



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Mineral paragenesis in veins associated with gold mineralisation in Devon.

Economic Minerals & Geochemical Baseline Programme

Predictive Mineral Deposit Models for Resource Management
(ESB74900051)

Internal Report IR/02/111



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/02/111

Mineral paragenesis in veins associated with gold mineralisation in Devon.

Jon E. Bouch and John McKervey

Editor

Tom Shepherd

The National Grid and other
Ordnance Survey data are used
with the permission of the
Controller of Her Majesty's
Stationery Office.
Ordnance Survey licence number
GD 272191/1999

Key words

Epithermal gold mineralisation;
vein paragenesis; calcite; silica;
Crediton Trough; Hopes Nose.

Front cover

Cover picture details, Plane
polarised optical
photomicrograph showing
complex vein fill from Watford
BH2.

Bibliographical reference

BOUCH, J.E. AND MCKERVEY, J
.. 2002. Mineral paragenesis in
veins associated with gold
mineralisation in Devon.. *British
Geological Survey Internal
Report*, IR/02/111. 61pp.

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham and Edinburgh; see contact details below or shop online at www.thebgs.co.uk

The London Information Office maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.thebgs.co.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgs london@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS

☎ 028-9066 6595 Fax 028-9066 2835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS) investigating mechanisms of gold mineralisation in the South West of England. It describes in detail the mineralogy and paragenesis of complex vein fills from an exploration borehole in the Crediton Trough area and from outcrops at Hope's Nose. The work aims to refine earlier observations and to provide background data to aid ongoing interpretation of the gold mineralisation mechanism in the area.

Acknowledgements

This work has benefited throughout from guidance and advice from Dr. T.J. Shepherd and M.T. Styles. This report has been edited by Dr. T.J. Shepherd.

Contents

Foreword	i
Acknowledgements	i
Contents	iii
Summary	v
1 Introduction	1
2 Techniques and Samples	3
2.1 Techniques	3
2.2 Analytical strategy	3
3 Results	5
3.1 Watford BH2 Samples	5
3.2 Hope's Nose Samples	9
4 Conclusions	11
References	13
Appendix 1 Sample Descriptions	15
Appendix 2 EPMA Point Analysis Data	61

FIGURES

Figure 1 MnO versus CaO and MgO for calcite and dolomite from Watford BH2, with analyses differentiated by calcite – dolomite association	9
Figure 2 MnO versus CaO and FeO versus MgO (wt%) for carbonates from Hope's Nose and Watford BH2	10

PLATES

Plate 1 Intergrown filamentous silica - smectite - microcrystalline quartz in the centre of a vein (A). This assemblage is locally replaced by carbonate (B), and the vein margin contains fibrous to blocky calcite – dolomite (C) replacing intergrown smectite – Fe-oxide. Sample WAT-00-06	5
Plate 2 Detail of intergrown filamentous silica (A) - smectite (B) - microcrystalline quartz (C). Sample WAT-00-06	5
Plate 3 Low magnification sample scan, showing zone of brown banded smectite – silica (A), adjacent to a zone of filamentous silica (B), and locally overprinted by later carbonates (C). Sample WAT-00-16	6

Plate 4	Variations in BSEM signal intensity within a zone of banded smectite and silica (A), relate to the proportions of silica within each band. Also evident is a band of filamentous silica – smectite – microquartz (B). Sample WAT-00-09.	6
Plate 5	Intergrown Fe-oxide (white) and clay (grey) with a laminated structure (A), filling a cavity between two bands of filamentous silica – smectite – microquartz (B). The margins of the patch are being invaded by fibrous to blocky calcite and dolomite (C). Sample WAT-00-09.	6
Plate 6	Vein-bridging, laminated Fe-oxide and clay (A). In this example the Fe-oxide – clay assemblage is overgrown by a later generation of fibrous to feathery dolomite – calcite (B). Sample WAT-00-14.	6
Plate 7	Low magnification sample scan showing patches of replacive, feathery calcite – dolomite (A). Later blocky calcite – dolomite (B and C) occurs at the vein margins, where it appears to be nucleating upon earlier silica – smectite (D). Sample WAT-00-09.	7
Plate 8	Detail of Plate 7, showing the replacive and feathery nature of the dolomite (A) – calcite (B) assemblage. Significant clay (C) is also trapped within this assemblage. Sample WAT-00-09.	7
Plate 9	Blocky calcite crystals (A) nucleated upon a band of filamentous silica – smectite – microquartz (B). The calcite is overlain by less euhedral dolomite with a fibrous character (C). Sample WAT-00-06.	7
Plate 10.	Fibrous calcite (A) nucleated upon and replacing vein-bridging silica – clay (B), overlain by fibrous to blocky dolomite (C), which displaces intergrown smectite – Fe-oxide (D). Sample WAT-21.	7
Plate 11	Irregularly intergrown calcite – dolomite (A) partially recrystallised to more coarsely crystalline calcite (B), within which discrete domains of dolomite and clays occur. Sample WAT-00-14.	8
Plate 12.	Irregularly intergrown calcite and dolomite (A), showing local evidence for recrystallisation (B), with relict patches of silica/microquartz (C) and Fe-oxide (D). Sample WAT-00-04.	8
Plate 13	Type 3 calcite vein (A) with marginal dolomite (B) and quartz (C), cutting earlier type 2 vein containing intergrown calcite – dolomite (D). Sample WAT-00-04.	8
Plate 14	Dolomite veins (A) re-activated by anastomosing calcite veins (B). An earlier generation of intergrown calcite-dolomite veining is also evident (C). Sample WAT-21.	8
Plate 15	Irregular to rhombic dolomite crystals (A), with minor Fe-oxides (B). Sample WAT-00-38.	10
Plate 16	Skeletal dolomite rhombs (A), minor apatite (B) and Fe-oxides (C), engulfed by massive, clear calcite (D). Sample WAT-00-38.	10
Plate 17	Dolomite (A) with rhombic ankerite overgrowths (B), engulfed by massive vein-filling ankerite (D). Sample WAT-00-37.	10

TABLES

Table 1)	Sample list and analytical strategy.	4
----------	---	---

Summary

This report describes the results of petrographical and electron microprobe elemental analysis on a suite of carbonate-dominated veins associated with gold mineralisation in South West England. Two localities were examined: 1) Thorverton, near Crediton and 2) Hope's Nose, near Torquay. Previous studies (Leake et al. 1992, Styles et al. 1997, Styles 1998, Clarke & Criddle 1982, Stanley et al. 1990) have reported comprehensively on the composition and distribution of gold grains from south Devon; some in-situ but mostly alluvial. However, very little information has been published on the principal gangue minerals. The objective of the work was to establish if there were similarities between auriferous carbonate veins in different geological environments that would improve the understanding of this unusual style of mineralisation.

At Thorverton, the veins are hosted in Permian basalts that occur within the lower Permo-Triassic 'red bed' sequence of the Crediton Trough. These contain a complex mineral assemblage with multiple generations of clays, silica, quartz, calcite, dolomite and ankerite. Samples were taken from borehole Watford BH2. The paragenetic sequence can be generalised as follows:

Stage 1. Formation of smectitic clays, and silica within the earliest generation of veining. This probably represents low temperature alteration of the basalt, and occurs in three approximately coeval associations:

- Filamentous silica – smectite – microquartz association
- Banded smectite – silica association
- Smectite – Fe-oxide association

Stage 2. Introduction of several generations of calcite and dolomite cements; the earliest of which tend to be less well crystallised and commonly display replacive textures relative to the clays-silica assemblages:

- Fibrous to feathery dolomite – calcite association
- Fibrous to blocky calcite – dolomite association

Stage 3. Further deposition of calcite and dolomite which tends to occur replacively in pre-existing veins, but also forming discrete, later generations of veins:

- Intergrown calcite – dolomite association. Minor gold grains have been noted in this association (see sample WAT-21).
- Simple calcite - dolomite association. This represents the last generation of carbonate observed in these samples, and is chemically slightly distinct from the earlier carbonates.

At Hope's Nose, the veins are hosted in Middle Devonian bedded, shelf and reef limestones, and are mineralogically simpler than those in the Crediton Trough. The veins are characterised by irregular to rhombic dolomite, which is cut by calcite veins and minor ankerite, that display significant colour variations, but only minor variations in chemistry. The Hope's Nose carbonates are characterised by low Mn-contents relative to the Watford BH2 carbonates.

Whilst this report provides descriptions of the mineralogy and paragenesis of carbonate veins known to host gold mineralisation within the region, only a single sample studied can be demonstrated to contain discrete gold grains (sample WAT-21). However, the data acquired for the carbonates significantly improve our understanding of the mineral paragenesis and afford an insight into the gold-enrichment processes.

1 Introduction

This report aims to provide a detailed assessment of the mineral paragenesis in a suite of complex veins/fractures associated with epithermal gold mineralisation in Devon. To this end a range of petrographical analyses and electron probe chemical mapping have been performed on two suites of samples.

The first suite of samples are from cores recovered from borehole Watford BH2, which was acquired during earlier investigations, on behalf of Crediton Minerals plc, of the gold prospectivity of Permian Basalts and associated veining and fractures in the Crediton Trough area of Devon (Leake *et al.* 1996, Styles *et al.* 1997, Styles 1998). During these earlier studies, financial and time constraints meant that relatively little attention could be paid to the detailed paragenesis of the gold-bearing veins. However, the earlier work reports that gold is only found in carbonate-dominated veins that have a complex multistage history of mineral growth and appears to be very late stage, associated with silica (Styles 1998). A generalised paragenesis (which appears to apply regionally) of smectitic clay → very-fine silica → turbid calcite → turbid dolomite → clear calcite has been established (Styles *et al.* 1998), although Styles (1998) reports that the precise sequence of mineral deposition varies both within and between samples. Styles (1998) described two general vein types in Watford BH1:

1. horizontal veins – *“with early turbid carbonates, followed by fibrous carbonate, in some places intergrown with quartz, clear carbonate and finally, in some examples, quartz, which may be iron stained.” These veins may show evidence for reactivation with “a very distinct vein of clear carbonate along the outer margin” of the fracture.*
2. vertical veins – *“many only contain clear carbonate. Others have earlier turbid carbonate and some, particularly in the high-assay zone have a later phase of turbid carbonate with ferruginous material. Several samples also have a late phase of brown-stained silica which is replacing the carbonate.”*

The second suite of samples are new samples taken from outcrops of gold mineralised veins at Hope’s Nose, Devon, which are hosted within bedded shelf and reef limestones.

Following Crediton Mineral’s decision to withdraw from the Crediton Prospect, further work is being undertaken by BGS to better understand the origin of gold mineralisation in the region. The current work aims to refine the observations made in the earlier study and provide microchemical analyses of both the gold-bearing and the non-gold-bearing vein systems to aid ongoing interpretation.

2 Techniques and Samples

For the purposes of comparison, a single polished thin-section sample (WAT-21; part of the suite of samples described by Styles; 1998) containing a complex array of mineral veins was selected for a preliminary assessment of the relative utility of conventional optical microscopy (OM), cathodoluminescence (CL) and back-scattered scanning electron microscopy (BSEM), in the elucidation of vein paragenesis.

Following this pilot investigation, the samples from Watford BH2 and Hope's Nose were examined by BSEM, and electron probe (EPMA). EPMA microchemical mapping and point analyses were used to chemically characterise selected areas of interest. The detailed results of this characterisation are given in Appendices 1 and 2. This characterisation also provided the basis for microbeam isotope analyses of the carbonate veins (reported separately by Shepherd, in prep.).

2.1 TECHNIQUES

Optical Microscopy (OM): observations and photomicrographs were acquired using a Zeiss Universal and a Zeiss AxioPlan2 microscope.

Cathodoluminescence (CL): observations and photomicrographs were taken using a Technosyn Model 8200 MkII cold-cathode cathodoluminoscope fitted to a dedicated petrological microscope.

Back-scattered scanning electron microscopy (BSEM): observations and images were acquired using a LEO 435VP digital scanning electron microscope fitted with a KE-developments four-element solid-state backscattered electron detector, and an Oxford Instruments ISIS 300 EDXA system (for mineral identification by qualitative and semi-quantitative energy-dispersive X-ray analysis).

Electron Probe Microanalysis (EPMA): analyses were made using a Cameca SX50 wavelength-dispersive electron micro-probe. Initially, the samples were mapped for Mg, Si, K, Ca, Mn, Fe, Sr and Ba at operating conditions of 15 kV and 45 nA. Count times of 90 ms were used for Sr, Ba and Mn, and 60 ms for the other elements. Subsequently some samples were mapped for Ca, Mn and Sr at operating conditions of 15 kV and 100 nA. Point analyses were performed on the same instrument operating at 15 kV and 20 nA using a 'defocused' beam size of 10µm. Sr concentrations of silicate phases on the X-ray maps are substantially over-represented due to an interference effect between the x-ray peaks of Si and Sr.

2.2 ANALYTICAL STRATEGY

During sample collection the veins within each sample were classified according to a simple scheme on the basis of the general characteristics and cross-cutting relationships (Shepherd pers. comm.), as follows:

- Type 1: early flat lying fibrous veins (1-4mm wide) with distinctive vein-wallrock margin. Some veins are segmented into fresh and oxidised patches.
- Type 2: flat lying to sub-vertical veins (<0.1mm-2mm wide) which cross cut and post date type 1, or invade it along it's margins.
- Type 3: high angle to vertical, thin (<1mm) carbonate veins which cross cut types 1 and 2.
- Type 4: complex, multistage, horizontal to vertical veins where horizontal appear to be a reactivation of type 1. They could also represent a more multistage version of type 2,
- Type 5: zoned, vertical to sub-vertical veins (3-6mm wide) with a central core of Fe-Mn carbonates which is often partially destroyed by a carbonate phase that branches across vein. These are auriferous veins.

A selection of samples containing each of these vein types were analysed (Table 1).

Table 1) Sample list and analytical strategy.

Sample	Core # (depth m)	MPL Code *	Section ID	VEIN TYPE 1 VEIN TYPE 2 VEIN TYPE 3 VEIN TYPE 4 VEIN TYPE 5	BSEM EPMA Microchemical Mapping EPMA Point Analyses Optical Microscopy Cathodo- luminescence
WATFORD BH2					
WAT-00-01	22 (28.94 - 29.85m)	G693	a	Y Y - - -	- - - - -
WAT-00-02	22 (28.94 - 29.85m)	G694	a	- - Y - -	- - - - -
WAT-00-03	22 (28.94 - 29.85m)	G695	a	Y - - - -	- - - - -
WAT-00-04	22 (28.94 - 29.85m)	G696	a	- Y (Y) - -	Y Y (5) Y (16) - -
WAT-00-05	22 (28.94 - 29.85m)	G697	a	- - Y - -	Y Y(2) Y (7) - -
WAT-00-06	22 (28.94 - 29.85m)	G698	a	Y - - - -	Y Y(2) Y (10) - -
WAT-00-07	22 (28.94 - 29.85m)	G699	b	- - - Y -	- - - - -
WAT-00-08	22 (28.94 - 29.85m)	G700	b	- - - Y -	- - - - -
WAT-00-09	22 (28.94 - 29.85m)	G701	b	- ?Y - Y -	Y - - - -
WAT-00-10	22 (28.94 - 29.85m)	G702	b	- ?Y - Y -	- - - - -
WAT-00-11	23 (29.82 - 30.45m)	G703	b	Y - - - -	- - - - -
WAT-00-12	23 (29.82 - 30.45m)	G704	b	- - Y - -	- - - - -
WAT-00-13	23 (29.82 - 30.45m)	G705	c	Y - - - -	- - - - -
WAT-00-14	23 (29.82 - 30.45m)	G706	c	Y - - - -	Y - - - -
WAT-00-15	23 (29.82 - 30.45m)	G707	c	- - - Y -	- - - - -
WAT-00-16	21 (28.05 - 28.94m)	G708	c	- - - - Y	Y Y (2) Y (12) - -
WAT-00-17	21 (28.05 - 28.94m)	G709	c	- - - - Y	Y - - - -
WAT-00-18	21 (28.05 - 28.94m)	G710	c	- - - - Y	- - - - -
WAT-00-19	21 (28.05 - 28.94m)	G711	d	- - - - Y	- - - - -
WAT-00-20	21 (28.05 - 28.94m)	G712	d	- - - - Y	- - - - -
WAT-00-21	20 (27.14 - 28.05m)	G713	d	- - - Y -	Y - - - -
WAT-00-22	20 (27.14 - 28.05m)	G714	d	- - - Y -	- - - - -
WAT-00-23	20 (27.14 - 28.05m)	G715	d	- - - Y -	Y Y (1) Y (10) - -
WAT-00-24	20 (27.14 - 28.05m)	G716	d	- - - Y -	- - - - -
WAT-00-25	18 (25.35 - 26.30m)	G717	e	- - - - -	- - - - -
WAT-00-26	18 (25.35 - 26.30m)	G718	e	- - - - -	- - - - -
WAT-00-27	12 (19.87 - 20.82m)	G719	e	- Y - - -	- - - - -
WAT-00-28	12 (19.87 - 20.82m)	G720	e	- Y - - -	- - - - -
WAT-00-29	11 (18.96 - 19.87m)	G721	e	- - - - -	- - - - -
WAT-00-30	11 (18.96 - 19.87m)	G722	e	- - - - -	- - - - -
WAT-00-31	11 (18.96 - 19.87m)	G723	f	- - - - -	- - - - -
WAT-00-32	10 (18.35-18.96m)	G724	f	- - - - -	- - - - -
WAT-00-33	1 (53.60 - 54.60m)	G725	f	- Y - ?Y -	- - - - -
WAT-00-34	3 (55.60 - 56.60m)	G726	f	- Y - ?Y -	- - - - -
WAT-00-35	8 (60.50 - 61.45m)	G727	f	- Y - - -	- - - - -
WAT-00-36	9 (61.45-62.45m)	G728	f	- - - - -	- - - - -
HOPES NOSE					
WAT-00-37	-	G729	g	- - - - -	Y Y (1) Y (25) - -
WAT-00-38	-	G730	g	- - - - -	Y Y (1) Y (10) - -
WAT-00-39	-	G731	g	- - - - -	Y - - - -
WAT-00-40	-	G732	h	- - - - -	Y - - - -
WAT-00-41	-	G733	h	- - - - -	Y - - - -
EARLIER "WATFORD" BOREHOLE SAMPLES					
WAT-21	-	n/a	-	Y - Y - -	Y - - Y -
WAT-24	-	n/a	-	- - - - -	Y - - Y Y

* "MPL Code" refers to a National Geoscience Data Centre approved, sample number that is unique within BGS. The full MPL code is derived by adding the prefix "MPL" to the sample number as quoted here (e.g. G693 = MPLG693). The shorthand version is used throughout this report.

The numbers in brackets in the EPMA microchemical mapping and point analyses columns indicate the number of areas mapped or points analysed.

3 Results

Descriptions of each sample with accompanying images and EPMA X-ray maps are presented in Appendix 1. The following sections attempt to summarise the vein mineralogy, however, given the complexity of the intergrowths between the various phases the vein mineralogy is described as a series of associations, in approximate paragenetic order for both the Watford BH2 samples and the Hope's Nose samples.

3.1 WATFORD BH2 SAMPLES

These samples display greater textural and mineralogical complexity than those from Hope's Nose and, as reported by Styles (1998) and Styles *et al.* (1998), contain an assemblage of clay (probable smectite), calcite, dolomite, silica and Fe-oxides.

3.1.1 Filamentous Silica – Smectite – Microquartz Association

This association is noted in veins of types 1, 4 and 5 and particularly well developed in samples WAT-00-06, WAT-00-09 and WAT-21 (Appendix 1). It occurs as a distinct band, typically towards the centre of the vein (Plate 1 and Plate 3). Filamentous strands of silica irregularly bridge the vein and are lined by smectite, which locally completely fills the spaces between the filaments. The smectite is overlain by microcrystalline quartz (small crystals are locally evident) which completely fills any remaining space (Plate 2). Also noted are patches of dendritic silica intergrown with smectite (e.g. WAT-00-21; Appendix 1). This assemblage is locally replaced by later generations of calcite and dolomite (Plate 1; and below).

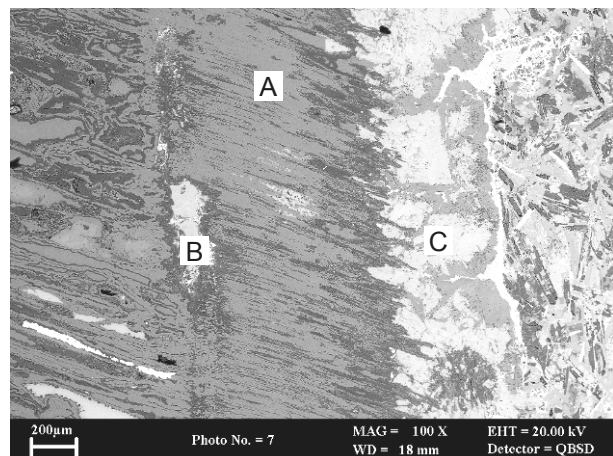


Plate 1 Intergrown filamentous silica - smectite - microcrystalline quartz in the centre of a vein (A). This assemblage is locally replaced by carbonate (B), and the vein margin contains fibrous to blocky calcite - dolomite (C) replacing intergrown smectite - Fe-oxide. Sample WAT-00-06.

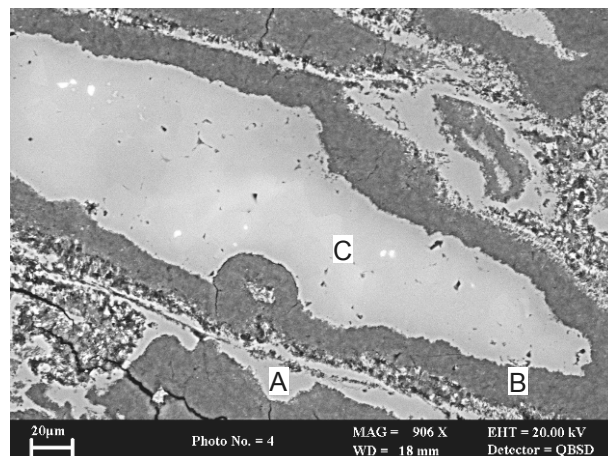


Plate 2 Detail of intergrown filamentous silica (A) - smectite (B) - microcrystalline quartz (C). Sample WAT-00-06.

3.1.2 Banded Smectite – Silica Association

This association is noted in veins of types 4 and 5, especially in samples WAT-00-09 and WAT-00-16 (Appendix 1). It occurs in distinct, but discontinuous bands/zones adjacent to the filamentous silica - smectite - microquartz assemblage described above (Plate 3). In detail this assemblage contains smectite and silica in intimate association. High magnification BSEM imaging and qualitative EDXA analysis indicate that the colour/BSEM brightness variations are due to

differences in the proportion of silica within a given band (Plate 4). This assemblage is also replaced by later carbonates (Plate 3).

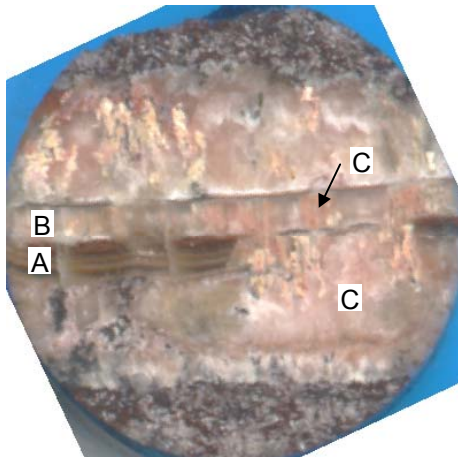


Plate 3 Low magnification sample scan, showing zone of brown banded smectite – silica (A), adjacent to a zone of filamentous silica (B), and locally overprinted by later carbonates (C). Sample WAT-00-16

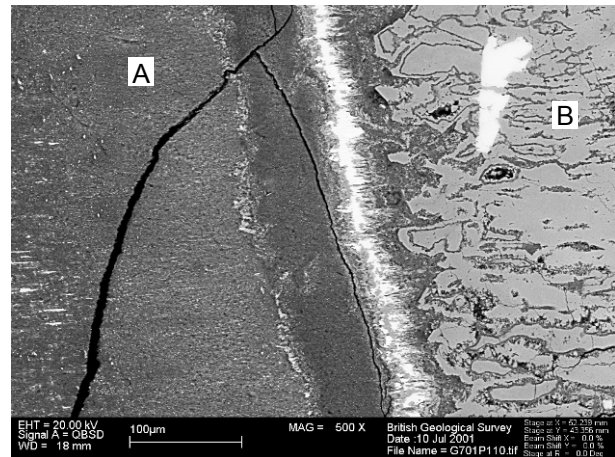


Plate 4 Variations in BSEM signal intensity within a zone of banded smectite and silica (A), relate to the proportions of silica within each band. Also evident is a band of filamentous silica – smectite – microquartz (B). Sample WAT-00-09.

3.1.3 Smectite – Fe-Oxide Association

This association is likely to be an alteration product and is seen in samples of vein types 1 and 4. It is clearly developed in samples WAT-00-06, WAT-00-09 and WAT-00-14 (Appendix 1) and comprises finely associated Fe-oxide and clay (again probable smectite), commonly with a laminated structure (Plate 5), and more rarely with a vein-lining and vein-bridging structure (Plate 6). This assemblage is considered to post-date the silica – smectite associations described above, as it occurs at the margins of such associations. It is replaced/overprinted and overgrown by later calcite and dolomite.

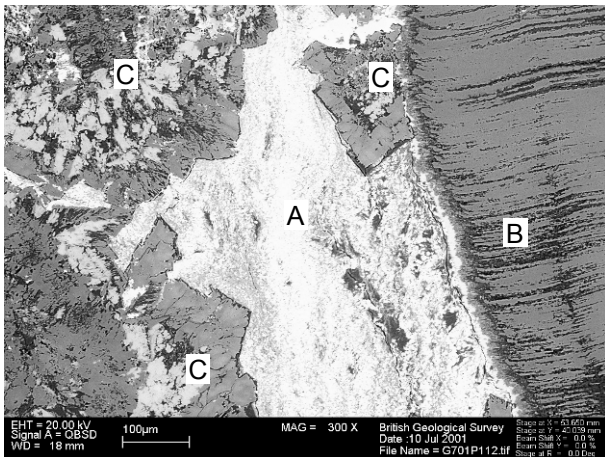


Plate 5 Intergrown Fe-oxide (white) and clay (grey) with a laminated structure (A), filling a cavity between two bands of filamentous silica – smectite – microquartz (B). The margins of the patch are being invaded by fibrous to blocky calcite and dolomite (C). Sample WAT-00-09.

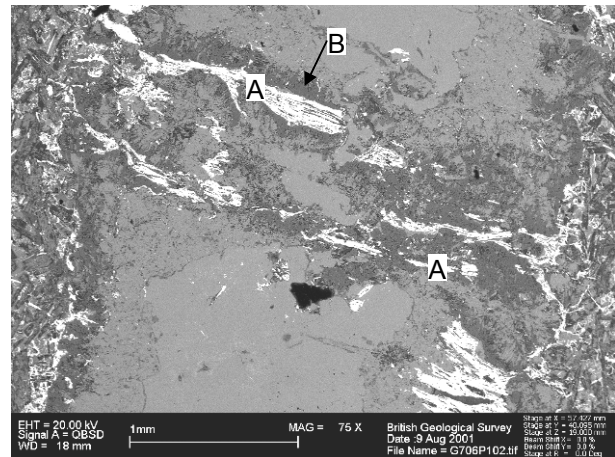


Plate 6 Vein-bridging, laminated Fe-oxide and clay (A). In this example the Fe-oxide – clay assemblage is overgrown by a later generation of fibrous to feathery dolomite – calcite (B). Sample WAT-00-14.

3.1.4 Fibrous to Feathery Dolomite – Calcite Association

This association appears to be the earliest of several distinct generations of calcite and dolomite, seen in veins of types 4 and 5, and is well developed in samples WAT-00-09 and WAT-00-16 (Appendix 1). In hand specimen this assemblage appears white to pink, and is clearly seen to cross-

cut the earlier silica – smectite assemblages (Plate 7). These patches are dominated by dolomite (Plate 6 and Plate 8) and include significant amounts of “trapped” clay (probably smectitic). The paragenetic relationship between this assemblage and the fibrous to blocky calcite – dolomite assemblage described below, is not entirely unequivocal and it is possible that the different assemblages are approximately coeval.

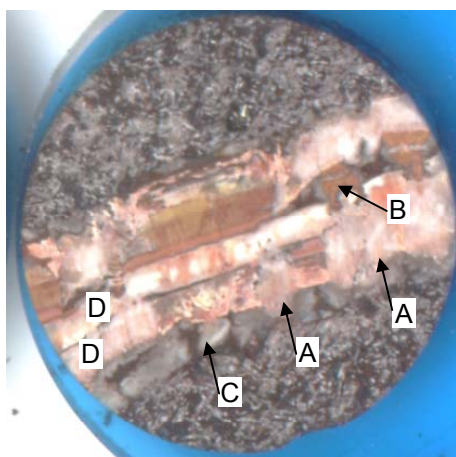


Plate 7 Low magnification sample scan showing patches of replacive, feathery calcite – dolomite (A). Later blocky calcite – dolomite (B and C) occurs at the vein margins, where it appears to be nucleating upon earlier silica – smectite (D). Sample WAT-00-09.

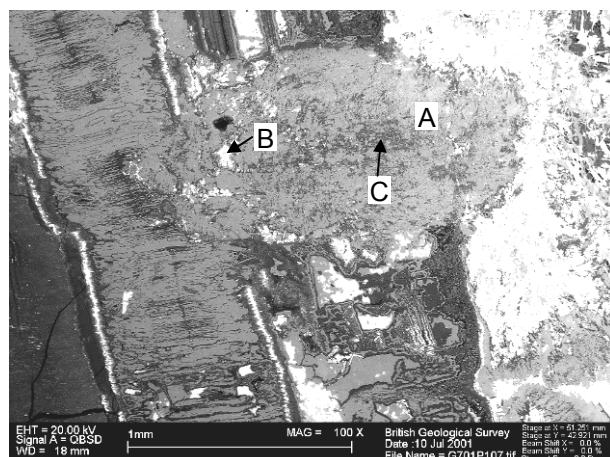


Plate 8 Detail of Plate 7, showing the replacive and feathery nature of the dolomite (A) – calcite (B) assemblage. Significant clay (C) is also trapped within this assemblage. Sample WAT-00-09.

3.1.5 Fibrous to Blocky Calcite – Dolomite Association

This association is typically seen at the margins of veins of types 1, 4 and 5 (particularly in samples WAT-00-06, WAT-00-09 and WAT-21; Appendix 1). Although it predominantly occurs at the vein margins, its relatively late position in the paragenesis is inferred from its replacive appearance, and by the fact that crystals commonly appear to be nucleated on earlier formed bands of silica – smectite (Plate 9 and Plate 10. see also Plate 1, Plate 5, and Plate 6). The cores of these patches are dominated by calcite which, locally occludes significant amounts of smectite, with the development of later dolomitic overgrowths.

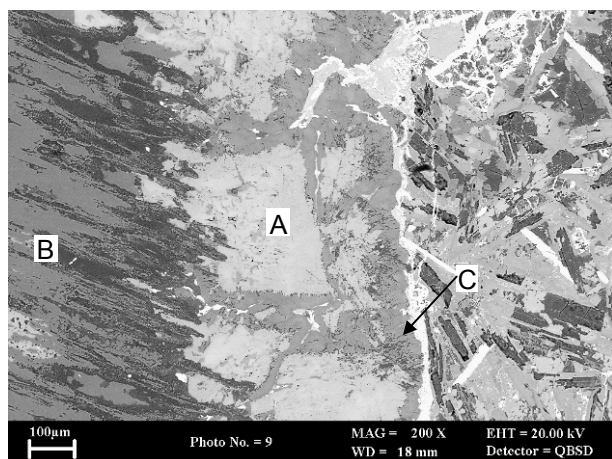


Plate 9 Blocky calcite crystals (A) nucleated upon a band of filamentous silica – smectite – microquartz (B). The calcite is overlain by less euhedral dolomite with a fibrous character (C). Sample WAT-00-06.

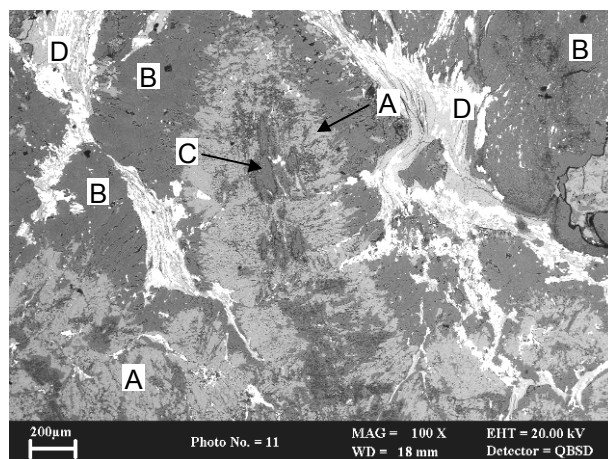


Plate 10. Fibrous calcite (A) nucleated upon and replacing vein-bridging silica – clay (B), overlain by fibrous to blocky dolomite (C), which displaces intergrown smectite – Fe-oxide (D). Sample WAT-21.

3.1.6 Intergrown Calcite – Dolomite Association

This association is seen in veins of types 1, 2, 4 and 5, and is very well developed in samples WAT-00-14, WAT-00-17 and WAT-21 (Appendix 1), with veins of type 2 being dominated by this

association. This calcite – dolomite association occurs in two related forms. The dominant form comprises irregular, relatively small crystals of calcite and dolomite with abundant inclusions of clay. In some veins, however, partial recrystallisation of this type of material has occurred with an increase in crystal sizes, and segregation of calcite and dolomite into discrete zones (Plate 11). Some relict patches of silica and smectite are evident in some samples (Plate 12). In sample WAT-21 gold grains are associated with this vein generation (see Appendix 1).

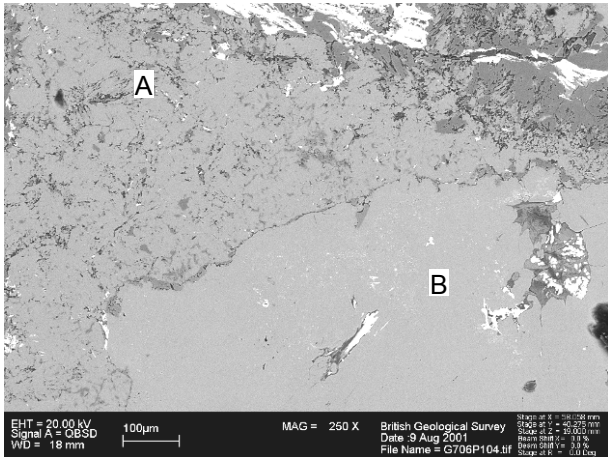


Plate 11 Irregularly intergrown calcite – dolomite (A) partially recrystallised to more coarsely crystalline calcite (B), within which discrete domains of dolomite and clays occur. Sample WAT-00-14.

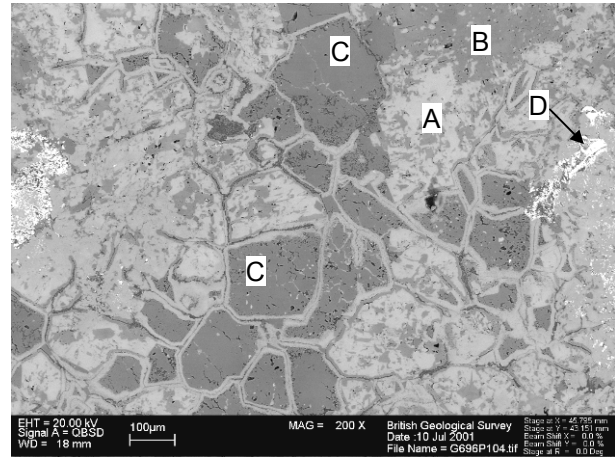


Plate 12. Irregularly intergrown calcite and dolomite (A), showing local evidence for recrystallisation (B), with relict patches of silica/microquartz (C) and Fe-oxide (D). Sample WAT-00-04.

3.1.7 Simple Calcite – Dolomite Association

This association is characteristic of, and is only observed within veins of type 3 (e.g. sample WAT-00-05). Type 3 veins are seen to cross-cut veins of other types (Plate 13), and are filled with compositionally homogeneous, clear to milky calcite. The vein margins are lined by minor amounts of dolomite and quartz (Plate 13 and Plate 14). Analysis of sample WAT-21 indicates that these veins are multigenerational, with distinct episodes of dolomite and calcite-filled fractures (Plate 14).

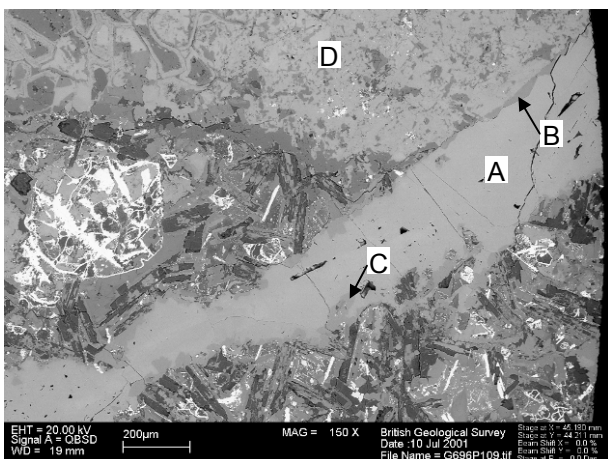


Plate 13 Type 3 calcite vein (A) with marginal dolomite (B) and quartz (C), cutting earlier type 2 vein containing intergrown calcite – dolomite (D). Sample WAT-00-04.

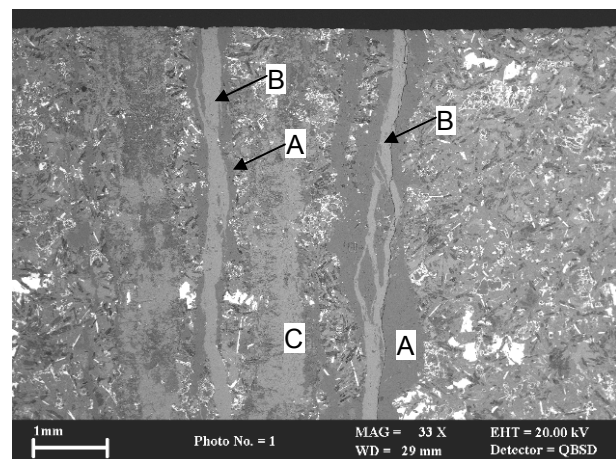


Plate 14 Dolomite veins (A) re-activated by anastomosing calcite veins (B). An earlier generation of intergrown calcite-dolomite veining is also evident (C). Sample WAT-21.

3.1.8 EPMA results

On account of larger crystal sizes and more homogeneous character, the EPMA point analyses of carbonates in veins from Watford BH2 has focussed upon the intergrown calcite – dolomite association and the simple calcite – dolomite association, although minor data is also available for

the fibrous to blocky calcite – dolomite association (see Appendix 2). This data, coupled with the X-ray mapping data indicate comparable / overlapping minor and trace element compositions for the calcite and dolomite in each association, with MnO content ranges from 0.37 to 3.08 wt%, FeO from <0.1 to 0.65 wt% and SrO and BaO concentrations of <0.1 wt%. However, the calcite in the simple calcite – dolomite association characteristic of vein type 3, may be slightly differentiated from calcite in the other associations using MnO versus CaO and MgO plots (Figure 1), although all the data for calcite in this association are derived from the same cluster of calcite dolomite crystals, which may or may not be representative.

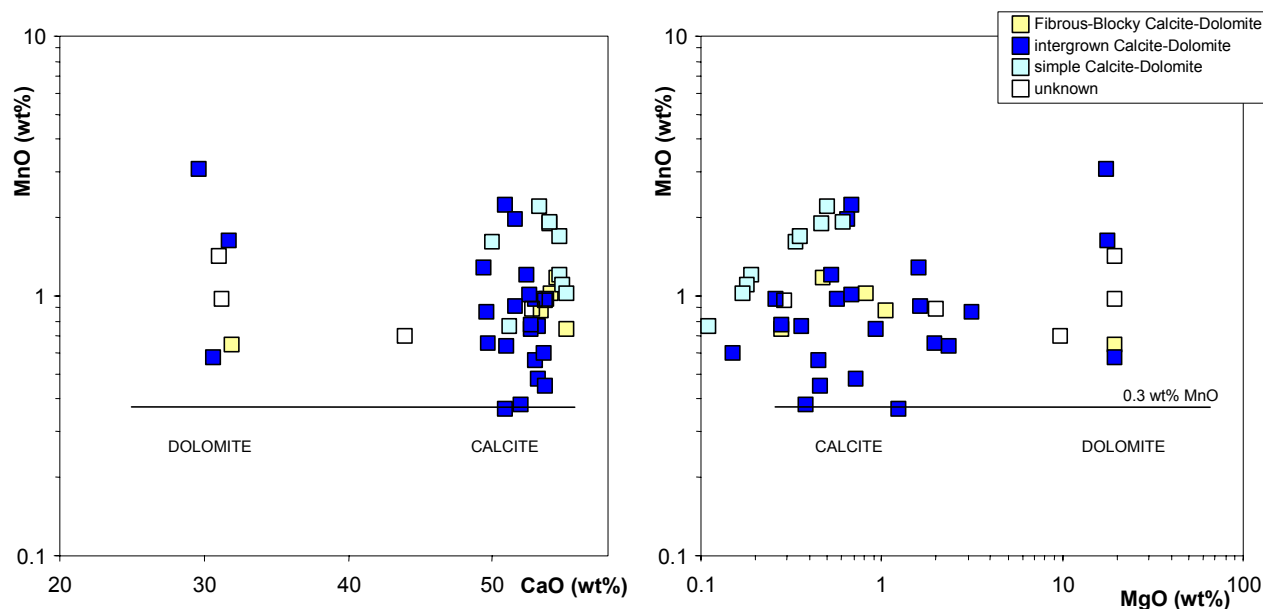


Figure 1 MnO versus CaO and MgO for calcite and dolomite from Watford BH2, with analyses differentiated by calcite – dolomite association.

3.2 HOPE'S NOSE SAMPLES

The Hope's Nose samples are of relatively simple mineralogy compared with those from Watford BH2, and almost exclusively comprise calcite and dolomite. However, several different calcite types are observed, and ankerite $[(\text{Mg,Fe,Mn})\text{Ca}(\text{CO}_3)_2]$ is also present.

Microcrystalline Dolomite: This phase makes up the groundmass of sample WAT-00-38, and in detail is seen to comprise a mixture of variably crystalline, rhombic dolomite crystals, Fe-oxides (which probably impart the purple-red colour of this sample in hand specimen) and rare apatite (Plate 15 and Plate 16).

Calcite: In hand specimen, calcite may appear clear, white or milky, slightly yellowish, or red. Under BSEM the calcite types are compositionally indistinct, with minor changes in BSEM signal intensity noted between the red and clear calcite types (sample WAT-00-41; Appendix 1). However, EPMA X-ray mapping indicates subtle variations in Ca, Mg and Sr concentrations within the different calcite types (Samples WAT-00-37 and WAT-00-38; Appendix 1). The calcite is coarsely crystalline, and is locally intimately associated with the microcrystalline dolomite.

Yellow-Brown Dolomite – Ankerite: This is noted in samples WAT-00-37 and WAT-00-38. Under BSEM, ankerite has a response that is not differentiable from that of calcite. It appears to overlie the dolomite (Plate 17).

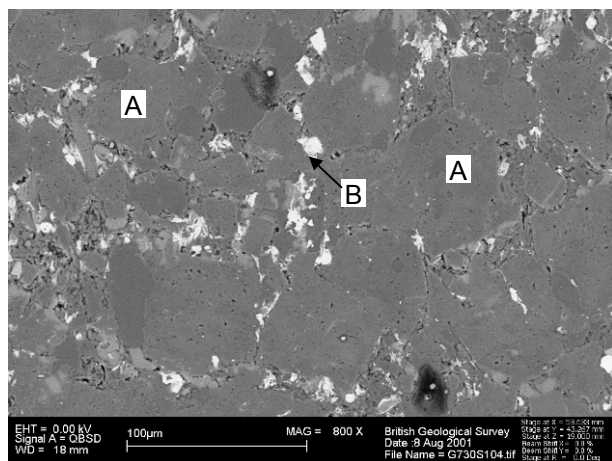


Plate 15 Irregular to rhombic dolomite crystals (A), with minor Fe-oxides (B). Sample WAT-00-38.

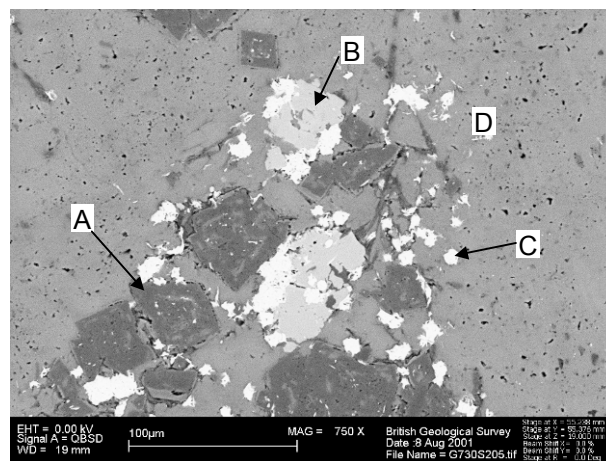


Plate 16 Skeletal dolomite rhombs (A), minor apatite (B) and Fe-oxides (C), engulfed by massive, clear calcite (D). Sample WAT-00-38.

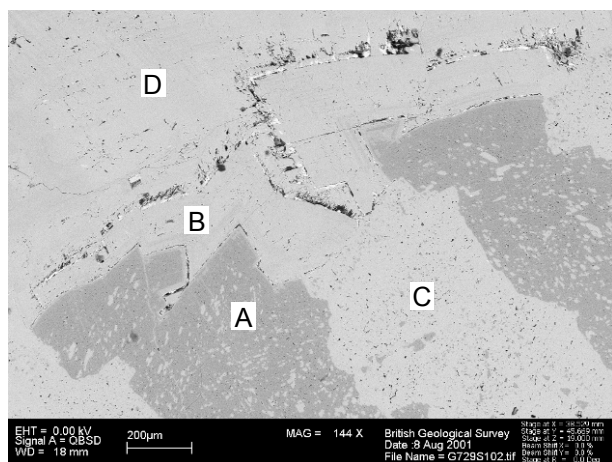


Plate 17 Dolomite (A) with rhombic ankerite overgrowths (B), engulfed by massive vein-filling ankerite (D). Sample WAT-00-37.

3.2.1 EPMA results

The Hope's Nose samples predominantly contain relatively pure calcite and dolomite ($\text{FeO} < 0.22$ wt%, MnO , SrO and $\text{BaO} < 0.1$ wt%; Appendix 2). Also present is conspicuous yellow-brown ankerite ($\text{MgO} = \text{c. } 10\text{--}15$ wt%, $\text{FeO} = \text{c. } 7.5\text{--}15$ wt%, and $\text{MnO } 0.09\text{--}0.27$ wt%; SrO and $\text{BaO} < 0.1$ wt%; Figure 2). The Hope's Nose carbonates can be clearly distinguished from the Watford borehole carbonates on the basis of their lower MnO contents (Figure 2).

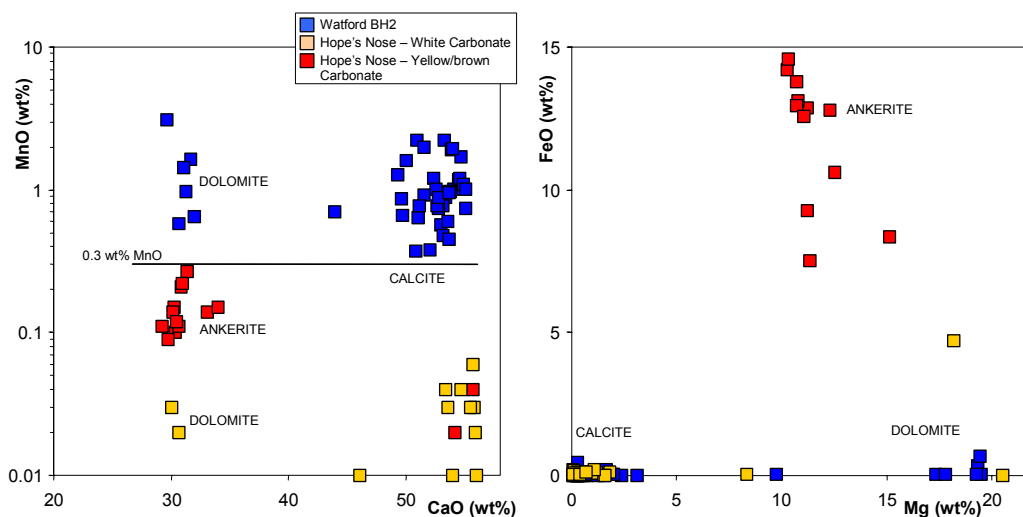


Figure 2 MnO versus CaO and FeO versus MgO (wt%) for carbonates from Hope's Nose and Watford BH2.

4 Conclusions

The samples of veins from Watford-BH2 record a complex history of fracturing, mineralisation and alteration within the host basalts. The paragenetic sequence can be generalised as follows:

Stage 1. Formation of smectitic clays and silica within the earliest generation of veining. This probably represents alteration of the basalt, and occurs in three approximately coeval associations:

- Filamentous silica – smectite – microquartz association
- Banded smectite – silica association
- Smectite – Fe-oxide association

Stage 2. Then follows several generations of calcite and dolomite cements. The earliest formed carbonates tend to be less well crystallised and commonly display replacive textures relative to the earlier clays and silica:

- Fibrous to feathery dolomite – calcite association
- Fibrous to blocky calcite – dolomite association

Stage 3. Later generations of calcite and dolomite cements. These tend to occur replacively in pre-existing veins, but also form discrete, late stage veins:

- Intergrown calcite – dolomite association. Minor gold grains have been noted in this association in sample WAT-21.
- Simple calcite – dolomite association. This association is the last generation observed in these samples, and is chemically slightly distinct from the earlier carbonates.

The veins from Hope's Nose are mineralogically simpler than those from Watford BH2, and are characterised by irregular to rhombic dolomite, which is cut by calcite veins and minor ankerite, that display significant colour variations, but only minor variations in chemistry. The Hope's Nose carbonates are characterised by low Mn-contents relative to the Watford BH2 carbonates.

Whilst this report provides descriptions of the mineralogy and paragenesis of carbonate veins known to host gold mineralisation within the region, only a single sample studied can be demonstrated to contain discrete gold grains (sample WAT-21). However, the data acquired for the carbonates significantly improve our understanding of the mineral paragenesis and afford an insight into the gold-enrichment processes.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

CLARK. A M, and CRIDDLE. A J. 1982. Palladium minerals from Hope's Nose, Torquay, Devon. *Miner.Mag.*, 46, 371-377

LEAKE. R C, SCRIVENER. R C, SHAW. M H, ROLLIN, K E, DABEK. K, MARSH. S H, BLAND. D J, and STYLES. M T. 1996. Crediton Trough Gold Exploration – Phase 1. A report to Crediton Minerals PLC. *British Geological Survey Technical Report WF 96/4C*

STANLEY. C J, CRIDDLE. A J, and LLOYD. D. 1990. Precious and base metal selenide mineralisation at Hope's Nose, Torquay, Devon. *Miner.Mag.*, 54, 485-493

STYLES. M T, LEAKE, R C, and BLAND. D J. 1997. A mineralogical study of basalts from “Watford” quarry, Devon. *British Geological Survey Technical Report WG/97/17C*.

STYLES, M T. 1998. A mineralogical study of cores from the Watford No.1 borehole, Devon. *British Geological Survey Technical Report WG/98/6/C*.

Appendix 1 Sample Descriptions

This appendix contains systematic descriptions of each of the samples studied using SEM. In addition, where EPMA X-ray mapping images are also available they are included here. Locations of individual EPMA point analyses (see Appendix 2 for data) are also indicated where appropriate.

Sample ID:	WAT-00-04
MPL Code:	G696
Core/Location:	Watford BH2; Box 22
Depth:	28.94 - 29.85 m
Vein Type:	Type 2 cut by Type 3
EPMA X-ray Mapping:	Yes

This sample contains a complex-zoned vein of Type 2, with a stained/ferruginous core (Vein “A”; Photos 1, 2, 3), and two offshoot ferruginous/stained veinlets (Vein “B”; Photos 1,2 4). Vein “A” is cut by a simple calcite vein of type 3 (Vein “C”; Photos 1, 2, 5):

1. Vein “A” is dominated by intimately intergrown calcite and dolomite, with minor clusters of microcrystalline quartz crystals surrounded, and locally cut by veinlets of calcite (Photo 3). This may indicate incomplete replacement of earlier silica with carbonate. The stained core to the vein evident in normal illumination is seen under BSEM to contain relatively abundant Fe-oxides.
2. Vein “B” (Photo 4) is of similar character to vein “A”, with calcite having lobate margins into the host basalt (replacive?) and minor inclusions of rhombic dolomite, patchy relict feldspars, and vein margin parallel trending patches of Fe-oxide and clay, which account for this vein’s ferruginous appearance in hand specimen.
3. Vein “C” (Photo 5) is of relatively simple character. The vein margins are lined by euhedral dolomite, euhedra and possibly corroded quartz, and the vein is filled by massive, compositionally homogeneous calcite.

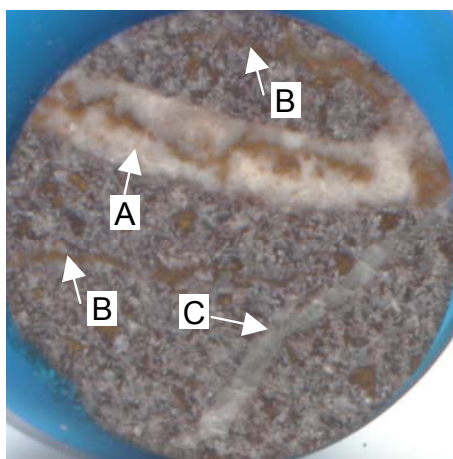


Photo 1) scan of entire sample, showing earlier, complex vein (Type 2; A), with ferruginous/stained offshoot (B) cut by later simple calcite vein (Type 3, C).

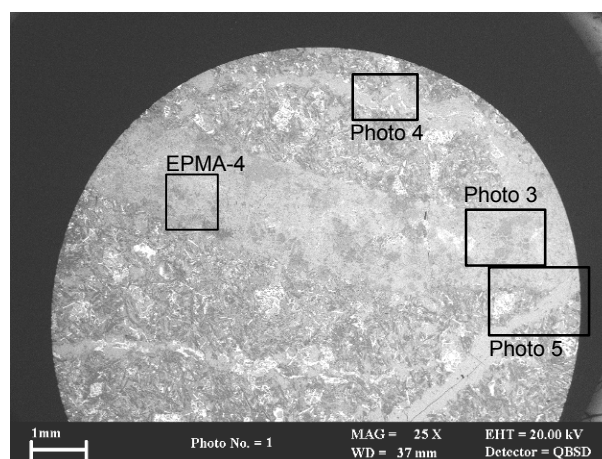


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photos 3, 4 and 5 are highlighted.

EPMA-1) X-Ray maps of Vein “A”; area as highlighted on Photo 3

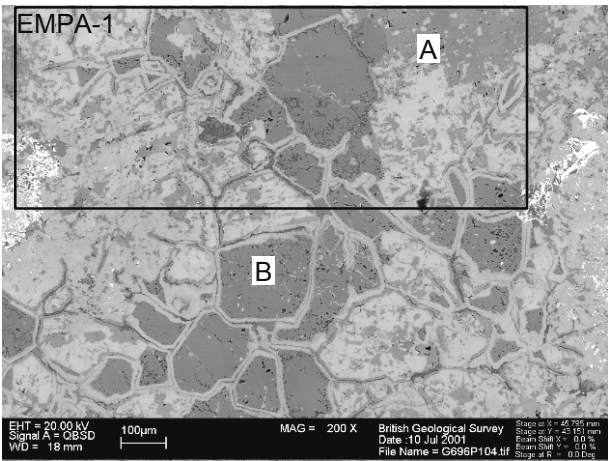
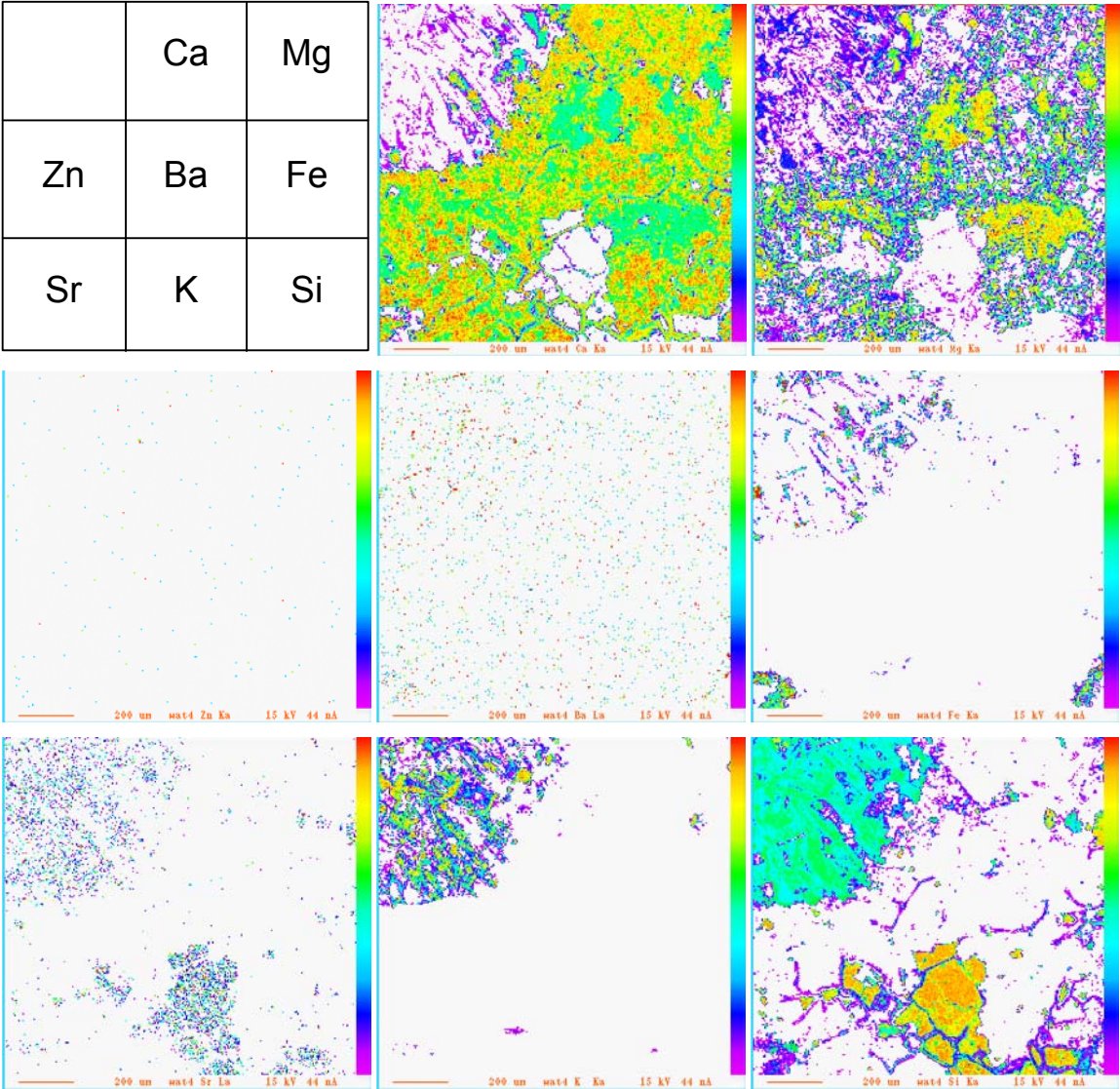


Photo 3) Detail of Type 2 vein showing predominance of intergrown dolomite and calcite (A), and minor residual domains of microcrystalline quartz (B). Area of X-ray mapping of EPMA-1 extends beyond field of view of this image.



EPMA-2) X-Ray maps of Vein "B"; area as highlighted on Photo 4

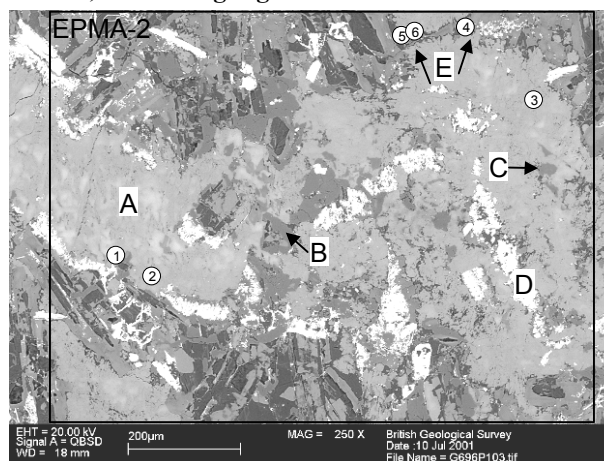
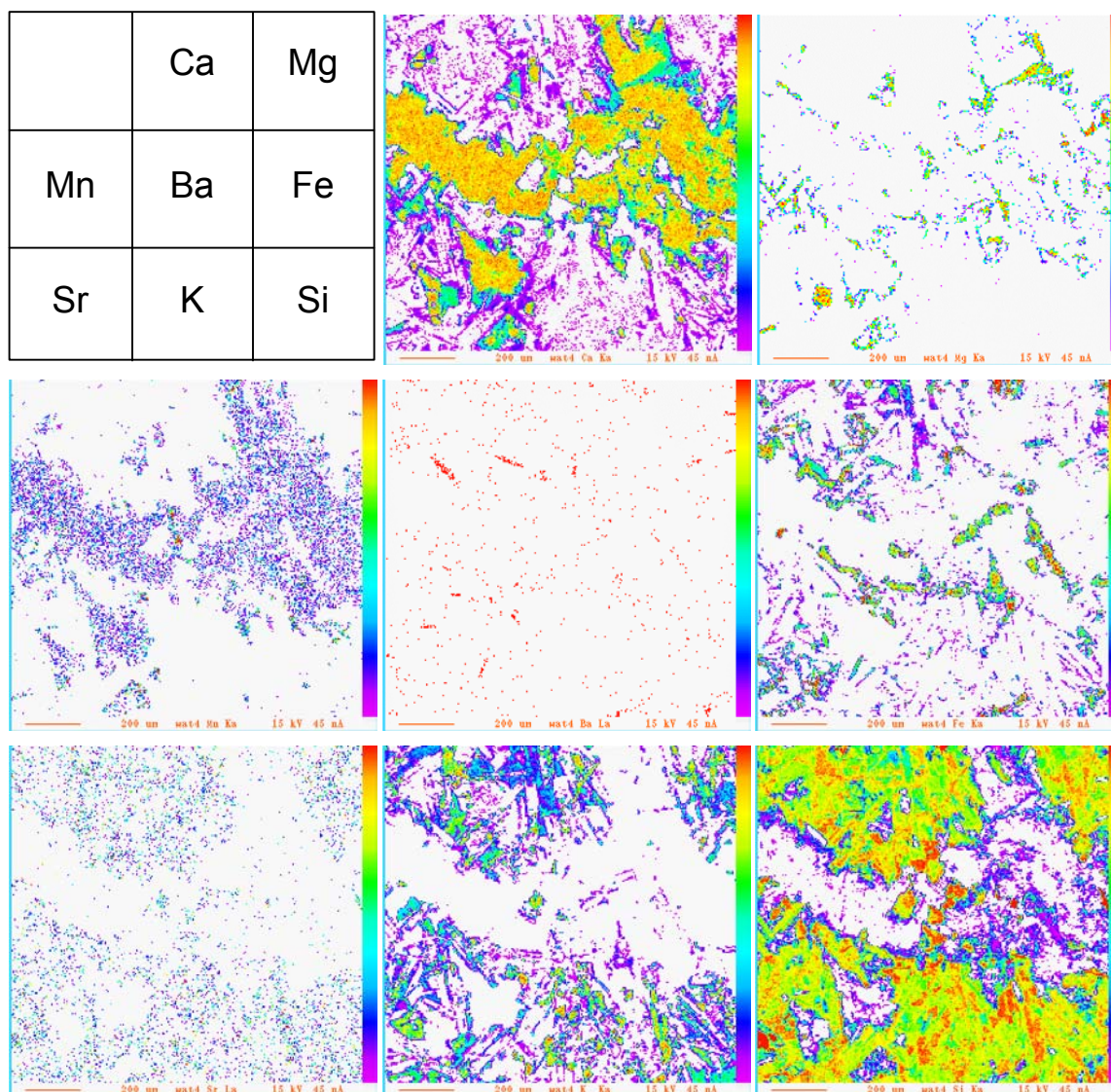


Photo 4) Ferruginous/stained veinlet of similar character to that seen in the centre of the main vein in this sample. This veinlet is dominated by calcite (A), with minor relict feldspars (B) and rhombic dolomite (C). Fe-oxides occur in bands subparallel to the veinlet margins (D). The calcite has lobate margins adjacent to the basalt host rock suggesting possible replacement (E). EPMA point analysis numbered 1-6.



EPMA-3) X-Ray maps of Vein “C”; area as highlighted on Photo 5

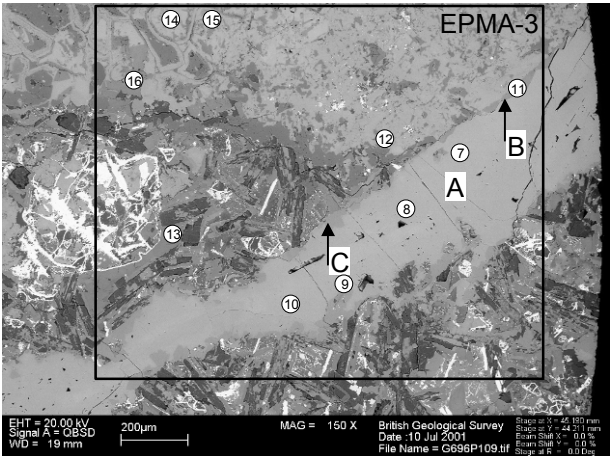
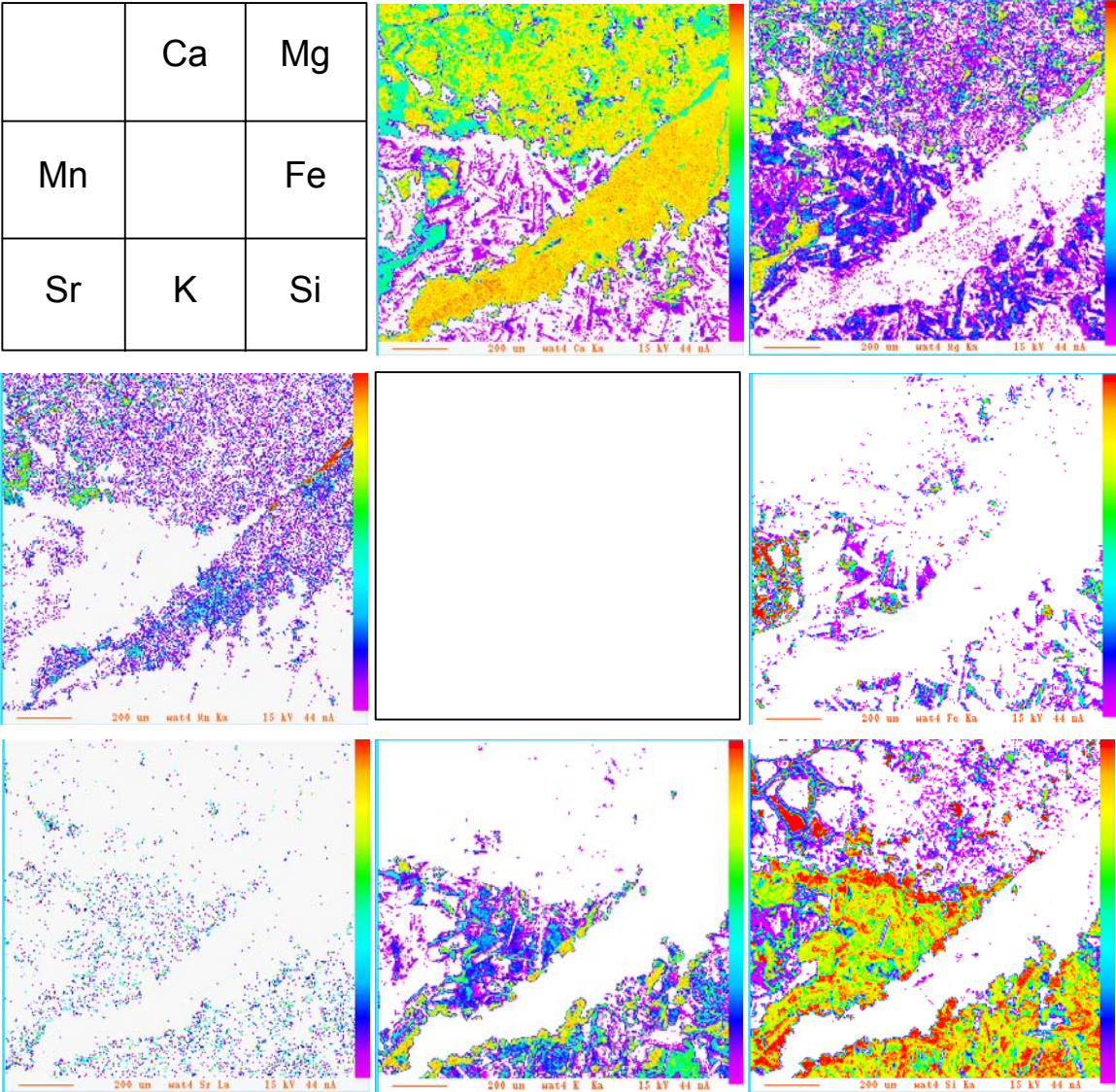
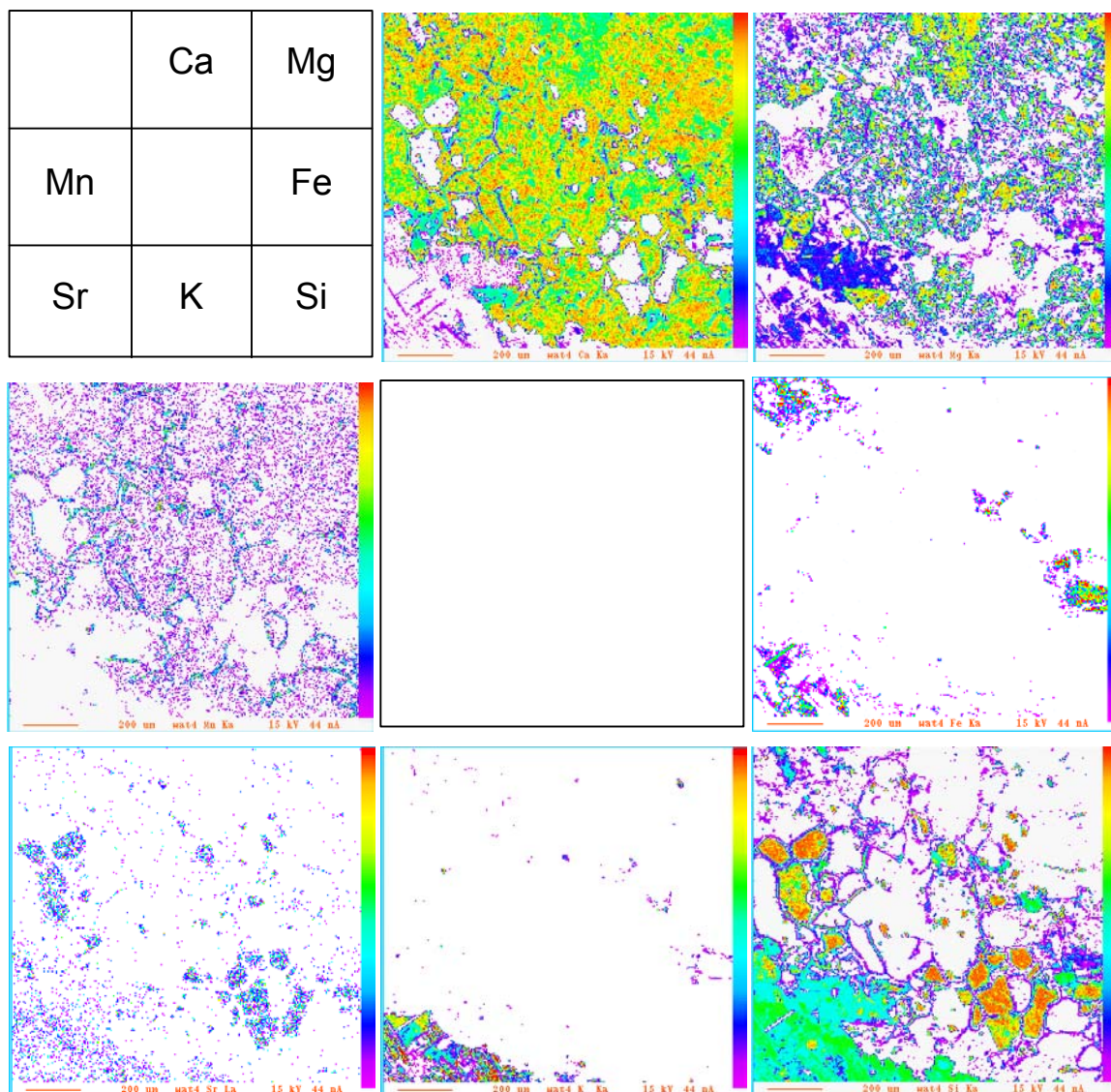


Photo 5) Detail of simple calcite-filled vein (a; Type 3), with marginal dolomite (b) and quartz (c), cutting complex vein Type 2. EPMA point analysis numbered 7-16.



EPMA-4) X-Ray maps of Vein "A"; area as highlighted on Photo 2.



Sample ID:	WAT-00-05
MPL Code:	G697
Core/Location:	Watford BH2: Box 22
Depth:	28.94 - 29.85 m
Vein Type:	3
EPMA X-ray Mapping:	Yes

The vein included in this sample is of relatively simple mineralogy, and texture being filled with homogeneous, massive calcite.

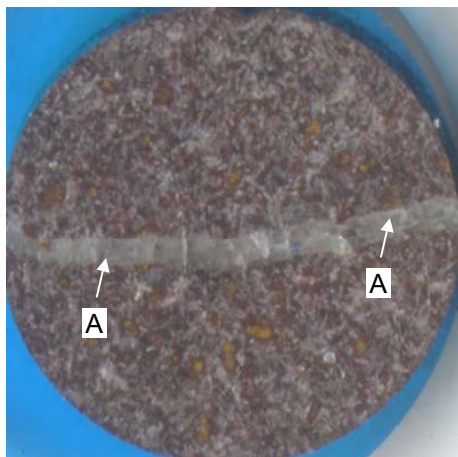


Photo 1) Scan of entire sample, showing single, simple vein cutting through basalt

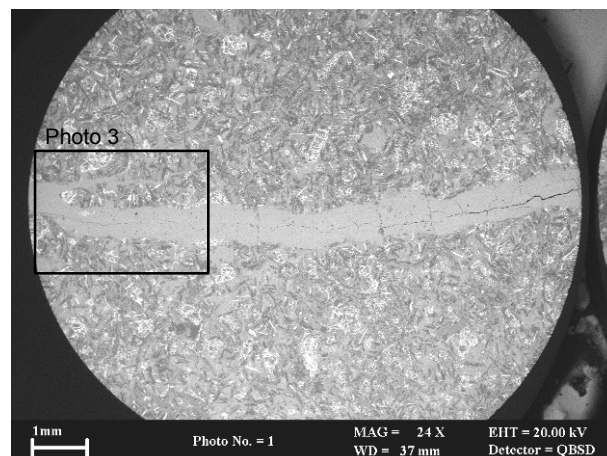


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photo 3 is highlighted.

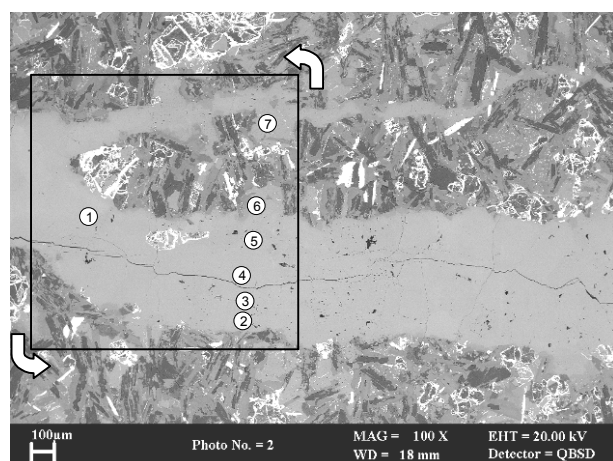
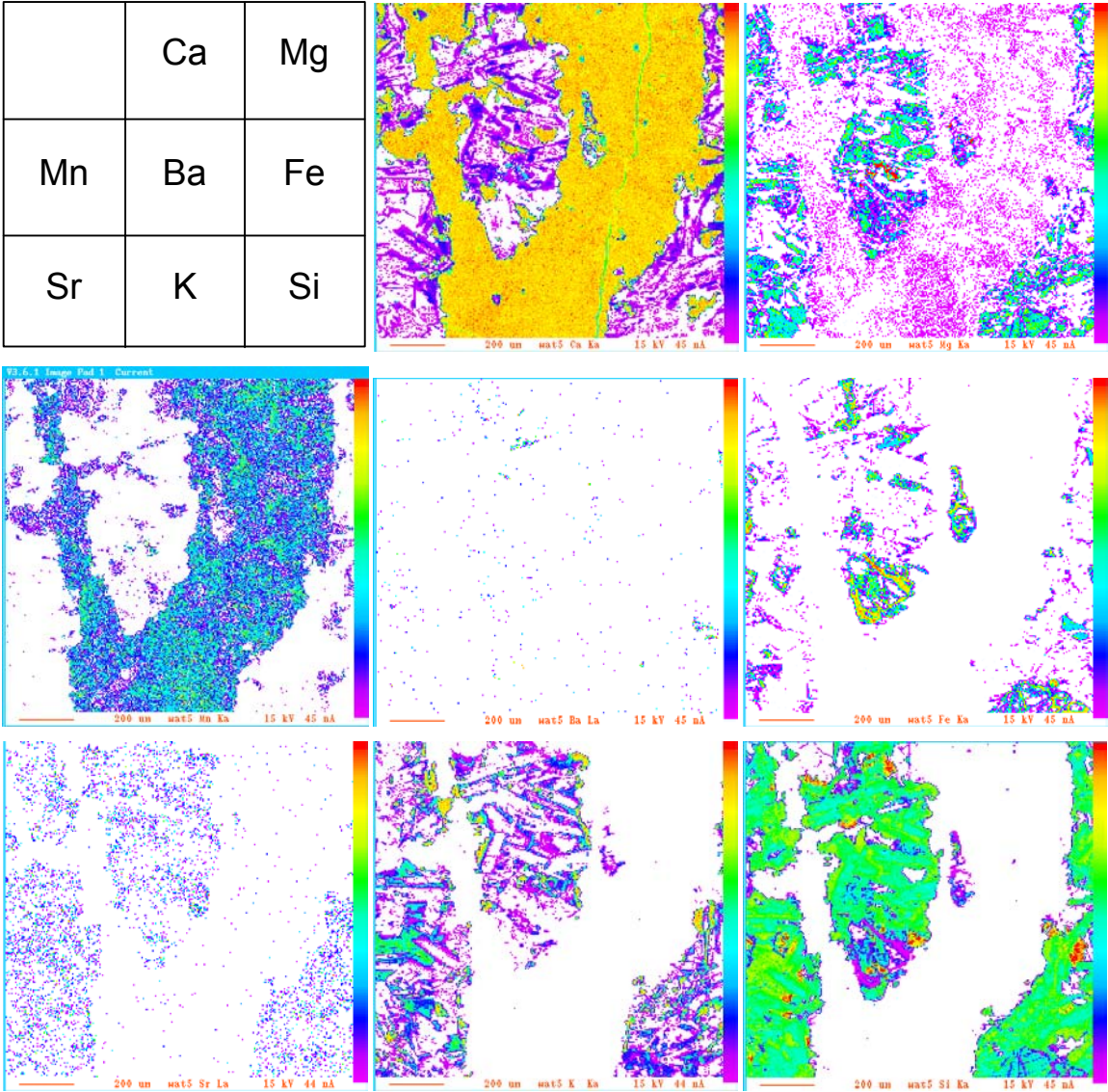


Photo 3) Detail of calcite filled vein. EPMA point analyses numbered 1-7.

EPMA X-Ray maps of area highlighted in Photo 3 (rotated 90° counter-clockwise)



Sample ID: WAT-00-06
 MPL Code: G698
 Core/Location: Watford BH2; Box 22
 Depth: 28.94 - 29.85 m
 Vein Type: 1
 EPMA X-ray Mapping: Yes

This vein is complex both in terms of mineralogy and texture:

1. the bulk of the vein comprises a complex intergrowth of filamentous silica, clay (probable smectite) and microcrystalline quartz (Photo 4).
2. along the margins of the vein, and down a plane of weakness in the centre of the vein, rhombic to feathery calcite, overgrown by dolomite are present (Photo 4). At the vein margins this calcite/dolomite appears to be replacing, and locally includes patches of a Mg-Ca-Fe-Al-silicate (clay).
3. red, possible ferruginous patches evident in hand specimen are shown to comprise patches of intimately associated calcite and dolomite (compare Photos 1 and 3).

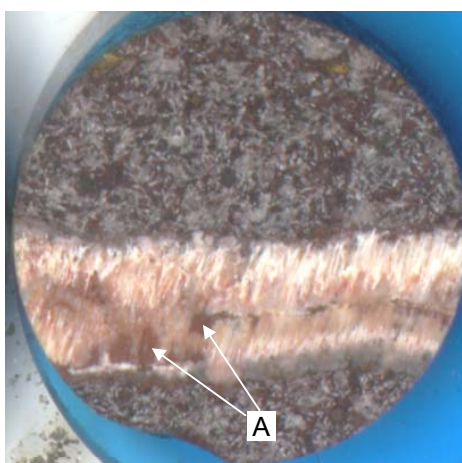


Photo 1) Scan of the entire sample, showing single, simple vein cutting through basalt. Stained/ferruginous patches are evident at A.

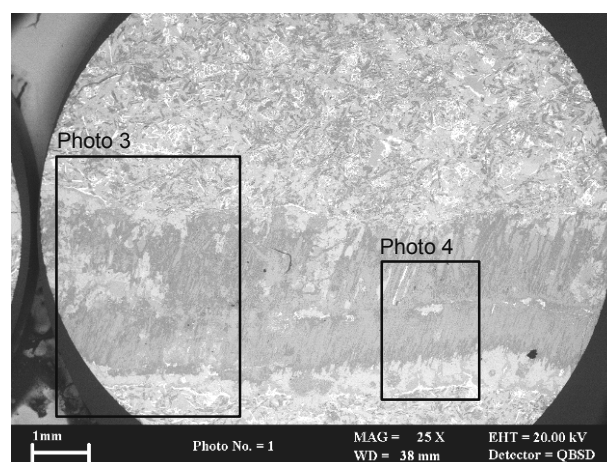


Photo 2) Low magnification BSE image of the entire sample. The locations of Photos 3 and 4 (rotated 90° counter clockwise relative to Photos 1 and 2) are highlighted.

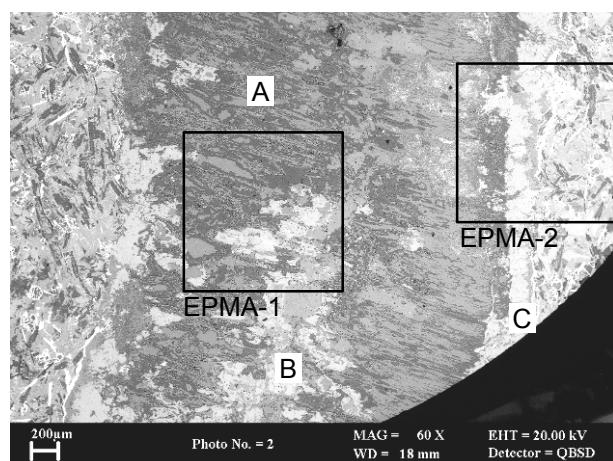


Photo 3) Detail of Photo 2, showing complex filamentous silica – smectite – microcrystalline quartz in vein center (A), being replaced along a plane of weakness in the vein centre by intergrown calcite and dolomite (B). The vein margins comprise blocky calcite with overlying feathered dolomite (C); see Photo 4 for more detail).

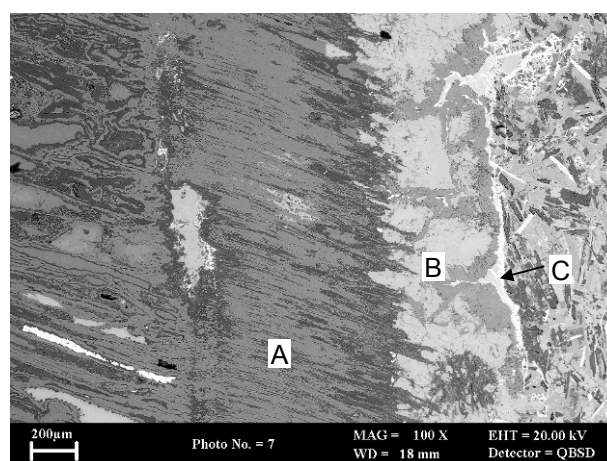


Photo 4) Detail of Photo 2 showing filamentous silica – smectite – microcrystalline quartz in centre of vein (A), with rhombic calcite + feathery dolomite overgrowths at vein margin (B). The calcite/dolomite at B appears to be growing into/replacing a mixture of Fe-oxide and clay at the vein margins (C).

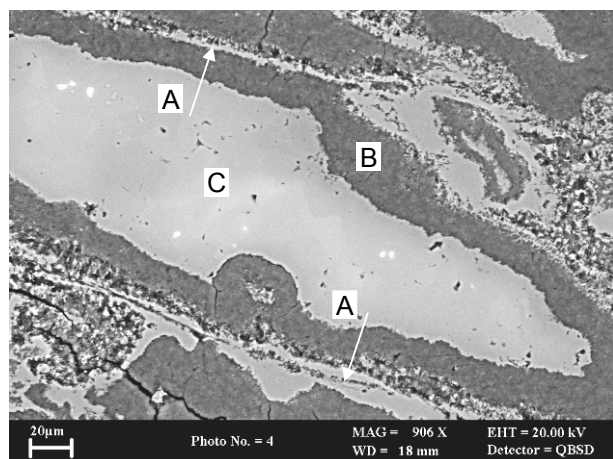


Photo 5) Detail of showing filamentous silica (A), which forms strands bridging the width of the vein. These strands appear to have a coating of probable smectite (Mg-Ca-Fe-Al-silicate; B) and void fills of microcrystalline quartz (C).

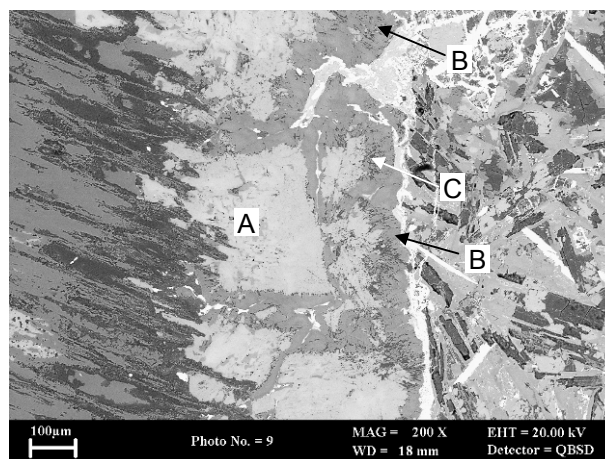
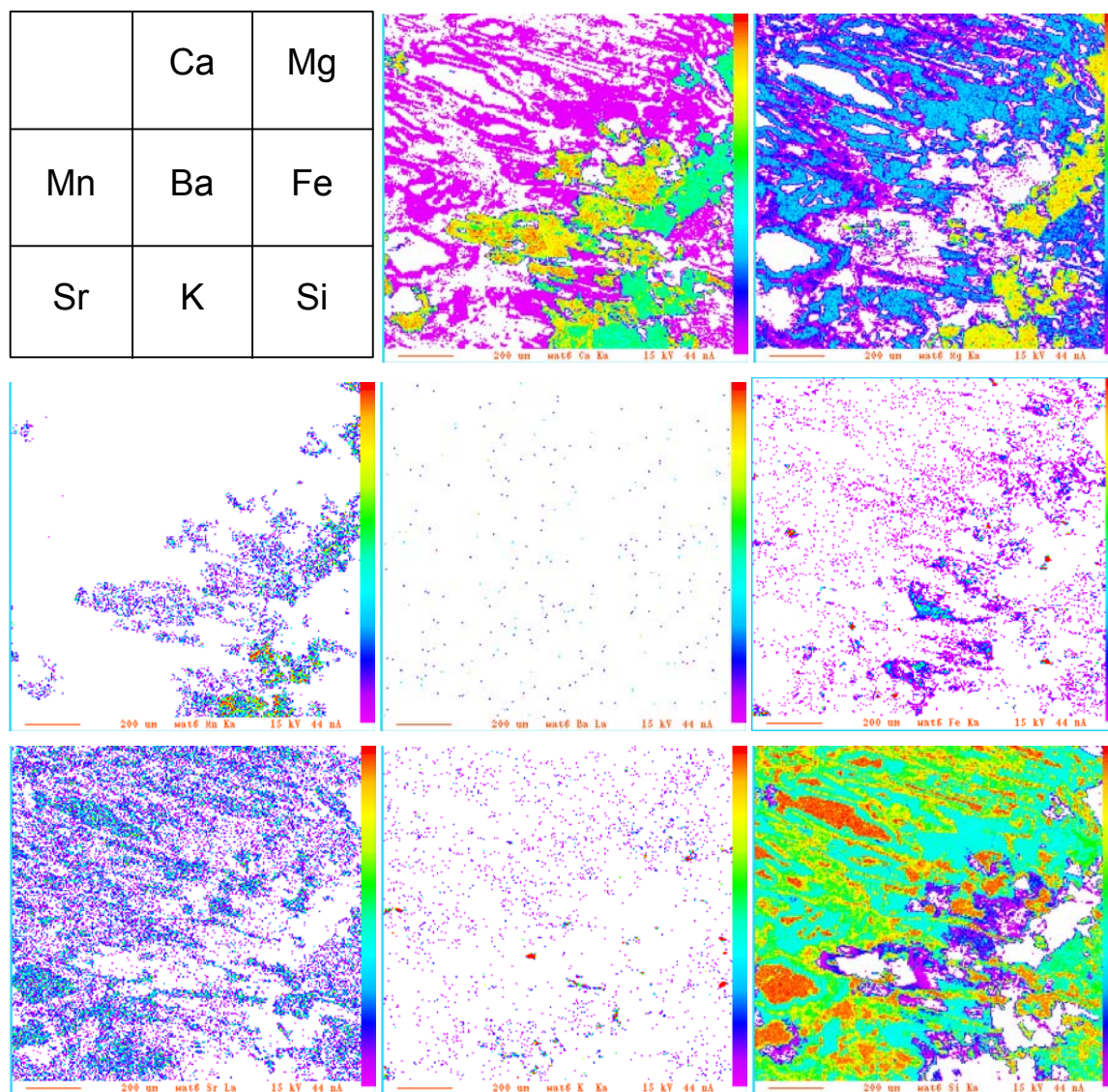


Photo 6) Detail of rhombic calcite (A) and feathery dolomite at the vein margin (B). Note also clay trapped within the feathery dolomite (C).

EPMA-1) X-Ray maps of area highlighted in Photo 3.



EPMA-2) X-Ray maps of area highlighted in Photo 3.

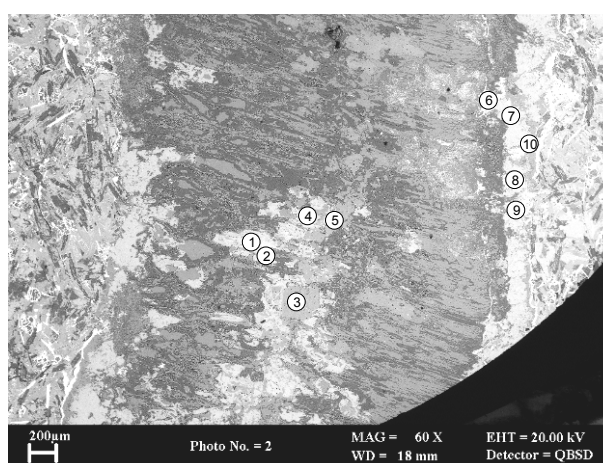
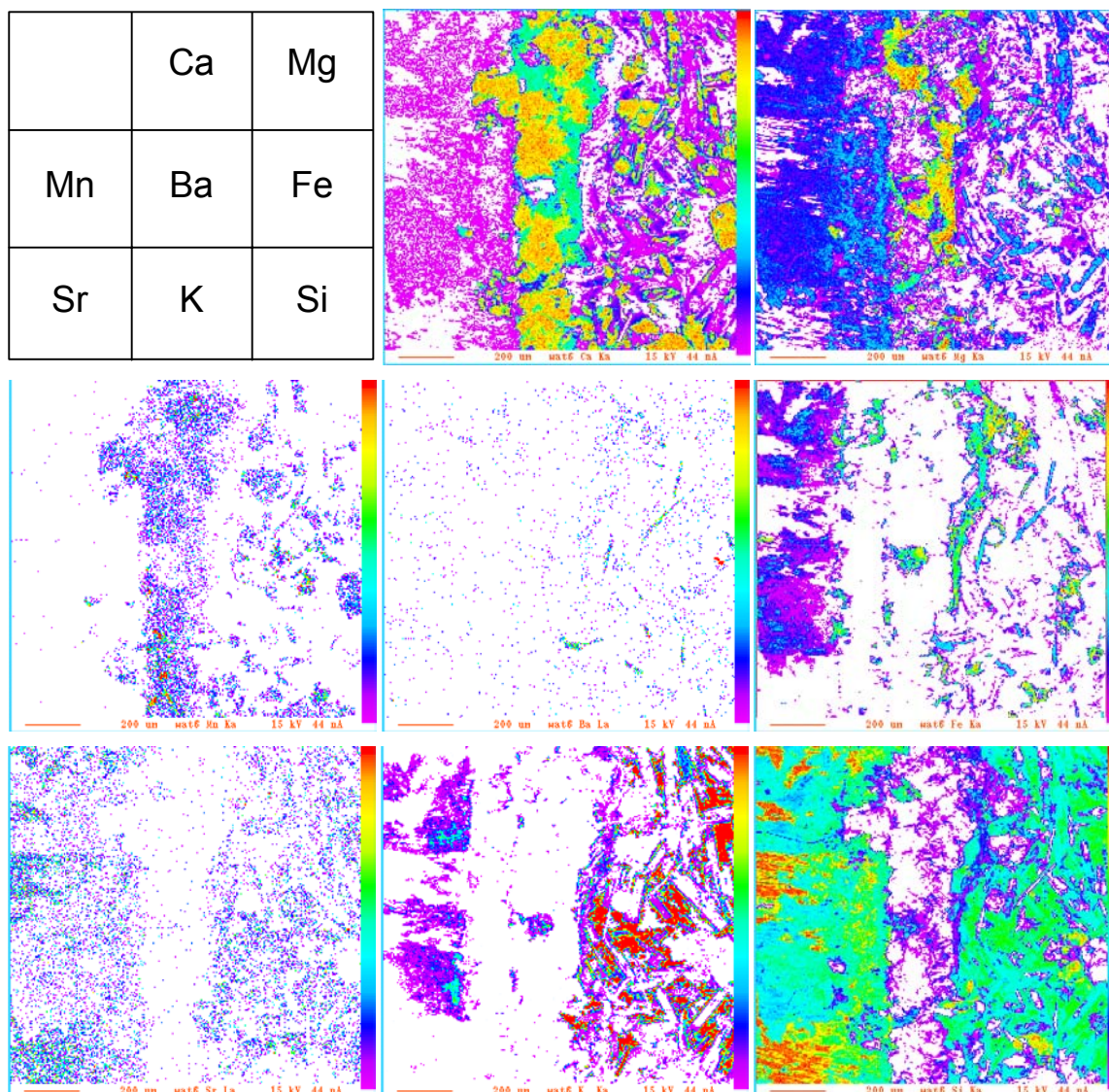


Photo 7) EPMA point analyses numbered 1-10.

Sample ID:	WAT-00-09
MPL Code:	G701
Core/Location:	Watford BH2, Box 22
Depth:	28.94 - 29.85 m
Vein Type:	Type 4, possibly overprinted by Type 2.
EPMA X-ray Mapping:	No

The vein included in this sample is very complex in character, although it shares some common features with those described in sample WAT-00-06 (G698):

1. The bulk of the vein is made up of a combination of filamentous silica – smectite – microcrystalline quartz (Photos 6 and 7; as seen in WAT-00-06), plus significant amounts of Ca-Mg-bearing clay (probably clay), mixed with varying amounts of silica (Photos 3, 4, and 5).
2. The vein margins are characterised by the presence of blocky to feathery calcite and dolomite, also as noted in sample WAT-00-06.
3. Two discreet patches of complete replacement/recrystallisation are also evident in hand specimen. In detail (see Photo 7), these are seen to comprise patches of irregular intergrown, locally feathery calcite and dolomite.



Photo 1) Scan of entire sample, showing complex, multistage vein.

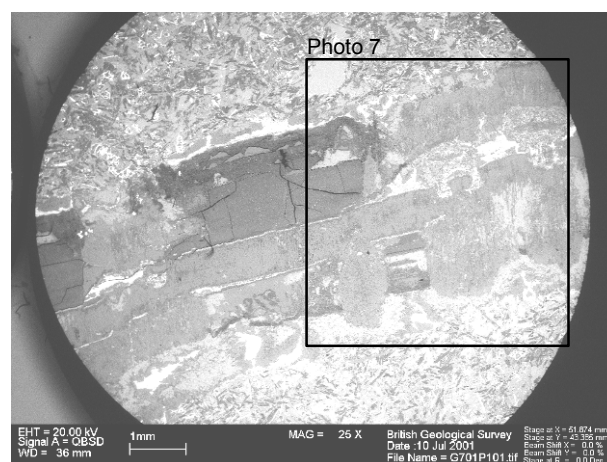


Photo 2) Low magnification BSEM image of the entire sample. Area of Photo 7 (SEM photomontage) is highlighted.

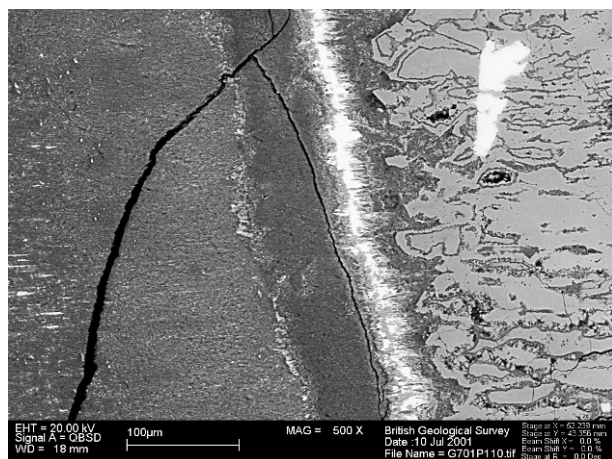


Photo 3) Detail of the margin of a clay-rich domain (left hand side of image). Differences in BSEM signal intensity relate to the amounts of silica/quartz associated with the clay (brighter signal = more silica). The right hand side of the image comprises filamentous silica – smectite – microcrystalline quartz as seen elsewhere.

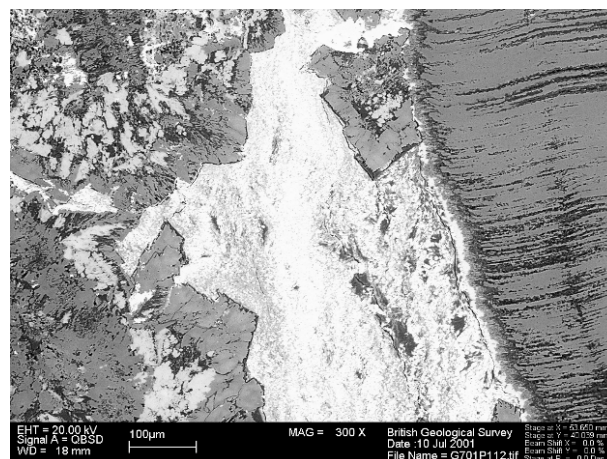


Photo 4) Detail showing feathery dolomite growing into a patch containing a mixture of Fe-oxide and clay. The feathery dolomite is seen to occur at the margins of patches of replacive, intergrown calcite and dolomite (see Photo 7).

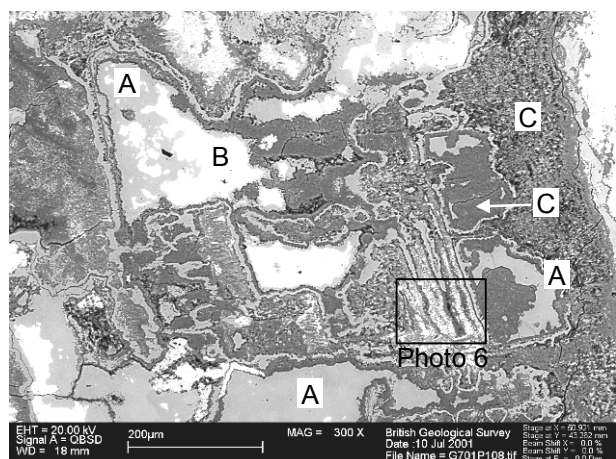


Photo 5) Detail of complex intergrowth of silica (A), an unidentified Ca-silicate (B) and a Ca-Mg-Al-silicate (probable smectite; C) mixed with variable amounts of quartz/silica.

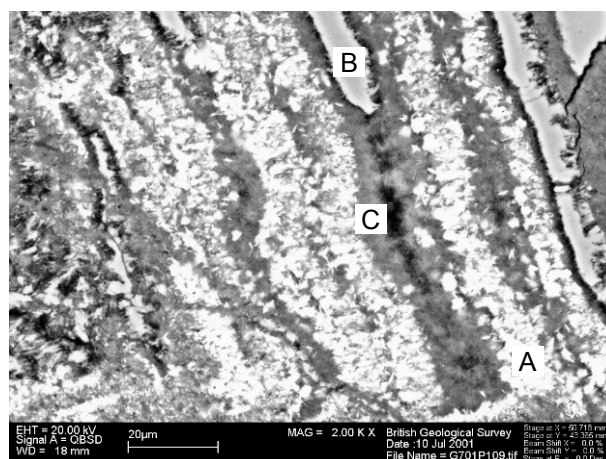


Photo 6) Detail of Photo 5, showing complex association of Fe-oxide (A), silica (B) and probable smectite (C).

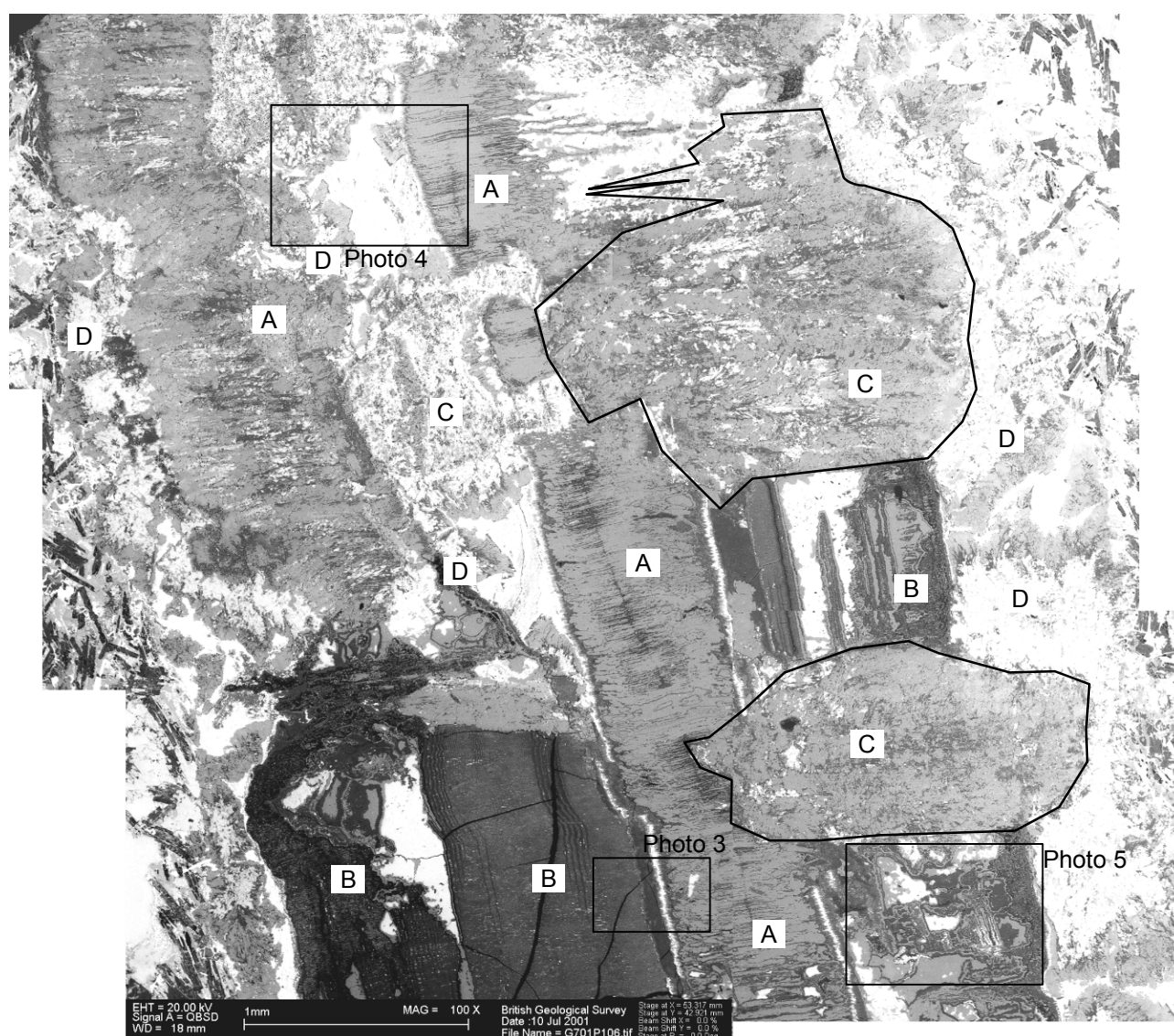


Photo 7) SEM photomontage showing area highlighted in Photo 2 (rotated 90° counter-clockwise). The very complex nature of this vein is confirmed with clay-rich, silica-rich and carbonate-rich domains all being observed. The silica-rich domains (A) are characterised by an association of vein-bridging filamentous silica – smectite – microcrystalline quartz. Clay-rich domains (B) display variations in the amount of silica/quartz mixed with the clay, which at this magnification produces differences in overall BSEM response (brighter = more silica). The carbonate-rich domains display complex feathery-replacement textures of intimately intergrown calcite and dolomite (C), which are overlain by more blocky (but still with irregular margins) patches of calcite and then dolomite (D).

Sample ID:	WAT-00-14
MPL Code:	G706
Core/Location:	Watford BH2; Box 23
Depth:	29.82 – 30.45 m
Vein Type:	1
EPMA X-ray Mapping:	No

The vein in this sample is characterised by:

4. Fe-oxides at the vein margins and also as vein-bridging lineaments (Photos 1, 2 and 3). There is evidence that these vein-bridging lineaments have been snapped as a result of further vein opening (Photo 3),
5. dolomite (appears white in hand specimen) overlies the Fe-oxides and has a feathered habit similar to that noted elsewhere (Photo 4).
6. the dolomite is overlain by intimately intergrown, irregular calcite and dolomite (appears pinkish in hand specimen). The calcite and dolomite at the vein centre (appears red in hand specimen) is notably better crystalline, with distinct calcite and dolomite crystals. This better crystalline calcite/dolomite displays curved/lobate margins against the intimately intergrown calcite/dolomite and is interpreted to represent a recrystallisation fabric (Photos 3 and 4).

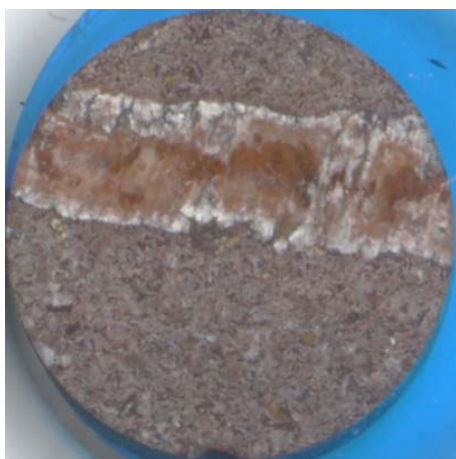


Photo 1) Scan of entire sample, showing complex, multistage vein.

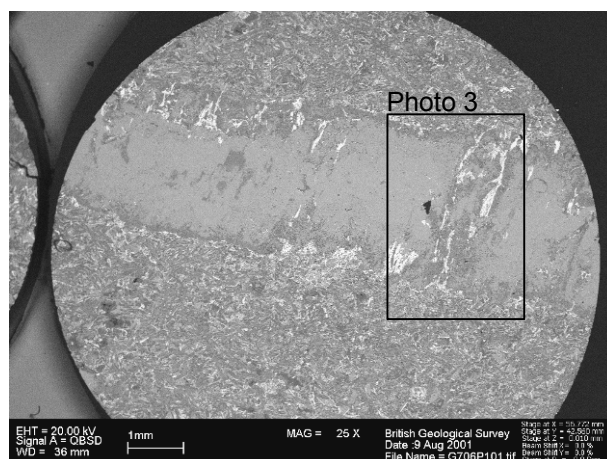


Photo 2) Low magnification BSEM image of the entire sample. Area of Photo 3 is highlighted.

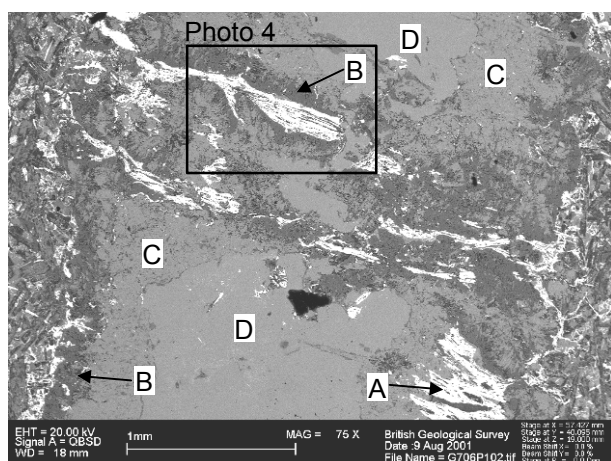


Photo 3) Vein marginal and vein-bridging Fe-oxides (A) are overlain by feathered dolomite (B). The centre of the vein is filled with intimately intergrown calcite/dolomite (C) which has partially recrystallised (D).

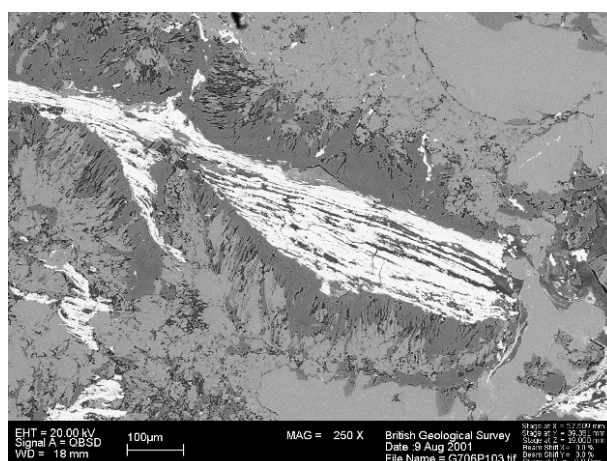


Photo 4) Detail of Photo 3 showing feathered dolomite overlying vein-bridging Fe-oxides, and partially recrystallised calcite-dolomite intergrowth.

Sample ID:	WAT-00-16
MPL Code:	G708
Core/Location:	Watford BH2; Box 21
Depth:	28.05 – 28.94 m
Vein Type:	5 (same vein as that sampled in WAT-00-17)
EPMA X-ray Mapping:	Yes

A complex multistage vein, which shares some common features with samples G698 and G701:

1. the core of the vein is filled with a filamentous silica – smectite – microcrystalline quartz assemblage as seen elsewhere. Directly adjacent to this feature is a zone containing silica which is brown and banded in hand specimen (Photo 1), but is homogeneous and featureless under BSEM (Photo 2; compositionally homogeneous). These silica zones are partially replaced and bounded by intergrown calcite and dolomite.
2. in hand specimen the intergrown calcite/dolomite appears pinkish in colour (Photo 1), and is associated with patches of clay (white in hand specimen). In detail (Photos 3 to 6), the calcite/dolomite displays a range of habits, including feathery, rhombic (Photos 4 and 5) and irregular (Photos 5 and 6).

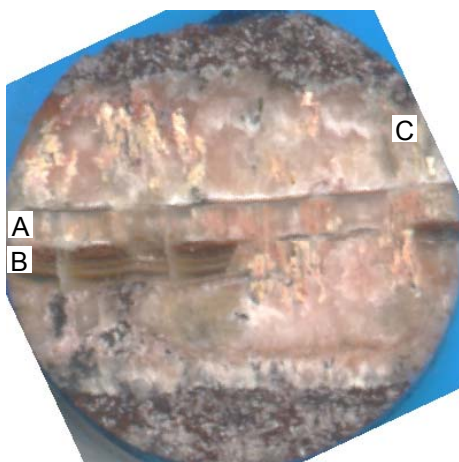


Photo 1) Scan of entire sample, showing complex vein. Filamentous silica (A) and banded silica (B) cut the centre of the sample, and are bounded and partially replaced by calcite and dolomite (C).

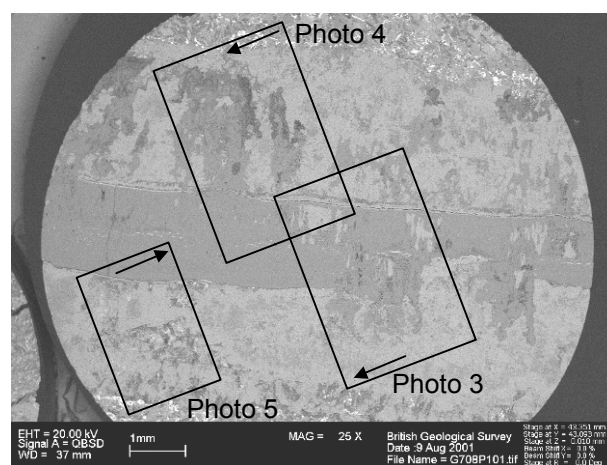


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photo 3, 4 and 5 are highlighted.

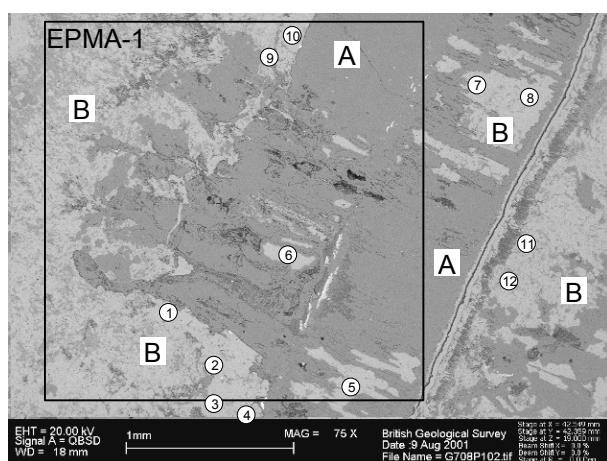


Photo 3) Detail of banded and filamentous silica (A) being patchily replaced by calcite and dolomite (B). EPMA point analyses numbered 1-10.

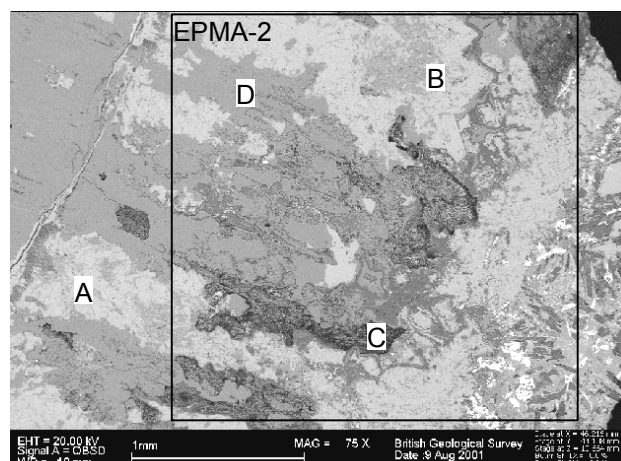


Photo 4) Detail showing intergrown feathery calcite and dolomite (A), euhedral calcite/dolomite rhombs (B), patchy clays (C) and relict patches of filamentous silica – smectite – microcrystalline quartz (D).

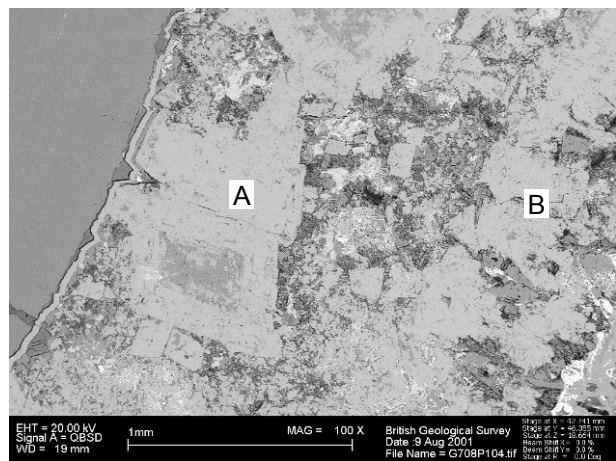


Photo 5) Detail of rhombic carbonate crystal with dolomite core and calcite margin (A). Also evident is an irregular association of calcite + dolomite + clay (B) from which the rhombic crystal appears to have recrystallised.

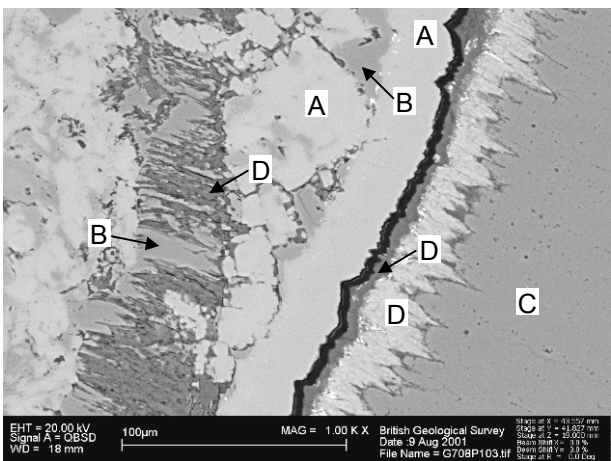
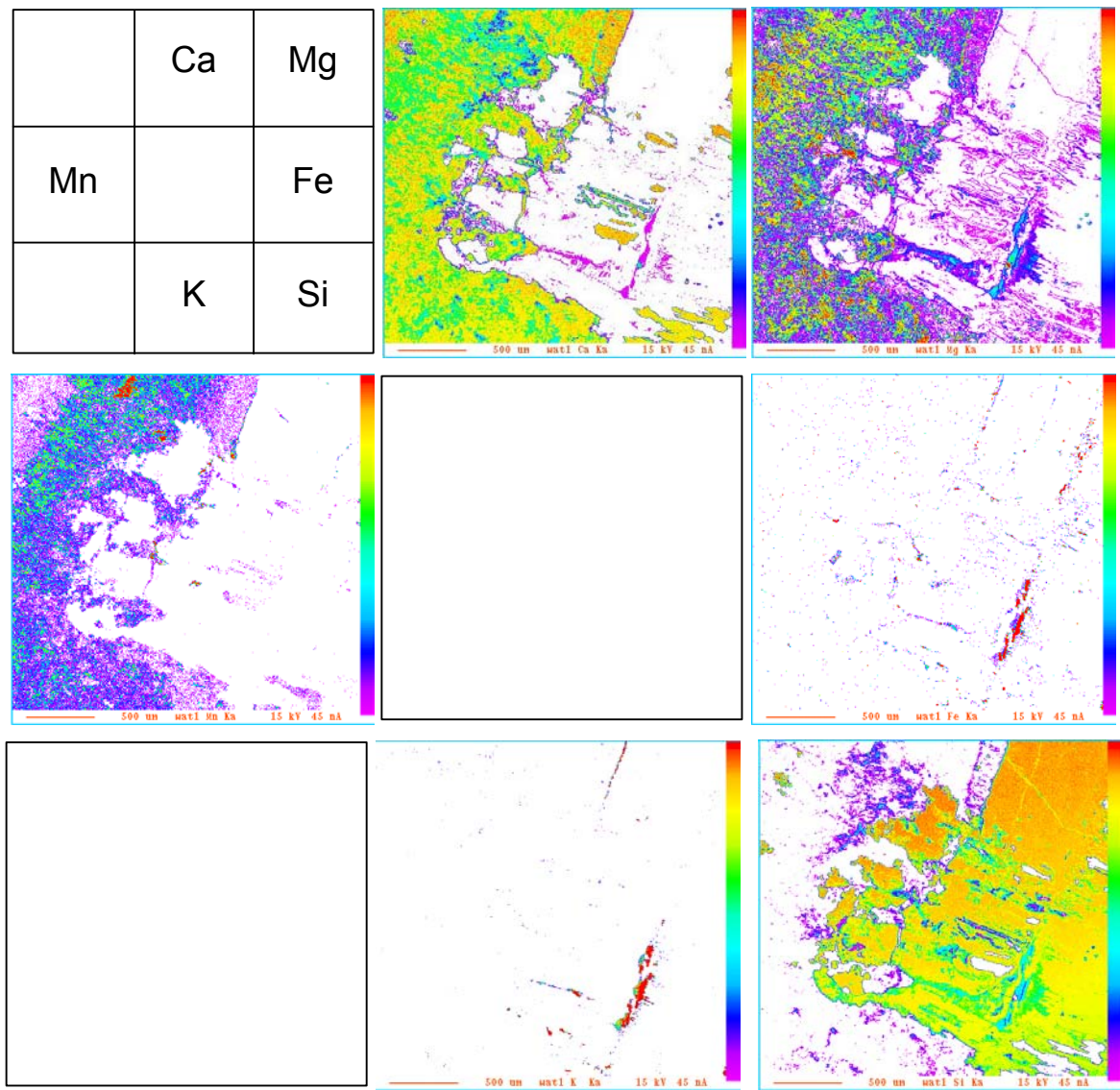
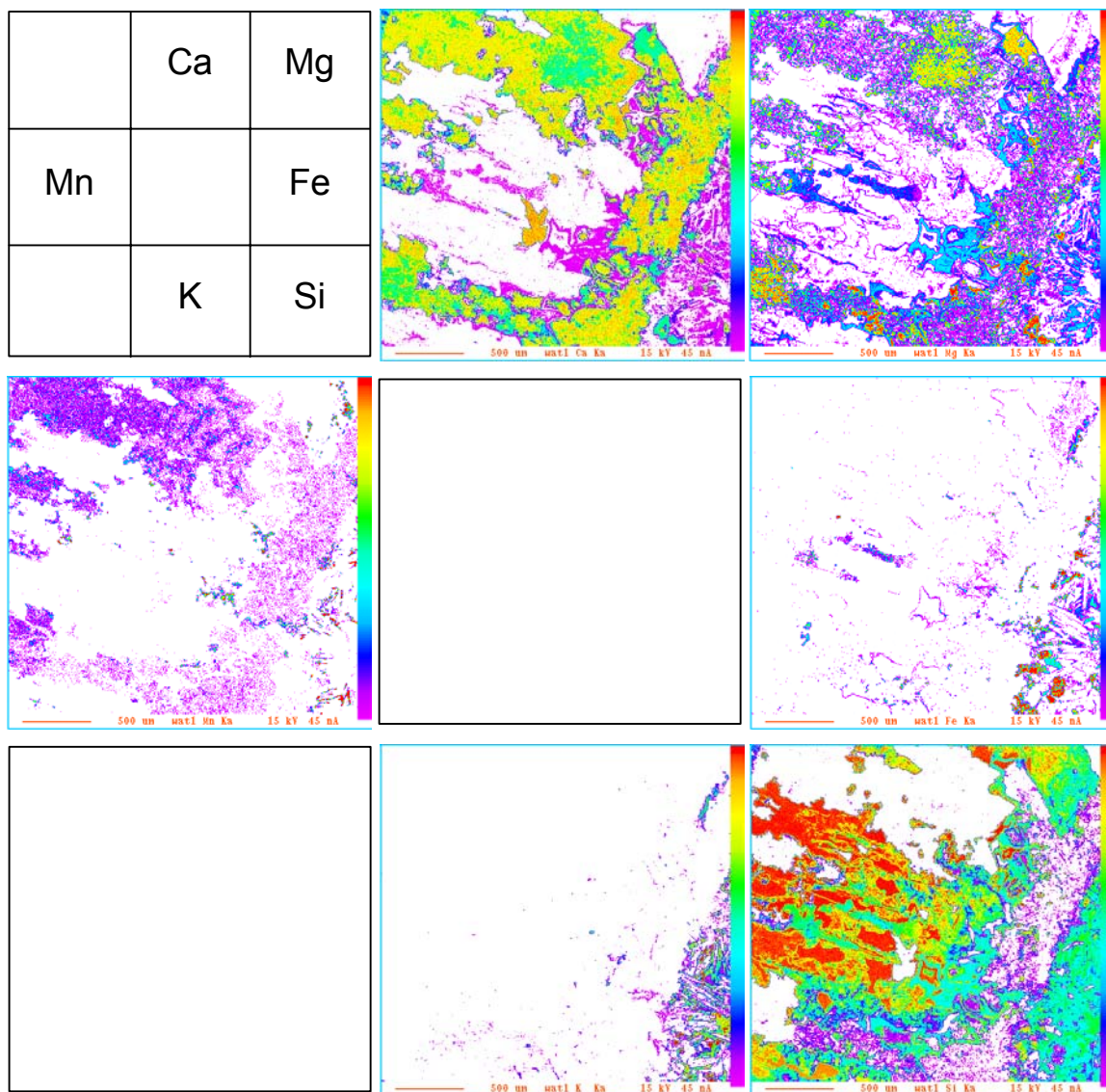


Photo 6) Detail showing the complex relationships between calcite (A), dolomite (B), silica (C) and clays (D).

EPMA-1) X-Ray maps of area highlighted in Photo 3.



EPMA-2) X-Ray maps of area highlighted in Photo 4.



Sample ID:	WAT-00-17
MPL Code:	G709
Core/Location:	Watford BH2; Box 21
Depth:	28.05 – 28.94 m
Vein Type:	5 (same vein as that sampled in WAT-00-16)
EPMA X-ray Mapping:	No

This sample is from the same vein as sample WAT-00-16, and some similarities are evident, although this vein appears to be more significantly altered.

3. the centre of the vein is dominated by silica which predominantly appears massive under SEM (Photos 2 and 3) although local colour variations (Photo 1) are evident.
4. on either side of the siliceous zone, there is a zone containing intimately associated calcite and dolomite, which mostly appears to be unstructured (Photo 4) although patchy recrystallisation and segregation of calcite/dolomite into distinct crystallographic zones is noted. Minor amounts of feathery calcite/dolomite as described elsewhere are also evident. Towards the margins of the vein, calcite becomes more abundant than dolomite and there is an increase in the proportion of silica and clay associated with the carbonate (Photo 4).
5. both these siliceous and carbonate-dominated zones are cross-cut by irregular calcite-cemented veins which show no evidence of compositional variability.

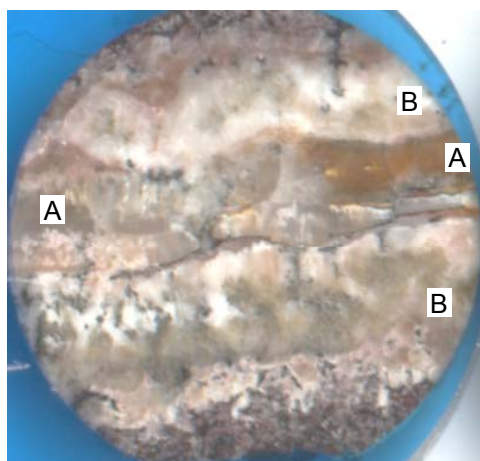


Photo 1) Scan of entire sample, showing complex vein. A siliceous domain occurs in the centre of the sample (A) and is bounded and partially replaced by calcite and dolomite (B).

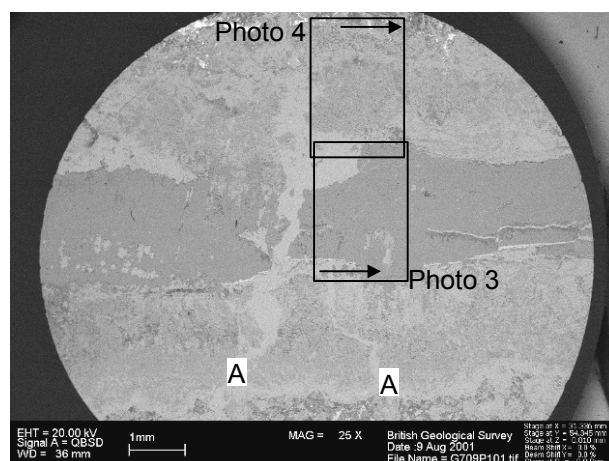


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photo 3 and 4 are highlighted. The main vein in this sample is cut by two irregular high-angle calcite veins (A)

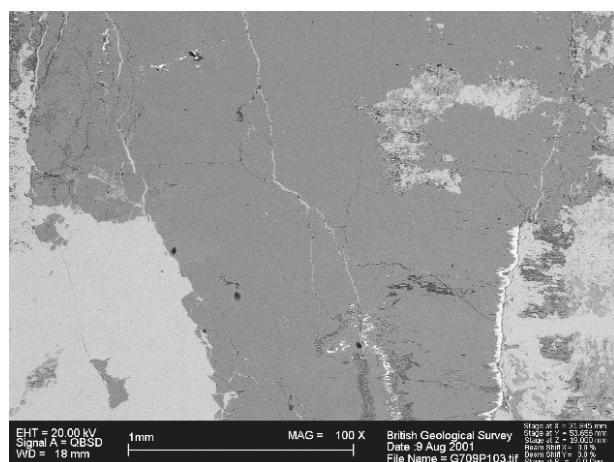


Photo 3) Detail relatively homogeneous siliceous band at the centre of the vein.

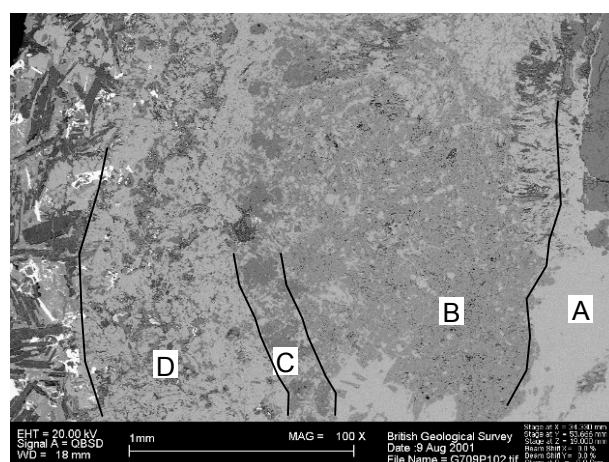


Photo 4) Detail of complexly intergrown calcite and dolomite. From the centre of the vein (left hand side of image), there is a calcite-rich band (A), a turbid mixed calcite/dolomite band (B), a calcite-rich band containing patches of silica (C), and a calcite-rich band containing abundant clay (D)

Sample ID: WAT-00-21
 MPL Code: G713
 Core/Location: Watford BH2; Box 20
 Depth: 27.14 – 28.05 m
 Vein Type: 4
 EPMA X-ray Mapping: No

This vein has a complex internal structure/mineral zonation, which can be divided into the following domains (see Photo 2):

- Domain 1 complexly intergrown silica and clay, being partially replaced by calcite (Photo 3).
- Domain 2 intergrown calcite and dolomite, locally showing signs of recrystallisation (Photo 4)
- Domain 3 complex association of silica (?amorphous or crystalline?), calcite and dolomite, which locally appear to have grown along strands of clay (Photo 5).
- Domain 4 under BSEM, this domain is similar in character to domain 3, but has a lower clay content.
- Domain 5 this comprises massive, compositionally homogeneous calcite, and is interpreted to be the same calcite as that seen in other samples of vein Type 3 (e.g. WAT-00-04).

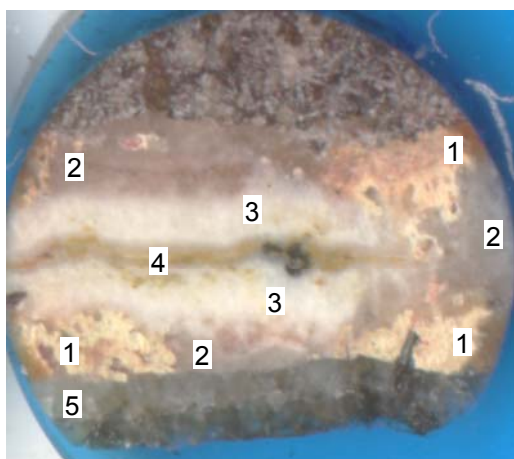


Photo 1) Scan of entire sample, showing complex vein, with mineralogically and texturally distinct domains (1 to 5 in text).

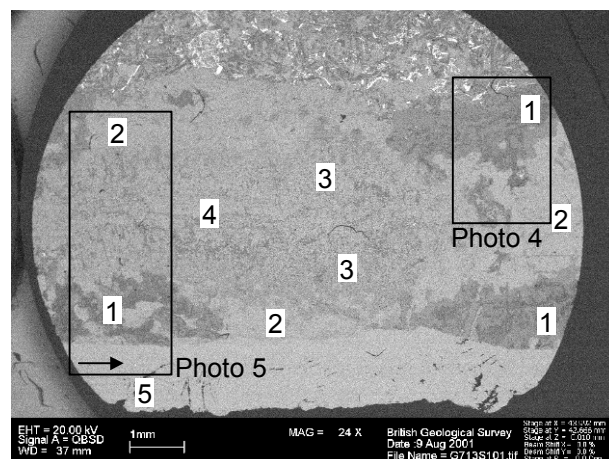


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photos 4 and 5 (SEM photomontage) are highlighted. Numbered domains correspond to descriptions in text.

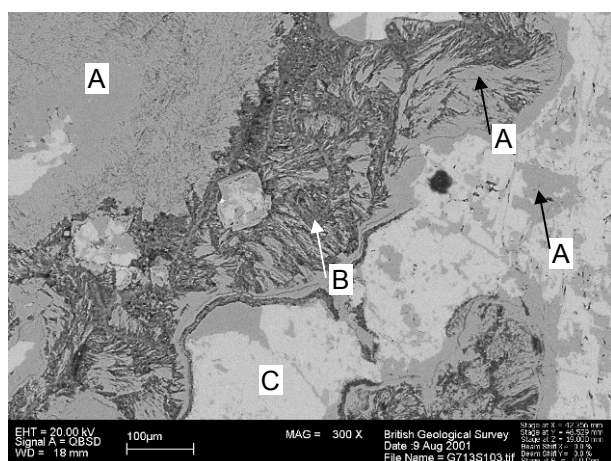


Photo 3) Complex intergrowth of dendritic silica (A), and clay (B), being replaced by calcite (C) within Domain 1.

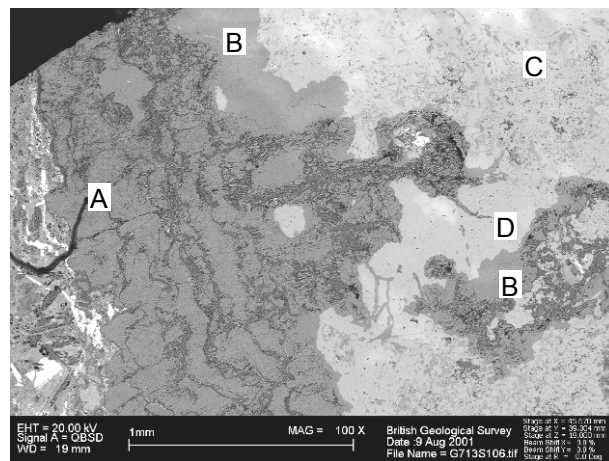


Photo 4) Detail of Domain 1 containing dendritic silica and clay (A), with marginal development of lobate (?amorphous) silica (B), which appears to replace intergrown calcite/dolomite (C), locally recrystallised (D) of Domain 2.

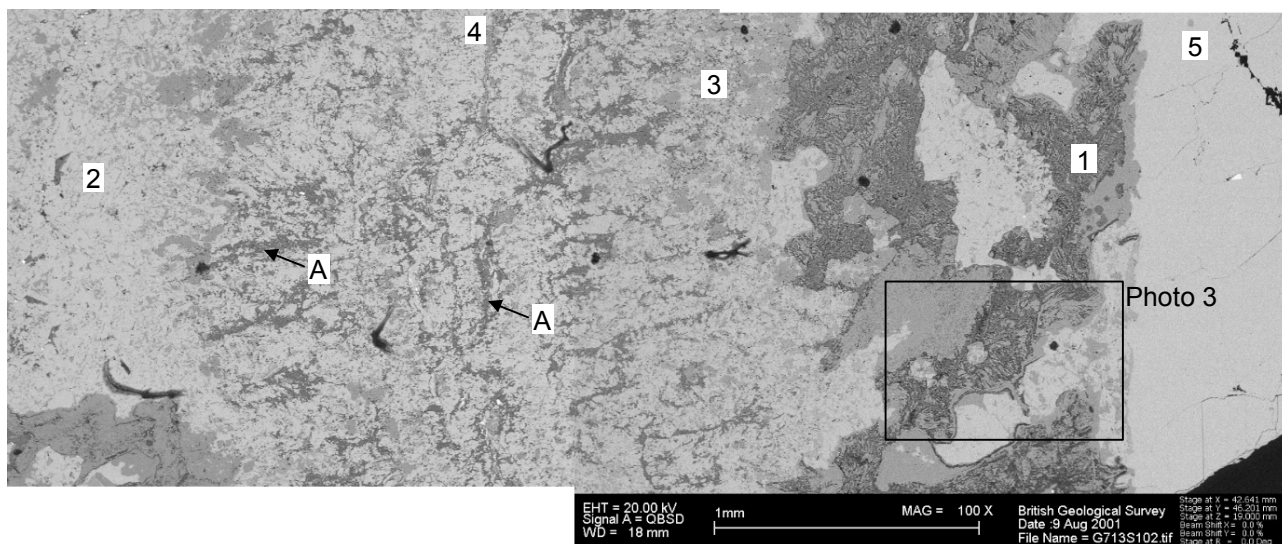


Photo 5) SEM photomontage showing clay-rich nature of Domain 1 (see Photos 3 and 4 for more details). Domain 3 contains very finely crystalline silica (?amorphous), calcite and dolomite which appear to have grown along stands of an unidentified clay (A). As noted in Photo 4, Domain 2 contains intergrown calcite and dolomite. Under BSEM, Domain 4 is only distinguished from Domain 3 by a reduced clay content. Finally, domain 5 comprises simple, massive calcite. In this vein, Domain 5 runs parallel to the more complex earlier vein (domains 1 to 4), but it is inferred that this calcite is of similar type to that seen in other samples of vein Type 3 (e.g. WAT-00-04).

Sample ID: WAT-00-23
 MPL Code: G715
 Core/Location: Watford BH2; Box 20
 Depth: 27.14-28.05 m
 Vein Type: 4
 EPMA X-ray Mapping: Yes

The dominant vein in this sample contains carbonate of two different colours. The earlier appears pinkish in hand specimen, and the later appears brown. BSEM and the results of EPMA X-ray mapping are unable to detect any compositional distinction between these carbonates. In detail, the vein is seen to contain variably crystalline (ranges from irregular to euhedral) calcite and dolomite, with relict patches of silica and clay (Photo 3).

The two smaller veinlets at the margin of the sample (Photos 1 and 4) may be associated with the later carbonate. One of the veins is lined with silica, and filled with calcite; the other contains intimately intergrown calcite and dolomite.

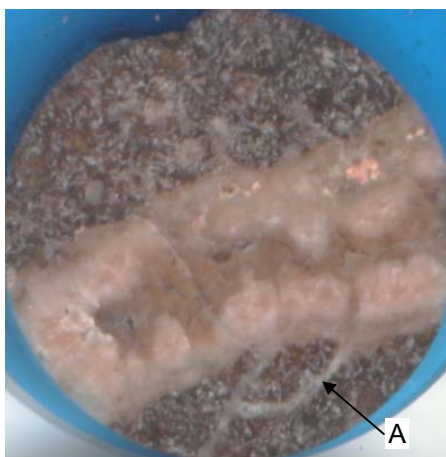


Photo 1) Scan of entire sample, showing carbonate fill with two distinct colours. The inner, "brownier" zone appears to be linked to the curving vein at the margin of the sample (A).

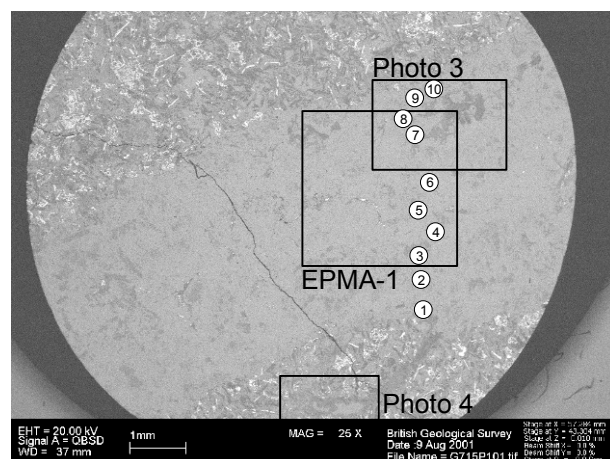


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photos 3 and 4, and EPMA X-ray mapping are highlighted. EPMA point analyses numbered 1-10.

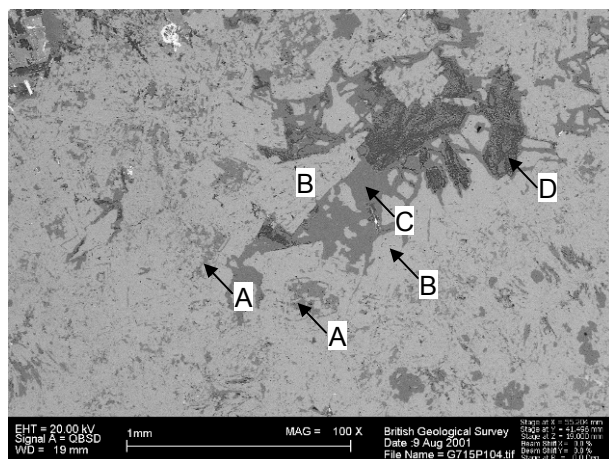


Photo 3) Detail of the center of the vein, containing locally euhedral carbonates (commonly with dolomite cores [A] and calcitic margins [B]). Relict patches of silica (C) and clay (D) are present. This texture is suggestive of replacement of silica by carbonate.

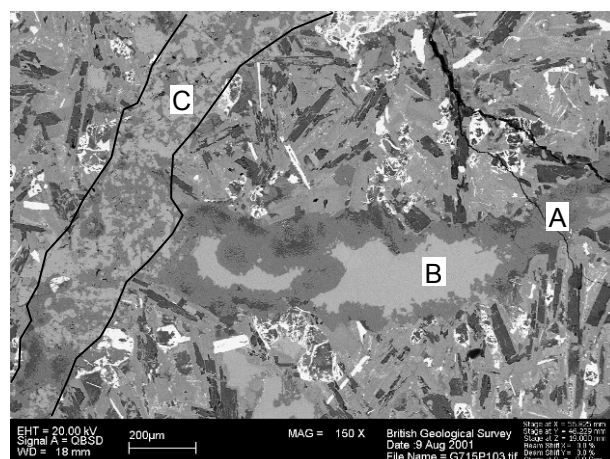
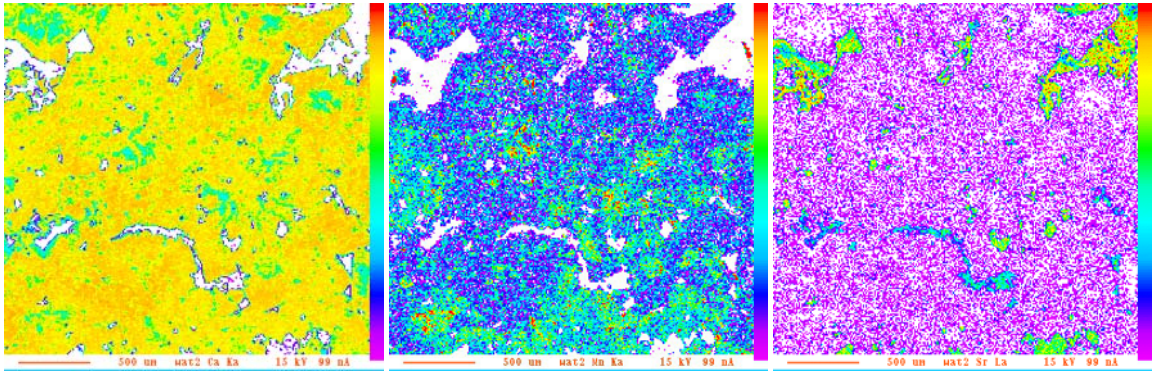


Photo 4) Detail of a silica-lined (A), and calcite-filled (B) veinlet, cut by a later vein containing intergrown calcite and dolomite (C).

EPMA-1) X-Ray maps of area highlighted in Photo 2.

Ca	Mn	Sr
----	----	----



Sample ID:	WAT-21
MPL Code:	n/a
Core/Location:	Watford BH2
Vein Type:	Type 4 cut by Type 3
EPMA X-ray Mapping:	No

A complex history of vein paragenesis is apparent, with the various vein-filling minerals commonly displaying very complex morphologies and intergrowths. The polished section contains three distinct generations of veins (Photo 1). Generations I and III directly correspond to veins of Types 1 and 3 (see page 2), but vein generation II is of ambiguous type.

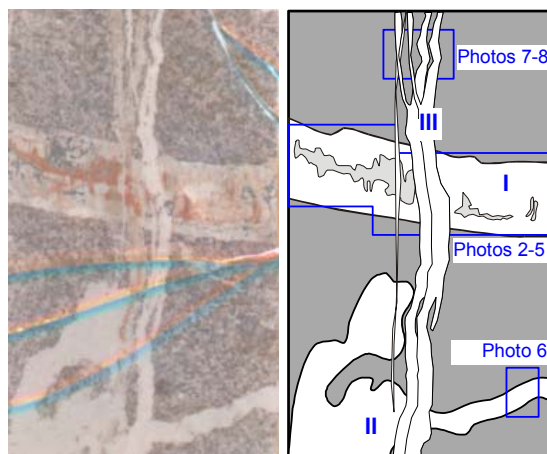


Photo 1) Scanned image (left hand side) and accompanying sketch (right hand side) of polished section WAT-21, showing three distinct vein generations (denoted I [vein Type 1], II and III [vein Type 3]) within basalt host rock.

GENERATION I – TYPE 1 VEIN

A near-horizontal vein with very complex paragenesis including calcite, dolomite, quartz ?amorphous silica, possible smectite, and Fe-Mn-oxides (Photos 1-5).

- the majority of the vein is filled with a fibrous intergrowth of microcrystalline quartz and probable smectite (Photo 3). The elongation of the intergrowth across the vein, indicates probable formation during vein opening. In detail, microcrystalline quartz crystals have nucleated on discontinuous, vein-bridging, filaments of silica (Photo 4). The microcrystalline quartz is engulfed by probable smectite (EDXA indicates c. 65% SiO₂, 25% Al₂O₃, 5% MgO, 5% CaO and minor Fe₂O₃), which forms a continuous lining around the quartz (Photo 4).

Both these phases are non-luminescent under CL (Photo 3). However, BSEM resolves both phases clearly, although differentiation between quartz and dolomite is based on subtle variations in grey-scale. The intergrowth between these phases is too fine to resolve by OM.

- within the fracture, calcite and dolomite are developed with an unusual feathery/fibrous morphology (Photo 5). The fibres are nucleated upon the vein-bridging microquartz-smectite intergrowth described above, but are elongate perpendicular to the Type 3 veins of generation III.
- the calcite and dolomite are both brightly luminescent under CL, which captures the textural relationships between the carbonates and the underlying non-luminescent microquartz-smectite intergrowth. However, similar information is apparent on the BSEM images (compare Photos 5b and 5c: calcite appears “bright” relative to dolomite under BSEM). Under OM, the calcite and dolomite display different optical characteristics, with the calcite being considerably more turbid than the dolomite. However, this mineralogical differentiation of calcite and dolomite in OM is only possible retrospectively following CL and/or BSEM imaging.
- the margins of this vein comprise relatively blocky calcite crystals with dolomite margins (Photo 2). This calcite-dolomite is clearly dissected by the vertical veins, but is of ambiguous timing relative to the feathery/fibrous calcite-dolomite described above.

Both calcite and dolomite are clearly resolved by BSEM and CL. It was hoped that CL may detect variations in luminescence between different carbonate generations related to subtle differences in chemistry not evident in the BSEM images. However, in this case, the luminescence characteristics of the blocky calcite-dolomite are indistinguishable to those noted above for the feathery/fibrous calcite-dolomite. Therefore, in this case, CL appears to add little that is not apparent from the BSEM images.

- the interstices between the phases described above are filled with opaque material, which BSEM analysis indicates to represent a mixture of K-Fe-Ca-Mg-bearing probable clay, and Fe-Mn oxides (Photo 2). These are non-luminescent under CL, and opaque under OM. Therefore, the only way to study these phases is by BSEM.

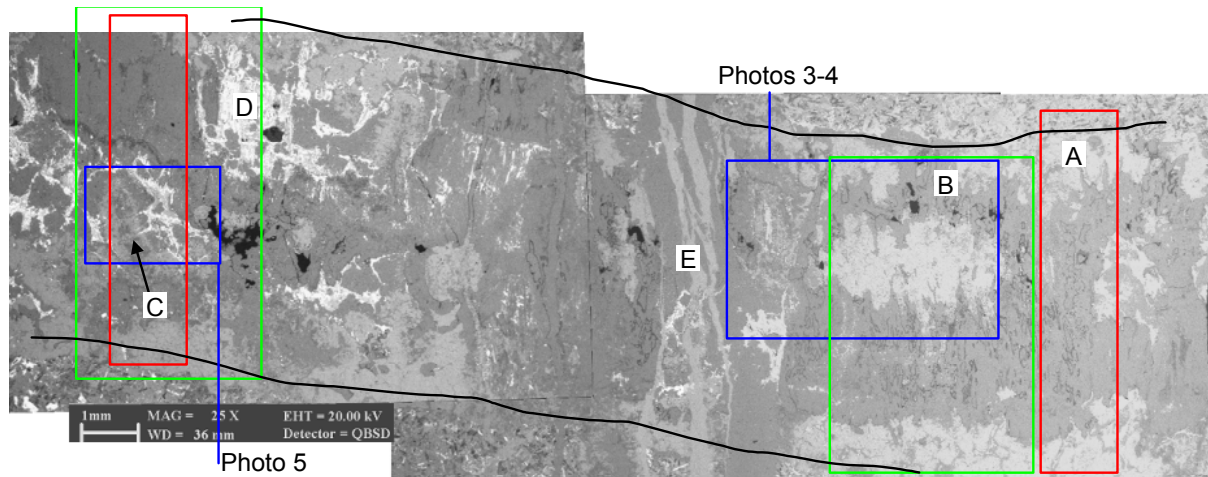


Photo 2) Montage of low magnification BSEM images across the horizontal, Type I vein (Generation I) shown in Photo 1. The vein margins are highlighted with BLACK lines. The vein contains blocky calcite and dolomite (A), intergrown filamentous silica – smectite – microcrystalline quartz (B), and feathery calcite and dolomite (C) growing into/replacing patches of Fe-oxides and clay (D). The vein is cut by vertical veins of generation II (E). Areas detailed in Photos 3-5 highlighted by colour coded boxes (GREEN = OM, RED = CL, BLUE = BSEM).

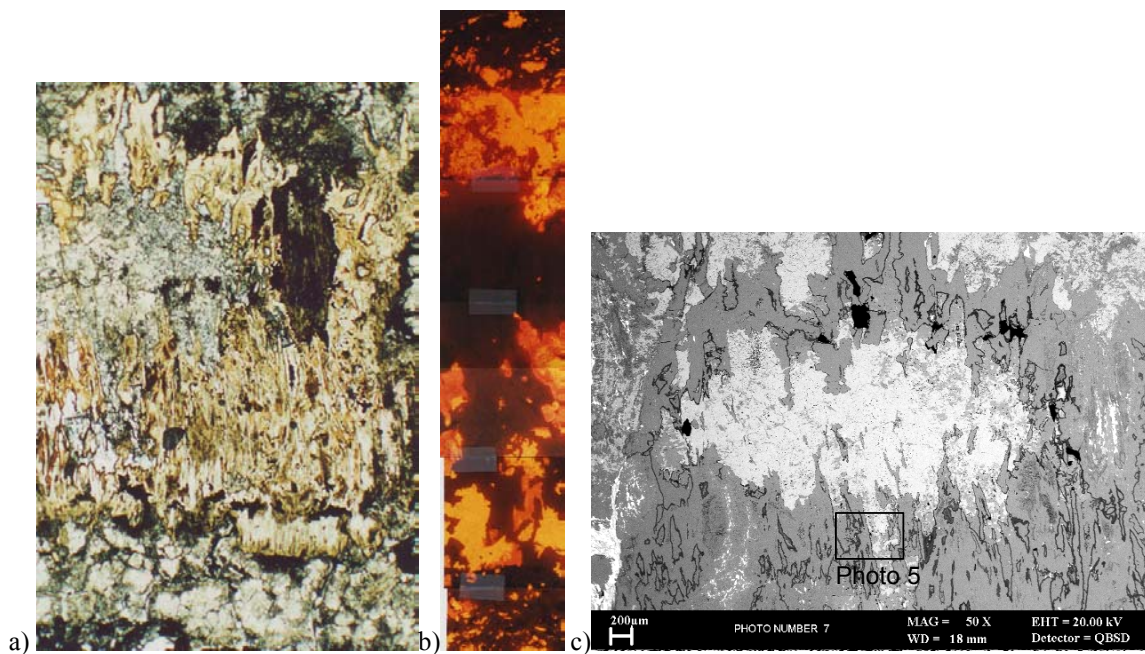


Photo 3) Details of area highlighted in Photo 2 imaged using (a) OM, (b) CL and (c) BSEM (all images are shown at approximately equivalent scale – see (c) for scale bar).

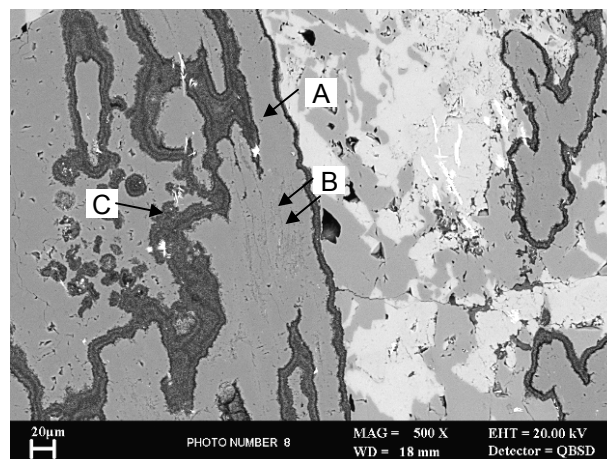


Photo 4) BSEM image of the area highlighted in Photo 3c. The image shows microcrystalline quartz (A), nucleated upon siliceous vein-bridging filaments (B), and engulfed by smectite (C).

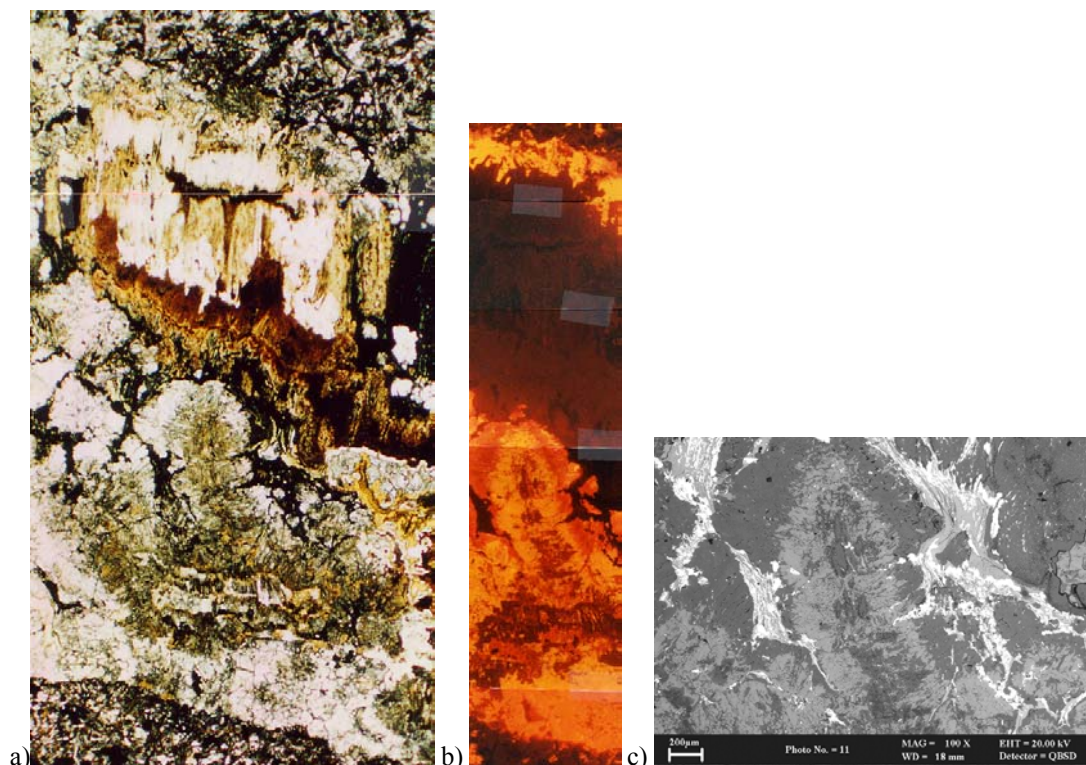


Photo 5) Details of area highlighted in Photo 2 imaged using (a) OM, (b) CL and (c) BSEM (all images are shown at approximately equivalent scale – see (c) for scale bar)

GENERATION II – VEIN OF AMBIGUOUS TYPE

An irregular, calcite-cemented feature which cross-cuts vein generation I. Minor native gold has been observed within this feature in WAT-21. OM provides little information other than indicating the irregular form of this vein/cement generation and a carbonate mineralogy. Under BSEM and CL (Photos 6a and 6b) this generation is seen to predominantly comprise moderately luminescent calcite, with irregular patches of less luminescent dolomite. Rare grains of native gold (Photo. 6a) are present within this vein generation.

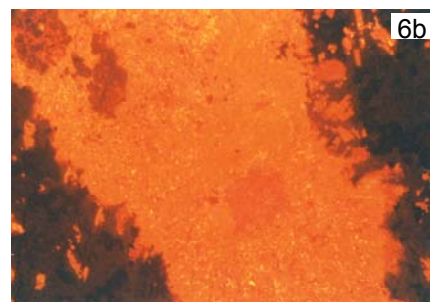
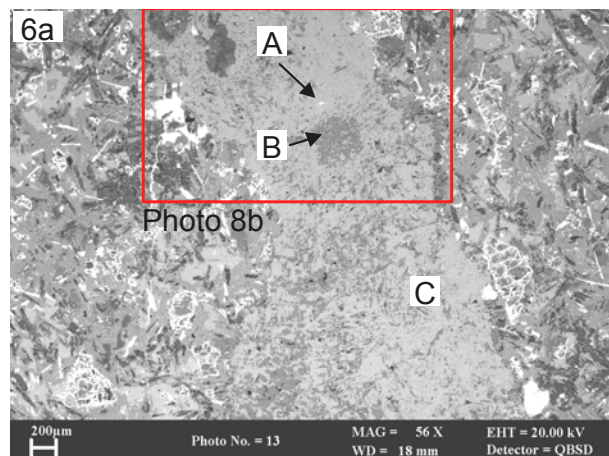


Photo 6 (left and above) Images of area highlighted in Photo 1 imaged using (a) BSEM and (b) CL techniques (both images are shown at approximately equivalent scale – see (a) for scale bar). A grain of native gold (A) sits within intergrown dolomite (B) and calcite (C).

GENERATION III – TYPE 3 VEINS

A set of near vertical, mm-scale calcite and dolomite-cemented veins of Type 3 (see Page 2). Within this generation, three distinct episodes (sub-generations) of veining with cross-cutting relationships are present:

- **IIIA:** although this episode is clearly visible to the naked eye (see image of entire polished section in Photo 1), it is turbid and poorly resolved using OM (Photo 8a). BSEM (Photo 8c) indicates intergrown blocky and relatively feathery calcite and dolomite. CL (Photo 8b) confirms the SEM observations, but also gives an indication of more systematic mineralogical/chemical variability. The CL images indicate relatively dull-luminescent vein margins (?predominantly dolomitic), which pass into more brightly luminescent blocky calcitic, and moderately

luminescent feathery calcite towards the vein centres. CL and BSEM analysis also indicate the presence of non-luminescent clays within the vein centres.

- **IIIB:** BSEM and CL (Photos 8b and 8c) indicates that this episode of fracturing contains dolomite cement, which is compositionally homogeneous.
- **IIIC:** this episode of veining appears to reactivate veins formed during episode IIB, and is calcitic and anatomising in character. Under OM (Photo 8a), differentiation of veins formed during episodes IIB and IIC is ambiguous, although IIC appears slightly more turbid. Under CL and BSEM (Photos 8b and 8c), veins formed during episodes IIB and IIC are clearly resolved.

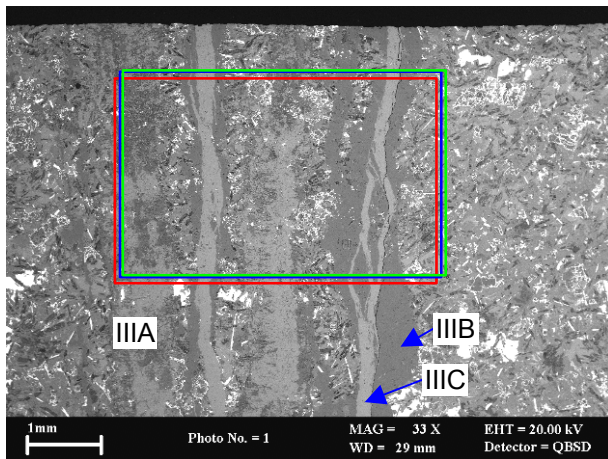


Photo 7 BSEM image of near vertical Type 3 veins (Generation III). Within this vein generation, three distinct sub-generations are evident (IIIA, IIIB and IIIC). Areas detailed in Photo 8 are highlighted by colour coded and labeled boxes (GREEN = OM, RED = CL, BLUE = BSEM)

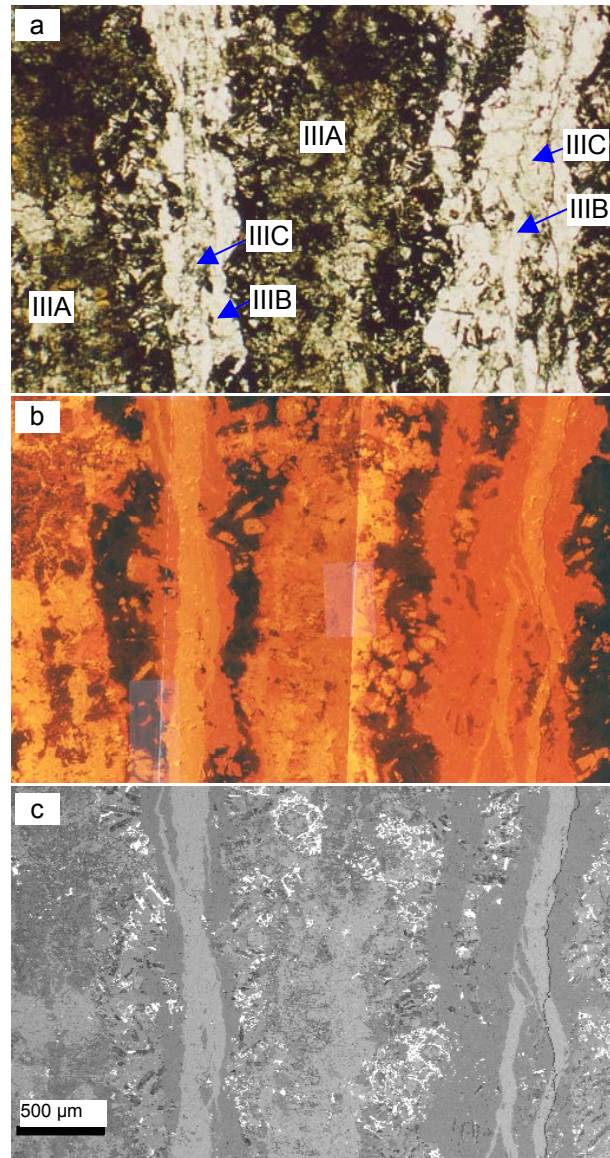
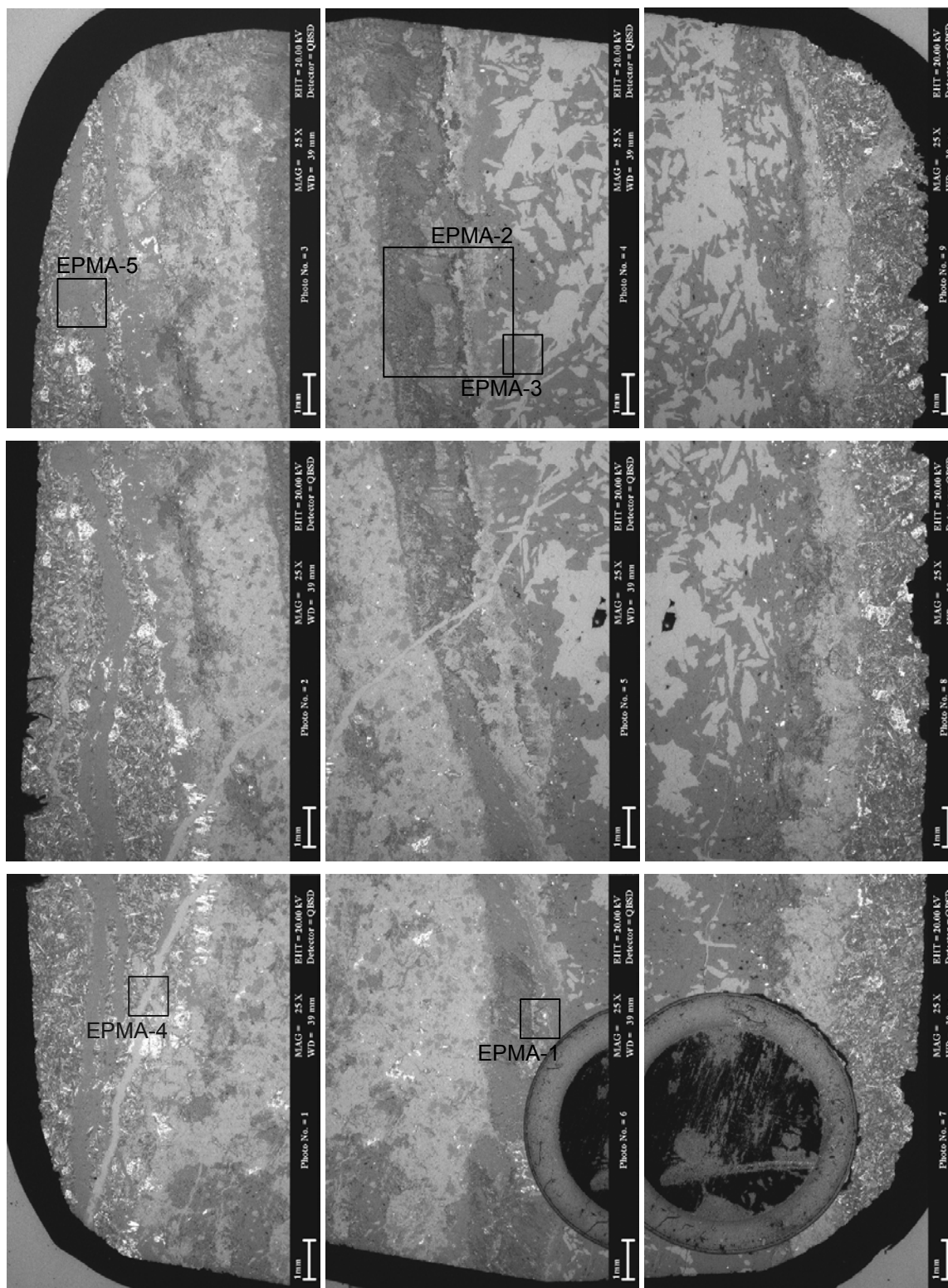
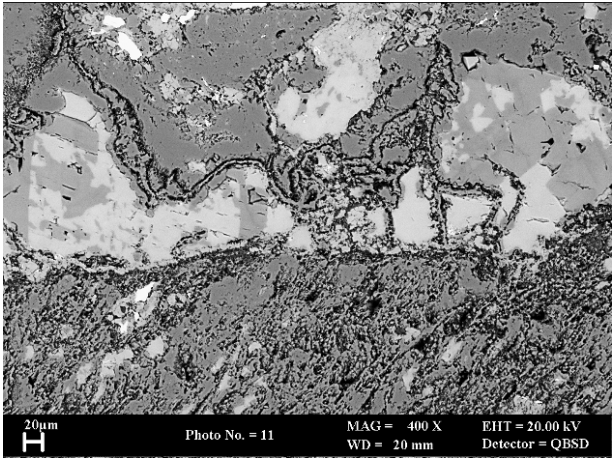


Photo 8) Details of area highlighted in Photo 7, imaged using (a) OM, (b) CL and (c) BSEM techniques (all images are shown at approximately equivalent scale – see (c) for scale bar). In (a) and (b), turbid carbonate veins containing a mixture of blocky and feathery calcite and dolomite are clearly evident (Generation IIIA). These are cross-cut by clear veins containing dolomite and calcite veins (Generation IIIB and IIIC respectively).

Sample ID: WAT-24
MPL Code: n/a
Core/Location: Watford BH2
Vein Type: unspecified
EPMA X-ray Mapping: Yes

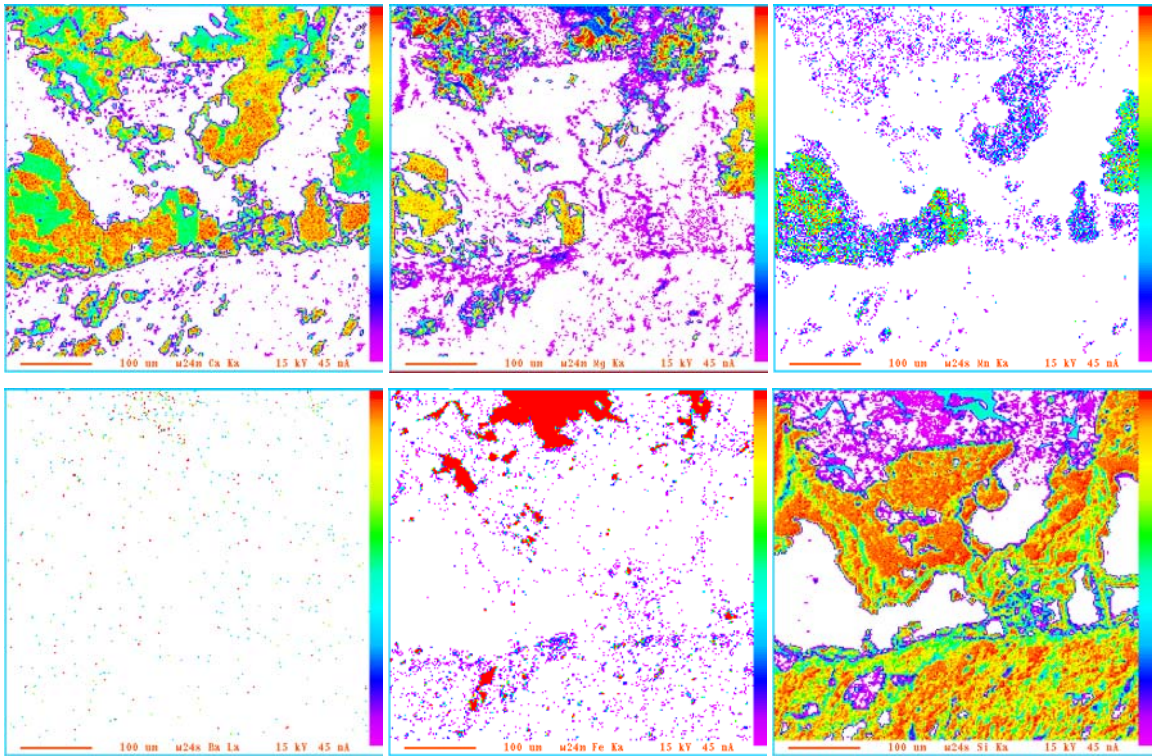


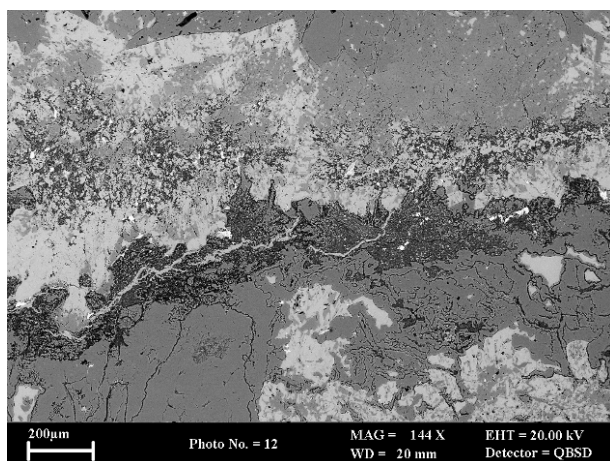


Ca	Mg	Mn
Ba	Fe	Si

Photo 2)

EPMA-1) X-Ray maps of area highlighted in Photos 1 and 2.

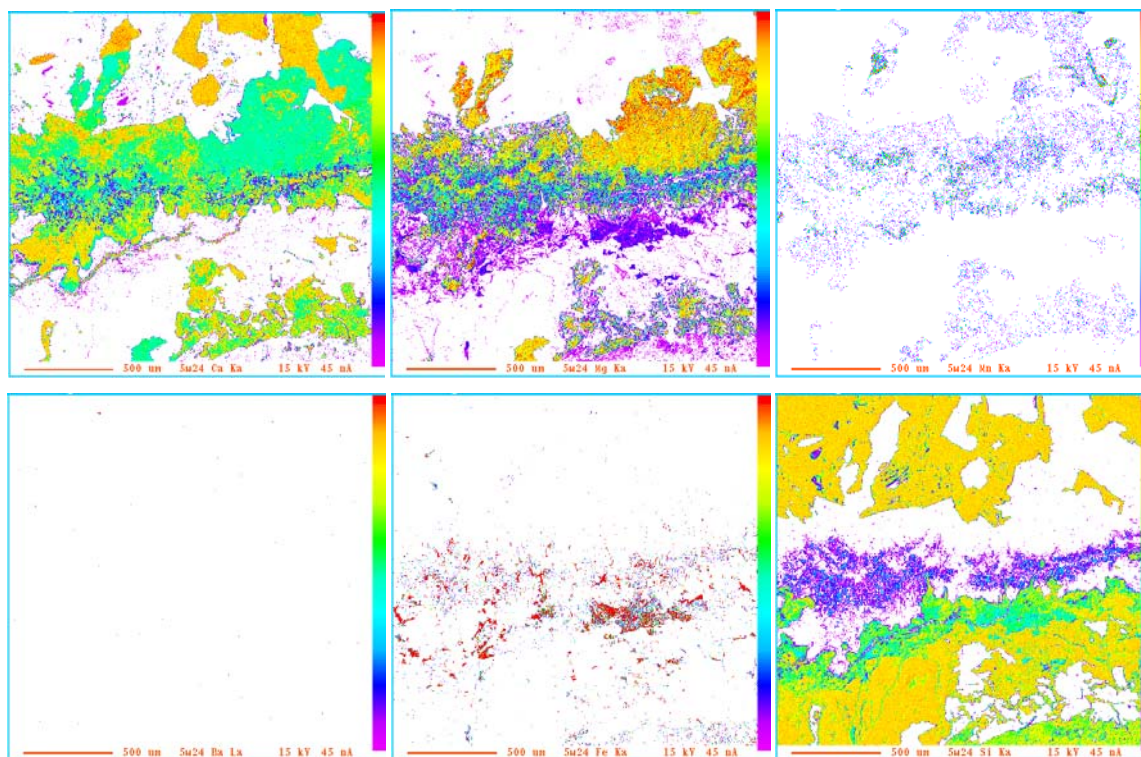




Ca	Mg	Mn
Ba	Fe	Si

Photo 3)

EPMA-2) X-Ray maps of area highlighted in Photos 1 and 3.



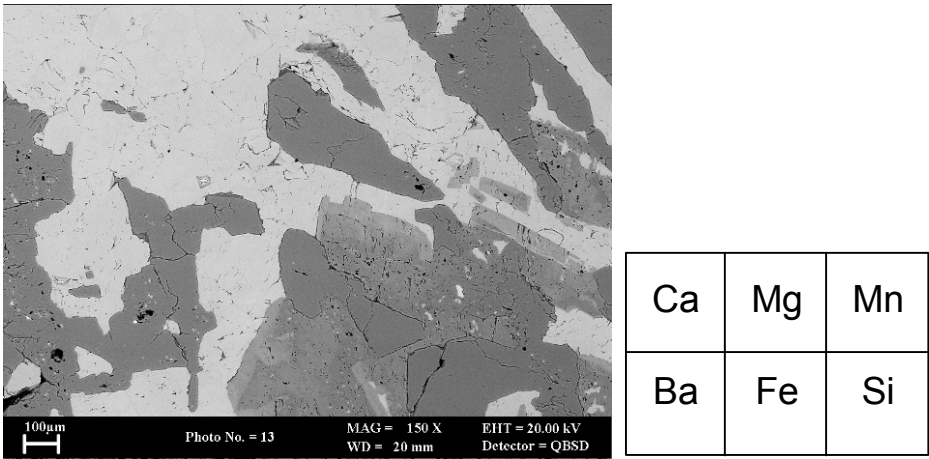
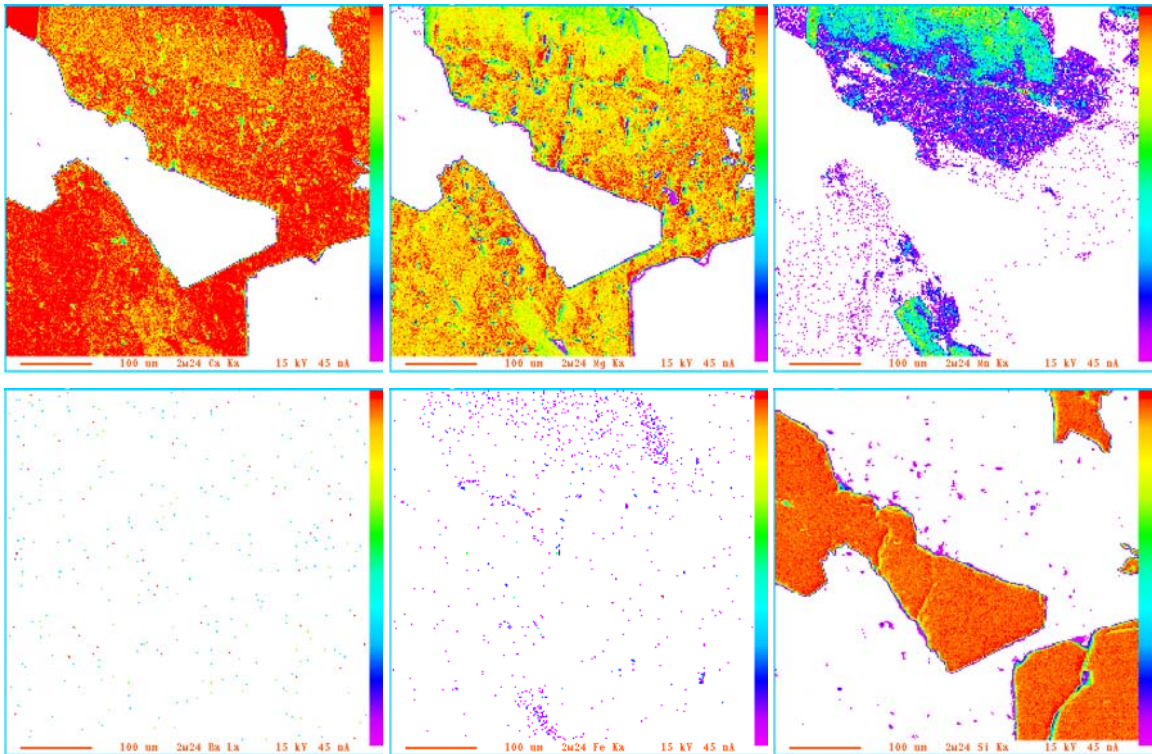
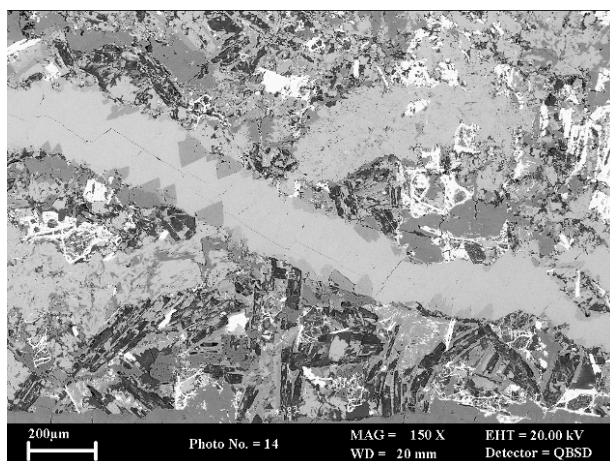


Photo 4)

EPMA-3) X-Ray maps of area highlighted in Photos 1 and 4.

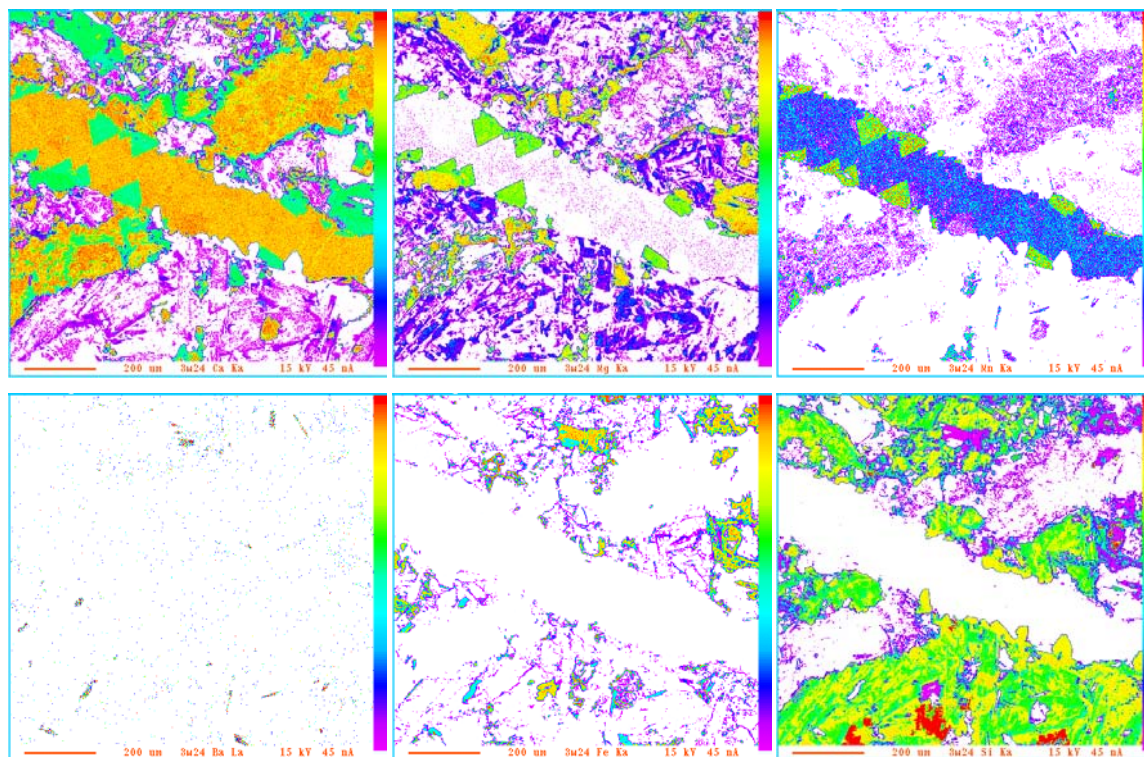


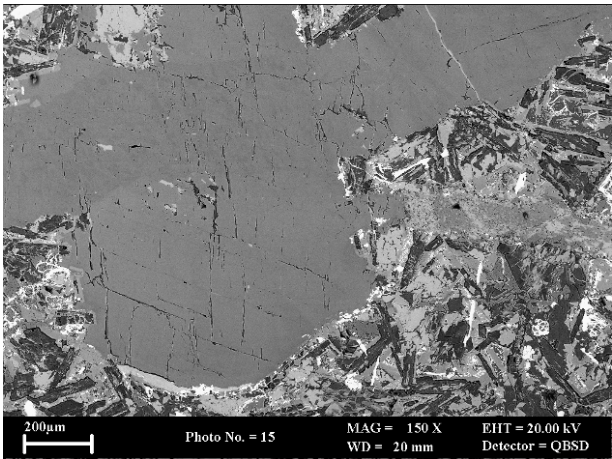


Ca	Mg	Mn
Ba	Fe	Si

Photo 5)

EPMA-4) X-Ray maps of area highlighted in Photos 1 and 5.

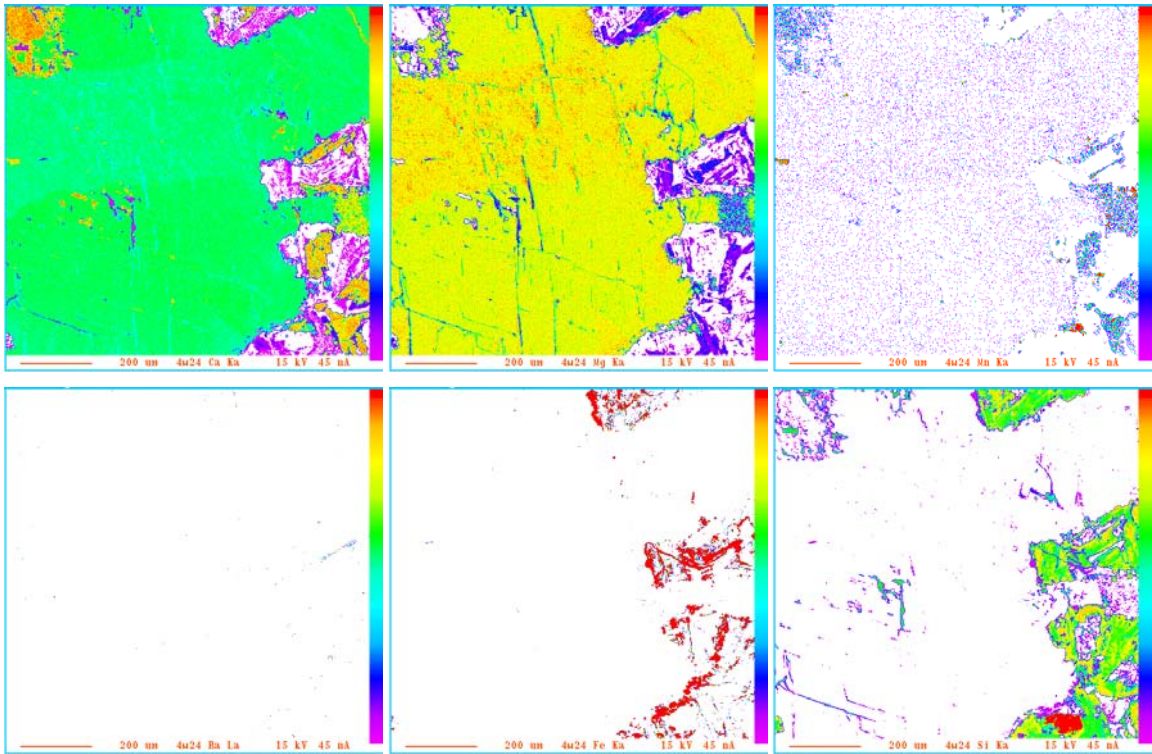




Ca	Mg	Mn
Ba	Fe	Si

Photo 6)

EPMA-5) X-Ray maps of area highlighted in Photos 1 and 6.



Sample ID: WAT-00-37
 MPL Code: G729
 Core/Location: Hopes Nose
 EPMA X-ray Mapping: Yes

This sample predominantly contains white/milky coarsely crystalline calcite, which under BSEM appears compositionally homogeneous (Photos 1 and 2), although small rhombs of dolomite, overlain by calcite overgrowths are present (Photos 3 and 4). The yellowish material evident within this calcite (Photos 1 and 3), is also calcite, which is under BSEM, compositionally indistinct from the milky calcite, although EPMA X-ray mapping and analysis detects 3 distinct calcite compositions on the basis of Mn-content (EPMA-1 and Chart 1).

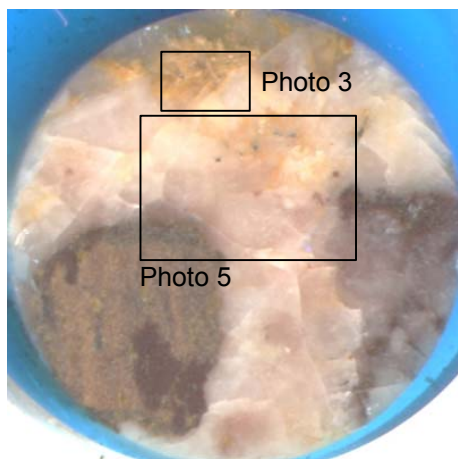


Photo 1) Scan of entire sample.

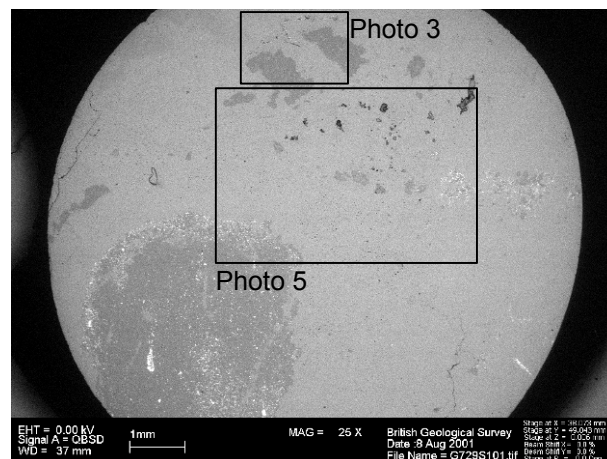


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photos 3 and 5 are highlighted.

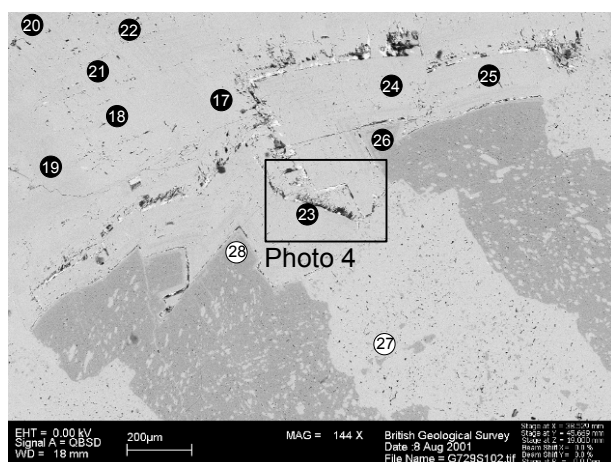


Photo 3) BSEM image showing rhombs of dolomite (darker grey), partially repalced and engulfed by ankerite (lighter grey). The numbered points correspond to EPMA point analyses (Appendix 2; black = ankherite, grey = calcite).

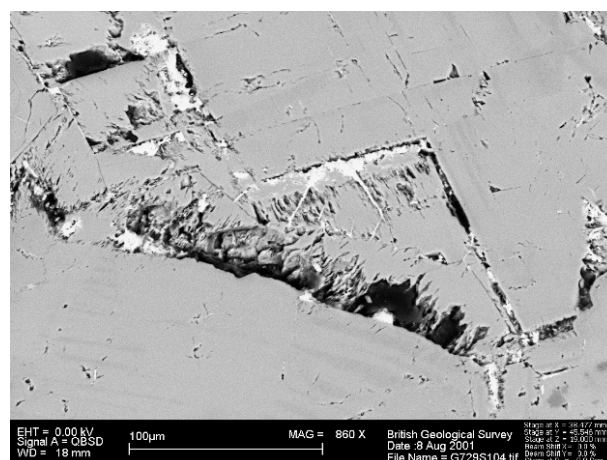


Photo 4) Detail of Photo 3 showing rhombic calcite (overgrowth on dolomite), overgrown by more irregular, feathery dolomite.

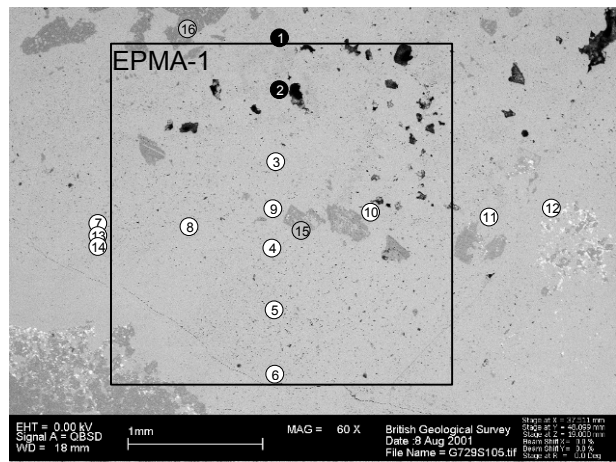


Photo 5) Massive calcite (paler grey) with engulfing/replacing rhombic dolomite crystals (darker grey). Under BSEM, the calcite appears compositionally homogeneous, although EPMA mapping and spot analyses indicate minor chemical variations. The numbered points correspond to EPMA point analyses (Appendix 2; white = calcite, grey = dolomite, black = ankerite).

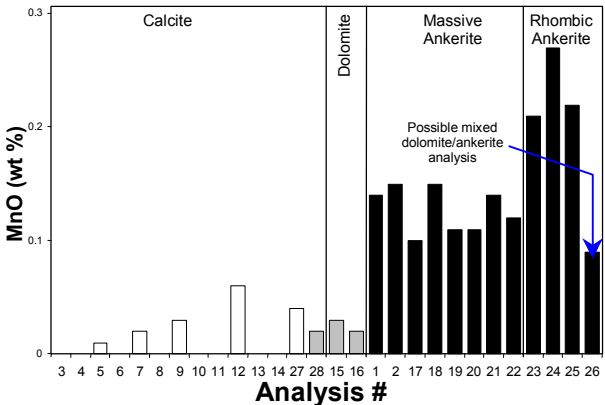
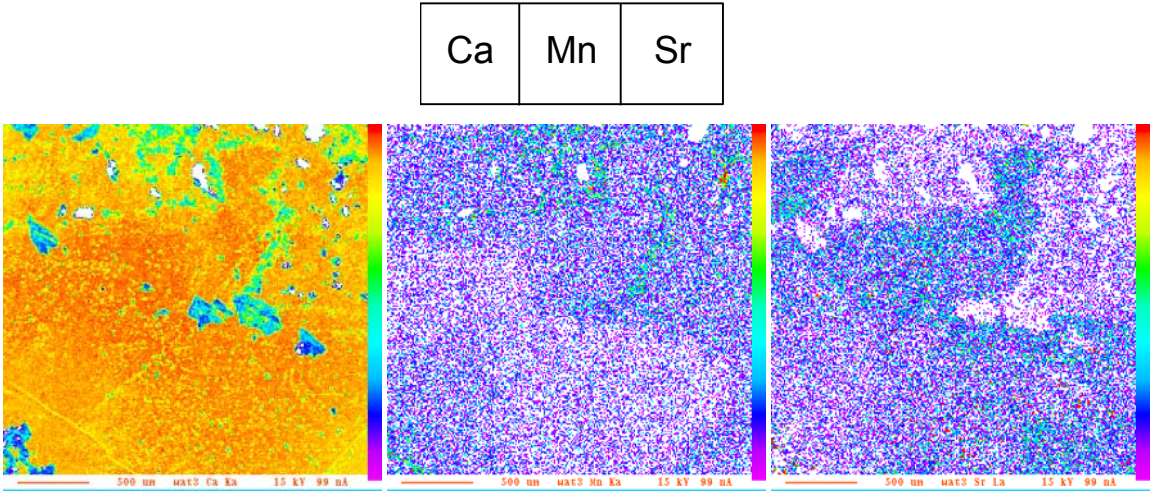


Chart 1) Mn concentrations (EPMA spot analysis data for analysis points identified on Photos 3 and 5), identifies three distinct calcite compositional types. Calcite and dolomite have variable, but low Mn-contents. Two distinct ankerite compositions, one with low (0.10-0.15 wt%), and one with high (>2.0 wt%) MnO content, appear to relate to the different ankerite generations.

EPMA-1) X-Ray maps of area highlighted in Photo 5.



Sample ID: WAT-00-38
 MPL Code: G730
 Core/Location: Hopes Nose
 EPMA X-ray Mapping: Yes

This sample comprises purplish (in hand specimen), finely crystalline (10-30 micron) dolomite rhombs and patchy Fe-oxides (Photos 4 and 5). This dolomite dominated assemblage is cut by coarsely crystalline clear and milky calcite cement. The milky calcite is characterised by lower Mn and higher Sr contents than the clear calcite (EPMA-1). These calcite veins and patches are typically lined with rhombs of dolomite that contain internal zones of calcite (Photos 4 and 5).

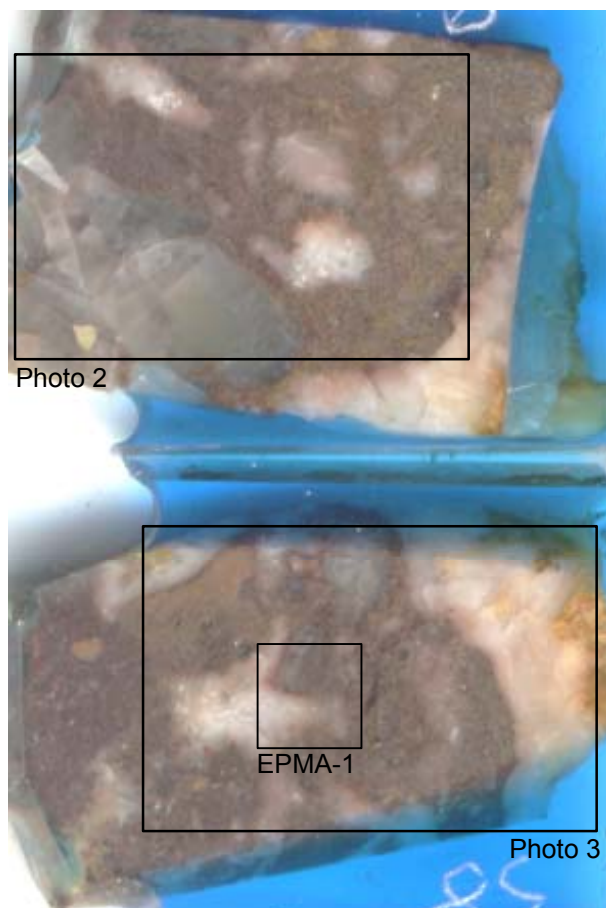
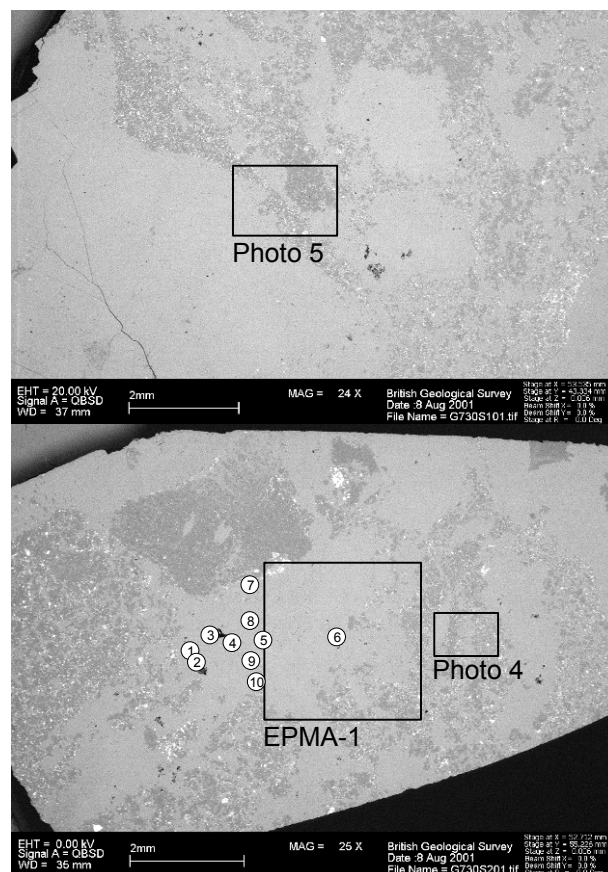


Photo 1) Scan of entire sample (subsample A at bottom, subsample B at top).



Photos 2 and 3) Low magnification BSE images of the entire samples (A at bottom, B at top). Areas of Photos 4 and 5, and EPMA X-ray mapping area 1 are highlighted. The numbered points correspond to EPMA point analyses (Appendix 2).

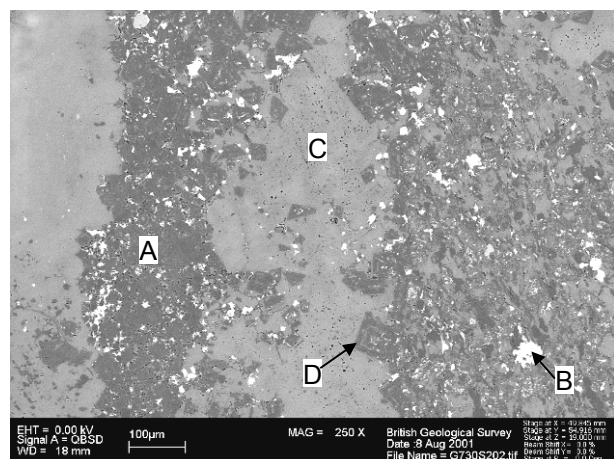


Photo 4) Detail showing patches of dolomite (A) and Fe-oxides (B), cut by patches of calcite (C), with rhombic dolomite at their margins (D).

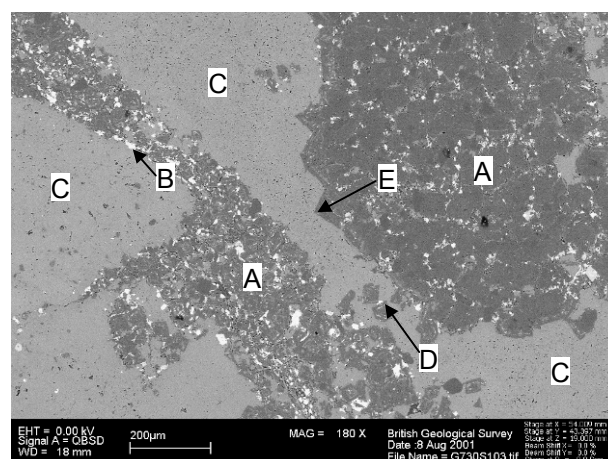
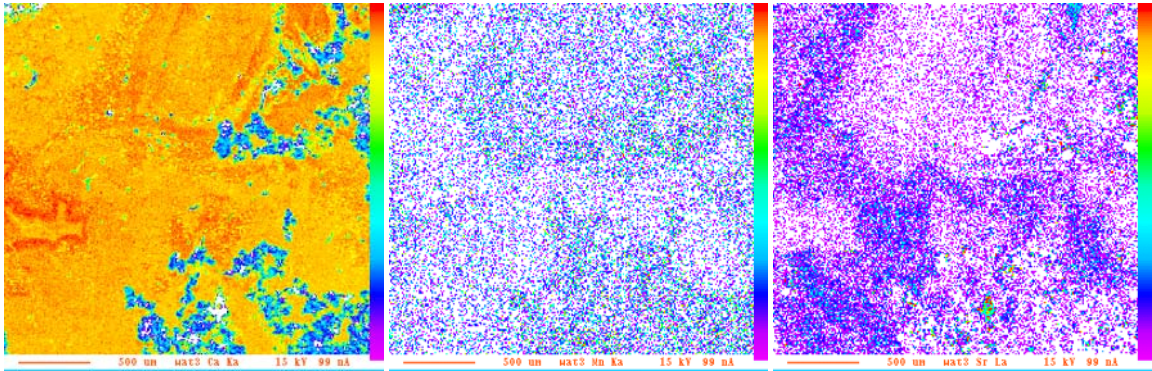


Photo 5) Detail showing patches of dolomite (A) and Fe-oxides (B), cut by patches of calcite (C), with rhombic dolomite at their margins (D).

EPMA-1) X-Ray maps of area highlighted in Photos 1 and 3.

Ca	Mn	Sr
----	----	----



Sample ID: WAT-00-39
 MPL Code: G731
 Core/Location: Hopes Nose
 EPMA X-ray Mapping: No

Optically and under BSEM, this sample is dominated by cloudy calcite which appears to be largely homogeneous. In detail the sample is cut by a number of lath-shaped voids, suggesting dissolution of a lath-shaped mineral. These pores are lined with irregular crystals of calcite, which under BSEM appear to be compositionally indistinct from the rest of the calcite in this sample.



Photo 1) Scan of entire sample.

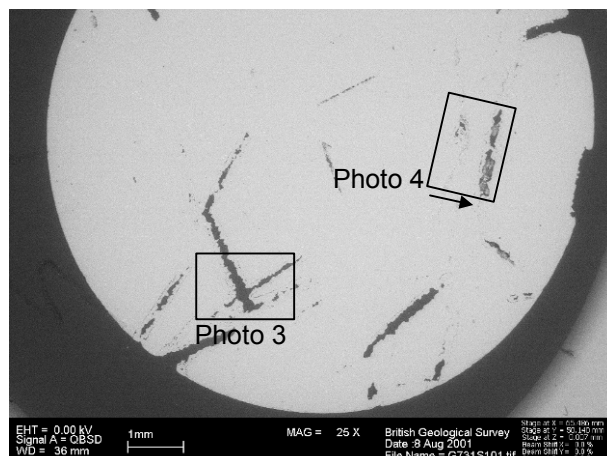


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photos 3 and 4 are highlighted

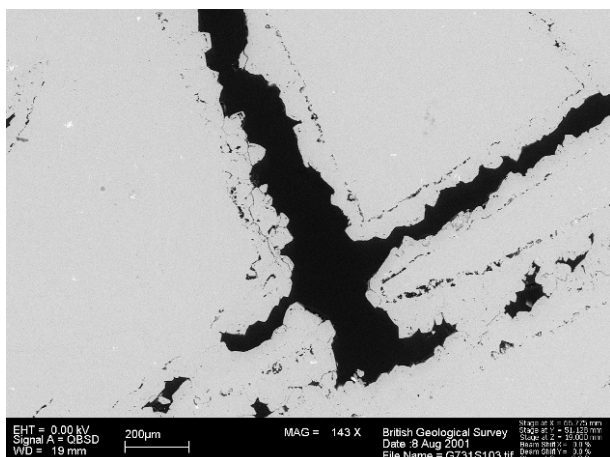


Photo 3) Lath-shaped (dissolution pores) within calcite lined by irregularly crystalline calcite.

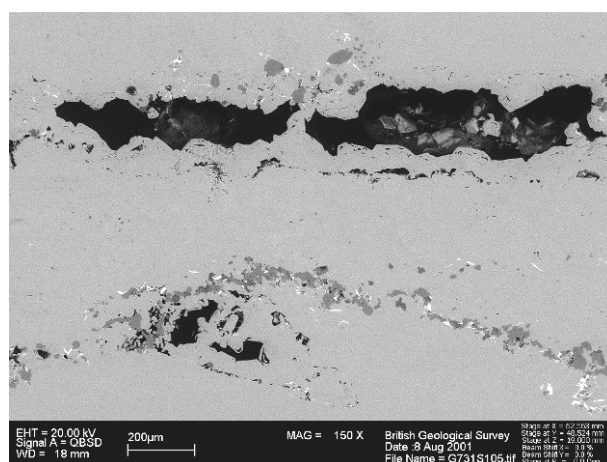


Photo 4) Lath-shaped (dissolution pores) within calcite lined by irregularly crystalline calcite.

Sample ID: WAT-00-40
 MPL Code: G732
 Core/Location: Hopes Nose
 EPMA X-ray Mapping: No

Optically and under BSEM, this sample is dominated by cloudy calcite which appears to be largely homogeneous (indistinguishable from that described for sample WAT-00-39). In detail the sample is cut by a number of lath-shaped voids, suggesting dissolution of a lath-shaped mineral. These pores are lined with irregular crystals of calcite, which under BSEM appear to the compositionally indistinct from the rest of the calcite in this sample.

The margins of this sample also includes a patch of more yellow calcite which under BSEM appears to be compositionally indistinguishable from the cloudy calcite.

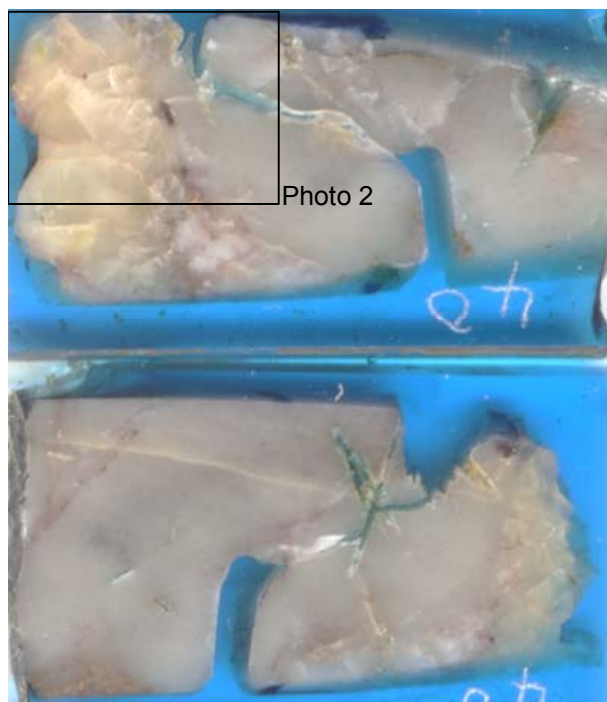


Photo 1) Scan of entire sample (subsample A at top, subsample B at bottom).

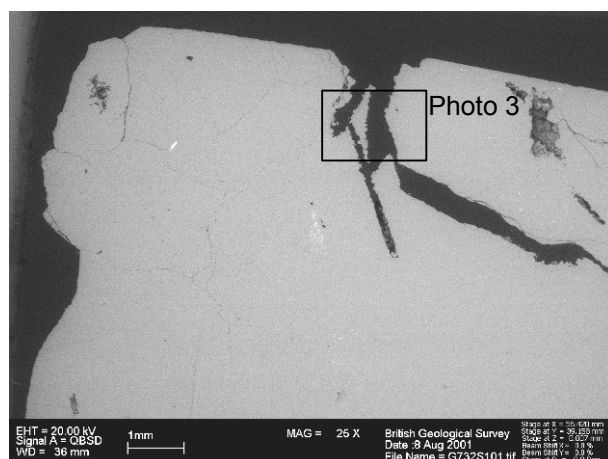


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photo 3 is highlighted

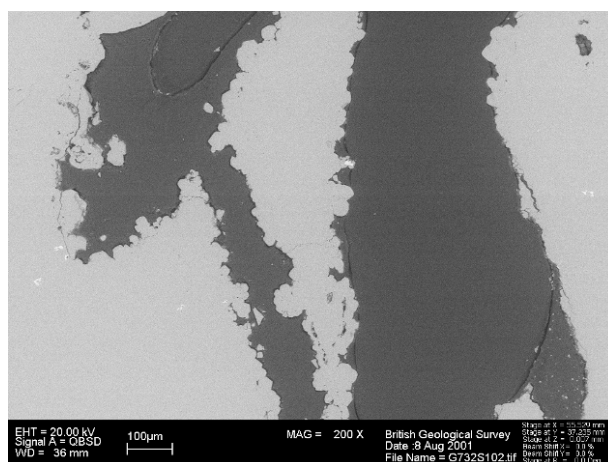


Photo 3) Lath-shaped void lined with irregularly crystalline calcite.

Sample ID: WAT-00-41
 MPL Code: G733
 Core/Location: Hopes Nose
 EPMA X-ray Mapping: No

This sample comprises red, near-homogeneous (although minor Fe-oxide inclusions are present) calcite. This red calcite is cut by veins/veinlets of clear to milky calcite, which, under BSEM, appear marginally brighter indicating a compositional difference (higher proportions of “heavier” elements) relative to the red calcite.

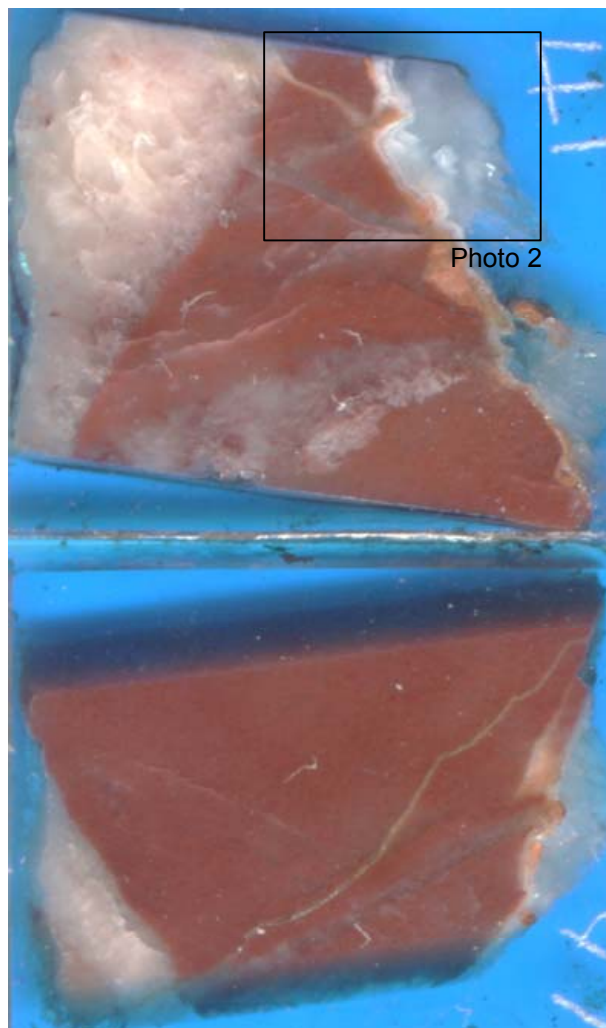


Photo 1) Scan of entire sample (subsample A at top, subsample B at bottom).

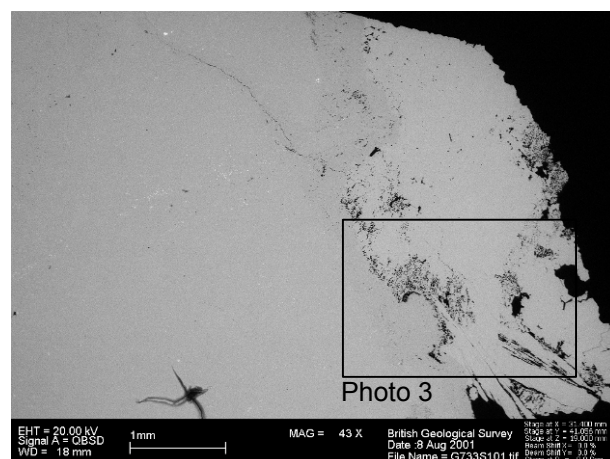


Photo 2) Low magnification BSEM image of the entire sample. Areas of Photo 3 is highlighted

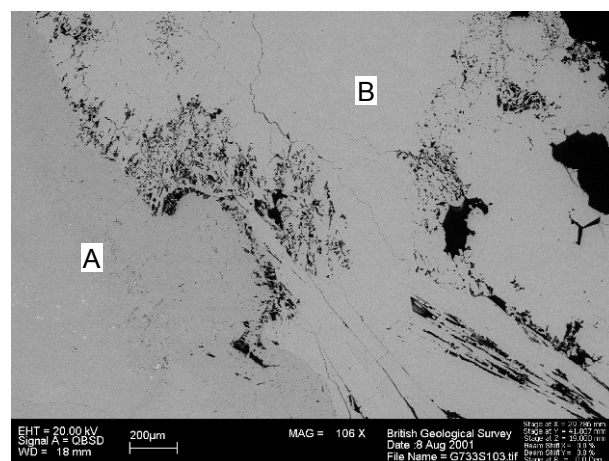


Photo 3) Compositional contrast between earlier, red calcite (A), and later milky calcite (B).

Appendix 2 EPMA Point Analysis Data

Appendix Table 2.1 EPMA results for carbonates in veins from Watford BH2 and Hope's Nose

Sample	MPL Code	#	Vein type	Association	Mineral	Oxide wt%							Molecular proportions (2 cations)						Comment
						MgO	CaO	MnO	FeO	SrO	BaO	Total	MgO	CaO	MnO	FeO	SrO	BaO	
WAT-00-04	G696	1	type 2	Interarown Cc-Dol	calcite	0.68	49.96	0.69	0.14	0.00	0.00	51.47	0.04	1.94	0.02	0.00	0.00	low total. not plotted	
WAT-00-04	G696	2	type 2	Interarown Cc-Dol	calcite	0.45	52.89	0.56	0.11	0.01	0.00	54.03	0.02	1.96	0.02	0.00	0.00		
WAT-00-04	G696	3	type 2	Interarown Cc-Dol	calcite	0.53	52.37	1.21	0.06	0.00	0.00	54.17	0.03	1.94	0.04	0.00	0.00		
WAT-00-04	G696	4	type 2	Interarown Cc-Dol	dolomite	19.45	30.66	0.58	0.65	0.00	0.00	51.34	0.92	1.04	0.02	0.02	0.00		
WAT-00-04	G696	5	type 2	Interarown Cc-Dol	calcite	0.82	50.11	0.69	0.05	0.00	0.00	51.66	0.04	1.93	0.02	0.00	0.00	low total. not plotted	
WAT-00-04	G696	6	type 2	Interarown Cc-Dol	calcite	0.15	53.55	0.60	0.08	0.04	0.00	54.42	0.01	1.97	0.02	0.00	0.00		
WAT-00-04	G696	7	type 3	Simple Cc-Dol	calcite	0.11	51.11	0.77	0.03	0.00	0.00	52.02	0.01	1.97	0.02	0.00	0.00		
WAT-00-04	G696	8	type 3	Simple Cc-Dol	calcite	0.43	48.39	1.60	0.00	0.00	0.00	50.42	0.02	1.93	0.05	0.00	0.00	low total. not plotted	
WAT-00-04	G696	9	type 3	Simple Cc-Dol	calcite	0.33	50.01	1.61	0.05	0.01	0.00	52.01	0.02	1.93	0.05	0.00	0.00		
WAT-00-04	G696	10	type 3	Simple Cc-Dol	calcite	0.12	50.38	0.79	0.03	0.02	0.00	51.34	0.01	1.97	0.02	0.00	0.00	low total. not plotted	
WAT-00-04	G696	11	type 3	Simple Cc-Dol	calcite	5.28	40.69	2.02	0.08	0.00	0.01	48.08	0.30	1.64	0.06	0.00	0.00	low total. not plotted	
WAT-00-04	G696	12	type 2	Interarown Cc-Dol	dolomite	18.39	29.90	0.64	0.10	0.00	0.01	49.03	0.91	1.07	0.02	0.00	0.00	low total. not plotted	
WAT-00-04	G696	13	aroundmass	-	dolomite	18.88	29.22	0.53	0.29	0.00	0.00	48.92	0.94	1.04	0.01	0.01	0.00	low total. not plotted	
WAT-00-04	G696	14	type 2	Interarown Cc-Dol	calcite	0.34	49.40	0.81	0.02	0.02	0.00	50.59	0.02	1.95	0.03	0.00	0.00	low total. not plotted	
WAT-00-04	G696	15	type 2	Interarown Cc-Dol	calcite	0.26	53.77	0.98	0.00	0.00	0.00	55.01	0.01	1.96	0.03	0.00	0.00		
WAT-00-04	G696	16	type 2	Interarown Cc-Dol	dolomite	17.34	29.60	3.08	0.03	0.00	0.01	50.06	0.86	1.05	0.09	0.00	0.00		
WAT-00-05	G697	1	type 3	Simple Cc-Dol	calcite	0.50	53.25	2.23	0.02	0.03	0.00	56.03	0.02	1.91	0.06	0.00	0.00	0.00	
WAT-00-05	G697	2	type 3	Simple Cc-Dol	calcite	0.19	54.58	1.21	0.01	0.00	0.00	55.99	0.01	1.96	0.03	0.00	0.00	0.00	
WAT-00-05	G697	3	type 3	Simple Cc-Dol	calcite	0.18	54.83	1.10	0.05	0.00	0.00	56.16	0.01	1.96	0.03	0.00	0.00	0.00	
WAT-00-05	G697	4	type 3	Simple Cc-Dol	calcite	0.46	53.89	1.91	0.04	0.03	0.00	56.33	0.02	1.92	0.05	0.00	0.00	0.00	
WAT-00-05	G697	5	type 3	Simple Cc-Dol	calcite	0.35	54.62	1.70	0.04	0.00	0.00	56.71	0.02	1.93	0.05	0.00	0.00	0.00	
WAT-00-05	G697	6	type 3	Simple Cc-Dol	calcite	0.61	53.92	1.94	0.06	0.03	0.00	56.56	0.03	1.91	0.05	0.00	0.00	0.00	
WAT-00-05	G697	7	type 3	Simple Cc-Dol	calcite	0.17	55.10	1.02	0.06	0.02	0.00	56.37	0.01	1.96	0.03	0.00	0.00	0.00	
WAT-00-06	G698	1	type 1	-	calcite	1.97	52.78	0.89	0.05	0.03	0.02	55.74	0.10	1.88	0.02	0.00	0.00	0.00	
WAT-00-06	G698	2	type 1	-	calcite	9.78	43.95	0.70	0.05	0.00	0.00	54.48	0.47	1.51	0.02	0.00	0.00	0.00	
WAT-00-06	G698	3	type 1	-	dolomite	19.49	31.21	0.98	0.06	0.00	0.00	51.74	0.92	1.06	0.03	0.00	0.00	0.00	
WAT-00-06	G698	4	type 1	-	dolomite	19.27	31.00	1.42	0.03	0.00	0.00	51.72	0.91	1.05	0.04	0.00	0.00	0.00	
WAT-00-06	G698	5	type 1	-	calcite	0.29	53.68	0.96	0.45	0.03	0.00	55.41	0.01	1.94	0.03	0.01	0.00	0.00	
WAT-00-06	G698	6	type 1	Fibrous-Blocky Cc-Dol	calcite	0.81	54.07	1.02	0.11	0.02	0.02	56.05	0.04	1.93	0.03	0.00	0.00	0.00	
WAT-00-06	G698	7	type 1	Fibrous-Blocky Cc-Dol	calcite	0.28	55.10	0.75	0.04	0.04	0.03	56.24	0.01	1.96	0.02	0.00	0.00	0.00	
WAT-00-06	G698	8	type 1	Fibrous-Blocky Cc-Dol	calcite	1.05	53.31	0.88	0.07	0.00	0.02	55.33	0.05	1.92	0.03	0.00	0.00	0.00	
WAT-00-06	G698	9	type 1	Fibrous-Blocky Cc-Dol	calcite	0.47	54.43	1.18	0.06	0.00	0.00	56.14	0.02	1.94	0.03	0.00	0.00	0.00	
WAT-00-06	G698	10	type 1	Fibrous-Blocky Cc-Dol	dolomite	19.33	31.94	0.65	0.35	0.00	0.01	52.28	0.90	1.07	0.02	0.01	0.00	0.00	
WAT-00-16	G708	1	type 5	Interarown Cc-Dol	calcite	0.36	53.14	0.77	0.04	0.01	0.00	54.32	0.02	1.96	0.02	0.00	0.00	0.00	
WAT-00-16	G708	2	type 5	Interarown Cc-Dol	calcite	0.57	52.93	0.98	0.06	0.03	0.01	54.58	0.03	1.94	0.03	0.00	0.00	0.00	
WAT-00-16	G708	3	type 5	Interarown Cc-Dol	calcite	0.68	52.57	1.01	0.03	0.02	0.00	54.31	0.03	1.93	0.03	0.00	0.00	0.00	
WAT-00-16	G708	4	type 5	Interarown Cc-Dol	calcite	0.92	52.68	0.75	0.04	0.03	0.00	54.42	0.05	1.93	0.02	0.00	0.00	0.00	
WAT-00-16	G708	5	type 5	Interarown Cc-Dol	calcite	0.28	52.64	0.78	0.02	0.01	0.01	53.74	0.01	1.96	0.02	0.00	0.00	0.00	
WAT-00-16	G708	6	type 5	Interarown Cc-Dol	calcite	0.71	53.13	0.48	0.01	0.00	0.00	54.33	0.04	1.95	0.01	0.00	0.00	0.00	
WAT-00-16	G708	7	type 5	Interarown Cc-Dol	calcite	0.45	53.64	0.45	0.03	0.02	0.00	54.59	0.02	1.96	0.01	0.00	0.00	0.00	
WAT-00-16	G708	8	type 5	Interarown Cc-Dol	calcite	0.68	50.90	2.25	0.03	0.01	0.00	53.87	0.04	1.90	0.07	0.00	0.00	0.00	
WAT-00-16	G708	9	type 5	Interarown Cc-Dol	calcite	1.62	51.51	0.92	0.20	0.00	0.00	54.25	0.08	1.89	0.03	0.01	0.00	0.00	
WAT-00-16	G708	10	type 5	Interarown Cc-Dol	calcite	2.36	50.97	0.64	0.02	0.03	0.00	54.02	0.12	1.86	0.02	0.00	0.00	0.00	
WAT-00-16	G708	11	type 5	Interarown Cc-Dol	calcite	0.64	51.51	1.98	0.02	0.01	0.00	54.16	0.03	1.91	0.06	0.00	0.00	0.00	
WAT-00-16	G708	12	type 5	Interarown Cc-Dol	calcite	3.11	49.58	0.87	0.00	0.00	0.00	53.56	0.16	1.82	0.03	0.00	0.00	0.00	
WAT-00-23	G715	1	type 4	Interarown Cc-Dol	calcite	0.35	50.72	0.76	0.02	0.01	0.02	51.88	0.02	1.96	0.02	0.00	0.00	0.00	low total. not plotted
WAT-00-23	G715	2	type 4	Interarown Cc-Dol	calcite	6.54	43.86	1.02	0.00	0.02	0.03	51.47	0.34	1.63	0.03	0.00	0.00	0.00	low total. not plotted
WAT-00-23	G715	3	type 4	Interarown Cc-Dol	calcite	1.60	49.33	1.28	0.05	0.00	0.04	52.30	0.08	1.87	0.04	0.00	0.00	0.00	
WAT-00-23	G715	4	type 4	Interarown Cc-Dol	calcite	1.13	50.53	0.08	0.05	0.00	0.00	51.79	0.06	1.94	0.00	0.00	0.00	0.00	low total. not plotted
WAT-00-23	G715	5	type 4	Interarown Cc-Dol	calcite	1.96	49.65	0.66	0.05	0.00	0.01	52.33	0.10	1.88	0.02	0.00	0.00	0.00	
WAT-00-23	G715	6	type 4	Interarown Cc-Dol	calcite	0.38	51.98	0.38	0.01	0.01	0.01	52.77	0.02	1.97	0.01	0.00	0.00	0.00	
WAT-00-23	G715	7	type 4	Interarown Cc-Dol	calcite	1.23	50.83	0.37	0.02	0.01	0.00	52.46	0.06	1.92	0.01	0.00	0.00	0.00	
WAT-00-23	G715	8	type 4	Interarown Cc-Dol	dolomite	17.29	30.40	1.43	0.00	0.00	0.00	49.12	0.87	1.09	0.04	0.00	0.00	0.00	low total. not plotted
WAT-00-23	G715	9	type 4	Interarown Cc-Dol	dolomite	17.79	31.69	1.63	0.03	0.00	0.01	51.15	0.86	1.10	0.04	0.00	0.00	0.00	
WAT-00-23	G715	10	type 4	Interarown Cc-Dol	calcite	1.41	49.50	0.82	0.03	0.00	0.00	51.76	0.08	1.90	0.02	0.00	0.00	0.00	low total. not plotted
WAT-00-37	G729	1	Hope's Nose	Yellow-brown carb.	ankerite	11.24	33.11	0.14	9.26	0.00	0.04	53.79	0.56	1.18	0.00	0.26	0.00	0.00	
WAT-00-37	G729	2	Hope's Nose	Yellow-brown carb.	ankerite	11.32	33.97	0.15											