. from d.

X-ray analysis of crystals A, B and C gave the following results:

A. contained Al and K. Identified as muscovite.

B. contained Cl and Na. Its cubic form identifies it as halite.

C. contained Cl and Na. This bluish-like substance may have been deposited from the fluid on opening the inclusion.
Scanning electron micrographs of daughter crystals in fluid inclusion cavities. Scale bars = 1μm. All spectra contained a Si peak which may have come from the daughter or host mineral (quartz). The crystals are labelled in the diagrams for easy reference.

a. Inclusion cavity containing two daughters (Sample No. 152V).
b. Close up of crystal B from a. X-ray analysis of crystals A and B gave the following results:
   A. Al and K. Its platey habit identified the crystal as muscovite.
   B. Fe and Mn. Identified as probably ferroan-rhodochrosite.
c. Inclusion cavity containing several daughters (Sample No. 73V).
d. Close up of crystals A and B from c. X-ray analysis gave the following results:
   A. Al, Cl, Fe, K, Mn and Na.
   B. No spectral peaks obtained.
Plate 93. A large xenolith of kaolinised country rock (killas) seen lying in intensely kaolinised granite in Melbur china clay pit.
Plate A1. A portion of the high vacuum extraction line used for the determination of the argon isotopic compositions of rocks and minerals at the Institute of Geological Sciences, London. The RF heating coil can be seen operating on the middle sample furnace.
Plate A 2. The high vacuum ergon extraction line. The roughing, diffusion and ion pumps lie underneath the bench. The mass spectrometer electronics are on the right.