Natural Resources Canada Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8499

# Detailed mineralogical data from hydrothermally altered igneous rocks at Clarke Head, Minas fault zone, western Nova Scotia

G. Pe-Piper, J. Nagle, D.J.W. Piper, and B. Boucher

2019

Canada

**GEOLOGICAL SURVEY OF CANADA**
**OPEN FILE 8499**

# Detailed mineralogical data from hydrothermally altered igneous rocks at Clarke Head, Minas fault zone, western Nova Scotia


## G. Pe-Piper[1], J. Nagle[1], D.J.W. Piper[2], and B. Boucher[3]

[1]Saint Mary's University, 933 Robie Street, Halifax, Nova Scotia B3H 3C3
[2]Geological Survey of Canada, 1 Challenger Drive, Dartmouth, Nova Scotia B2Y 4A2
[3]Department of Earth Sciences, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick E3B 5A3


## 2019




Permanent link: https://doi.org/10.4095/313604
This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

**Recommended citation**
Pe-Piper, G., Nagle, J., Piper, D.J.W., and Boucher, B., 2019. Detailed mineralogical data from hydrothermally altered igneous rocks at Clarke Head, Minas fault zone, western Nova Scotia; Geological Survey of Canada, Open File 8499, 382 p. https://doi.org/10.4095/313604

Publications in this series have not been edited; they are released as submitted by the author.

## Preface

This study is based on re-investigation of rocks previously studied in a joint project between the Geological Survey of Canada and Saint Mary's University under the former Mineral Development Agreements. The study provides further information on unusual igneous intrusions preserved in deformed blocks in the Clarke Head fault zone, previously described in Geological Survey of Canada Open File 8314 (Pe-Piper et al., 2017a). These can be compared with the vein minerals present elsewhere in the Minas Fault Zone in order to better understand the geological setting of mineralization along this major fault zone.


## Acknowledgements

This work was funded by a Natural Sciences and Engineering Research Council of Canada Discovery Grant to GP-P. We thank Randy Corney for his work preparing difficult samples, Xiang Yang for assistance with scanning electron microscopy at Saint Mary's University, and Dr Peter Giles for reviewing this Open File.



## Author's addresses

GEORGIA PE-PIPER, JUSTIN NAGLE

Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3, Canada

gpiper@smu.ca

DAVID J.W. PIPER

Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada

david.piper@canada.ca

BRANDON BOUCHER, Department of Earth Sciences, University of New Brunswick, 2 Bailey Drive, Fredericton, NB E3B 5A3, Canada

**Table of Contents**

## ABSTRACT

Fault zone megabreccia exposed at Clarke Head, near Parrsboro, Nova Scotia, is located in a fault splay of the mid-Carboniferous Minas Fault Zone (MFZ). Lower Carboniferous sedimentary rocks and Upper Devonian–Lower Carboniferous gabbro, diorite and syenite occur as megablocks within the fault zone and have been previously reported in Geological Survey of Canada Open File 8314. This study describes the magmatic and alteration minerals of additional samples of very coarse grained syenite and diorite-tonalite. It also presents the results of LA-ICPMS analyses of rutile and titanite from the syenite. REE patterns in the rutile are largely carried in felsic melt inclusions or ilmenite-magnetite inclusions. Based on U-Pb LA-ICPMS analyses of rutile, the syenite was likely emplaced ~ 360 Ma and no younger than 353 Ma, and was thus synchronous with the late phases of the Cobequid Highland Na-rich A-type granite plutonism. However, only at Clarke Head is there extreme Na- and Cl-rich metasomatism, indicated by scapolite and Cl-rich hastingsite, and the Cl-rich fluids are interpreted to have been derived from regional halite evaporites at faulted basin margins. The same Cl-rich fluids resulted in local dissolution-reprecipitation of Ti and Zr and resetting of the U-Pb system in the altered rutile, at 337.4 ± 3.5 Ma. This provides a minimum age for the Windsor Group evaporites.

# INTRODUCTION

This Open File builds on the data and ideas presented in the Geological Survey of Canada Open File (OF) 8314 by Pe-Piper et al. (2017a). Nine new samples have been collected from the outcrops described in OF 8314 and from nearby outcrops (Table 1). In addition three samples from OF 8314 were chosen for further mineralogical study. The studied samples include gabbro (one sample from OF 8314); five diorite–tonalite samples, all new, and six syenite samples, two from OF 8314 (9928a, b) and four from the coarsest parts of the syenite outcrop (9956a, b, c, d) (Fig. 1).

The igneous rocks in the central part of the Clarke Head section that we have studied (Fig. 1) include gabbro, which was intruded by coarse-grained to pegmatitic syenite, and a variety of intermediate igneous rocks (diorite, tonalite) from a rockfall or a collapsed stack at the headland (Pe-Piper et al., 2017a). These latter rocks include either xenoliths or in-situ country rock of hornfels that resembles Horton Group siltstones and shales. All the igneous rocks have been affected by several hydrothermal events, at different times during the evolution of both the Cobequid Shear Zone (CSZ) and the Minas Fault Zone (MFZ). In OF 8314 we established the relative ages of both magmatic and secondary minerals in the studied samples. In this report we have attempted to establish the geochronology of the magmatic and hydrothermal events, to correlate the hydrothermal events with the sequence of vein minerals in the CSZ and MFZ (Pe-Piper et al., 2018) and more generally with the geological evolution of Atlantic Canada through the Carboniferous.

In situ laser-ablation inductively-coupled-plasma mass spectrometry (LA- ICPMS), at the University of New Brunswick- Fredericton, has been used for U-Pb geochronology and to study trace elements in rutile and titanite. However, hydrothermal scapolite and analcime are the most common secondary mineral components and critical for deciphering the petrological-geochemical evolution of the rocks. Scapolite and analcime were largely studied by energy dispersive spectroscopy (EDS) using a scanning electron microscope (SEM) at Saint Mary's University.

## ORGANISATION OF THE OPEN FILE

The main body of this report consists of eleven data appendices. Appendices 1 and 11 describe the detailed mineralogy of the new samples (9956a, b, c, d, 9957, 9958a, b and 9959) using back-scattered electron (BSE) images and energy dispersive spectroscopy (EDS) analyses for chemical composition. Appendix 2 provides more detailed mineralogical documentation of an interesting 9 mm long rutile crystal from a coarse grained syenite (9956c). We needed this documentation in order later to investigate the distribution of specific chemical elements, notably Zr. Appendix 3 presents X-ray fluorescence (XRF) maps of particular elements in each studied polished thin section. Elemental abundance is shown with a colour scale normalised to the maximum X-ray counts, to provide an overview of the chemistry of the rock-forming minerals and to display the textures of the minerals. Such maps are presented both as composite maps showing the elements Ca, K, Fe, Ti, and in some cases Si, and as maps of individual major and trace elements.

The trace element geochemistry of rutile and titanite was investigated using LA- ICPMS. Appendix 4 gives the SEM-BSE images of the analysed spots of both rutile and titanite in polished thin sections of gabbro, diorite, and syenite, together with the laser ablation trace element analyses for these samples. Based on these analyses, it appeared that only rutile from the syenites (9928, 9956) gave coherent geochemical results.

The positions of dated spots in rutile grains by U-Pb LA- ICPMS are given in Appendix 5. Appendix 6 presents the geochemical profile (raster) data across the dated spots. Appendix 7 presents the results of Raman spectroscopy of the rutile grains, to confirm that they are rutile and not the polymorphs anatase or brookite. Optical properties also confirm that the dated grains are rutile.

Of the LA- ICPMS trace element analyses, the rare earth element (REE) patterns show interesting variation that was investigated further by examining the relationship between REE patterns and the mode of occurrence for both rutile and titanite. Appendix 8 presents the rutile data and Appendix 9 the titanite data.

The polished thin sections of diorite provide important information on the sequence of alteration events, that have probably also affected the gabbro and syenite. Representative microphotographs and corresponding BSE images are given in Appendix 10.

In addition to the appendices, we provide a short text description of the results of our mineralogical and petrographic observations of the new studied samples of diorite and very coarse grained syenite. The important findings from the laser ablation trace element geochemistry for rutile together with the laser ablation U/Pb dating of rutile are discussed in a paper in *American Mineralogist* (Pe-Piper et al., 2019). We did not succeed in dating titanite (there was not enough U), but we plan a future paper around the LA- ICPMS data on titanite that are presented in this open file. Another paper on scapolite and analcime including stable isotope data on scapolite together with the highlights of the mineralogical data for scapolite from this open file, has been submitted to *Chemical Geology* (Pe-Piper et al., submitted). An additional paper on titanite is planned and Tables 2 and 3 summarize the new EDS analyses of this mineral.

# METHODS

## SEM and Raman spectroscopy studies

Polished thin sections were examined by petrographic microscope. Carbon-coated polished thin sections were analyzed by Scanning Electron Microscope (SEM) located at the Regional Analytical Centre of Saint Mary's University acquiring back-scattered electron (BSE) images and energy dispersive spectroscopy (EDS) chemical analyses of minerals. The SEM used is a Tescan Mira 3 FESEM with a maximum resolution up to 1.2 nm at 30 kV. This SEM is also equipped with an INCA X-max 80 $mm^2$ silicon-drift detector EDS system, with a detection limit >0.1%. The SEM uses a tungsten filament to supply electrons to produce a BSE image of the grains on the polished thin section. Minerals in general are identified on the basis of their chemical composition compared with mineral compositions reported in the literature. Hydrous or carbonate mineral phases or those containing ferric iron ($Fe^{3+}$) were identified by inspection of un-normalized EDS data, with low totals corresponding to mineral structures containing water, $CO_3^{2-}$, and/or ferric iron. The identification of such minerals is described in more detail in Appendix 4 of Pe-Piper et al. (2017a). A reflected-light microscope was used to distinguish magnetite from hematite.

The $TiO_2$ mineral polymorphs were distinguished by Raman laser spectroscopy, using a Horiba Jobin-Yvon LabRam HR confocal microscope (LRM) (Appendix 3 in Pe-Piper et al., 2018c). The LRM uses a 100mW 532 nm Nd-YAG diode laser from Toptica Phonotics and a Synapse charge-coupled device from Horiba Jobin-Yvon. The LRM also uses a 100x Olympus MPIaN objective lens for image analyses. The spectra were collected in one spectral window of 0-1600 $cm^{-1}$.

Selected locations in some samples were also used for elemental mapping of quantitative compositional data that were processed by the QuantMap package in Oxford Instrument's INCA program and reported as oxides. The color bar at the bottom of each elemental image is scaled to the corrected EDS analysis (volatile free). Mineral abbreviations follow Whitney and Evans (2010). The term Fe-oxide mixture (Fe-ox) is used to describe unresolved fine-grained mixtures of Fe-oxyhydroxides including hematite and goethite.

**Laser ablation trace element analysis and U-Pb dating of rutile**

Laser-ablation inductively coupled plasma mass spectrometry (LA- ICPMS) was carried out at the Department of Earth Sciences, University of New Brunswick-Fredericton on 30 µm thick polished thin sections**.** The instrument used is an Australian Scientific Instruments M-50 193nm ArF excimer laser ablation system (Compex Pro 110) connected to an Agilent 7700x ICPMS.

Trace element analysis used a 33 µm spot size with energy of 5 $J/cm^2$ (laser fluence). The standards used were the NIST610 and NIST612 glass standards, BHVO (Hawaiian basalt), and MKED (internal standard). Gas flow rates were 930 ml/min for argon, 300 ml/min for ultra pure helium, and 2 ml/min for ultra pure nitrogen. The laser and ICPMS are tuned using NIST610 to maximize sensitivity while also minimizing oxide production to <0.2% (as monitored by ThO+/Th+) and, for trace-element analyses, double-charged production to <0.3% (as monitored by 22M+/44Ca++). These tuning conditions help minimize the most common isotope interferences. In particular, there is no evidence for Ar-Ti interferences on Sr and Y. The second rotary vacuum pump was also used, which increases the sensitivities of medium and heavy masses. A 30 s background with a 30 s ablation counting time was used. Repeated analyses of standard titanite MKED during analytical runs give values and standard deviations close to those reported by Spandler et al. (2016). During trace element analyses, Si and Ca were measured to make sure that rutile and titanite, which are texturally closely related, could be differentiated. Only analyses with <0.2 wt % $SiO_2$ and CaO are used.

XRF maps (Appendix 3) used the Bruker M4 Tornado with a Rh X-ray tube, a working energy of 50 KV and 400 microamps, and a scan speed of 6.5 mm/s. The color scale was normalised to the maximum X-ray counts for Ti (rutile), Fe (magnetite), K (K-feldspar), Ca (calcite), and Si (quartz).

Similar conditions were used for U-Pb dating of rutile, using laboratory standards R10 and R13. Instrumental settings and calculation procedures are detailed by McFarlane (2015). Analytical spots with a 45 µm diameter were chosen from areas of rutile crystals appearing homogenous in BSE images, which were also used to identify if any Fe-oxide was present. No zoning in rutile has been detected. Only analyses within 7% of concordancy were used; all but one (with 20 cps) had $^{204}$Pb values <12 cps, which is less than the internal 2σ error. As a result, no common Pb correction was applied. $^{208}$Pb was measured but not used because the rutile standard has very low $^{232}$Th and thus very large errors for the $^{208}$Pb/$^{232}$Th system.

# ADDITIONAL DATA PRESENTATION

### Introduction

Nine new samples (Table 1) were collected in the field along the Clarke Head section (Fig. 1) from the same or from outcrops close to outcrops described in Pe-Piper et al. (2017a). The new sample collection was focused on the diorite-tonalite outcrops and the coarser parts of the syenite outcrop. Polished thin sections from all these sample were described using both petrographic microscope and scanning electron microscope (SEM). The detailed descriptions using petrographic microscope, BSE images and EDS mineral analyses are given in appendices 1 and 11. In this section, we present our results in the form of a summary for each sample. Such a summary includes lithologies of hydrothermally altered igneous rocks, type(s) of alteration, type of veins seen in these rocks, overall paragenetic sequence of such veins as indicated by both the EDS mineral analyses and the BSE images, and notes on other important features. The purpose of these descriptions was to be able to identify the best grains of the minerals rutile, titanite and scapolite, so as to be able to do more advanced research on them.

## Detailed Descriptions of samples

### *Sample 9956a*

Host: Scapolitized analcime syenite

Magmatic minerals: Analcime, K-feldspar, rutile, titanite

Secondary minerals: Epidote, Fe-oxides/hydroxides, rutile, scapolite, titanite, analcime

Notes:

1. Titanite commonly overgrows rutile and is overgrown by Fe-oxides/hydroxides (Figures 1-1.21, 1-1.32).
2. There is more than one generation of titanite (see grey-scale difference in Figures 1-1.21, 1-1.47, 1-1.49) and rutile (Figures 1-1.21, 1-1.24, 1-1.50).
3. Chlorite is usually found around the large rutile grains that have been overgrown by titanite (Figures 1-1.21, 1-1.24, 1-1.31) or as veinlets/stringers cross-cutting analcime (Figure 1-1.51).

### *Sample 9956b*

Host: Scapolitized analcime syenite

Magmatic minerals: Analcime, albite, K-feldspar, quartz, rutile, titanite

Secondary minerals: Analcime, calcite, Fe-oxides/hydroxides, rutile, scapolite, titanite, zircon

Notes:

1. Patches of rutile crystals (Figures 1-2.5, 1-2.12).
2. Dark brown patches in light brown patches of rutile (Figure 1-2.20).

### *Sample 9956c*

Host: Scapolitized analcime syenite

Magmatic minerals: K-feldspar, analcime, rutile, titanite

Secondary minerals: Chlorite, Fe-oxides/hydroxides, rutile, scapolite, analcime, titanite

Notes:

1. This sample contains megacrysts of rutile (up to ~6 mm) that have been overgrown and/or partially replaced by titanite and Fe-oxides/hydroxides (Figures 1-3.2, 1-3.11, 1-3.16, 1-3.36, 1-3.38).
2. There is more than one generation of titanite (see grey-scale difference Figure 1-3.5).

3. The replacement of rutile by titanite is very clear in Figure 1-3.13.
4. The chlorite postdates a titanite generation and predates Fe-oxide (Figure 1-3.13).
5. A large rutile crystal has apparent exsolution lamellae of Fe-oxide (Figure 1-3.4).
6. The titanite overgrowths on rutile can be equant, subequant, irregular, continuous or discontinuous.
7. Epidote postdates scapolite, analcime, and chlorite (Figure 1-3.43).
8. Strongly zoned large crystals of rutile (dark brown cores and light brown rims) are present in this sample. Such crystals are further overgrown by Fe-oxide and titanite (Figure 1-3.42).

***Sample 9956d***

Host: Scapolitized analcime syenite

Magmatic minerals: Analcime, quartz, rutile, titanite

Secondary minerals: Chlorite, Fe-oxides/hydroxides, rutile, scapolite, analcime, titanite

Notes:

1. Titanite commonly overgrows and replaces rutile (Figures 1-4.4, 1-4.5). Fe-oxide also overgrows and replaces titanite and rutile, but the Fe-oxide overgrowths are better expressed, because the Fe-oxide precipitation texturally appears to be later (Figures 1-4.30,1-4.31).
2. Titanite has often been seen cross-cutting the scapolite and analcime mat (Figure 1-4.6).
3. Titanite in this sample postdates chlorite and analcime (Figures 1-4.6, 1-4.7).
4. Titanite and rutile appear to occur also commonly as late interstitial grains (Figures 1-4.12, 1-4.24, 1-4.26, 1-4.32).
5. The Fe-oxides not only replace both rutile and titanite relics, but also rim individual relics of rutile (Figure 1-4.10).

***Sample 9957***

Host: Altered diorite

Magmatic minerals: K-feldspar, albite, quartz

Accessory and alteration minerals: analcime, apatite, calcite, chlorite, epidote, Fe-oxides, titanite

Types of alteration:

a) Calcite ± chlorite

b) Epidote ± apatite

c) Scapolite

Sequence of alteration in diorite:

Scapolite, analcime → calcite ± chlorite → epidote → apatite ± titanite → Fe-oxides/hydroxides ± titanite?

Notes:

1. Epidote cross-cuts older minerals such as calcite, quartz, and albite (Fig. 11-1.3).
2. Calcite and chlorite appear to fill voids in the quartz and albite (Fig. 11-1.5, 7)
3. Apatite replaces epidote (Fig. 11-1.9) and calcite (Fig. 11-1.5).
4. Scapolite occurs in large patches and/or replaces K-feldspar (Fig. 11-1.11).

***Sample 9958a***

Host: Altered diorite

Magmatic minerals: K-feldspar, hornblende, quartz, albite

Accessory and alteration minerals: apatite, chlorite, actinolite, Fe-oxides/hydroxides, pyrite, titanite, quartz, albite, xenolith: zoisite

Types of alteration + veins (probably from early to late):

a) Hornblende → actinolite, ?albite

b) Scapolite + analcime

c) Epidote + quartz

d) Titanite, Fe-oxides

Notes:

1. This sample is cut by scapolite veins and patches. In the larger scapolitic veins and close to their contacts with the host diorite, there are many half-digested xenoliths of hornblende and actinolite (Figs. 11-2.26, 27, 29).
2. Analcime occurs interstitially between scapolite crystals (Fig. 11-2.9, 16) or along grain boundaries (Figs. 11-2.13, 14).
3. Apatite postdates epidote (Fig. 11-2.4).
4. Secondary titanite (Fig. 11-2.19), with well developed crystal facies, fills voids in a scapolite patch.
5. A patch probably of zoisite crystals with straight extinction in the fabric direction (Fig. 11-2.29) has been seen in the scapolite vein that cuts the host diorite. The patch is considered

as either a xenolith or in-situ hornfelsed country rock (Figs. 11-2.27,28). The zoisite is cross-cut by scapolite, analcime, quartz, and albite (Fig. 11-2.25b).

***Sample 9958b***

Host: Altered diorite

Magmatic minerals: Hornblende, K-feldspar, quartz, albite

Minor and alteration minerals: albite, apatite, chlorite, actinolite, Fe-hydroxides, kaolinite, titanite, zircon

Types of alteration (probably from early to late):

a) Hornblende → actinolite

b) Albite

Types of veins:

a) Scapolite + analcime

b) Quartz + epidote

Notes:

1. Analcime usually is found along scapolite grain boundaries or interstitially between scapolite grains (Fig. 11-3.7). It has also replaced K-feldspar (Fig. 11-3.11).
2. There is a difference in grain size for scapolite that is cut by quartz + epidote vein (Fig. 11-3.7). The size difference is probably due to cataclastic deformation of the site.
3. There seems to be mineral brecciation along the contact between scapolite vein and epidotized host diorite (Fig. 11-3.3). The mineral textures from this figure suggest that the epidote veins postdate the scapolite + analcime veins and their emplacement was accompanied by brecciation.

***Sample 9959***

Host: Altered diorite

Magmatic minerals: quartz, biotite

Accessory and alteration minerals: apatite, Fe-oxides/hydroxides, scapolite, titanite, chlorite.

Types of veins:

a) Scapolite

Notes:

1. Scapolite is partially replaced by a fine grained clay mineral (Fig. 11-4.9)

2. The host rock contains epidote + quartz, which is most likely postdates the magmatic minerals (see sample 9958a, b).

3. A clay mineral follows grain boundaries and irregular fractures in the scapolite vein (Fig. 11-4.5).

4) Scapolite postdates quartz + epidote based on cross-cutting relationships (Fig. 11-4.7).

## HIGHLIGHTS OF THE NEW FINDINGS

We anticipate that the products of combining both the analytical data listed in this report and the work in OF 8314 (Pe-Piper et al. 2017a) will be papers in externally refereed journals. Such publications will include the two following papers:

1. **Geochronology and trace element mobility in rutile from a Carboniferous syenite pegmatite.** In press for *American Mineralogist*.

In this paper we have demonstrated the following:

1. The pegmatitic syenite (9928, 9956), based on the U/Pb LA- ICPMS of the rutile, was likely emplaced ~ 360Ma and no younger than 353 Ma. Therefore it was synchronous with the late phases of the Cobequid Highland A-type granite plutonism, which are dated between 365 ±4 Ma and 358 ±4 (Dunning et al., 2002; Pe-Piper et al., 2004).

2. Most magmatic rutile, with little evidence of later hydrothermal alteration, has REE patterns a) with 1-50 times chondrite enrichment, LREE>HREE, and a Eu anomaly, that results probably from felsic melt inclusions (e.g. Papoutsa et al., 2016), or b) rather flat patterns with 0.1-10 time chondrite enrichment, probably present in ilmenite exsolution lamellae. Ilmenite has a rather flat normalised REE pattern (Villemant 1988; Nielsen et al., 1992), and ilmenite has been seen as exsolution lamellae within magmatic rutile in the syenite (sample 9928).

3. Our data show that there was dissolution of magmatic phases and important transport of Zr and Ti by halogen-rich fluids that resulted in scapolitization of the syenite. Such transport may affect the use of Zr in the rutile geothermometer (Tomkins et al. 2007). Such fluids resulted in local dissolution-reprecipitation of Ti and Zr and resetting of the U-Pb system in the altered rutile, at 337.4±3.5 Ma.

2. **Scapolite and analcime: monitors of hydrothermal fluids involved in the alteration of a shear zone plutonic complex**. Revision returned to *Chemical Geology*

In this paper we have demonstrated the following:

1. The large scapolite veins in the mafic rocks (samples 9957, 9958) appear to be comparable to scapolite dykes seen in the scapolitized Humboldt gabbroic complex of Nevada (Speed, 1962; Vanko and Bishop, 1982), where dykes (weakness paths) were the favourable channels for circulation of the scapolitizing fluids. It is probably for the same reason that the hydrothermal fluids travelled along the cleavage planes of perthite crystals replacing the albite lamellae with analcime and the rest of the K-feldspar with scapolite.

2. The scapolitizing fluids were probably also responsible for the precipitation of anthophyllite seen in cavities between analcime crystals suggesting that analcime precipitation predates scapolitization. Speed (1962) also suggested for the Humboldt gabbroic complex that scapolite in some places had replaced early-formed pods of albitized and analcimized rocks. In our case analcime appears to predate, postdate or to be synchronous with the scapolite.

3. The regional A-type granite plutonism was Na- and halogen rich (Papoutsa et al., 2016), with widespread late-magmatic albitization and F-related mobility of REE minerals (Pe-Piper et al., 2017b). However, only at Clarke Head is there extreme Na- and Cl-rich metasomatism, indicated by scapolite and Cl-rich hastingsite (with >0.8 wt% chlorine content). Cl-rich fluids were derived from regional halite evaporites at faulted basin margins. The main circulating fluids were likely of magmatic origin, based on the $\delta^{18}O$ of replacement scapolite and veins of scapolite. As NaCl supply was reduced, scapolite became more Ca–rich.

## REFERENCES

Dunning, G.R., Barr, S.M., Giles, P.S., McGregor, D.C., Pe-Piper, G., and Piper, D.J.W. (2002) Chronology of Devonian to early Carboniferous rifting and igneous activity in southern Magdalen Basin based on U-Pb (zircon) dating. Canadian Journal of Earth Sciences, 39(8), 1219–1237.

McFarlane, C.R. (2015) A geochronological framework for sedimentation and Mesoproterozoic tectono-magmatic activity in lower Belt–Purcell rocks exposed west of Kimberley, British Columbia. Canadian Journal of Earth Sciences, 52(7), 444–465.

Nielsen, R.L., Gallahan, W.E., and Newberger, F. (1992) Experimentally determined mineral-melt partition coefficients for Sc, Y and REE for olivine, orthopyroxene, pigeonite, magnetite and ilmenite. Contributions to Mineralogy and Petrology, 110(4), 488–499.

Papoutsa, A., Pe-Piper, G., and Piper, D.J.W. (2016) Systematic mineralogical diversity in A-type granitic intrusions: Control of magmatic source and geological processes. Geological Society of America Bulletin, 128(3-4), 487–501.

Pe-Piper, G., Reynolds, P.H., Nearing, J., and Piper, D.J.W. (2004) Evolution of a Late Paleozoic shear zone in the Cobequid Highlands, Nova Scotia: an $^{40}Ar/^{39}Ar$ geochronology study. Canadian Journal of Earth Sciences, 41, 1425–1436.

Pe-Piper, G., Nagle, J., and Piper, D.J.W, 2017a: Igneous rocks and hydrothermal alteration of Lower Carboniferous sedimentary rocks, Clarke Head, Minas Fault Zone, western Nova Scotia. Geological Survey of Canada Open File 8314, 639 pp.

Pe-Piper, G., Piper, D.J.W., Papoutsa, A., and Wisen, J., 2017b. The fractured latest Devonian granites of the West Moose River Pluton along the Cobequid Shear Zone, Nova Scotia: implications for regional mineralisation. Canadian Journal of Earth Sciences, 54, 1119-1138.

Pe-Piper, G., Piper, D. J.W., McFarlane, C. R., Sangster, C., Zhang, Y., and Boucher, B. (2018). Petrology, chronology and sequence of vein systems: Systematic magmatic and hydrothermal history of a major intracontinental shear zone, Canadian Appalachians. Lithos, 304, 298–310.

Pe-Piper, G., Nagle, J., Piper, D.J.W, and McFarlane, C.R. (2019) Geochronology and trace element mobility in rutile from a Carboniferous syenite pegmatite and the role of halogens. American Mineralogist (*in press*)

Pe-Piper, G., Piper, D.J.W, and Nagle, J. (*submitted*) Scapolite and analcime: monitors of hydrothermal fluids that altered plutonic rocks in a major shear zone. Chemical Geology.

Spandler, C., Hammerli, J., Sha, P., Hilbert-Wolf, H., Hu, Y., Roberts, E., and Schmitz, M. (2016). MKED1: a new titanite standard for in situ analysis of Sm–Nd isotopes and U–Pb geochronology. Chemical Geology, 425, 110–126.

Tomkins, H.S., Powell, R., and Ellis, D.J. (2007) The pressure dependence of the zirconium-in-rutile thermometer. Journal of Metamorphic Geology, 25, 703–713.

Vanko, D.A. and Bishop, F.C. (1982) Occurrence and origin of marialitic scapolite in the Humboldt Lopolith, NW Nevada. Contributions to Mineralogy and Petrology, 81(4), 277–289.

Villemant, B. (1988) Trace element evolution in the Phlegrean Fields (Central Italy): fractional crystallization and selective enrichment. Contributions to Mineralogy and Petrology, 98(2), 169–183.

Whitney, D.L. and Evans, B.W. (2010) Abbreviations for names of rock-forming minerals. American Mineralogist, 95,185–187.

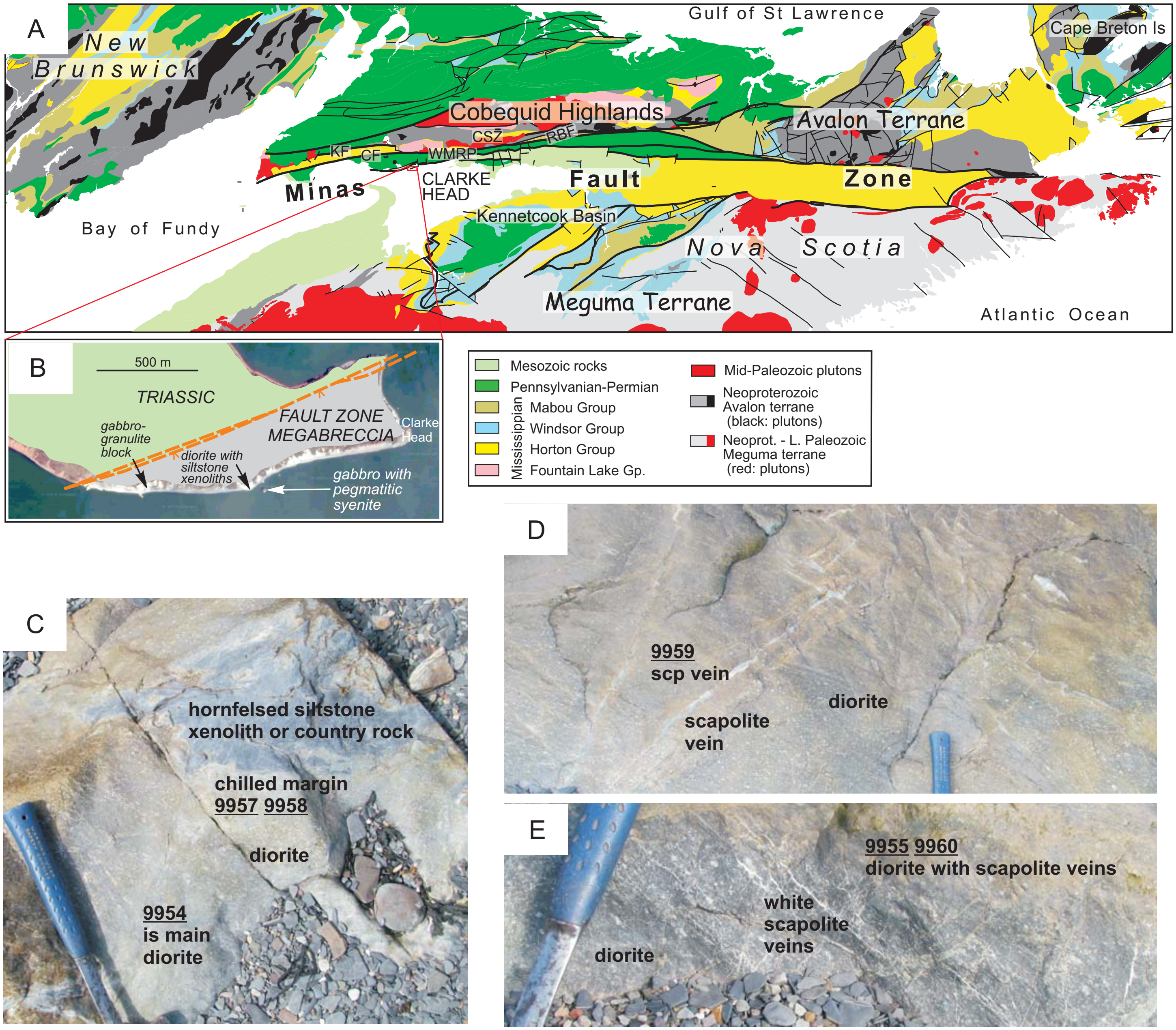



Figure 1. (A) Regional map showing location of the Minas Fault Zone.
(B) Detail of Clarke Head showing location of igneous rocks.
(C-E) Field photographs of diorite in rockfall showing setting of samples.

# Tables

Table 1: Summary of research activities on the new samples from Clarke Head.

| Locality | Sample | Lithology Description | Field Photo | Scanned PTS | Micro-scope | Appendix XRF Map | Appendix LA-ICPMS | Appendix EDS-SEM analyses | Minerals in the host rock | Mineral assemblage of veins |
|---|---|---|---|---|---|---|---|---|---|---|
| 45° 22.690'N 64° 14.983'W | 9956a | Syenite | | ✓ | ✓ | 3-5 | 4 | 1-1 | Anl, Ep, Kfs, Rt, Scp, Ttn, Fe-oxides/hydroxides | |
| | 9956b | Syenite | | ✓ | ✓ | 3-6 | 4 | 1-2 | Ab, Anl, Kfs, Qz, Rt, Scp, Ttn, Zrn, Fe-oxides/hydroxides | |
| | 9956c | Syenite | | ✓ | ✓ | 3-7 | 4 | 1-3 | Anl, Chl, Kfs, Rt, Scp, Ttn, Fe-oxides/hydroxides | |
| | 9956d | Syenite | | ✓ | ✓ | 3-8 | 4 | 1-4 | Anl, Chl, Kfs, Qz, Rt, Scp, Ttn, Fe-oxides/hydroxides | |
| 45° 22.679'N 64° 15.026'W | 9954a | Altered diorite | Fig. 1C | ✓ | ✓ | 3-4 | 4 | App. 1 Pe-Piper et al. (2017a) | Ab, Ap, Bt, Cal, Kfs, Ms, Qz, Fe-oxides/hydroxides | |
| | 9957 | Chilled margin against grey sandstone xenolith | Fig. 1C | ✓ | ✓ | 3-9 | 4 | 11-1 | Ab, Anl, Ap, Cal, Chl, Ep, Kfs, Qz, Ttn, Fe-oxides/hydroxides | Scp |
| | 9958a | Mafic rock from a rockfall that is cut by scapolite veins | Fig. 1C | ✓ | ✓ | 3-10 | 4 | 11-2 | Ab, Act, Anl, Ap, Chl, Ep, Hb, Kfs, Qz, Scp, Ttn, Fe-oxides/hydroxides | Zoisite in xenolith |
| | 9958b | Mafic rock from a rockfall that is cut by scapolite veins | Fig. 1C | ✓ | ✓ | | | 11-3 | Ab, Act, Anl, Ap, Chl, Ep, Hbl, Kfs, Kln, Qz, Scp, Ttn, Zrn, Fe-oxides/hydroxides | |
| | 9959 | Thin white scapolite veins. Some planar, some deformed | Fig. 1D | ✓ | ✓ | | | 11-4 | Ap, Bt, Chl, Ep, Qz, Ttn, Fe-oxides/hydroxides | Scp |

Mineral abbreviaton: ab=albite, act=actinolite, anl=analcime, ap=apatite, bt=biotite, cal=calcite, chl=chlorite, ep=epidote, hbl=hornblende, Kfs=K-feldspar, kln=kaolinite, ms=muscovite, plag=plagioclase, qz=quartz, scp=scapolite, ttn=titanite, zrn=zircon. PTS = polished thin section.

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.

| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 2 | 2 | Ttn | 2 | 33.24 | 35.17 | 2.94 | 0.72 | | | 27.93 | | | | | | | | | | | 100 | 109 |
| 9956a | 2 | 3 | Ttn | 2 | 33.28 | 35.10 | 2.70 | 0.82 | | | 28.10 | | | | | | | | | | | 100 | 109 |
| 9956a | 2 | 6 | Ttn | 2 | 33.35 | 34.87 | 2.92 | 0.65 | | | 28.22 | | | | | | | | | | | 100 | 109 |
| 9956a | 3 | 1 | Ttn | 2 | 32.26 | 37.38 | 2.99 | 0.25 | | | 27.13 | | | | | | | | | | | 100 | 109 |
| 9956a | 4 | 3 | Ttn | 2 | 33.13 | 34.84 | 2.74 | 1.24 | | | 28.05 | | | | | | | | | | | 100 | 109 |
| 9956a | 4 | 4 | Ttn | 2 | 33.41 | 34.75 | 2.52 | 1.28 | | | 28.04 | | | | | | | | | | | 100 | 109 |
| 9956a | 5 | 1 | Ttn | 6 | 33.70 | 34.66 | 2.51 | 0.86 | | | 27.63 | | | | | | | 0.65 | | | | 100 | 108 |
| 9956a | 7 | 1 | Ttn | 1,6 | 33.53 | 35.10 | 2.22 | 1.21 | | | 27.94 | | | | | | | | | | | 100 | 107 |
| 9956a | 7 | 2 | Ttn | 1,6 | 33.69 | 35.03 | 2.47 | 1.09 | | | 27.71 | | | | | | | | | | | 100 | 108 |
| 9956a | 8 | 1 | Ttn | 1 | 33.65 | 33.09 | 3.57 | 1.39 | | | 28.30 | | | | | | | | | | | 100 | 110 |
| 9956a | 8 | 3 | Ttn | 3 | 33.59 | 35.49 | 2.25 | 0.80 | | | 27.88 | | | | | | | | | | | 100 | 108 |
| 9956a | 10 | 3 | Ttn | 3 | 33.29 | 35.89 | 2.57 | 0.51 | | | 27.74 | | | | | | | | | | | 100 | 111 |
| 9956a | 12 | 3 | Ttn | 3 | 32.93 | 38.21 | 0.98 | | | | 27.89 | | | | | | | | | | | 100 | 111 |
| 9956a | 12 | 5 | Ttn | 3 | 32.66 | 37.74 | 1.31 | 0.33 | | | 27.96 | | | | | | | | | | | 100 | 111 |
| 9956a | 13 | 1 | Ttn | 6,9 | 32.98 | 36.09 | 1.82 | 0.99 | | | 28.13 | | | | | | | | | | | 100 | 112 |
| 9956a | 13 | 2 | Ttn | 6,9 | 33.30 | 36.02 | 1.94 | 0.79 | | | 27.95 | | | | | | | | | | | 100 | 107 |
| 9956a | 14 | 3 | Ttn | 1 | 33.02 | 35.51 | 2.23 | 1.05 | | | 28.18 | | | | | | | | | | | 100 | 111 |
| 9956a | 14 | 5 | Ttn | 1 | 32.95 | 35.48 | 2.35 | 1.06 | | | 28.17 | | | | | | | | | | | 100 | 108 |
| 9956a | 14 | 7 | Ttn | 1 | 32.90 | 37.68 | 0.99 | 0.37 | | | 28.06 | | | | | | | | | | | 100 | 112 |
| 9956a | 15 | 1 | Ttn | 6,9 | 32.86 | 38.42 | 0.59 | 0.28 | | | 27.85 | | | | | | | | | | | 100 | 111 |
| 9956a | 15 | 3 | Ttn | 6,9 | 32.76 | 38.24 | 0.74 | 0.34 | | | 27.92 | | | | | | | | | | | 100 | 110 |
| 9956a | 15 | 4 | Ttn | 6,9 | 32.96 | 38.15 | 0.64 | 0.30 | | | 27.95 | | | | | | | | | | | 100 | 110 |
| 9956a | 15 | 5 | Ttn | 6,9 | 32.97 | 36.64 | 1.58 | 0.84 | | | 27.97 | | | | | | | | | | | 100 | 110 |
| 9956a | 16 | 4 | Ttn | 2 | 33.27 | 30.78 | 5.89 | 0.44 | | | 28.06 | | | | | 1.56 | | | | | | 100 | 112 |
| 9956a | 16 | 6 | Ttn | 2 | 32.84 | 36.65 | 2.41 | 0.33 | | | 27.77 | | | | | | | | | | | 100 | 111 |
| 9956a | 17 | 2 | Ttn | 2,6 | 33.18 | 31.26 | 4.96 | 0.85 | | | 27.65 | | | | | 2.10 | | | | | | 100 | 112 |
| 9956a | 18 | 2 | Ttn | 2,6 | 33.40 | 35.60 | 2.11 | 0.71 | | | 28.18 | | | | | | | | | | | 100 | 110 |
| 9956a | 18 | 3 | Ttn | 2,6 | 33.05 | 32.39 | 4.56 | | | | 28.03 | | | | | 1.97 | | | | | | 100 | 111 |
| 9956a | 19 | 1 | Ttn | 2 | 32.70 | 35.08 | 2.27 | 1.31 | | | 27.97 | | | 0.55 | | | | | | 0.13 | | 100 | 109 |
| 9956a | 20 | 1 | Ttn | 3 | 33.45 | 34.30 | 2.91 | 1.25 | | | 28.09 | | | | | | | | | | | 100 | 110 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 20 | 4 | Ttn | 3 | 33.18 | 35.24 | 2.16 | 1.04 | | | 28.38 | | | | | | | | | | | 100 | 109 |
| 9956a | 21 | 2 | Ttn | 2 | 33.08 | 35.25 | 2.07 | 1.41 | | | 28.18 | | | | | | | | | | | 100 | 108 |
| 9956a | 21 | 4 | Ttn | 2 | 32.99 | 35.67 | 2.16 | 1.14 | | | 28.05 | | | | | | | | | | | 100 | 110 |
| 9956a | 22 | 1 | Ttn | 6,9 | 32.84 | 37.75 | 1.08 | 0.34 | | | 27.99 | | | | | | | | | | | 100 | 106 |
| 9956a | 22 | 2 | Ttn | 6,9 | 33.01 | 38.12 | 0.67 | 0.30 | | | 27.90 | | | | | | | | | | | 100 | 107 |
| 9956a | 22 | 3 | Ttn | 6,9 | 32.93 | 38.03 | 0.81 | 0.29 | | | 27.94 | | | | | | | | | | | 100 | 112 |
| 9956a | 22 | 4 | Ttn | 6,9 | 32.70 | 38.24 | 0.83 | 0.33 | | | 27.91 | | | | | | | | | | | 100 | 107 |
| 9956a | 22 | 5 | Ttn | 6,9 | 32.82 | 37.73 | 0.88 | 0.69 | | | 27.89 | | | | | | | | | | | 100 | 109 |
| 9956a | 23 | 2 | Ttn | 2 | 33.53 | 34.17 | 3.11 | 0.93 | | | 28.26 | | | | | | | | | | | 100 | 107 |
| 9956a | 23 | 3 | Ttn | 2 | 33.68 | 34.33 | 3.02 | 0.84 | | | 28.14 | | | | | | | | | | | 100 | 108 |
| 9956a | 23 | 5 | Ttn | 6 | 33.14 | 36.15 | 2.28 | 0.49 | | | 27.94 | | | | | | | | | | | 100 | 112 |
| 9956a | 24 | 1 | Ttn | 4 | 33.05 | 31.74 | 5.33 | | | | 27.88 | | | | | 2.00 | | | | | | 100 | 113 |
| 9956a | 25 | 1 | Ttn | 4 | 33.22 | 34.59 | 3.03 | 1.34 | | | 27.82 | | | | | | | | | | | 100 | 111 |
| 9956a | 26 | 2 | Ttn | 6 | 33.00 | 36.38 | 1.53 | 0.69 | | | 27.75 | | | | | | | 0.66 | | | | 100 | 111 |
| 9956a | 26 | 5 | Ttn | 6 | 32.81 | 37.72 | 1.05 | 0.40 | | | 28.02 | | | | | | | | | | | 100 | 110 |
| 9956a | 27 | 1 | Ttn | 6 | 32.79 | 35.24 | 1.98 | 0.82 | | | 27.76 | | | | | | | | | 1.40 | | 100 | 114 |
| 9956a | 27 | 2 | Ttn | 6 | 33.08 | 33.86 | 2.79 | 1.09 | | | 27.93 | | | | | | | | | 1.26 | | 100 | 110 |
| 9956a | 28 | 1 | Ttn | 2 | 32.98 | 34.67 | 2.62 | 0.68 | | | 27.88 | | | | | | | | | 1.18 | | 100 | 113 |
| 9956a | 28 | 4 | Ttn | 2 | 32.64 | 34.19 | 3.05 | 0.74 | | | 28.15 | | | | | | | | | 1.23 | | 100 | 111 |
| 9956a | 29 | 1 | Ttn | 6 | 33.12 | 34.94 | 2.10 | 0.86 | | | 27.80 | | | | | | | | | 1.17 | | 100 | 110 |
| 9956a | 29 | 3 | Ttn | 6 | 32.94 | 36.77 | 1.20 | 0.28 | | | 27.58 | | | | | | | | | 1.23 | | 100 | 109 |
| 9956a | 29 | 4 | Ttn | 6 | 32.99 | 33.68 | 2.97 | 0.83 | | | 27.49 | | | | | 0.91 | | | | 1.13 | | 100 | 107 |
| 9956a | 29 | 5 | Ttn | 6 | 33.19 | 35.15 | 2.33 | 0.48 | | | 27.66 | | | | | | | | | 1.20 | | 100 | 106 |
| 9956a | 29 | 6 | Ttn | 6 | 32.96 | 32.90 | 3.43 | 1.32 | | | 28.08 | | | | | | | | | 1.30 | | 100 | 110 |
| 9956a | 29 | 11 | Ttn + | 6 | 40.39 | 23.41 | 8.72 | 0.41 | | | 20.11 | 5.91 | | | | | | | | 1.04 | | 100 | 111 |
| 9956a | 29 | 12 | Ttn | 6 | 33.36 | 34.57 | 2.73 | 0.46 | | | 27.65 | | | | | | | | | 1.23 | | 100 | 107 |
| 9956a | 30 | 1 | Ttn | 6 | 33.33 | 34.08 | 3.04 | 0.86 | | | 28.23 | | | | | | | | | 0.45 | | 100 | 108 |
| 9956a | 30 | 2 | Ttn | 3,6 | 33.01 | 34.69 | 2.97 | 0.66 | | | 28.00 | | | | | | | | | 0.66 | | 100 | 110 |
| 9956a | 31 | 1 | Ttn | 1 | 32.77 | 37.39 | 1.12 | 0.64 | | | 27.81 | | | | | | | | | 0.28 | | 100 | 107 |
| 9956a | 31 | 2 | Ttn | 1,6 | 32.81 | 36.76 | 1.37 | 0.76 | | | 27.91 | | | | | | | | | 0.38 | | 100 | 107 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 31 | 3 | Ttn | 1,6 | 32.63 | 36.66 | 1.52 | 0.79 | | | 27.95 | | | | | | | | | 0.46 | | 100 | 109 |
| 9956a | 32 | 3 | Ttn | 2 | 32.93 | 37.97 | 0.87 | 0.43 | | | 27.80 | | | | | | | | | | | 100 | 105 |
| 9956a | 32 | 4 | Ttn | 2 | 32.86 | 37.54 | 1.41 | 0.32 | | | 27.87 | | | | | | | | | | | 100 | 104 |
| 9956a | 32 | 6 | Ttn | 2 | 32.67 | 38.06 | 0.58 | 0.88 | | | 27.82 | | | | | | | | | | | 100 | 107 |
| 9956a | 33 | 1 | Ttn | 3,6 | 33.49 | 34.30 | 3.01 | 1.03 | | | 28.17 | | | | | | | | | | | 100 | 104 |
| 9956a | 33 | 4 | Ttn | 3,6 | 33.37 | 35.70 | 2.00 | 0.82 | | | 28.12 | | | | | | | | | | | 100 | 104 |
| 9956a | 34 | 1 | Ttn | 2 | 33.00 | 36.36 | 1.82 | 0.92 | | | 27.90 | | | | | | | | | | | 100 | 111 |
| 9956a | 35 | 1 | Ttn | 6,9 | 33.00 | 37.79 | 0.88 | 0.49 | | | 27.84 | | | | | | | | | | | 100 | 107 |
| 9956a | 35 | 2 | Ttn | 2 | 33.28 | 35.60 | 2.19 | 1.00 | | | 27.94 | | | | | | | | | | | 100 | 109 |
| 9956a | 35 | 4 | Ttn | 6,9 | 32.90 | 36.52 | 1.37 | 0.84 | | | 27.71 | | | | | | | 0.66 | | | | 100 | 107 |
| 9956a | 35 | 5 | Ttn | 6,9 | 32.89 | 37.90 | 0.82 | 0.75 | | | 27.64 | | | | | | | | | | | 100 | 108 |
| 9956a | 37 | 1 | Ttn | 6,9 | 33.03 | 36.64 | 1.34 | 0.54 | | | 27.72 | | | | | | | 0.74 | | | | 100 | 108 |
| 9956a | 37 | 2 | Ttn | 2 | 33.24 | 35.02 | 2.54 | 1.10 | | | 28.10 | | | | | | | | | | | 100 | 109 |
| 9956a | 37 | 6 | Ttn | 2 | 32.83 | 36.75 | 1.62 | 0.76 | | | 28.03 | | | | | | | | | | | 100 | 107 |
| 9956a | 38 | 2 | Ttn | 2 | 33.16 | 35.09 | 2.47 | 1.00 | | | 28.28 | | | | | | | | | | | 100 | 111 |
| 9956b | 1 | 1 | Ttn | 1 | 33.09 | 37.91 | 0.94 | 0.29 | | | 27.77 | | | | | | | | | | | 100 | 111 |
| 9956b | 1 | 4 | Ttn | 2 | 33.10 | 36.66 | 1.43 | 0.76 | | | 28.06 | | | | | | | | | | | 100 | 111 |
| 9956b | 1 | 5 | Ttn | 1 | 33.50 | 35.81 | 1.98 | 0.63 | | | 28.08 | | | | | | | | | | | 100 | 109 |
| 9956b | 2 | 1 | Ttn | 1 | 33.07 | 35.58 | 2.48 | 0.77 | | | 28.10 | | | | | | | | | | | 100 | 112 |
| 9956b | 2 | 2 | Ttn | 4 | 33.40 | 34.29 | 2.83 | 1.18 | | | 28.29 | | | | | | | | | | | 100 | 113 |
| 9956b | 3 | 3 | Ttn | 2 | 33.18 | 34.67 | 2.92 | 1.12 | | | 28.11 | | | | | | | | | | | 100 | 111 |
| 9956b | 4 | 2 | Ttn | 3 | 32.47 | 34.49 | 4.40 | 1.43 | | | 26.80 | | | | | | | | | | 0.40 | 100 | 110 |
| 9956b | 4 | 4 | Ttn | 7 | 33.36 | 30.54 | 5.67 | 0.67 | | | 27.51 | | | | | 1.97 | | | | | 0.28 | 100 | 111 |
| 9956b | 4 | 5 | Ttn | 7 | 32.37 | 0.48 | 22.63 | 24.02 | | 19.89 | | | | | | | | | | | 0.61 | 100 | 101 |
| 9956b | 4 | 6 | Ttn | 7 | 33.99 | 31.77 | 4.45 | 1.43 | | | 27.87 | | | | | | | | | | 0.49 | 100 | 110 |
| 9956b | 4 | 10 | Ttn | 7 | 33.69 | 33.75 | 2.82 | 1.25 | | | 28.02 | | | | | | | | | | 0.49 | 100 | 111 |
| 9956b | 4 | 11 | Ttn | 7 | 33.18 | 33.35 | 3.69 | 0.63 | | | 27.69 | | | | | 1.01 | | | | | 0.45 | 100 | 113 |
| 9956b | 4 | 12 | Ttn | 7 | 33.16 | 36.27 | 1.78 | 0.45 | | | 27.85 | | | | | | | | | | 0.49 | 100 | 112 |
| 9956b | 4 | 13 | Ttn | 7 | 36.67 | 34.14 | 4.70 | 0.60 | | | 22.49 | 0.84 | | | | | | | | | 0.57 | 100 | 106 |
| 9956b | 5 | 2 | Ttn | 2 | 33.76 | 34.05 | 3.02 | 1.01 | | | 27.92 | | | | | | | | | | 0.24 | 100 | 110 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 5 | 3 | Ttn | 2 | 33.30 | 34.60 | 2.77 | 1.23 | | | 27.87 | | | | | | | | | | 0.24 | 100 | 110 |
| 9956b | 6 | 1 | Ttn | 6 | 33.01 | 37.81 | 0.88 | | | | 27.91 | | | | | | | | 0.39 | | | 100 | 114 |
| 9956b | 6 | 3 | Ttn | 6 | 33.03 | 37.19 | 1.20 | 0.37 | | | 28.21 | | | | | | | | | | | 100 | 113 |
| 9956b | 7 | 1 | Ttn | 2 | 32.83 | 37.08 | 1.25 | 0.68 | | | 27.93 | | | | | | | | | | 0.24 | 100 | 115 |
| 9956b | 8 | 2 | Ttn | 2 | 32.69 | 37.89 | 1.11 | 0.45 | | | 27.86 | | | | | | | | | | | 100 | 112 |
| 9956b | 9 | 2 | Ttn | 3 | 32.91 | 37.25 | 1.63 | 0.45 | | | 27.76 | | | | | | | | | | | 100 | 111 |
| 9956b | 10 | 2 | Ttn | 2 | 32.88 | 36.60 | 1.76 | 0.45 | | | 27.49 | | | | | 0.82 | | | | | | 100 | 115 |
| 9956b | 10 | 4 | Ttn | 2 | 33.74 | 36.00 | 2.14 | 0.59 | | | 27.52 | | | | | | | | | | | 100 | 113 |
| 9956b | 10 | 5 | Ttn | 2 | 33.26 | 37.16 | 1.56 | 0.35 | | | 27.66 | | | | | | | | | | | 100 | 113 |
| 9956b | 10 | 8 | Ttn | 2 | 33.17 | 36.44 | 2.64 | 0.60 | | | 26.72 | 0.44 | | | | | | | | | | 100 | 114 |
| 9956b | 13 | 3 | Ttn | 3 | 33.15 | 36.21 | 2.03 | 0.58 | | | 28.02 | | | | | | | | | | | 100 | 114 |
| 9956b | 14 | 1 | Ttn | 6,9 | 33.89 | 34.86 | 2.31 | 1.92 | | 1.20 | 25.81 | | | | | | | | | | | 100 | 111 |
| 9956b | 14 | 2 | Ttn | 6,9 | 33.52 | 36.38 | 1.22 | 0.58 | | | 27.41 | | | | | | | 0.89 | | | | 100 | 110 |
| 9956b | 15 | 1 | Ttn | 6,9 | 32.89 | 37.56 | 1.13 | 0.45 | | | 27.97 | | | | | | | | | | | 100 | 113 |
| 9956b | 15 | 2 | Ttn | 6,9 | 33.02 | 37.39 | 1.01 | 0.74 | | | 27.85 | | | | | | | | | | | 100 | 110 |
| 9956b | 15 | 3 | Ttn | 6,9 | 33.08 | 36.17 | 1.92 | 0.70 | | | 28.13 | | | | | | | | | | | 100 | 114 |
| 9956b | 16 | 2 | Ttn | 2 | 33.39 | 34.41 | 2.96 | 0.92 | | | 28.32 | | | | | | | | | | | 100 | 108 |
| 9956b | 16 | 3 | Ttn | 2 | 33.53 | 34.58 | 2.93 | 1.10 | | | 27.86 | | | | | | | | | | | 100 | 109 |
| 9956b | 16 | 6 | Ttn | 2 | 33.45 | 34.48 | 3.02 | 1.23 | | | 27.83 | | | | | | | | | | | 100 | 113 |
| 9956c | 1 | 2 | Ttn | 2 | 33.25 | 35.32 | 2.29 | 1.00 | | | 28.14 | | | | | | | | | | | 100 | 114 |
| 9956c | 1 | 4 | Ttn | 2 | 32.98 | 36.50 | 1.75 | 0.69 | | | 28.08 | | | | | | | | | | | 100 | 110 |
| 9956c | 1 | 6 | Ttn | 2 | 33.22 | 35.66 | 2.12 | 0.90 | | | 28.11 | | | | | | | | | | | 100 | 109 |
| 9956c | 3 | 1 | Ttn | 6,9 | 33.05 | 36.90 | 1.37 | 0.55 | | | 28.14 | | | | | | | | | | | 100 | 113 |
| 9956c | 3 | 5 | Ttn | 2 | 33.06 | 37.91 | 0.86 | 0.40 | | | 27.76 | | | | | | | | | | | 100 | 111 |
| 9956c | 3 | 6 | Ttn | 2 | 33.30 | 35.29 | 2.04 | 1.38 | | | 27.98 | | | | | | | | | | | 100 | 105 |
| 9956c | 3 | 8 | Ttn | 2 | 32.67 | 37.92 | 1.11 | 0.45 | | | 27.86 | | | | | | | | | | | 100 | 109 |
| 9956c | 4 | 2 | Ttn | 2? | 33.30 | 36.80 | 1.37 | 0.71 | | | 27.83 | | | | | | | | | | | 100 | 109 |
| 9956c | 4 | 4 | Ttn | 2?,6 | 33.29 | 36.81 | 1.28 | 0.76 | | | 27.87 | | | | | | | | | | | 100 | 111 |
| 9956c | 6 | 1 | Ttn | 6? | 32.97 | 37.84 | 0.96 | 0.48 | | | 27.75 | | | | | | | | | | | 100 | 112 |
| 9956c | 6 | 6 | Ttn | 6? | 33.33 | 34.73 | 2.53 | 1.17 | | | 28.24 | | | | | | | | | | | 100 | 111 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 7 | 2 | Ttn | 2 | 32.71 | 33.89 | 3.22 | 0.95 | | | 27.92 | | | | | 1.31 | | | | | | 100 | 113 |
| 9956c | 7 | 3 | Ttn | 2 | 32.98 | 34.86 | 2.58 | 1.74 | | | 27.84 | | | | | | | | | | | 100 | 114 |
| 9956c | 7 | 6 | Ttn | 2 | 32.66 | 34.87 | 2.67 | 0.78 | | | 27.76 | | | | | 1.26 | | | | | | 100 | 114 |
| 9956c | 8 | 2 | Ttn | 2 | 32.80 | 37.73 | 0.81 | 0.50 | | | 28.15 | | | | | | | | | | | 100 | 113 |
| 9956c | 8 | 3 | Ttn | 2 | 33.73 | 34.50 | 2.21 | 1.40 | | 0.83 | 26.48 | | | | | | | 0.85 | | | | 100 | 113 |
| 9956c | 9 | 2 | Ttn | 1 | 33.10 | 35.72 | 2.08 | 0.71 | | | 27.77 | | | | | | | | | | 0.61 | 100 | 112 |
| 9956c | 10 | 3 | Ttn | 6,2 | 33.30 | 34.39 | 3.14 | 0.99 | | | 28.18 | | | | | | | | | | | 100 | 112 |
| 9956c | 11 | 1 | Ttn | 6,2 | 33.56 | 34.84 | 2.84 | 0.67 | | | 28.09 | | | | | | | | | | | 100 | 111 |
| 9956c | 11 | 4 | Ttn | 6,2 | 32.73 | 31.34 | 5.40 | 0.42 | | | 27.25 | | | | | 2.85 | | | | | | 100 | 116 |
| 9956c | 12 | 1 | Ttn | 6,2 | 33.02 | 37.22 | 1.32 | 0.50 | | | 27.95 | | | | | | | | | | | 100 | 109 |
| 9956c | 13 | 1 | Ttn | 6,2 | 33.68 | 33.84 | 3.03 | 1.22 | | | 28.22 | | | | | | | | | | | 100 | 107 |
| 9956c | 13 | 3 | Ttn | 6,2 | 33.38 | 35.88 | 1.91 | 0.77 | | | 28.07 | | | | | | | | | | | 100 | 110 |
| 9956c | 14 | 1 | Ttn | 6 | 33.15 | 37.28 | 1.30 | 0.43 | | | 27.84 | | | | | | | | | | | 100 | 111 |
| 9956c | 15 | 3 | Ttn | 6,2 | 33.72 | 33.98 | 3.04 | 1.25 | | | 28.01 | | | | | | | | | | | 100 | 109 |
| 9956c | 15 | 4 | Ttn | 6,2 | 38.19 | 32.65 | 3.47 | | | | 24.05 | 0.51 | | | | 1.12 | | | | | | 100 | 106 |
| 9956c | 16 | 1 | Ttn | 6,2 | 33.61 | 34.88 | 2.52 | 1.15 | | | 27.84 | | | | | | | | | | | 100 | 110 |
| 9956c | 16 | 4 | Ttn | 6,2 | 33.37 | 36.22 | 1.84 | 0.65 | | | 27.92 | | | | | | | | | | | 100 | 112 |
| 9956c | 17 | 1 | Ttn | 6 | 33.41 | 35.96 | 1.83 | 0.65 | | | 28.16 | | | | | | | | | | | 100 | 112 |
| 9956c | 17 | 2 | Ttn | 6 | 33.13 | 37.12 | 1.19 | 0.40 | | | 28.16 | | | | | | | | | | | 100 | 111 |
| 9956c | 17 | 3 | Ttn | 6 | 33.41 | 34.54 | 2.71 | 1.15 | | | 28.19 | | | | | | | | | | | 100 | 111 |
| 9956c | 17 | 4 | Ttn | 6 | 32.94 | 36.75 | 1.64 | 0.65 | | | 28.01 | | | | | | | | | | | 100 | 112 |
| 9956c | 17 | 5 | Ttn | 6 | 33.24 | 36.22 | 1.79 | 0.61 | | | 28.15 | | | | | | | | | | | 100 | 110 |
| 9956c | 18 | 1 | Ttn | 6,1 | 33.30 | 35.88 | 1.98 | 0.83 | | | 28.01 | | | | | | | | | | | 100 | 108 |
| 9956c | 18 | 2 | Ttn | 6 | 32.89 | 37.63 | 1.02 | 0.34 | | | 28.12 | | | | | | | | | | | 100 | 109 |
| 9956c | 18 | 3 | Ttn | 6 | 33.39 | 35.17 | 1.98 | 0.67 | | | 28.10 | | | | | | | 0.69 | | | | 100 | 108 |
| 9956c | 18 | 4 | Ttn | 6,2 | 32.59 | 33.40 | 3.13 | 1.27 | | | 27.98 | | | | | 1.61 | | | | | | 100 | 110 |
| 9956c | 18 | 7 | Ttn | 6,2 | 33.16 | 35.75 | 2.18 | 0.88 | | | 28.03 | | | | | | | | | | | 100 | 113 |
| 9956c | 19 | 1 | Ttn | 6 | 32.67 | 37.28 | 1.33 | 0.49 | | | 28.23 | | | | | | | | | | | 100 | 111 |
| 9956c | 20 | 1 | Ttn | 6,9 | 32.96 | 36.59 | 1.58 | 0.68 | | | 28.19 | | | | | | | | | | | 100 | 114 |
| 9956c | 20 | 2 | Ttn | 6,9 | 33.17 | 36.37 | 1.75 | 0.75 | | | 27.95 | | | | | | | | | | | 100 | 114 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 20 | 3 | Ttn | 6,9 | 33.46 | 34.64 | 2.82 | 1.08 | | | 28.00 | | | | | | | | | | | 100 | 112 |
| 9956c | 20 | 4 | Ttn | 6,9 | 33.24 | 36.67 | 1.50 | 0.71 | | | 27.88 | | | | | | | | | | | 100 | 113 |
| 9956c | 20 | 5 | Ttn | 6,9 | 33.59 | 34.82 | 2.55 | 1.18 | | | 27.85 | | | | | | | | | | | 100 | 113 |
| 9956c | 21 | 1 | Ttn | 6 | 33.17 | 36.94 | 1.34 | 0.50 | | | 28.04 | | | | | | | | | | | 100 | 110 |
| 9956c | 21 | 2 | Ttn | 6 | 32.83 | 34.15 | 2.71 | 1.10 | | | 27.80 | | | | | 1.40 | | | | | | 100 | 110 |
| 9956c | 21 | 3 | Ttn | 6 | 33.56 | 35.02 | 2.49 | 0.99 | | | 27.94 | | | | | | | | | | | 100 | 114 |
| 9956c | 21 | 4 | Ttn | 6 | 33.53 | 35.22 | 2.44 | 0.86 | | | 27.95 | | | | | | | | | | | 100 | 112 |
| 9956c | 21 | 5 | Ttn | 6 | 32.56 | 32.21 | 3.22 | 2.42 | | | 27.18 | | | | | 2.40 | | | | | | 100 | 117 |
| 9956c | 21 | 7 | Ttn | 6 | 32.89 | 39.15 | 0.30 | | | | 27.66 | | | | | | | | | | | 100 | 113 |
| 9956c | 21 | 10 | Ttn | 6 | 33.40 | 34.87 | 2.52 | 1.09 | | | 28.12 | | | | | | | | | | | 100 | 116 |
| 9956c | 21 | 12 | Ttn | 6 | 33.10 | 36.67 | 1.56 | 0.70 | | | 27.98 | | | | | | | | | | | 100 | 116 |
| 9956c | 21 | 13 | Ttn | 6 | 33.20 | 34.71 | 2.64 | 0.99 | | | 28.45 | | | | | | | | | | | 100 | 115 |
| 9956c | 22 | 1 | Ttn | 8 | 33.26 | 36.48 | 1.40 | 0.70 | | | 27.90 | | | | | | | | | | 0.26 | 100 | 113 |
| 9956c | 23 | 1 | Ttn | 6,1 | 33.04 | 34.81 | 2.46 | 1.35 | | | 27.69 | | | | | | | | | | 0.65 | 100 | 112 |
| 9956c | 23 | 2 | Ttn | 6,1 | 32.92 | 36.48 | 1.45 | 0.76 | | | 27.91 | | | | | | | | | | 0.49 | 100 | 113 |
| 9956c | 23 | 3 | Ttn | 6,1 | 33.20 | 34.56 | 2.49 | 1.32 | | | 27.85 | | | | | | | | | | 0.57 | 100 | 113 |
| 9956c | 24 | 1 | Ttn | 2 | 32.96 | 35.07 | 2.26 | 1.39 | | | 27.65 | | | | | | | | | | 0.67 | 100 | 112 |
| 9956c | 25 | 2 | Ttn | 6,2 | 33.04 | 36.77 | 1.32 | 0.55 | | | 27.76 | | | | | | | | | | 0.55 | 100 | 112 |
| 9956c | 25 | 3 | Ttn | 6,2 | 33.51 | 34.26 | 2.64 | 1.31 | | | 27.74 | | | | | | | | | | 0.54 | 100 | 110 |
| 9956c | 26 | 2 | Ttn | 2 | 33.13 | 33.94 | 3.03 | 1.48 | | | 27.81 | | | | | | | | | | 0.61 | 100 | 112 |
| 9956c | 26 | 3 | Ttn | 2 | 32.84 | 36.58 | 2.22 | 0.33 | | | 27.28 | | | | | | | | | | 0.75 | 100 | 114 |
| 9956c | 26 | 5 | Ttn | 2 | 33.06 | 36.52 | 1.75 | 0.64 | | | 27.45 | | | | | | | | | | 0.59 | 100 | 112 |
| 9956c | 27 | 1 | Ttn | 1 | 32.95 | 32.39 | 3.27 | 0.98 | | | 27.37 | | | | | 1.90 | | 0.70 | | | 0.44 | 100 | 114 |
| 9956c | 28 | 2 | Ttn | 2 | 33.17 | 31.42 | 4.53 | 1.05 | | | 27.79 | | | | | 2.03 | | | | | | 100 | 114 |
| 9956c | 28 | 3 | Ttn | 2 | 33.50 | 33.22 | 4.15 | 0.99 | | | 28.15 | | | | | | | | | | | 100 | 113 |
| 9956c | 28 | 4 | Ttn | 2 | 33.34 | 36.06 | 2.02 | 0.56 | | | 28.01 | | | | | | | | | | | 100 | 115 |
| 9956c | 29 | 2 | Ttn | 2,6 | 33.14 | 32.90 | 3.62 | 1.19 | | | 27.50 | | | | | 1.64 | | | | | | 100 | 112 |
| 9956c | 29 | 3 | Ttn + | 2 | 28.38 | 44.35 | 2.95 | 1.15 | | | 23.16 | | | | | | | | | | | 100 | 113 |
| 9956c | 29 | 4 | Ttn | 2,6 | 33.49 | 35.73 | 2.05 | 0.69 | | | 28.04 | | | | | | | | | | | 100 | 112 |
| 9956c | 29 | 5 | Ttn | 2,6 | 33.23 | 35.82 | 2.09 | 0.77 | | | 28.10 | | | | | | | | | | | 100 | 110 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 30 | 1 | Ttn | 1 | 33.20 | 35.43 | 2.93 | | | | 28.43 | | | | | | | | | | | 100 | 112 |
| 9956c | 30 | 3 | Ttn | 2 | 32.95 | 31.44 | 4.90 | 0.82 | | | 27.63 | | | | | 2.26 | | | | | | 100 | 113 |
| 9956c | 30 | 4 | Ttn | 2 | 33.35 | 33.94 | 2.75 | 1.25 | | | 28.04 | | | | | | | 0.66 | | | | 100 | 113 |
| 9956c | 30 | 6 | Ttn | 2 | 33.05 | 33.32 | 3.14 | 1.29 | | | 27.95 | | | | | 1.25 | | | | | | 100 | 111 |
| 9956c | 31 | 2 | Ttn | 2 | 33.02 | 36.26 | 2.05 | 0.83 | | | 27.84 | | | | | | | | | | | 100 | 113 |
| 9956c | 31 | 3 | Ttn | 2 | 33.01 | 37.29 | 1.28 | 0.55 | | | 27.87 | | | | | | | | | | | 100 | 113 |
| 9956c | 31 | 4 | Ttn | 2 | 32.91 | 34.85 | 2.71 | 1.48 | | | 28.05 | | | | | | | | | | | 100 | 112 |
| 9956c | 32 | 2 | Ttn | 2 | 32.82 | 38.11 | 0.81 | 0.36 | | | 27.91 | | | | | | | | | | | 100 | 110 |
| 9956c | 32 | 4 | Ttn | 1 | 32.92 | 37.44 | 1.11 | 0.44 | | | 28.09 | | | | | | | | | | | 100 | 112 |
| 9956c | 32 | 5 | Ttn | 2 | 33.09 | 37.60 | 1.14 | | | | 28.17 | | | | | | | | | | | 100 | 116 |
| 9956c | 32 | 6 | Ttn | 2 | 33.11 | 36.63 | 1.62 | 0.58 | | | 28.06 | | | | | | | | | | | 100 | 117 |
| 9956c | 32 | 7 | Ttn | 2 | 33.27 | 35.73 | 2.03 | 0.83 | | | 28.13 | | | | | | | | | | | 100 | 114 |
| 9956c | 33 | 2 | Ttn | 2 | 33.03 | 34.41 | 2.78 | 0.81 | | | 27.87 | | | | | 1.11 | | | | | | 100 | 112 |
| 9956c | 33 | 4 | Ttn | 2,6? | 33.33 | 35.74 | 2.21 | 0.61 | | | 28.10 | | | | | | | | | | | 100 | 112 |
| 9956d | 1 | 3 | Ttn | 2 | 33.24 | 35.33 | 2.23 | 0.95 | | | 28.26 | | | | | | | | | | | 100 | 113 |
| 9956d | 2 | 1 | Ttn | 2 | 33.31 | 36.88 | 1.27 | 0.70 | | | 27.84 | | | | | | | | | | | 100 | 116 |
| 9956d | 2 | 6 | Ttn | 2 | 33.43 | 35.67 | 2.11 | 0.81 | | | 27.97 | | | | | | | | | | | 100 | 112 |
| 9956d | 3 | 1 | Ttn | 6,9 | 33.30 | 37.19 | 1.16 | 0.48 | | | 27.87 | | | | | | | | | | | 100 | 116 |
| 9956d | 3 | 2 | Ttn | 6,9 | 33.47 | 35.54 | 2.12 | 1.02 | | | 27.86 | | | | | | | | | | | 100 | 116 |
| 9956d | 3 | 3 | Ttn | 6,9 | 33.31 | 37.48 | 1.05 | 0.36 | | | 27.80 | | | | | | | | | | | 100 | 115 |
| 9956d | 3 | 4 | Ttn | 6,9 | 33.29 | 37.89 | 0.81 | 0.28 | | | 27.73 | | | | | | | | | | | 100 | 115 |
| 9956d | 4 | 1 | Ttn | 6,9 | 33.01 | 37.09 | 1.21 | 0.69 | | | 28.00 | | | | | | | | | | | 100 | 112 |
| 9956d | 4 | 2 | Ttn | 6,9 | 33.03 | 37.65 | 0.98 | 0.73 | | | 27.61 | | | | | | | | | | | 100 | 113 |
| 9956d | 4 | 3 | Ttn | 6,9 | 33.35 | 36.56 | 1.62 | 0.58 | | | 27.89 | | | | | | | | | | | 100 | 114 |
| 9956d | 4 | 4 | Ttn | 6,9 | 33.08 | 37.51 | 1.05 | 0.56 | | | 27.81 | | | | | | | | | | | 100 | 111 |
| 9956d | 5 | 2 | Ttn | 2 | 32.95 | 37.64 | 0.87 | 0.43 | | | 28.11 | | | | | | | | | | | 100 | 112 |
| 9956d | 5 | 3 | Ttn | 2 | 33.51 | 37.23 | 1.03 | 0.40 | | | 27.84 | | | | | | | | | | | 100 | 114 |
| 9956d | 6 | 2 | Ttn | 2 | 32.81 | 38.18 | 0.53 | 0.68 | | | 27.81 | | | | | | | | | | | 100 | 112 |
| 9956d | 7 | 2 | Ttn | 2 | 33.35 | 35.47 | 2.13 | 0.96 | | | 28.10 | | | | | | | | | | | 100 | 113 |
| 9956d | 8 | 1 | Ttn | 6 | 33.08 | 35.93 | 2.09 | 0.78 | | | 28.11 | | | | | | | | | | | 100 | 114 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.



| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 8 | 2 | Ttn | 6 | 33.26 | 35.21 | 2.40 | 0.78 | | | 28.35 | | | | | | | | | | | 100 | 115 |
| 9956d | 8 | 3 | Ttn | 6 | 33.37 | 35.01 | 2.53 | 1.10 | | | 27.99 | | | | | | | | | | | 100 | 112 |
| 9956d | 8 | 4 | Ttn | 6 | 33.13 | 36.41 | 1.46 | 0.47 | | | 27.63 | | | | | | | 0.89 | | | | 100 | 112 |
| 9956d | 8 | 5 | Ttn | 6 | 32.98 | 34.15 | 2.53 | 1.14 | | | 27.70 | | | | | 1.50 | | | | | | 100 | 113 |
| 9956d | 8 | 6 | Ttn | 6 | 33.72 | 34.28 | 3.06 | 0.93 | | 0.41 | 27.31 | 0.29 | | | | | | | | | | 100 | 109 |
| 9956d | 9 | 1 | Ttn | 6 | 33.01 | 34.51 | 2.58 | 0.86 | | | 27.76 | | | | | 1.27 | | | | | | 100 | 116 |
| 9956d | 9 | 2 | Ttn | 6 | 33.13 | 34.56 | 2.36 | 1.03 | | | 27.71 | | | | | 1.21 | | | | | | 100 | 112 |
| 9956d | 10 | 2 | Ttn | 4 | 32.92 | 31.84 | 4.61 | 0.40 | | | 27.57 | | | | | 2.43 | | | | | 0.22 | 100 | 114 |
| 9956d | 10 | 5 | Ttn | 4 | 32.85 | 30.61 | 5.62 | 0.39 | | | 27.50 | | | | | 2.81 | | | | | 0.22 | 100 | 116 |
| 9956d | 11 | 1 | Ttn | 9 | 32.93 | 33.10 | 3.18 | 0.77 | | | 27.75 | | | | | 1.81 | | | | | 0.48 | 100 | 114 |
| 9956d | 11 | 2 | Ttn | 4 | 32.81 | 29.12 | 5.71 | 1.30 | | | 27.28 | | | | | 3.43 | | | | | 0.35 | 100 | 115 |
| 9956d | 11 | 5 | Ttn | 4 | 34.66 | 32.95 | 3.95 | 0.52 | | | 25.78 | | | | | 1.71 | | | | | 0.43 | 100 | 110 |
| 9956d | 12 | 3 | Ttn | 3,6 | 32.57 | 38.54 | 0.56 | 0.91 | | | 27.13 | | | | | | | | | | 0.28 | 100 | 114 |
| 9956d | 13 | 1 | Ttn | 1 | 33.45 | 37.30 | 1.37 | | | | 27.51 | | | | | | | | | | 0.36 | 100 | 113 |
| 9956d | 13 | 4 | Ttn | 3 | 33.28 | 34.91 | 2.59 | 0.42 | | | 27.38 | | | | | 1.17 | | | | | 0.25 | 100 | 114 |
| 9956d | 14 | 1 | Ttn | 6 | 33.52 | 35.05 | 2.91 | 0.51 | | | 27.81 | | | | | | | | | | 0.19 | 100 | 112 |
| 9956d | 14 | 2 | Ttn | 6 | 33.84 | 34.88 | 2.27 | 1.05 | | | 27.47 | | | | | | | | | | 0.49 | 100 | 112 |
| 9956d | 15 | 2 | Ttn | 4 | 32.59 | 35.74 | 2.64 | 0.50 | | | 26.63 | | | | | 1.60 | | | | | 0.30 | 100 | 115 |
| 9956d | 16 | 1 | Ttn | 3,6 | 33.51 | 35.22 | 2.26 | 0.83 | | | 27.81 | | | | | | | | | | 0.37 | 100 | 112 |
| 9956d | 16 | 3 | Ttn | 3,6 | 33.53 | 35.20 | 2.07 | 1.12 | | | 27.66 | | | | | | | | | | 0.42 | 100 | 113 |
| 9956d | 16 | 4 | Ttn | 3,6 | 33.81 | 33.74 | 2.99 | 1.11 | | | 27.88 | | | | | | | | | | 0.46 | 100 | 112 |
| 9956d | 16 | 5 | Ttn | 3,6 | 33.69 | 34.11 | 2.84 | 1.13 | | | 27.90 | | | | | | | | | | 0.33 | 100 | 112 |
| 9956d | 16 | 7 | Ttn | 3,6 | 34.50 | 33.58 | 3.24 | 1.21 | | | 27.10 | | | | | | | | | | 0.36 | 100 | 111 |
| 9956d | 17 | 2 | Ttn | 2,6 | 33.46 | 34.39 | 2.98 | 0.94 | | | 28.03 | | | | | | | | | | 0.20 | 100 | 110 |
| 9956d | 17 | 3 | Ttn | 6 | 33.44 | 34.95 | 2.69 | 0.59 | | | 27.86 | | | | | | | | | | 0.47 | 100 | 111 |
| 9956d | 18 | 2 | Ttn | 4,6 | 33.22 | 35.95 | 2.02 | 0.69 | | | 27.68 | | | | | | | | | | 0.45 | 100 | 112 |
| 9956d | 18 | 4 | Ttn | 4,6 | 35.00 | 33.69 | 3.44 | 0.75 | | | 26.83 | | | | | | | | | | 0.30 | 100 | 108 |
| 9956d | 19 | 1 | Ttn | 1 | 33.21 | 33.95 | 2.80 | 1.08 | | | 27.56 | | | | | 1.06 | | | | | 0.35 | 100 | 112 |
| 9956d | 19 | 2 | Ttn | 1 | 33.48 | 34.96 | 2.35 | 1.15 | | | 27.71 | | | | | | | | | | 0.36 | 100 | 112 |
| 9956d | 19 | 3 | Ttn | 1 | 33.04 | 33.17 | 4.13 | 0.36 | | | 27.52 | | | | | 1.33 | | | | | 0.45 | 100 | 114 |

Table 2: Summary table of titanite SEM-EDS analyses of Appendix 1.

| Sample | Site | Position | Mineral | Mode of Occurrence | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 19 | 5 | Ttn | 2 | 33.45 | 34.79 | 2.27 | 1.29 | | | 27.64 | | | | | | | | | | 0.55 | 100 | 110 |
| 9956d | 19 | 7 | Ttn | 2 | 33.37 | 35.92 | 1.87 | 0.79 | | | 27.63 | | | | | | | | | | 0.42 | 100 | 110 |
| 9956d | 20 | 1 | Ttn | 6 | 33.62 | 34.03 | 3.09 | 0.98 | | | 28.01 | | | | | | | | | | 0.27 | 100 | 111 |
| 9956d | 20 | 4 | Ttn | 5 | 33.29 | 36.08 | 1.87 | 0.76 | | | 27.71 | | | | | | | | | | 0.29 | 100 | 110 |
| 9956d | 20 | 6 | Ttn | 6 | 33.80 | 33.16 | 2.94 | 1.17 | | | 27.95 | | | | | | | 0.73 | | | 0.25 | 100 | 110 |
| 9956d | 21 | 1 | Ttn | 2 | 33.39 | 35.20 | 2.14 | 1.36 | | | 27.91 | | | | | | | | | | | 100 | 111 |
| 9956d | 22 | 1 | Ttn | 6,9 | 32.67 | 35.49 | 2.00 | 0.89 | | | 27.91 | | | | | 1.02 | | | | | | 100 | 114 |
| 9956d | 23 | 3 | Ttn | 2,9 | 32.64 | 31.67 | 3.06 | 2.04 | | | 27.02 | | | | | 1.69 | | 1.34 | 0.53 | | | 100 | 115 |
| 9956d | 24 | 1 | Ttn | 1 | 33.71 | 35.90 | 1.91 | 0.72 | | | 27.75 | | | | | | | | | | | 100 | 112 |
| 9956d | 24 | 2 | Ttn | 1 | 33.18 | 36.87 | 1.27 | 0.74 | | | 27.93 | | | | | | | | | | | 100 | 113 |
| 9956d | 24 | 3 | Ttn | 1 | 33.14 | 38.61 | 0.50 | | | | 27.75 | | | | | | | | | | | 100 | 114 |
| 9956d | 24 | 4 | Ttn | 1,6 | 33.63 | 37.92 | 0.79 | | | | 27.66 | | | | | | | | | | | 100 | 113 |
| 9956d | 24 | 5 | Ttn | 1 | 33.54 | 35.67 | 2.27 | 0.74 | | | 27.77 | | | | | | | | | | | 100 | 113 |
| 9956d | 24 | 6 | Ttn | 1,6 | 33.31 | 36.82 | 1.43 | 0.45 | | | 27.99 | | | | | | | | | | | 100 | 113 |

Modes of Occurrence

1: Equant crystal with some euhedral faces
2: Equant overgrowth usually with some euhedral faces
3: Sub-equant overgrowth
4: Discontinuous sub-equant overgrowth
5: Interstitial overgrowth
6: Interstitial grain
7: Small irregular discrete crystals
8: Equant crystal exsolving rutile
9: Replacive
10: (Magmatic) intergrowth of titanite + rutile, replacement of rutile by titanite
11: Corona or discontinuous corona.

Table 3: Atomic formulae of titanite based on 5 oxygens. 

| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 2 | 2 | Ttn | 2 | 1.072 | 0.853 | 0.112 | 0.019 | | | 0.965 | | | | | | | | | 3.020 |
| 9956a | 2 | 3 | Ttn | 2 | 1.074 | 0.852 | 0.103 | 0.022 | | | 0.972 | | | | | | | | | 3.023 |
| 9956a | 2 | 6 | Ttn | 2 | 1.075 | 0.846 | 0.111 | 0.018 | | | 0.975 | | | | | | | | | 3.024 |
| 9956a | 3 | 1 | Ttn | 2 | 1.039 | 0.905 | 0.113 | 0.007 | | | 0.936 | | | | | | | | | 3.000 |
| 9956a | 4 | 3 | Ttn | 2 | 1.071 | 0.847 | 0.104 | 0.034 | | | 0.972 | | | | | | | | | 3.029 |
| 9956a | 4 | 4 | Ttn | 2 | 1.080 | 0.845 | 0.096 | 0.035 | | | 0.971 | | | | | | | | | 3.027 |
| 9956a | 5 | 1 | Ttn | 6 | 1.085 | 0.839 | 0.095 | 0.023 | | | 0.953 | | | | 0.014 | | | | | 3.008 |
| 9956a | 7 | 1 | Ttn | 1,6 | 1.084 | 0.853 | 0.085 | 0.033 | | | 0.967 | | | | | | | | | 3.021 |
| 9956a | 7 | 2 | Ttn | 1,6 | 1.087 | 0.850 | 0.094 | 0.029 | | | 0.957 | | | | | | | | | 3.017 |
| 9956a | 8 | 1 | Ttn | 1 | 1.086 | 0.804 | 0.136 | 0.038 | | | 0.979 | | | | | | | | | 3.042 |
| 9956a | 8 | 3 | Ttn | 3 | 1.083 | 0.861 | 0.085 | 0.022 | | | 0.963 | | | | | | | | | 3.014 |
| 9956a | 10 | 3 | Ttn | 3 | 1.072 | 0.869 | 0.098 | 0.014 | | | 0.957 | | | | | | | | | 3.010 |
| 9956a | 12 | 3 | Ttn | 3 | 1.063 | 0.927 | 0.037 | | | | 0.964 | | | | | | | | | 2.991 |
| 9956a | 12 | 5 | Ttn | 3 | 1.056 | 0.918 | 0.050 | 0.009 | | | 0.969 | | | | | | | | | 3.001 |
| 9956a | 13 | 1 | Ttn | 6,9 | 1.068 | 0.879 | 0.069 | 0.027 | | | 0.976 | | | | | | | | | 3.019 |
| 9956a | 13 | 2 | Ttn | 6,9 | 1.075 | 0.875 | 0.074 | 0.021 | | | 0.967 | | | | | | | | | 3.013 |
| 9956a | 14 | 3 | Ttn | 1 | 1.069 | 0.865 | 0.085 | 0.028 | | | 0.977 | | | | | | | | | 3.024 |
| 9956a | 14 | 5 | Ttn | 1 | 1.066 | 0.864 | 0.090 | 0.029 | | | 0.977 | | | | | | | | | 3.025 |
| 9956a | 14 | 7 | Ttn | 1 | 1.064 | 0.917 | 0.038 | 0.010 | | | 0.972 | | | | | | | | | 3.001 |
| 9956a | 15 | 1 | Ttn | 6,9 | 1.063 | 0.934 | 0.022 | 0.008 | | | 0.965 | | | | | | | | | 2.992 |
| 9956a | 15 | 3 | Ttn | 6,9 | 1.060 | 0.931 | 0.028 | 0.009 | | | 0.968 | | | | | | | | | 2.996 |
| 9956a | 15 | 4 | Ttn | 6,9 | 1.066 | 0.928 | 0.024 | 0.008 | | | 0.968 | | | | | | | | | 2.994 |
| 9956a | 15 | 5 | Ttn | 6,9 | 1.067 | 0.892 | 0.060 | 0.023 | | | 0.970 | | | | | | | | | 3.011 |
| 9956a | 16 | 4 | Ttn | 2 | 1.082 | 0.753 | 0.226 | 0.012 | | | 0.978 | | | | | | | 0.160 | | 3.212 |
| 9956a | 16 | 6 | Ttn | 2 | 1.059 | 0.889 | 0.092 | 0.009 | | | 0.959 | | | | | | | | | 3.007 |
| 9956a | 17 | 2 | Ttn | 2,6 | 1.088 | 0.771 | 0.192 | 0.023 | | | 0.971 | | | | | | | 0.218 | | 3.263 |
| 9956a | 18 | 2 | Ttn | 2,6 | 1.078 | 0.864 | 0.080 | 0.019 | | | 0.975 | | | | | | | | | 3.017 |
| 9956a | 18 | 3 | Ttn | 2,6 | 1.081 | 0.797 | 0.176 | | | | 0.982 | | | | | | | 0.204 | | 3.239 |
| 9956a | 19 | 1 | Ttn | 2 | 1.059 | 0.854 | 0.087 | 0.035 | | | 0.970 | | | | | | 0.015 | | | 3.021 |
| 9956a | 20 | 1 | Ttn | 3 | 1.081 | 0.833 | 0.111 | 0.034 | | | 0.972 | | | | | | | | | 3.031 |
| 9956a | 20 | 4 | Ttn | 3 | 1.074 | 0.858 | 0.082 | 0.028 | | | 0.984 | | | | | | | | | 3.027 |
| 9956a | 21 | 2 | Ttn | 2 | 1.073 | 0.860 | 0.079 | 0.038 | | | 0.979 | | | | | | | | | 3.028 |
| 9956a | 21 | 4 | Ttn | 2 | 1.068 | 0.868 | 0.082 | 0.031 | | | 0.973 | | | | | | | | | 3.022 |
| 9956a | 22 | 1 | Ttn | 6,9 | 1.062 | 0.918 | 0.041 | 0.009 | | | 0.970 | | | | | | | | | 3.000 |
| 9956a | 22 | 2 | Ttn | 6,9 | 1.067 | 0.927 | 0.026 | 0.008 | | | 0.966 | | | | | | | | | 2.994 |

Table 3: Atomic formulae of titanite based on 5 oxygens.



| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 22 | 3 | Ttn | 6,9 | 1.064 | 0.925 | 0.031 | 0.008 | | | 0.968 | | | | | | | | | 2.995 |
| 9956a | 22 | 4 | Ttn | 6,9 | 1.058 | 0.930 | 0.032 | 0.009 | | | 0.967 | | | | | | | | | 2.996 |
| 9956a | 22 | 5 | Ttn | 6,9 | 1.063 | 0.919 | 0.034 | 0.019 | | | 0.968 | | | | | | | | | 3.002 |
| 9956a | 23 | 2 | Ttn | 2 | 1.082 | 0.829 | 0.118 | 0.025 | | | 0.977 | | | | | | | | | 3.030 |
| 9956a | 23 | 3 | Ttn | 2 | 1.085 | 0.832 | 0.115 | 0.023 | | | 0.971 | | | | | | | | | 3.026 |
| 9956a | 23 | 5 | Ttn | 6 | 1.069 | 0.877 | 0.087 | 0.013 | | | 0.965 | | | | | | | | | 3.011 |
| 9956a | 24 | 1 | Ttn | 4 | 1.079 | 0.779 | 0.205 | | | | 0.975 | | | | | | | 0.206 | | 3.245 |
| 9956a | 25 | 1 | Ttn | 4 | 1.073 | 0.841 | 0.115 | 0.036 | | | 0.963 | | | | | | | | | 3.028 |
| 9956a | 26 | 2 | Ttn | 6 | 1.066 | 0.884 | 0.058 | 0.019 | | | 0.960 | | | | 0.014 | | | | | 3.000 |
| 9956a | 26 | 5 | Ttn | 6 | 1.061 | 0.918 | 0.040 | 0.011 | | | 0.971 | | | | | | | | | 3.001 |
| 9956a | 27 | 1 | Ttn | 6 | 1.075 | 0.869 | 0.076 | 0.022 | | | 0.975 | | | | | | | | | 3.018 |
| 9956a | 27 | 2 | Ttn | 6 | 1.082 | 0.833 | 0.108 | 0.030 | | | 0.979 | | | | | | | | | 3.031 |
| 9956a | 28 | 1 | Ttn | 2 | 1.077 | 0.851 | 0.101 | 0.019 | | | 0.975 | | | | | | | | | 3.022 |
| 9956a | 28 | 4 | Ttn | 2 | 1.068 | 0.841 | 0.118 | 0.020 | | | 0.986 | | | | | | | | | 3.033 |
| 9956a | 29 | 1 | Ttn | 6 | 1.082 | 0.859 | 0.081 | 0.023 | | | 0.973 | | | | | | | | | 3.019 |
| 9956a | 29 | 3 | Ttn | 6 | 1.076 | 0.903 | 0.046 | 0.008 | | | 0.965 | | | | | | | | | 2.998 |
| 9956a | 29 | 4 | Ttn | 6 | 1.085 | 0.833 | 0.115 | 0.023 | | | 0.969 | | | | | | | 0.095 | | 3.119 |
| 9956a | 29 | 5 | Ttn | 6 | 1.082 | 0.862 | 0.089 | 0.013 | | | 0.966 | | | | | | | | | 3.012 |
| 9956a | 29 | 6 | Ttn | 6 | 1.080 | 0.810 | 0.132 | 0.036 | | | 0.985 | | | | | | | | | 3.044 |
| 9956a | 29 | 12 | Ttn | 6 | 1.086 | 0.847 | 0.105 | 0.013 | | | 0.965 | | | | | | | | | 3.015 |
| 9956a | 30 | 1 | Ttn | 6 | 1.080 | 0.831 | 0.116 | 0.023 | | | 0.980 | | | | | | | | | 3.031 |
| 9956a | 30 | 2 | Ttn | 3,6 | 1.072 | 0.847 | 0.114 | 0.018 | | | 0.974 | | | | | | | | | 3.024 |
| 9956a | 31 | 1 | Ttn | 1 | 1.063 | 0.913 | 0.043 | 0.017 | | | 0.967 | | | | | | | | | 3.003 |
| 9956a | 31 | 2 | Ttn | 1,6 | 1.066 | 0.898 | 0.052 | 0.021 | | | 0.972 | | | | | | | | | 3.009 |
| 9956a | 31 | 3 | Ttn | 1,6 | 1.062 | 0.897 | 0.058 | 0.021 | | | 0.974 | | | | | | | | | 3.012 |
| 9956a | 32 | 3 | Ttn | 2 | 1.065 | 0.923 | 0.033 | 0.012 | | | 0.963 | | | | | | | | | 2.996 |
| 9956a | 32 | 4 | Ttn | 2 | 1.061 | 0.912 | 0.054 | 0.009 | | | 0.964 | | | | | | | | | 3.000 |
| 9956a | 32 | 6 | Ttn | 2 | 1.060 | 0.928 | 0.022 | 0.024 | | | 0.967 | | | | | | | | | 3.001 |
| 9956a | 33 | 1 | Ttn | 3,6 | 1.081 | 0.833 | 0.114 | 0.028 | | | 0.974 | | | | | | | | | 3.029 |
| 9956a | 33 | 4 | Ttn | 3,6 | 1.078 | 0.867 | 0.076 | 0.022 | | | 0.973 | | | | | | | | | 3.017 |
| 9956a | 34 | 1 | Ttn | 2 | 1.067 | 0.885 | 0.069 | 0.025 | | | 0.967 | | | | | | | | | 3.013 |
| 9956a | 35 | 1 | Ttn | 6,9 | 1.067 | 0.919 | 0.034 | 0.013 | | | 0.964 | | | | | | | | | 2.997 |
| 9956a | 35 | 2 | Ttn | 2 | 1.075 | 0.865 | 0.083 | 0.027 | | | 0.967 | | | | | | | | | 3.018 |
| 9956a | 35 | 4 | Ttn | 6,9 | 1.064 | 0.888 | 0.052 | 0.023 | | | 0.960 | | | | 0.014 | | | | | 3.001 |
| 9956a | 35 | 5 | Ttn | 6,9 | 1.065 | 0.923 | 0.031 | 0.020 | | | 0.958 | | | | | | | | | 2.997 |

Table 3: Atomic formulae of titanite based on 5 oxygens.



| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 37 | 1 | Ttn | 6,9 | 1.066 | 0.889 | 0.051 | 0.015 | | | 0.958 | | | | 0.016 | | | | | 2.995 |
| 9956a | 37 | 2 | Ttn | 2 | 1.075 | 0.851 | 0.097 | 0.030 | | | 0.973 | | | | | | | | | 3.026 |
| 9956a | 37 | 6 | Ttn | 2 | 1.063 | 0.895 | 0.062 | 0.021 | | | 0.972 | | | | | | | | | 3.012 |
| 9956a | 38 | 2 | Ttn | 2 | 1.072 | 0.854 | 0.094 | 0.027 | | | 0.980 | | | | | | | | | 3.027 |
| 9956b | 1 | 1 | Ttn | 1 | 1.068 | 0.921 | 0.036 | 0.008 | | | 0.961 | | | | | | | | | 2.993 |
| 9956b | 1 | 4 | Ttn | 2 | 1.071 | 0.892 | 0.055 | 0.021 | | | 0.972 | | | | | | | | | 3.010 |
| 9956b | 1 | 5 | Ttn | 1 | 1.081 | 0.869 | 0.075 | 0.017 | | | 0.971 | | | | | | | | | 3.013 |
| 9956b | 2 | 1 | Ttn | 1 | 1.068 | 0.864 | 0.094 | 0.021 | | | 0.972 | | | | | | | | | 3.020 |
| 9956b | 2 | 2 | Ttn | 4 | 1.080 | 0.834 | 0.108 | 0.032 | | | 0.980 | | | | | | | | | 3.033 |
| 9956b | 3 | 3 | Ttn | 2 | 1.072 | 0.843 | 0.111 | 0.030 | | | 0.973 | | | | | | | | | 3.030 |
| 9956b | 4 | 2 | Ttn | 3 | 1.051 | 0.839 | 0.168 | 0.039 | | | 0.929 | | | | | | | | | 3.026 |
| 9956b | 4 | 4 | Ttn | 7 | 1.092 | 0.752 | 0.219 | 0.018 | | | 0.965 | | | | | | | 0.204 | | 3.250 |
| 9956b | 4 | 5 | Ttn | 7 | 1.043 | 0.012 | 0.859 | 0.647 | | 0.955 | | | | | | | | | | 3.516 |
| 9956b | 4 | 6 | Ttn | 7 | 1.099 | 0.772 | 0.170 | 0.039 | | | 0.965 | | | | | | | | | 3.044 |
| 9956b | 4 | 10 | Ttn | 7 | 1.092 | 0.823 | 0.108 | 0.034 | | | 0.973 | | | | | | | | | 3.031 |
| 9956b | 4 | 11 | Ttn | 7 | 1.083 | 0.818 | 0.142 | 0.017 | | | 0.968 | | | | | | | 0.104 | | 3.132 |
| 9956b | 4 | 12 | Ttn | 7 | 1.075 | 0.884 | 0.068 | 0.012 | | | 0.967 | | | | | | | | | 3.007 |
| 9956b | 4 | 13 | Ttn | 7 | 1.157 | 0.810 | 0.175 | 0.016 | | | 0.760 | 0.051 | | | | | | | | 2.970 |
| 9956b | 5 | 2 | Ttn | 2 | 1.090 | 0.827 | 0.115 | 0.027 | | | 0.966 | | | | | | | | | 3.025 |
| 9956b | 5 | 3 | Ttn | 2 | 1.078 | 0.843 | 0.106 | 0.033 | | | 0.967 | | | | | | | | | 3.026 |
| 9956b | 6 | 1 | Ttn | 6 | 1.066 | 0.918 | 0.033 | | | | 0.966 | | | 0.010 | | | | | | 2.994 |
| 9956b | 6 | 3 | Ttn | 6 | 1.068 | 0.904 | 0.046 | 0.010 | | | 0.977 | | | | | | | | | 3.005 |
| 9956b | 7 | 1 | Ttn | 2 | 1.065 | 0.905 | 0.048 | 0.018 | | | 0.971 | | | | | | | | | 3.006 |
| 9956b | 8 | 2 | Ttn | 2 | 1.058 | 0.922 | 0.042 | 0.012 | | | 0.966 | | | | | | | | | 2.999 |
| 9956b | 9 | 2 | Ttn | 3 | 1.063 | 0.905 | 0.062 | 0.012 | | | 0.960 | | | | | | | | | 3.002 |
| 9956b | 10 | 2 | Ttn | 2 | 1.069 | 0.895 | 0.067 | 0.012 | | | 0.958 | | | | | | | 0.084 | | 3.086 |
| 9956b | 10 | 4 | Ttn | 2 | 1.086 | 0.871 | 0.081 | 0.016 | | | 0.949 | | | | | | | | | 3.003 |
| 9956b | 10 | 5 | Ttn | 2 | 1.072 | 0.901 | 0.059 | 0.009 | | | 0.955 | | | | | | | | | 2.997 |
| 9956b | 10 | 8 | Ttn | 2 | 1.067 | 0.882 | 0.100 | 0.016 | | | 0.921 | 0.027 | | | | | | | | 3.014 |
| 9956b | 13 | 3 | Ttn | 3 | 1.070 | 0.879 | 0.077 | 0.016 | | | 0.969 | | | | | | | | | 3.012 |
| 9956b | 14 | 1 | Ttn | 6,9 | 1.091 | 0.844 | 0.088 | 0.052 | | 0.058 | 0.890 | | | | | | | | | 3.022 |
| 9956b | 14 | 2 | Ttn | 6,9 | 1.080 | 0.881 | 0.046 | 0.016 | | | 0.946 | | | | 0.019 | | | | | 2.988 |
| 9956b | 15 | 1 | Ttn | 6,9 | 1.064 | 0.914 | 0.043 | 0.012 | | | 0.969 | | | | | | | | | 3.001 |
| 9956b | 15 | 2 | Ttn | 6,9 | 1.068 | 0.910 | 0.039 | 0.020 | | | 0.965 | | | | | | | | | 3.002 |
| 9956b | 15 | 3 | Ttn | 6,9 | 1.069 | 0.879 | 0.073 | 0.019 | | | 0.974 | | | | | | | | | 3.015 |

Table 3: Atomic formulae of titanite based on 5 oxygens.

| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 16 | 2 | Ttn | 2 | 1.078 | 0.835 | 0.113 | 0.025 | | | 0.979 | | | | | | | | | 3.030 |
| 9956b | 16 | 3 | Ttn | 2 | 1.081 | 0.839 | 0.111 | 0.030 | | | 0.963 | | | | | | | | | 3.024 |
| 9956b | 16 | 6 | Ttn | 2 | 1.079 | 0.837 | 0.115 | 0.033 | | | 0.962 | | | | | | | | | 3.026 |
| 9956c | 1 | 2 | Ttn | 2 | 1.075 | 0.859 | 0.087 | 0.027 | | | 0.975 | | | | | | | | | 3.023 |
| 9956c | 1 | 4 | Ttn | 2 | 1.066 | 0.888 | 0.067 | 0.019 | | | 0.973 | | | | | | | | | 3.012 |
| 9956c | 1 | 6 | Ttn | 2 | 1.074 | 0.867 | 0.081 | 0.024 | | | 0.973 | | | | | | | | | 3.019 |
| 9956c | 3 | 1 | Ttn | 6,9 | 1.069 | 0.897 | 0.052 | 0.015 | | | 0.975 | | | | | | | | | 3.008 |
| 9956c | 3 | 5 | Ttn | 2 | 1.068 | 0.921 | 0.033 | 0.011 | | | 0.961 | | | | | | | | | 2.994 |
| 9956c | 3 | 6 | Ttn | 2 | 1.078 | 0.859 | 0.078 | 0.037 | | | 0.971 | | | | | | | | | 3.023 |
| 9956c | 3 | 8 | Ttn | 2 | 1.057 | 0.923 | 0.042 | 0.012 | | | 0.966 | | | | | | | | | 2.999 |
| 9956c | 4 | 2 | Ttn | 2? | 1.076 | 0.894 | 0.052 | 0.019 | | | 0.963 | | | | | | | | | 3.004 |
| 9956c | 4 | 4 | Ttn | 2?,6 | 1.076 | 0.895 | 0.049 | 0.021 | | | 0.965 | | | | | | | | | 3.005 |
| 9956c | 6 | 1 | Ttn | 6? | 1.066 | 0.920 | 0.037 | 0.013 | | | 0.961 | | | | | | | | | 2.996 |
| 9956c | 6 | 6 | Ttn | 6? | 1.078 | 0.845 | 0.096 | 0.032 | | | 0.978 | | | | | | | | | 3.029 |
| 9956c | 7 | 2 | Ttn | 2 | 1.070 | 0.834 | 0.124 | 0.026 | | | 0.979 | | | | | | | 0.136 | | 3.169 |
| 9956c | 7 | 3 | Ttn | 2 | 1.069 | 0.850 | 0.099 | 0.047 | | | 0.967 | | | | | | | | | 3.032 |
| 9956c | 7 | 6 | Ttn | 2 | 1.068 | 0.858 | 0.103 | 0.021 | | | 0.973 | | | | | | | 0.130 | | 3.153 |
| 9956c | 8 | 2 | Ttn | 2 | 1.062 | 0.919 | 0.031 | 0.014 | | | 0.977 | | | | | | | | | 3.003 |
| 9956c | 8 | 3 | Ttn | 2 | 1.085 | 0.835 | 0.084 | 0.038 | | 0.040 | 0.913 | | | | 0.018 | | | | | 3.011 |
| 9956c | 9 | 2 | Ttn | 1 | 1.075 | 0.873 | 0.080 | 0.019 | | | 0.966 | | | | | | | | | 3.013 |
| 9956c | 10 | 3 | Ttn | 6,2 | 1.075 | 0.835 | 0.119 | 0.027 | | | 0.974 | | | | | | | | | 3.030 |
| 9956c | 11 | 1 | Ttn | 6,2 | 1.081 | 0.844 | 0.108 | 0.018 | | | 0.969 | | | | | | | | | 3.021 |
| 9956c | 11 | 4 | Ttn | 6,2 | 1.079 | 0.777 | 0.210 | 0.012 | | | 0.962 | | | | | | | 0.297 | | 3.336 |
| 9956c | 12 | 1 | Ttn | 6,2 | 1.067 | 0.905 | 0.050 | 0.014 | | | 0.968 | | | | | | | | | 3.003 |
| 9956c | 13 | 1 | Ttn | 6,2 | 1.087 | 0.822 | 0.115 | 0.033 | | | 0.976 | | | | | | | | | 3.033 |
| 9956c | 13 | 3 | Ttn | 6,2 | 1.078 | 0.872 | 0.073 | 0.021 | | | 0.971 | | | | | | | | | 3.014 |
| 9956c | 14 | 1 | Ttn | 6 | 1.070 | 0.905 | 0.049 | 0.012 | | | 0.963 | | | | | | | | | 3.000 |
| 9956c | 15 | 3 | Ttn | 6,2 | 1.088 | 0.825 | 0.116 | 0.034 | | | 0.968 | | | | | | | | | 3.030 |
| 9956c | 15 | 4 | Ttn | 6,2 | 1.209 | 0.778 | 0.130 | | | | 0.816 | 0.031 | | | | | | 0.112 | | 3.076 |
| 9956c | 16 | 1 | Ttn | 6,2 | 1.085 | 0.847 | 0.096 | 0.031 | | | 0.963 | | | | | | | | | 3.021 |
| 9956c | 16 | 4 | Ttn | 6,2 | 1.077 | 0.879 | 0.070 | 0.018 | | | 0.965 | | | | | | | | | 3.009 |
| 9956c | 17 | 1 | Ttn | 6 | 1.079 | 0.873 | 0.070 | 0.018 | | | 0.974 | | | | | | | | | 3.013 |
| 9956c | 17 | 2 | Ttn | 6 | 1.071 | 0.902 | 0.045 | 0.011 | | | 0.975 | | | | | | | | | 3.004 |
| 9956c | 17 | 3 | Ttn | 6 | 1.080 | 0.839 | 0.103 | 0.031 | | | 0.976 | | | | | | | | | 3.029 |
| 9956c | 17 | 4 | Ttn | 6 | 1.065 | 0.894 | 0.063 | 0.018 | | | 0.970 | | | | | | | | | 3.010 |

Table 3: Atomic formulae of titanite based on 5 oxygens.

| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 17 | 5 | Ttn | 6 | 1.074 | 0.880 | 0.068 | 0.016 | | | 0.974 | | | | | | | | | 3.012 |
| 9956c | 18 | 1 | Ttn | 6,1 | 1.076 | 0.872 | 0.075 | 0.022 | | | 0.969 | | | | | | | | | 3.015 |
| 9956c | 18 | 2 | Ttn | 6 | 1.064 | 0.915 | 0.039 | 0.009 | | | 0.974 | | | | | | | | | 3.001 |
| 9956c | 18 | 3 | Ttn | 6 | 1.077 | 0.853 | 0.075 | 0.018 | | | 0.971 | | | | 0.015 | | | | | 3.010 |
| 9956c | 18 | 4 | Ttn | 6,2 | 1.072 | 0.826 | 0.121 | 0.035 | | | 0.986 | | | | | | | 0.167 | | 3.208 |
| 9956c | 18 | 7 | Ttn | 6,2 | 1.072 | 0.869 | 0.083 | 0.024 | | | 0.970 | | | | | | | | | 3.018 |
| 9956c | 19 | 1 | Ttn | 6 | 1.058 | 0.908 | 0.051 | 0.013 | | | 0.979 | | | | | | | | | 3.009 |
| 9956c | 20 | 1 | Ttn | 6,9 | 1.067 | 0.890 | 0.060 | 0.018 | | | 0.977 | | | | | | | | | 3.013 |
| 9956c | 20 | 2 | Ttn | 6,9 | 1.072 | 0.884 | 0.067 | 0.020 | | | 0.968 | | | | | | | | | 3.011 |
| 9956c | 20 | 3 | Ttn | 6,9 | 1.080 | 0.841 | 0.107 | 0.029 | | | 0.968 | | | | | | | | | 3.025 |
| 9956c | 20 | 4 | Ttn | 6,9 | 1.074 | 0.891 | 0.057 | 0.019 | | | 0.965 | | | | | | | | | 3.006 |
| 9956c | 20 | 5 | Ttn | 6,9 | 1.084 | 0.845 | 0.097 | 0.032 | | | 0.963 | | | | | | | | | 3.022 |
| 9956c | 21 | 1 | Ttn | 6 | 1.072 | 0.898 | 0.051 | 0.014 | | | 0.971 | | | | | | | | | 3.005 |
| 9956c | 21 | 2 | Ttn | 6 | 1.076 | 0.842 | 0.105 | 0.030 | | | 0.976 | | | | | | | 0.145 | | 3.175 |
| 9956c | 21 | 3 | Ttn | 6 | 1.083 | 0.850 | 0.095 | 0.027 | | | 0.966 | | | | | | | | | 3.020 |
| 9956c | 21 | 4 | Ttn | 6 | 1.082 | 0.854 | 0.093 | 0.023 | | | 0.966 | | | | | | | | | 3.018 |
| 9956c | 21 | 5 | Ttn | 6 | 1.082 | 0.805 | 0.126 | 0.067 | | | 0.968 | | | | | | | 0.252 | | 3.301 |
| 9956c | 21 | 7 | Ttn | 6 | 1.062 | 0.951 | 0.011 | | | | 0.957 | | | | | | | | | 2.981 |
| 9956c | 21 | 10 | Ttn | 6 | 1.079 | 0.847 | 0.096 | 0.029 | | | 0.973 | | | | | | | | | 3.025 |
| 9956c | 21 | 12 | Ttn | 6 | 1.070 | 0.892 | 0.059 | 0.019 | | | 0.969 | | | | | | | | | 3.009 |
| 9956c | 21 | 13 | Ttn | 6 | 1.074 | 0.844 | 0.101 | 0.027 | | | 0.986 | | | | | | | | | 3.031 |
| 9956c | 22 | 1 | Ttn | 8 | 1.077 | 0.889 | 0.053 | 0.019 | | | 0.968 | | | | | | | | | 3.007 |
| 9956c | 23 | 1 | Ttn | 6,1 | 1.076 | 0.852 | 0.094 | 0.037 | | | 0.966 | | | | | | | | | 3.025 |
| 9956c | 23 | 2 | Ttn | 6,1 | 1.070 | 0.892 | 0.056 | 0.021 | | | 0.972 | | | | | | | | | 3.010 |
| 9956c | 23 | 3 | Ttn | 6,1 | 1.080 | 0.845 | 0.095 | 0.036 | | | 0.970 | | | | | | | | | 3.027 |
| 9956c | 24 | 1 | Ttn | 2 | 1.074 | 0.859 | 0.087 | 0.038 | | | 0.965 | | | | | | | | | 3.023 |
| 9956c | 25 | 2 | Ttn | 6,2 | 1.073 | 0.898 | 0.051 | 0.015 | | | 0.966 | | | | | | | | | 3.003 |
| 9956c | 25 | 3 | Ttn | 6,2 | 1.088 | 0.836 | 0.101 | 0.036 | | | 0.965 | | | | | | | | | 3.025 |
| 9956c | 26 | 2 | Ttn | 2 | 1.078 | 0.830 | 0.116 | 0.040 | | | 0.969 | | | | | | | | | 3.034 |
| 9956c | 26 | 3 | Ttn | 2 | 1.065 | 0.893 | 0.085 | 0.009 | | | 0.948 | | | | | | | | | 3.000 |
| 9956c | 26 | 5 | Ttn | 2 | 1.073 | 0.891 | 0.067 | 0.017 | | | 0.954 | | | | | | | | | 3.003 |
| 9956c | 27 | 1 | Ttn | 1 | 1.086 | 0.803 | 0.127 | 0.027 | | | 0.966 | | | | 0.015 | | | 0.198 | | 3.223 |
| 9956c | 28 | 2 | Ttn | 2 | 1.089 | 0.776 | 0.175 | 0.029 | | | 0.978 | | | | | | | 0.211 | | 3.258 |
| 9956c | 28 | 3 | Ttn | 2 | 1.079 | 0.804 | 0.157 | 0.027 | | | 0.971 | | | | | | | | | 3.038 |
| 9956c | 28 | 4 | Ttn | 2 | 1.076 | 0.875 | 0.077 | 0.015 | | | 0.968 | | | | | | | | | 3.011 |

Table 3: Atomic formulae of titanite based on 5 oxygens.



| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 29 | 2 | Ttn | 2,6 | 1.086 | 0.811 | 0.140 | 0.033 | | | 0.965 | | | | | | | 0.170 | | 3.204 |
| 9956c | 29 | 4 | Ttn | 2,6 | 1.081 | 0.867 | 0.078 | 0.019 | | | 0.969 | | | | | | | | | 3.013 |
| 9956c | 29 | 5 | Ttn | 2,6 | 1.073 | 0.870 | 0.080 | 0.021 | | | 0.972 | | | | | | | | | 3.017 |
| 9956c | 30 | 1 | Ttn | 1 | 1.069 | 0.858 | 0.111 | | | | 0.980 | | | | | | | | | 3.018 |
| 9956c | 30 | 3 | Ttn | 2 | 1.083 | 0.777 | 0.190 | 0.023 | | | 0.973 | | | | | | | 0.235 | | 3.280 |
| 9956c | 30 | 4 | Ttn | 2 | 1.077 | 0.825 | 0.105 | 0.034 | | | 0.970 | | | | 0.014 | | | | | 3.025 |
| 9956c | 30 | 6 | Ttn | 2 | 1.082 | 0.820 | 0.121 | 0.035 | | | 0.980 | | | | | | | 0.129 | | 3.167 |
| 9956c | 31 | 2 | Ttn | 2 | 1.067 | 0.881 | 0.078 | 0.022 | | | 0.964 | | | | | | | | | 3.013 |
| 9956c | 31 | 3 | Ttn | 2 | 1.067 | 0.907 | 0.049 | 0.015 | | | 0.965 | | | | | | | | | 3.002 |
| 9956c | 31 | 4 | Ttn | 2 | 1.066 | 0.849 | 0.103 | 0.040 | | | 0.974 | | | | | | | | | 3.033 |
| 9956c | 32 | 2 | Ttn | 2 | 1.061 | 0.927 | 0.031 | 0.010 | | | 0.967 | | | | | | | | | 2.996 |
| 9956c | 32 | 4 | Ttn | 1 | 1.065 | 0.911 | 0.042 | 0.012 | | | 0.973 | | | | | | | | | 3.003 |
| 9956c | 32 | 5 | Ttn | 2 | 1.068 | 0.913 | 0.043 | | | | 0.974 | | | | | | | | | 2.998 |
| 9956c | 32 | 6 | Ttn | 2 | 1.070 | 0.890 | 0.062 | 0.016 | | | 0.971 | | | | | | | | | 3.009 |
| 9956c | 32 | 7 | Ttn | 2 | 1.075 | 0.869 | 0.077 | 0.022 | | | 0.974 | | | | | | | | | 3.018 |
| 9956c | 33 | 2 | Ttn | 2 | 1.078 | 0.844 | 0.107 | 0.022 | | | 0.974 | | | | | | | 0.115 | | 3.139 |
| 9956c | 33 | 4 | Ttn | 2,6? | 1.076 | 0.867 | 0.084 | 0.016 | | | 0.971 | | | | | | | | | 3.015 |
| 9956d | 1 | 3 | Ttn | 2 | 1.075 | 0.859 | 0.085 | 0.026 | | | 0.979 | | | | | | | | | 3.024 |
| 9956d | 2 | 1 | Ttn | 2 | 1.076 | 0.896 | 0.048 | 0.019 | | | 0.964 | | | | | | | | | 3.003 |
| 9956d | 2 | 6 | Ttn | 2 | 1.079 | 0.866 | 0.080 | 0.022 | | | 0.967 | | | | | | | | | 3.015 |
| 9956d | 3 | 1 | Ttn | 6,9 | 1.075 | 0.903 | 0.044 | 0.013 | | | 0.964 | | | | | | | | | 3.000 |
| 9956d | 3 | 2 | Ttn | 6,9 | 1.081 | 0.863 | 0.081 | 0.028 | | | 0.964 | | | | | | | | | 3.016 |
| 9956d | 3 | 3 | Ttn | 6,9 | 1.075 | 0.910 | 0.040 | 0.010 | | | 0.961 | | | | | | | | | 2.995 |
| 9956d | 3 | 4 | Ttn | 6,9 | 1.074 | 0.920 | 0.031 | 0.008 | | | 0.959 | | | | | | | | | 2.991 |
| 9956d | 4 | 1 | Ttn | 6,9 | 1.068 | 0.903 | 0.046 | 0.019 | | | 0.971 | | | | | | | | | 3.006 |
| 9956d | 4 | 2 | Ttn | 6,9 | 1.068 | 0.916 | 0.037 | 0.020 | | | 0.957 | | | | | | | | | 2.997 |
| 9956d | 4 | 3 | Ttn | 6,9 | 1.076 | 0.887 | 0.062 | 0.016 | | | 0.964 | | | | | | | | | 3.005 |
| 9956d | 4 | 4 | Ttn | 6,9 | 1.069 | 0.912 | 0.040 | 0.015 | | | 0.963 | | | | | | | | | 2.999 |
| 9956d | 5 | 2 | Ttn | 2 | 1.066 | 0.916 | 0.033 | 0.012 | | | 0.974 | | | | | | | | | 3.001 |
| 9956d | 5 | 3 | Ttn | 2 | 1.081 | 0.903 | 0.039 | 0.011 | | | 0.962 | | | | | | | | | 2.996 |
| 9956d | 6 | 2 | Ttn | 2 | 1.063 | 0.930 | 0.020 | 0.018 | | | 0.965 | | | | | | | | | 2.997 |
| 9956d | 7 | 2 | Ttn | 2 | 1.078 | 0.862 | 0.081 | 0.026 | | | 0.973 | | | | | | | | | 3.020 |
| 9956d | 8 | 1 | Ttn | 6 | 1.069 | 0.874 | 0.080 | 0.021 | | | 0.974 | | | | | | | | | 3.017 |
| 9956d | 8 | 2 | Ttn | 6 | 1.075 | 0.856 | 0.091 | 0.021 | | | 0.981 | | | | | | | | | 3.024 |
| 9956d | 8 | 3 | Ttn | 6 | 1.078 | 0.851 | 0.096 | 0.030 | | | 0.969 | | | | | | | | | 3.023 |

Table 3: Atomic formulae of titanite based on 5 oxygens.



| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 8 | 4 | Ttn | 6 | 1.068 | 0.883 | 0.055 | 0.013 | | | 0.954 | | | | 0.019 | | | | | 2.993 |
| 9956d | 8 | 5 | Ttn | 6 | 1.082 | 0.843 | 0.098 | 0.031 | | | 0.973 | | | | | | | 0.156 | | 3.182 |
| 9956d | 8 | 6 | Ttn | 6 | 1.085 | 0.830 | 0.116 | 0.025 | | 0.020 | 0.942 | 0.018 | | | | | | | | 3.036 |
| 9956d | 9 | 1 | Ttn | 6 | 1.079 | 0.849 | 0.099 | 0.024 | | | 0.972 | | | | | | | 0.131 | | 3.154 |
| 9956d | 9 | 2 | Ttn | 6 | 1.083 | 0.850 | 0.091 | 0.028 | | | 0.970 | | | | | | | 0.125 | | 3.147 |
| 9956d | 10 | 2 | Ttn | 4 | 1.085 | 0.789 | 0.179 | 0.011 | | | 0.973 | | | | | | | 0.253 | | 3.290 |
| 9956d | 10 | 5 | Ttn | 4 | 1.084 | 0.760 | 0.219 | 0.011 | | | 0.973 | | | | | | | 0.293 | | 3.340 |
| 9956d | 11 | 1 | Ttn | 9 | 1.086 | 0.821 | 0.124 | 0.021 | | | 0.980 | | | | | | | 0.189 | | 3.220 |
| 9956d | 11 | 2 | Ttn | 4 | 1.095 | 0.731 | 0.225 | 0.036 | | | 0.975 | | | | | | | 0.362 | | 3.424 |
| 9956d | 11 | 5 | Ttn | 4 | 1.126 | 0.805 | 0.151 | 0.014 | | | 0.897 | | | | | | | 0.176 | | 3.169 |
| 9956d | 12 | 3 | Ttn | 3,6 | 1.058 | 0.942 | 0.021 | 0.025 | | | 0.944 | | | | | | | | | 2.990 |
| 9956d | 13 | 1 | Ttn | 1 | 1.080 | 0.906 | 0.052 | | | | 0.951 | | | | | | | | | 2.989 |
| 9956d | 13 | 4 | Ttn | 3 | 1.085 | 0.856 | 0.100 | 0.011 | | | 0.956 | | | | | | | 0.121 | | 3.129 |
| 9956d | 14 | 1 | Ttn | 6 | 1.080 | 0.850 | 0.111 | 0.014 | | | 0.960 | | | | | | | | | 3.015 |
| 9956d | 14 | 2 | Ttn | 6 | 1.095 | 0.849 | 0.087 | 0.028 | | | 0.953 | | | | | | | | | 3.012 |
| 9956d | 15 | 2 | Ttn | 4 | 1.068 | 0.881 | 0.102 | 0.014 | | | 0.935 | | | | | | | 0.166 | | 3.166 |
| 9956d | 16 | 1 | Ttn | 3,6 | 1.085 | 0.857 | 0.086 | 0.022 | | | 0.964 | | | | | | | | | 3.015 |
| 9956d | 16 | 3 | Ttn | 3,6 | 1.087 | 0.858 | 0.079 | 0.030 | | | 0.961 | | | | | | | | | 3.015 |
| 9956d | 16 | 4 | Ttn | 3,6 | 1.094 | 0.821 | 0.114 | 0.030 | | | 0.967 | | | | | | | | | 3.027 |
| 9956d | 16 | 5 | Ttn | 3,6 | 1.090 | 0.830 | 0.108 | 0.031 | | | 0.967 | | | | | | | | | 3.026 |
| 9956d | 16 | 7 | Ttn | 3,6 | 1.111 | 0.813 | 0.123 | 0.033 | | | 0.935 | | | | | | | | | 3.014 |
| 9956d | 17 | 2 | Ttn | 2,6 | 1.081 | 0.836 | 0.113 | 0.025 | | | 0.970 | | | | | | | | | 3.026 |
| 9956d | 17 | 3 | Ttn | 6 | 1.082 | 0.850 | 0.103 | 0.016 | | | 0.966 | | | | | | | | | 3.016 |
| 9956d | 18 | 2 | Ttn | 4,6 | 1.076 | 0.876 | 0.077 | 0.019 | | | 0.961 | | | | | | | | | 3.009 |
| 9956d | 18 | 4 | Ttn | 4,6 | 1.121 | 0.811 | 0.130 | 0.020 | | | 0.921 | | | | | | | | | 3.003 |
| 9956d | 19 | 1 | Ttn | 1 | 1.086 | 0.835 | 0.108 | 0.030 | | | 0.966 | | | | | | | 0.110 | | 3.134 |
| 9956d | 19 | 2 | Ttn | 1 | 1.085 | 0.852 | 0.090 | 0.031 | | | 0.962 | | | | | | | | | 3.019 |
| 9956d | 19 | 3 | Ttn | 1 | 1.079 | 0.815 | 0.159 | 0.010 | | | 0.963 | | | | | | | 0.137 | | 3.164 |
| 9956d | 19 | 5 | Ttn | 2 | 1.086 | 0.850 | 0.087 | 0.035 | | | 0.962 | | | | | | | | | 3.020 |
| 9956d | 19 | 7 | Ttn | 2 | 1.081 | 0.875 | 0.071 | 0.021 | | | 0.959 | | | | | | | | | 3.008 |
| 9956d | 20 | 1 | Ttn | 6 | 1.086 | 0.827 | 0.118 | 0.026 | | | 0.970 | | | | | | | | | 3.028 |
| 9956d | 20 | 4 | Ttn | 5 | 1.077 | 0.878 | 0.071 | 0.021 | | | 0.961 | | | | | | | | | 3.009 |
| 9956d | 20 | 6 | Ttn | 6 | 1.092 | 0.806 | 0.112 | 0.032 | | | 0.967 | | | | 0.016 | | | | | 3.023 |
| 9956d | 21 | 1 | Ttn | 2 | 1.080 | 0.857 | 0.082 | 0.037 | | | 0.967 | | | | | | | | | 3.022 |
| 9956d | 22 | 1 | Ttn | 6,9 | 1.068 | 0.873 | 0.077 | 0.024 | | | 0.978 | | | | | | | 0.105 | | 3.126 |

Table 3: Atomic formulae of titanite based on 5 oxygens.

| Sample | Site | Position | Mineral | Mode of Occurrence | Si | Ti | Al | $Fe_t^{2+}$ | Mn | Mg | Ca | Na | K | Cr | V | Ni | P | F | Cl | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 23 | 3 | Ttn | 2,9 | 1.075 | 0.784 | 0.119 | 0.056 | | | 0.953 | | | 0.014 | 0.029 | | | 0.176 | | 3.207 |
| 9956d | 24 | 1 | Ttn | 1 | 1.087 | 0.870 | 0.073 | 0.019 | | | 0.958 | | | | | | | | | 3.007 |
| 9956d | 24 | 2 | Ttn | 1 | 1.073 | 0.897 | 0.048 | 0.020 | | | 0.968 | | | | | | | | | 3.006 |
| 9956d | 24 | 3 | Ttn | 1 | 1.069 | 0.937 | 0.019 | | | | 0.959 | | | | | | | | | 2.984 |
| 9956d | 24 | 4 | Ttn | 1,6 | 1.083 | 0.918 | 0.030 | | | | 0.954 | | | | | | | | | 2.984 |
| 9956d | 24 | 5 | Ttn | 1 | 1.081 | 0.865 | 0.086 | 0.020 | | | 0.959 | | | | | | | | | 3.011 |
| 9956d | 24 | 6 | Ttn | 1,6 | 1.075 | 0.894 | 0.054 | 0.012 | | | 0.968 | | | | | | | | | 3.004 |

Modes of Occurrence

1: Equant crystal with some euhedral faces
2: Equant overgrowth usually with some euhedral faces
3: Sub-equant overgrowth
4: Discontinuous sub-equant overgrowth
5: Interstitial overgrowth
6: Interstitial grain
7: Small irregular discrete crystals
8: Equant crystal exsolving rutile
9: Replacive
10: (Magmatic) intergrowth of titanite + rutile, replacement of rutile by titanite
11: Corona or discontinuous corona.

# Appendix 1: Scanning Electron Microscope (SEM), Backscattered Electron Images (BSE) and Energy Dispersive Spectroscopy (EDS) geochemical analyses for the coarse-grained syenite with dark minerals (samples 9956a, b, c, d).

# Appendix 1-1: SEM-BSE images and EDS mineral analyses for sample 9956a.

**Sample 9956a**

**Host: Scapolitized analcime syenite**

Magmatic minerals: Analcime, K-feldspar, rutile, titanite

Secondary Minerals: Epidote, Fe-oxides/hydroxides, rutile, scapolite, titanite

**Notes:**

1. Titanite commonly overgrows rutile and is overgrown by Fe-oxides/hydroxides (Figures 1-1.21,1-1.32).

2. There is more than one generation of titanite (see grey-scale difference in Figures 1-1.21,1-1.47,1-1.49) and rutile (Figures 1-1.21,1-1.24,1-1.50).

3. Chlorite is usually found around the large rutile grains that have been overgrown by titanite (Figures 1-1.21,1-1.24,1-1.31) or as veinlets/stringers cross-cutting analcime (Figure 1-1.51).

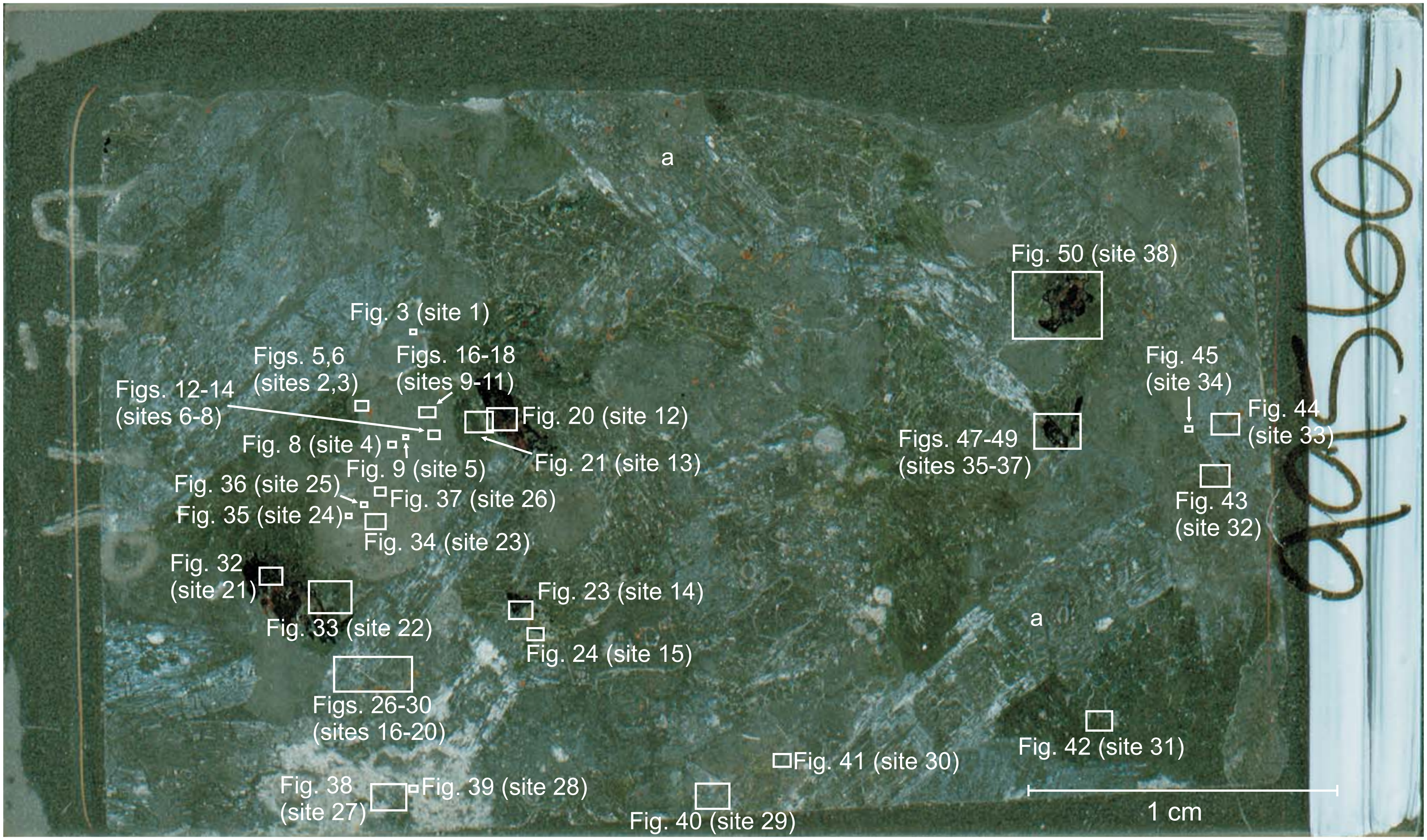



Figure 1-1.1: Scanned thin section of sample 9956a showing the location of analyzed sites. This sample is from a coarse-grained syenite with dark minerals (sites 12-15,21-22,35-38). Megacrysts of K-feldspar now scapolitized (positions a).

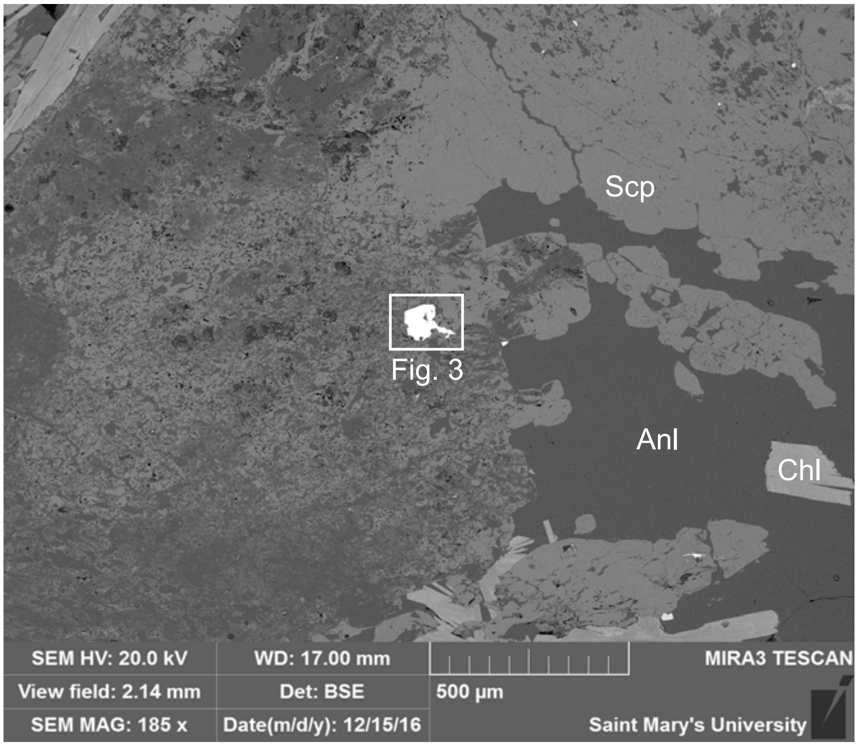
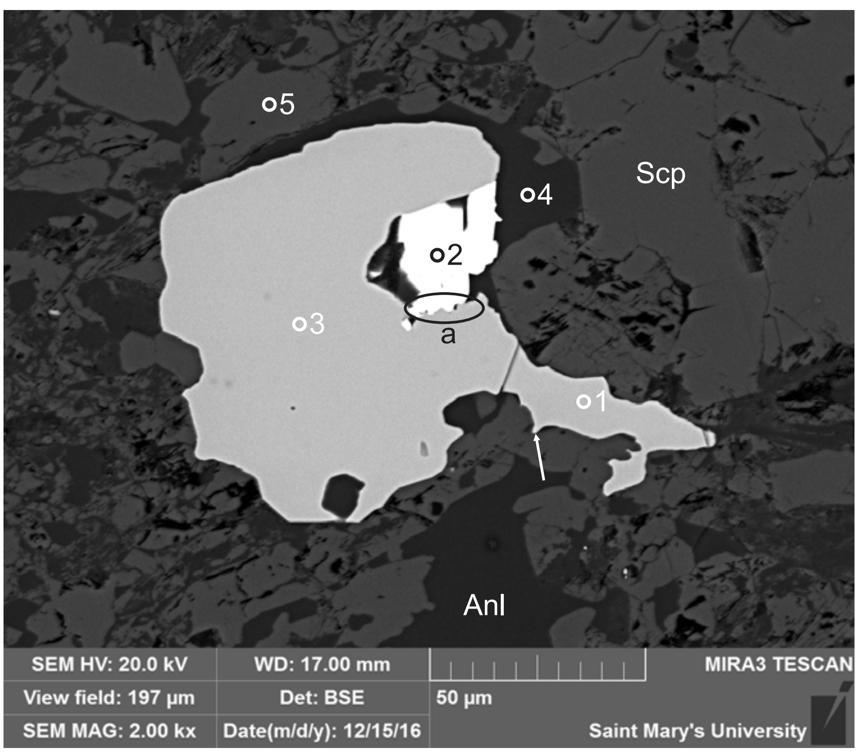



Figure 1-1.2: Sample 9956a (SEM).




1:Rutile
2:Ti-Magnetite
3:Rutile
4:Analcime
5:Scapolite

Figure 1-1.3: Sample 9956a site 1 (SEM). This site consists of a small anhedral rutile (1,3) crystal that is being overgrown by Fe-oxides/hydroxides (position a). Scapolite (5) and analcime (4) appear to predate rutile (arrow).

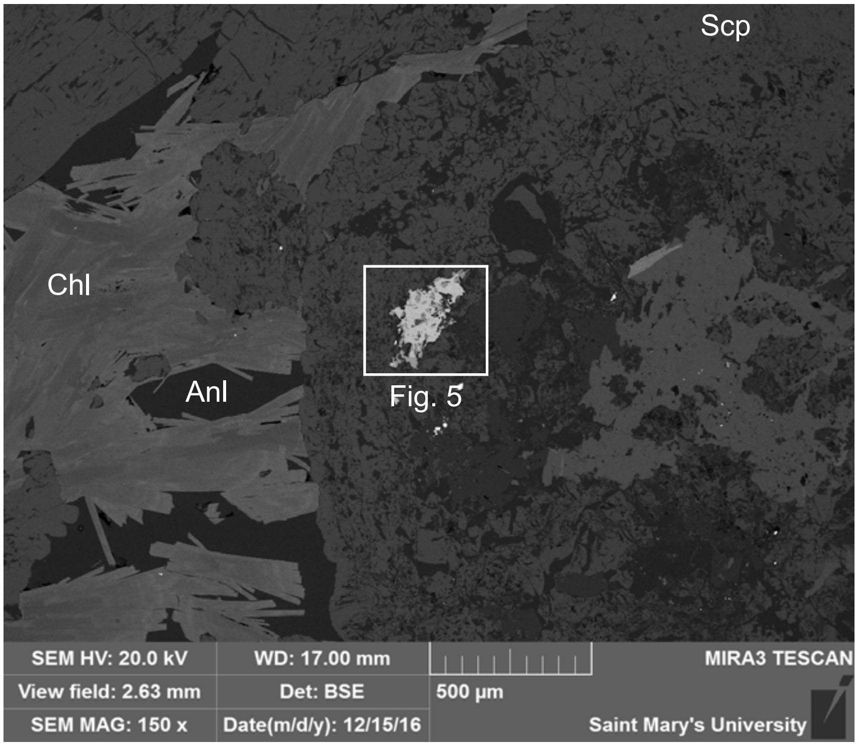
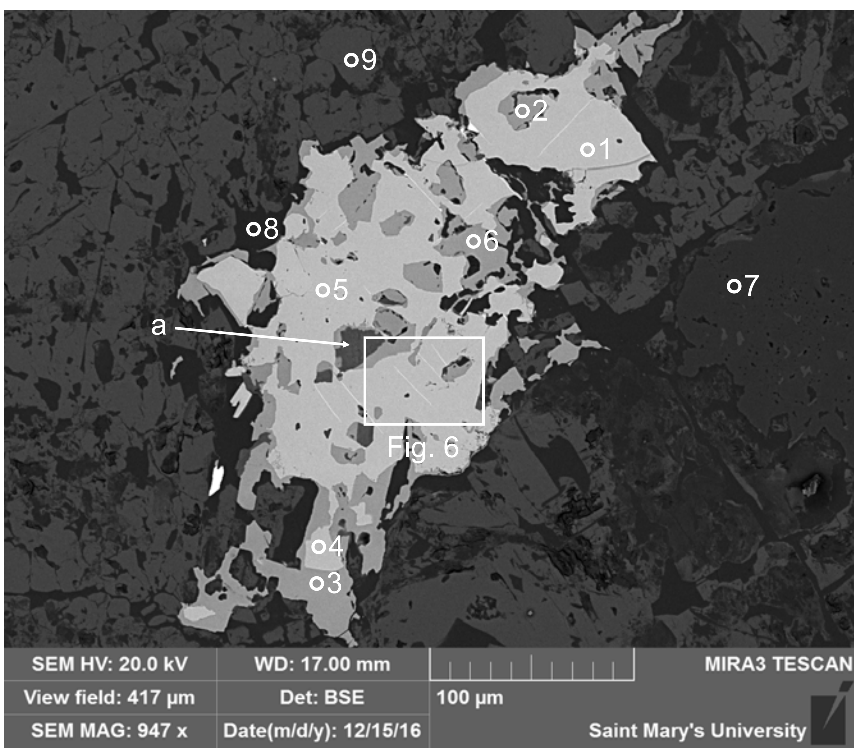
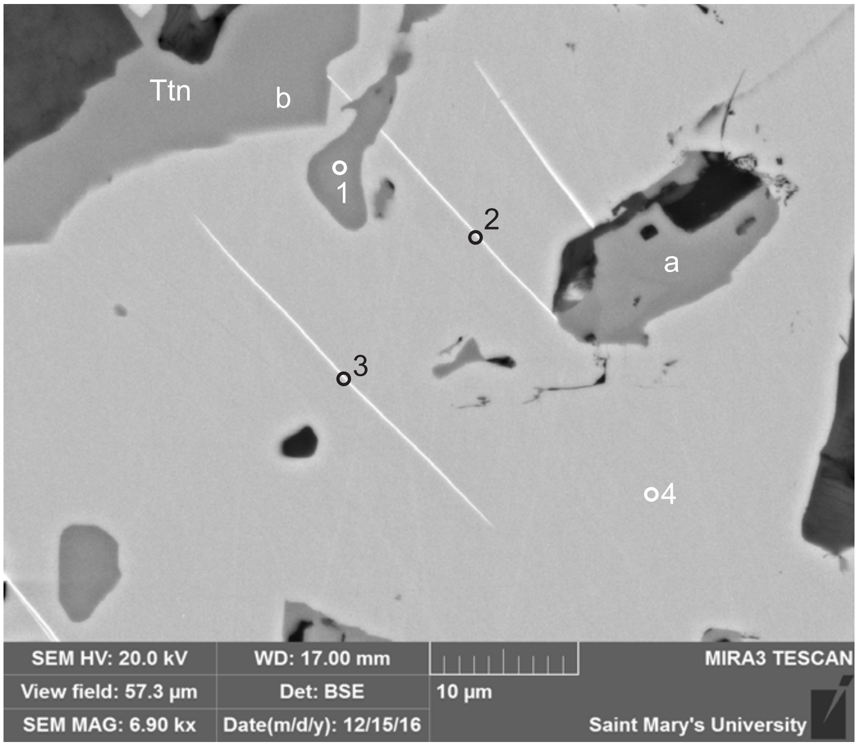



Figure 1-1.4: Sample 9956a (SEM).




1:Rutile
2:Titanite
3:Titanite
4:Rutile
5:Rutile
6:Titanite
7:Albite
8:Analcime
9:Scapolite

Figure 1-1.5: Sample 9956a site 2 (SEM). This site consists of a large >200 µm rutile (1,4-5) crystal that has an equant overgrowth of titanite (3,6). Voids in the crystal appear to be filled with analcime (postion a).




1:Titanite
2:Rutile + Ilm
3:Rutile + Ilm
4:Rutile

Figure 1-1.6: Sample 9956a site 3 (SEM). Exsolution lamellae (Ilm) on rutile (4), with sub-equant overgrowths of titanite (position b). Voids in the rutile appear to be filled with titanite (position a).

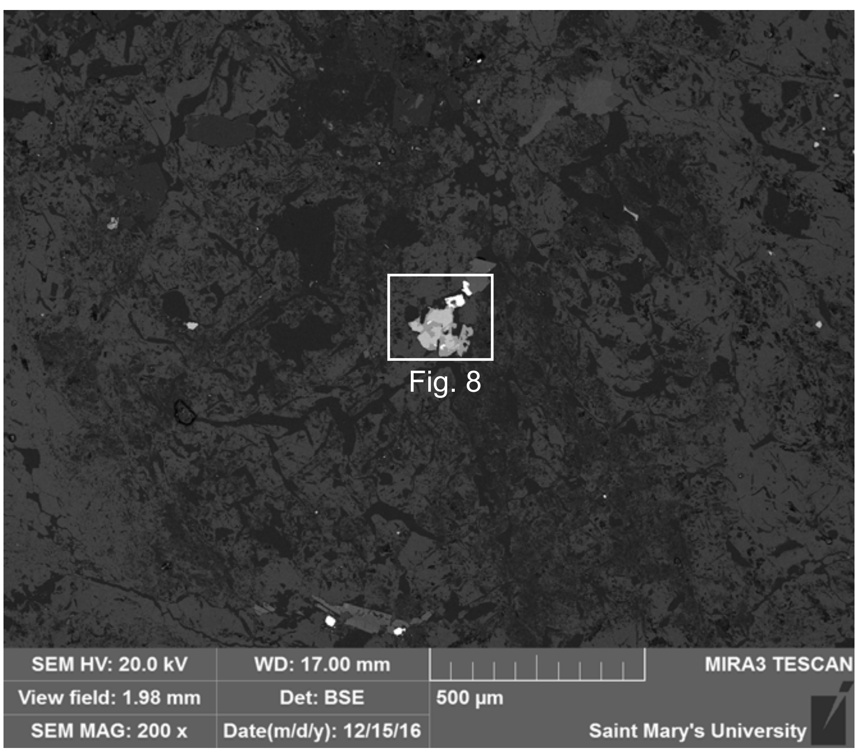



Figure 1-1.7: Sample 9956a (SEM).

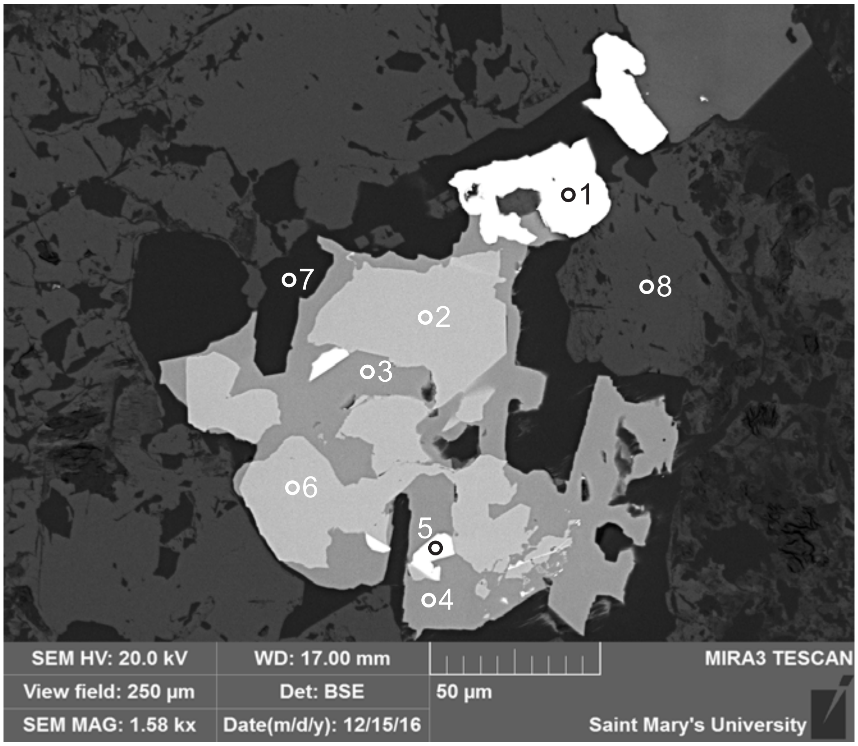



Figure 1-1.8: Sample 9956a site 4 (SEM). This site consists of a small anhedral rutile (2,6) that has an eqant overgrowth of titanite (3-4) that is then overgrown by Fe-oxides/hydroxides (1,5). Appears to have formed in the interstices between grains.

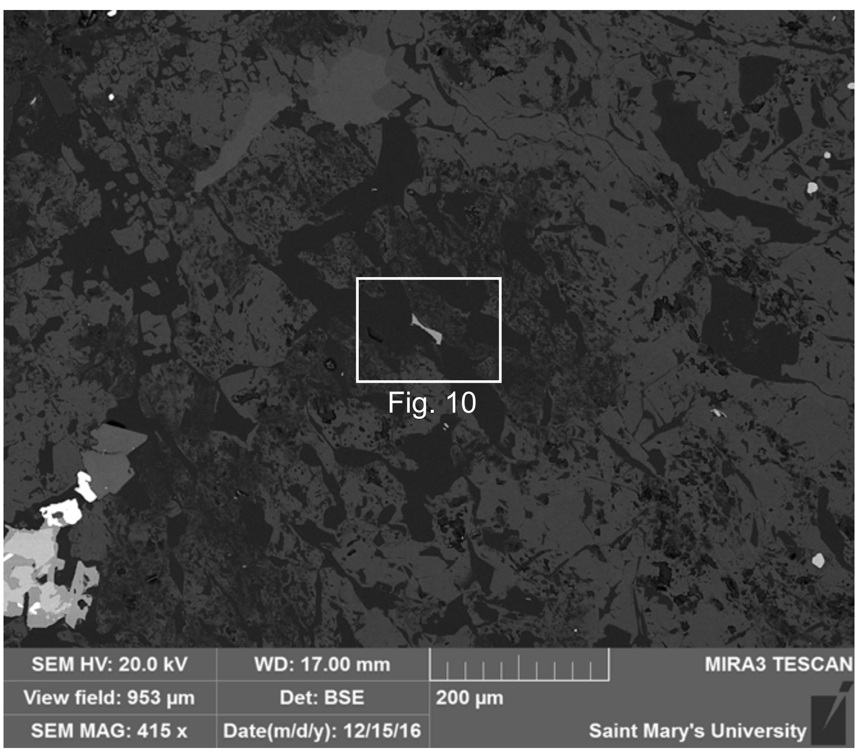
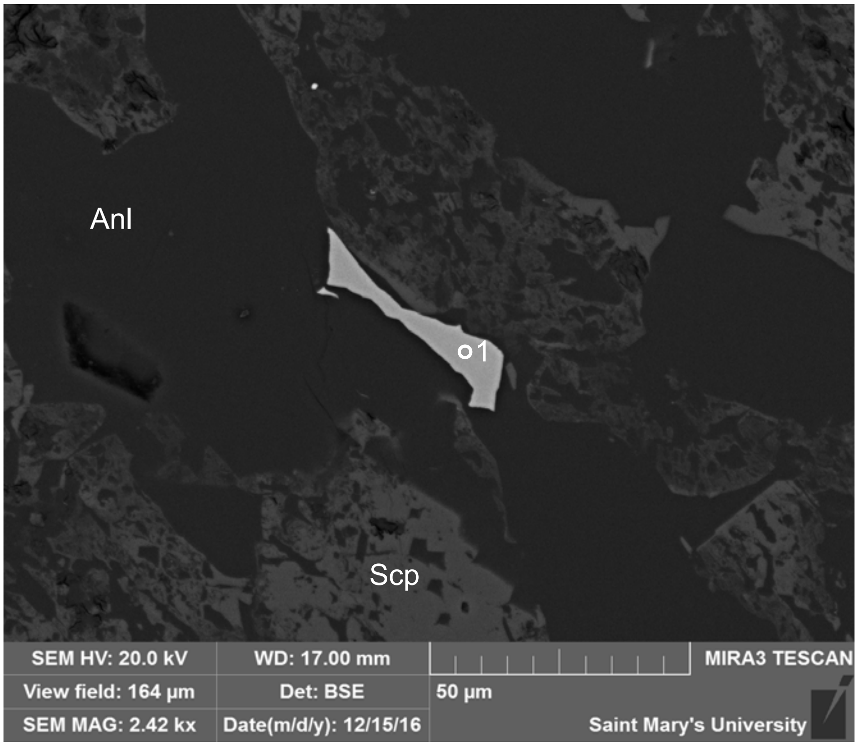



Figure 1-1.9: Sample 9956a (SEM).




1:Titanite

Figure 1-1.10: Sample 9956a site 5 (SEM). Small interstitial crystal of titanite (1).

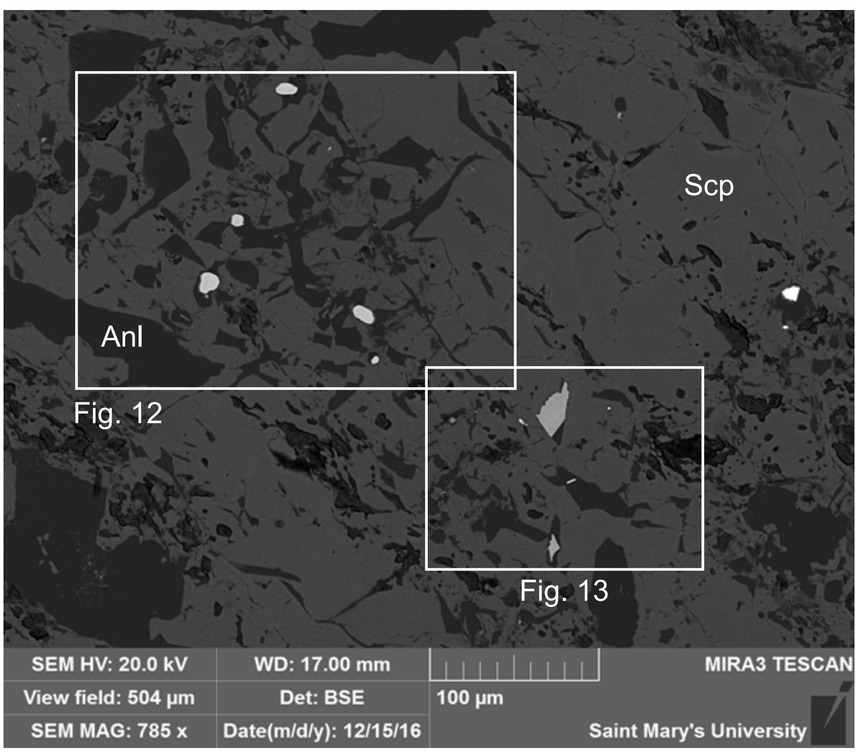
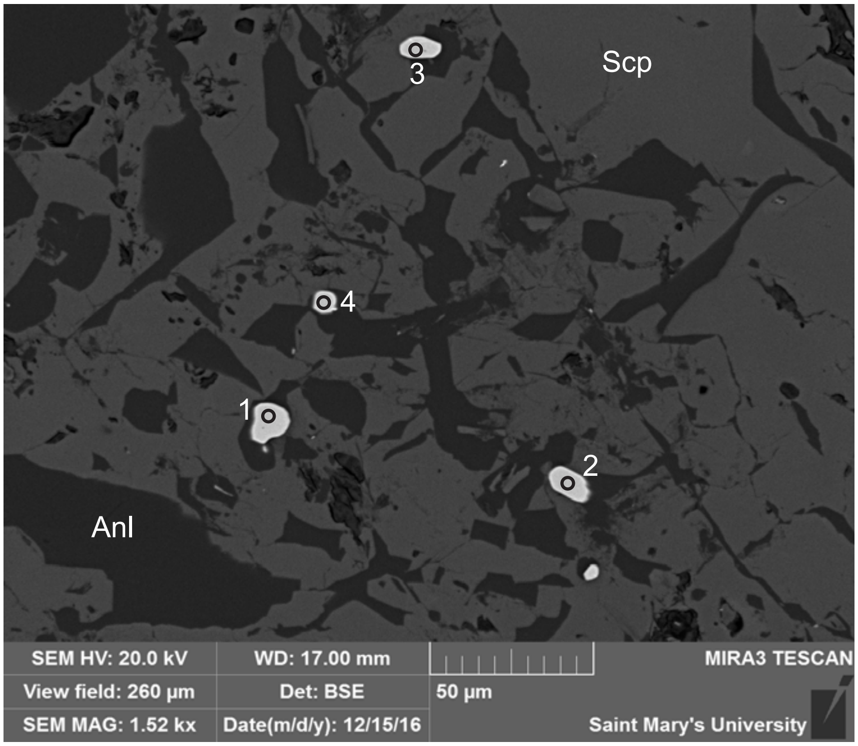
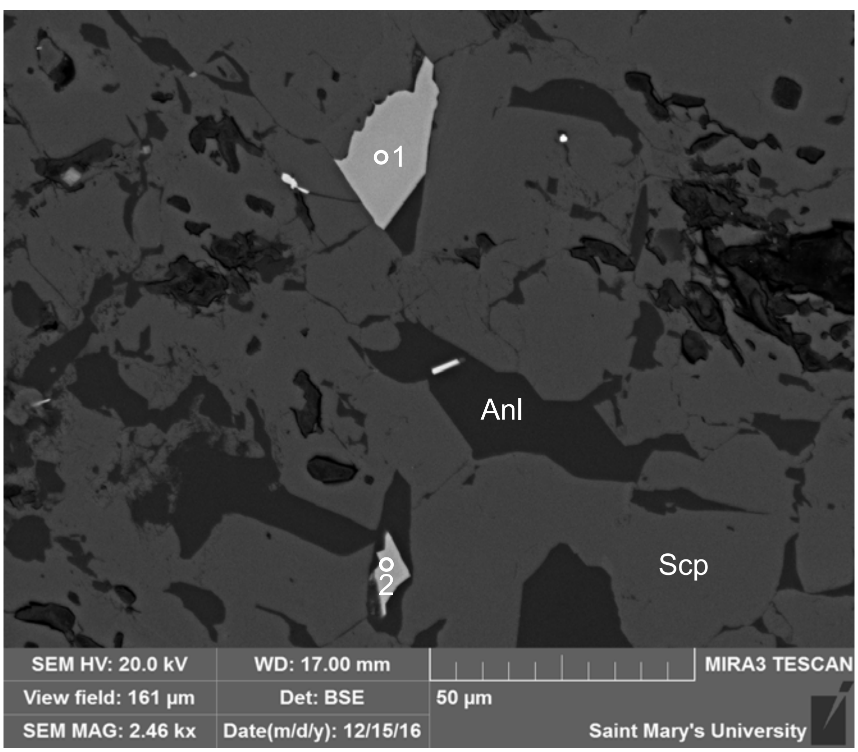



Figure 1-1.11: Sample 9956a (SEM).




1:Rutile
2:Rutile + FeO
3:Rutile + FeO
4:Rutile

Figure 1-1.12: Sample 9956a site 6 (SEM). This site consists of small ~20μm euhedral rutile crystals (1-4).




1:Titanite
2:Titanite

Figure 1-1.13: Sample 9956a site 7 (SEM). This site consists of small equant titanite (1-2) crystals that appear to be interstitial.

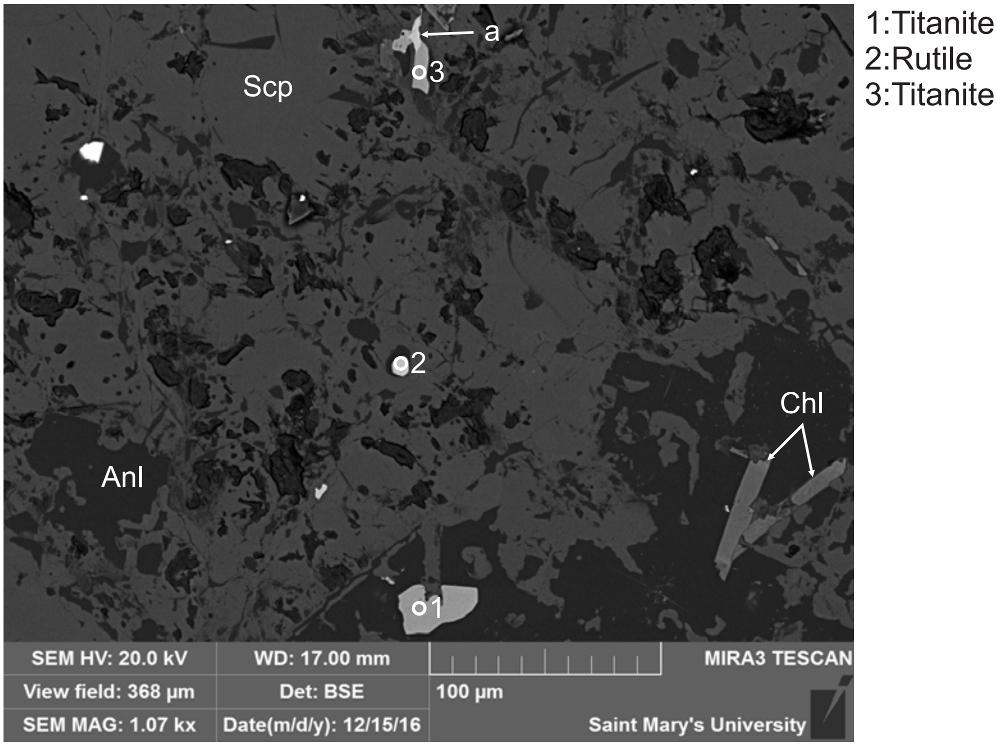



Figure 1-1.14: Sample 9956a site 8 (SEM). This site consists of a small rutile (2) crystal and titanite (1,3) crystals. Titanite (3) appears to be a subeqant overgrowth on rutile (position a). Titanite (1) is an eqant crystal.

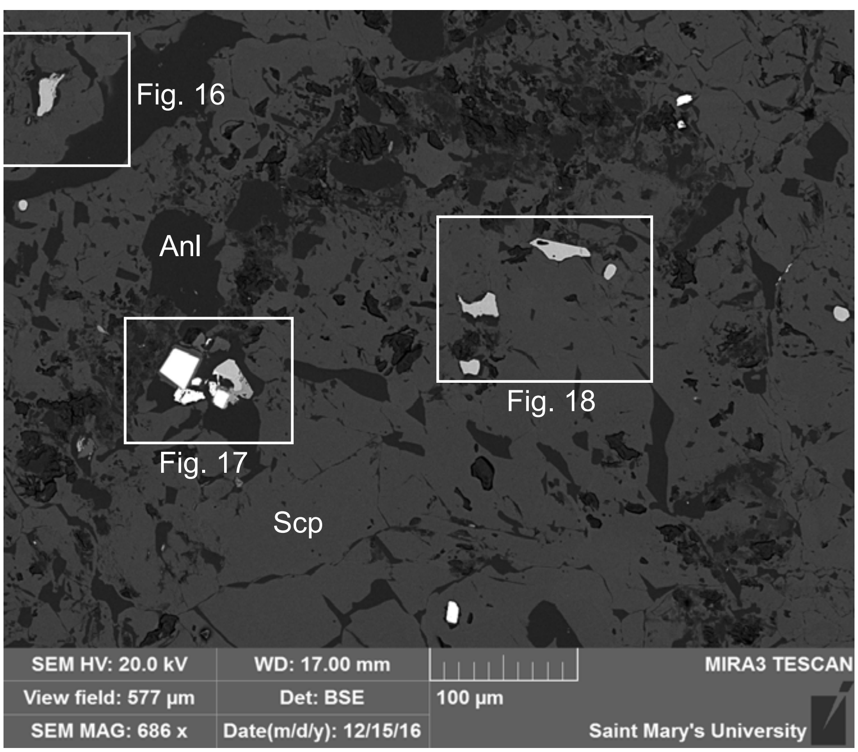
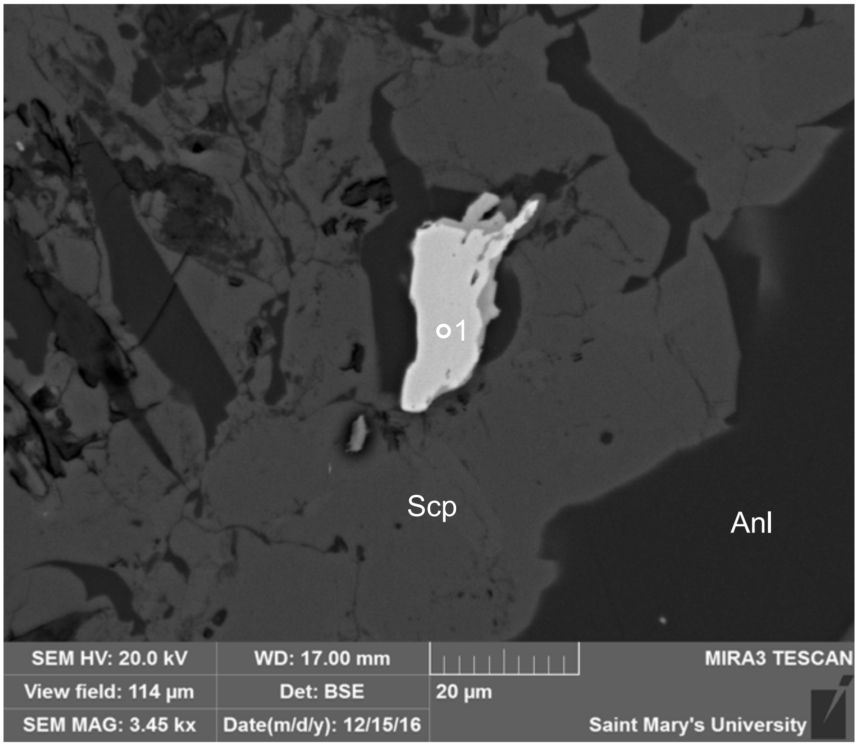
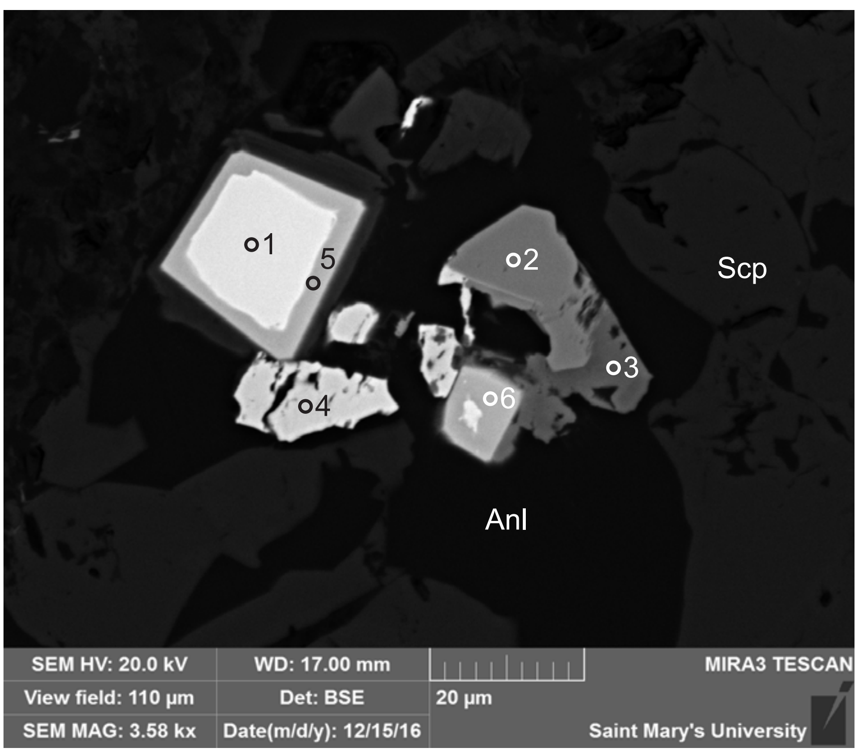



Figure 1-1.15: Sample 9956a (SEM).



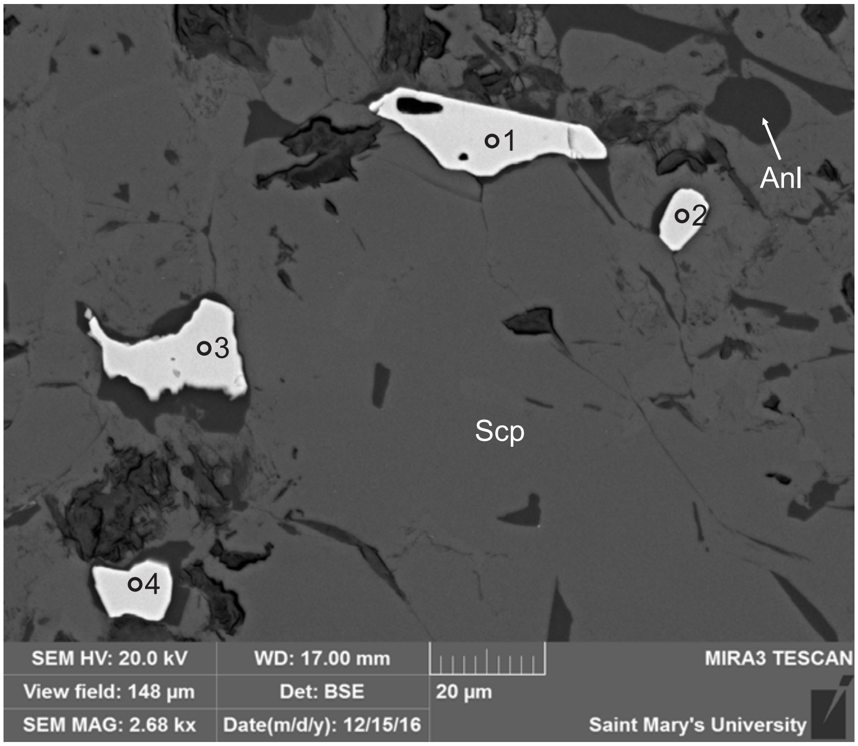

1:Rutile

Figure 1-1.16: Sample 9956a site 9 (SEM). Small anhedral rutile (1) crystal with a discontinuous of titanite overgrowth.




1:Pyrite
2:Rutile
3:Titanite
4:Limonite
5:Magnetite
6:Limonite

Figure 1-1.17: Sample 9956a site 10 (SEM). This site consists of Fe-oxides/hydroxides (4-6) that cross-cut rutile (2) and titanite (3). Rutile appears to have a subequant overgrowth of titanite and seems to have formed in the interstices between grains, now replaced by analcime. A subhedral pyrite (1) grain is overgrown by magnetite (5).




1:Rutile
2:Rutile
3:Rutile
4:Rutile

Figure 1-1.18: Sample 9956a site 11 (SEM). This site consists of small anhedral rutile (1-4) crystals. Some contain few voids others contain no voids.

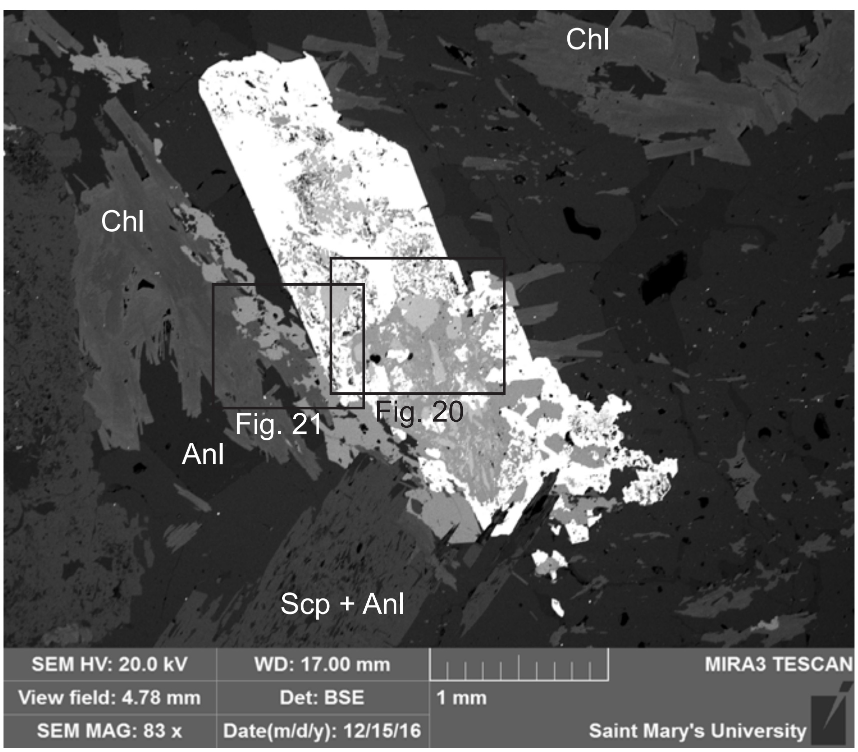



Figure 1-1.19: Sample 9956a (SEM).

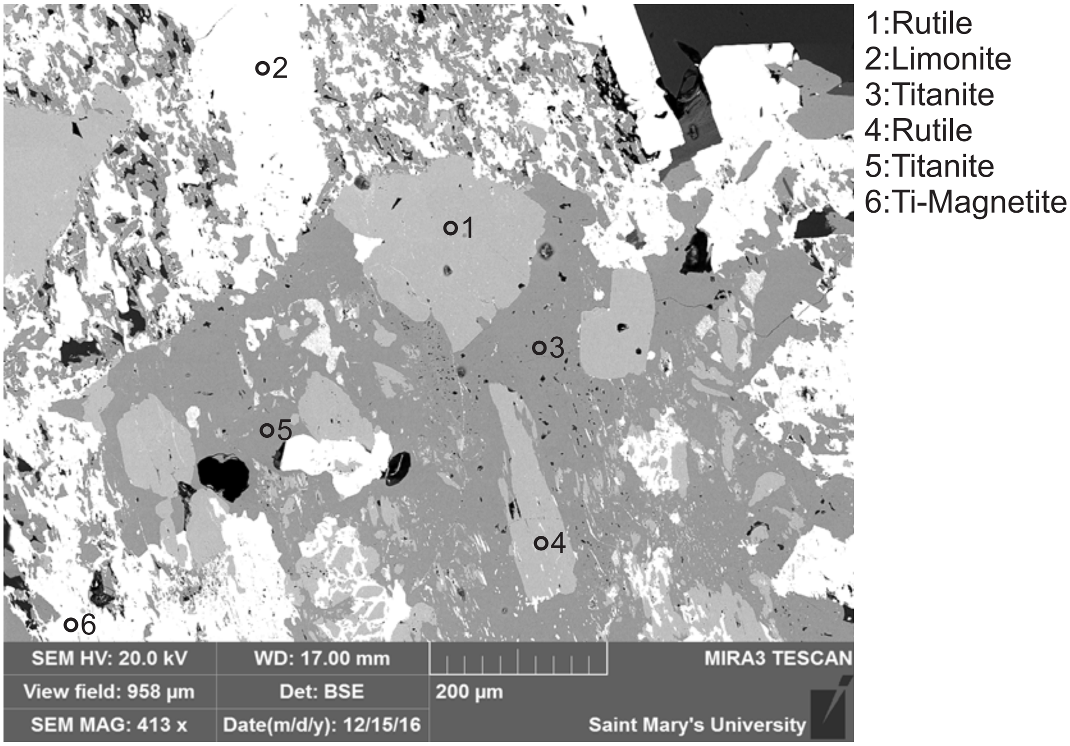



Figure 1-1.20: Sample 9956a site 12 (SEM). Titanite (3,5) displays a subequant overgrowth on rutile (1,4). Late Fe-oxides/hydroxides overgrow rutile and titanite. Some of the rutile crystals contain voids.

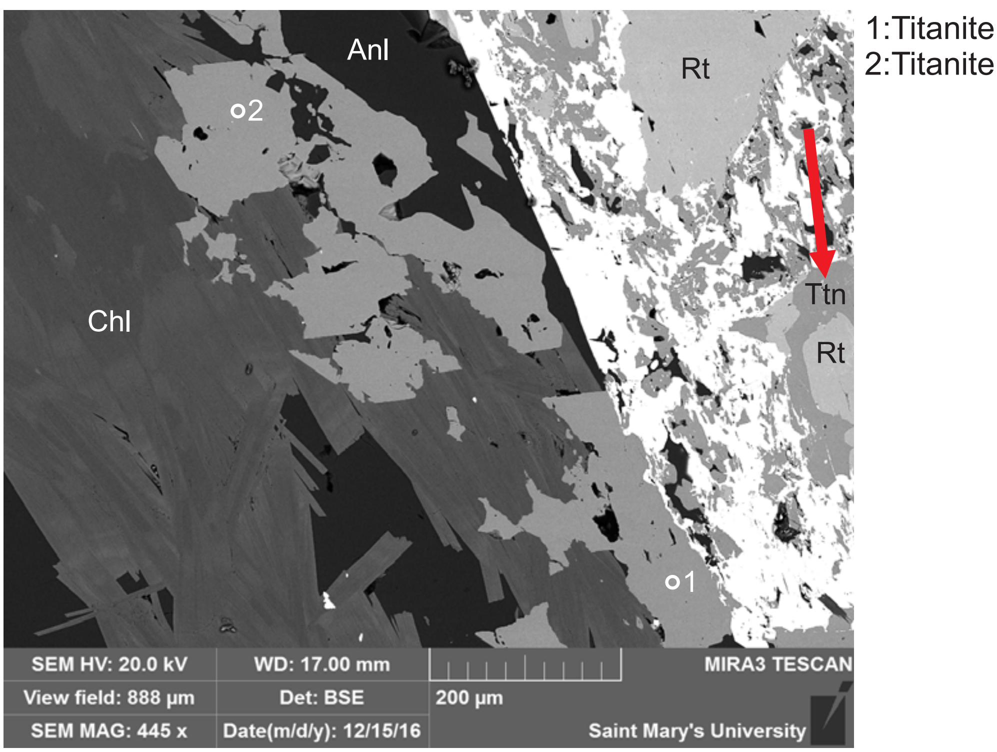



Figure 1-1.21: Sample 9956a site 13 (SEM). This site most likely contains secondary titanite (1-2) that may be ?replacive or interstitial (difference in brightness compared to titanite overgrowths on probably magmatic rutile (arrow)).

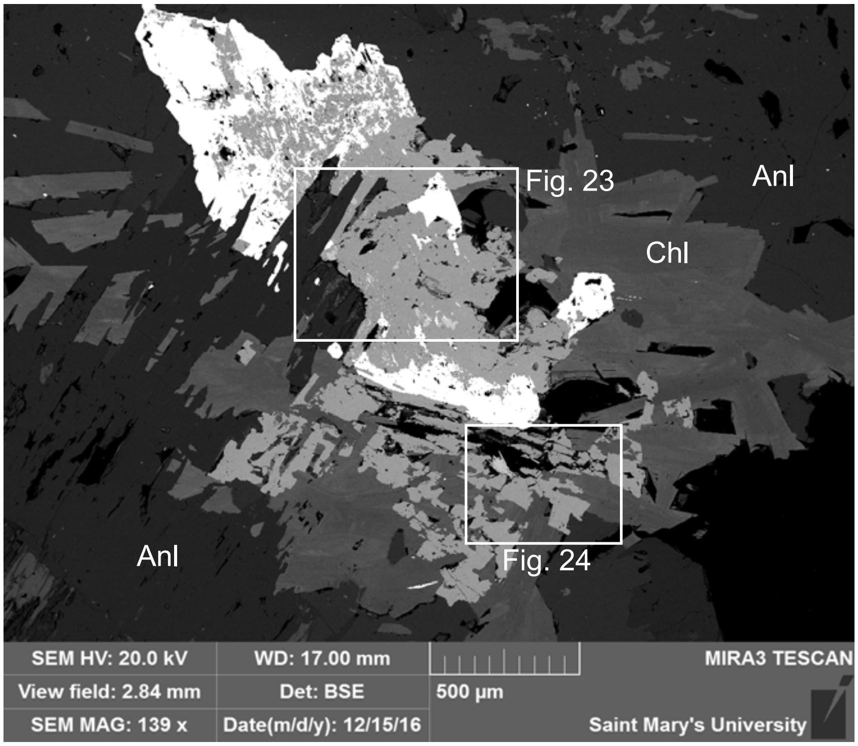
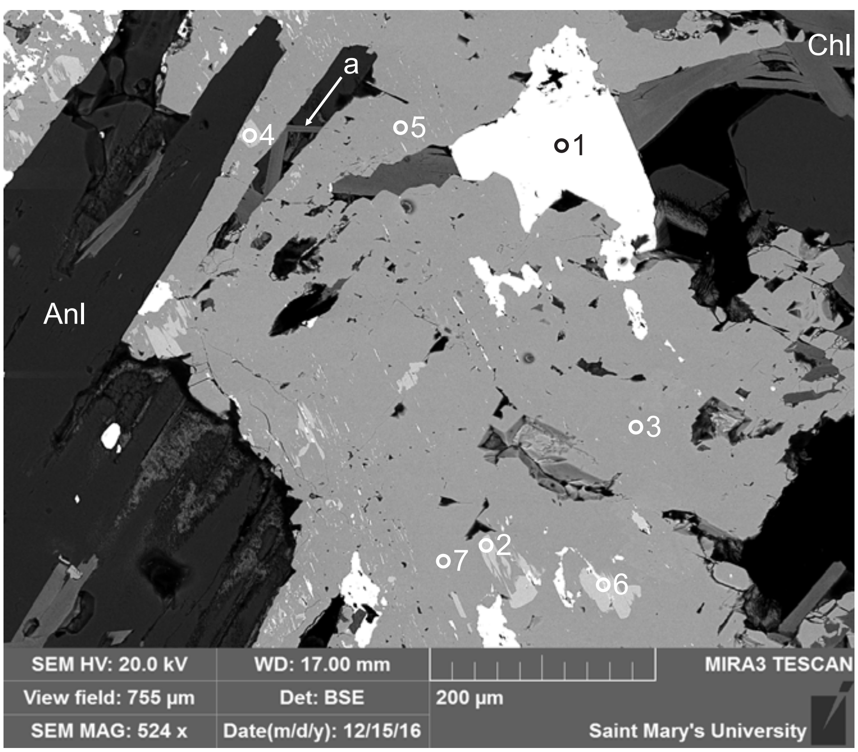
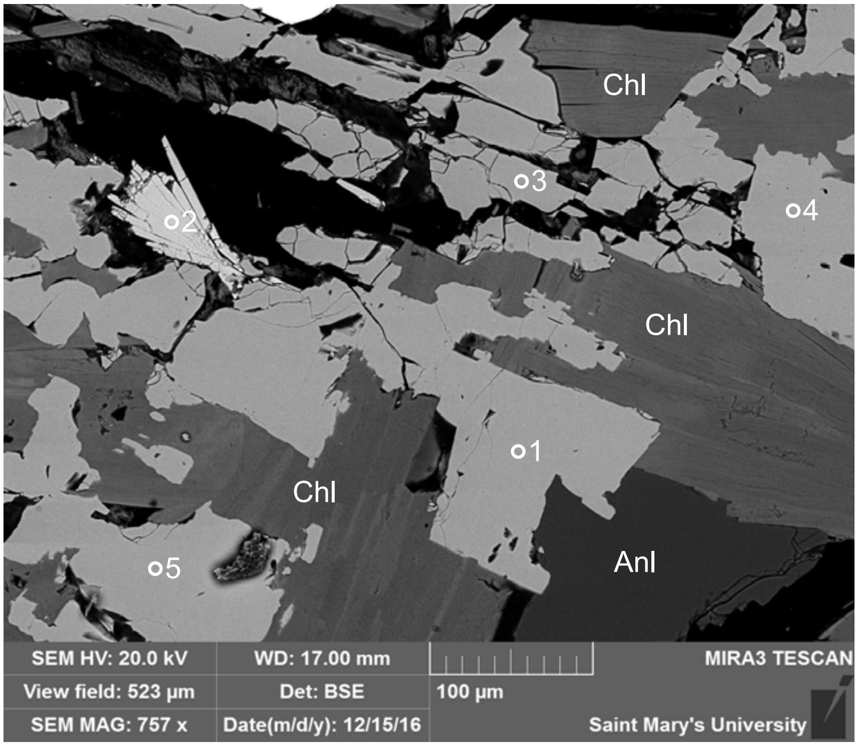



Figure 1-1.22: Sample 9956a (SEM).




1:Limonite
2:Rutile
3:Titanite
4:Rutile
5:Titanite
6:Rutile
7:Titanite

Figure 1-1.23: Sample 9956a site 14 (SEM). This site consists of a large subequant titanite (3,5,7) crystal with rutile (2,4,6) relics that is postdated by Fe-oxides/hydroxides (1). It also appears to have overprinted chlorite (position a).




1:Titanite
2:Rutile
3:Titanite
4:Titanite
5:Titanite

Figure 1-1.24: Sample 9956a site 15 (SEM). Titanite (1,3-5) appears to be ?replacive or interstitial. Small crystal of radiating (probably secondary) rutile (2) has grown in the void.

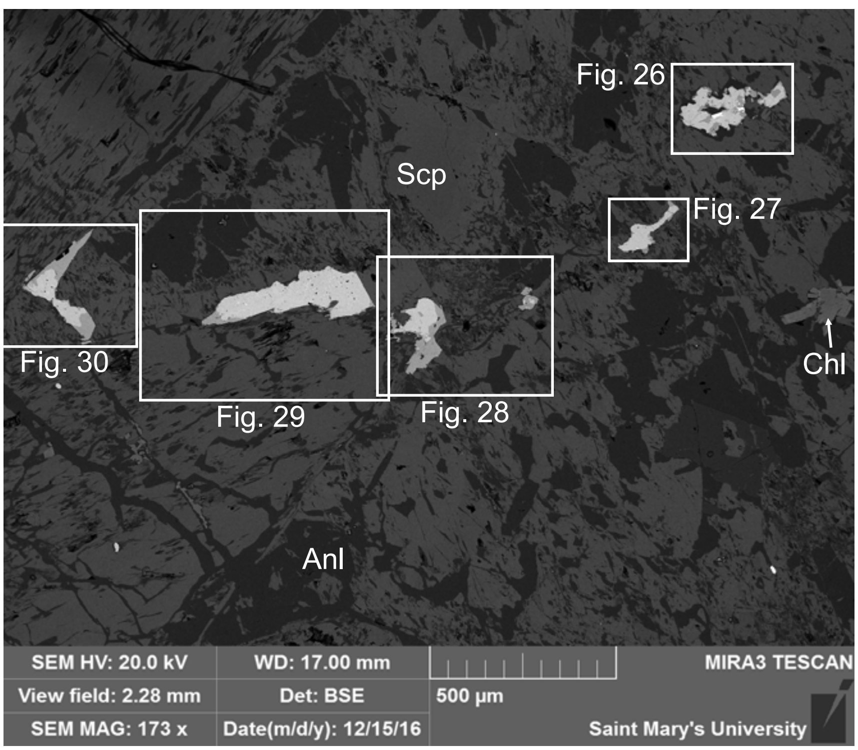
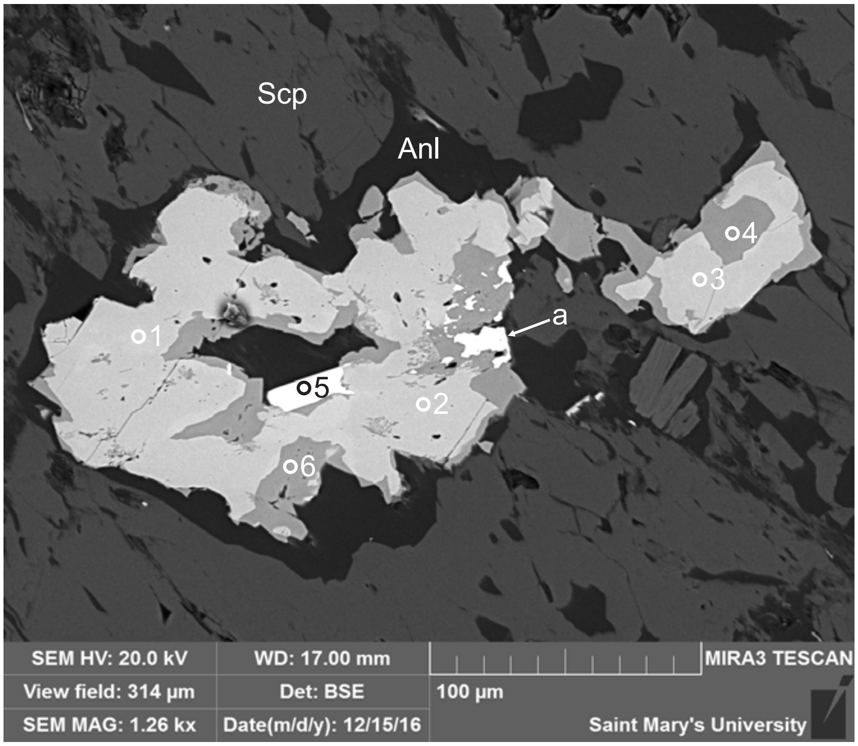
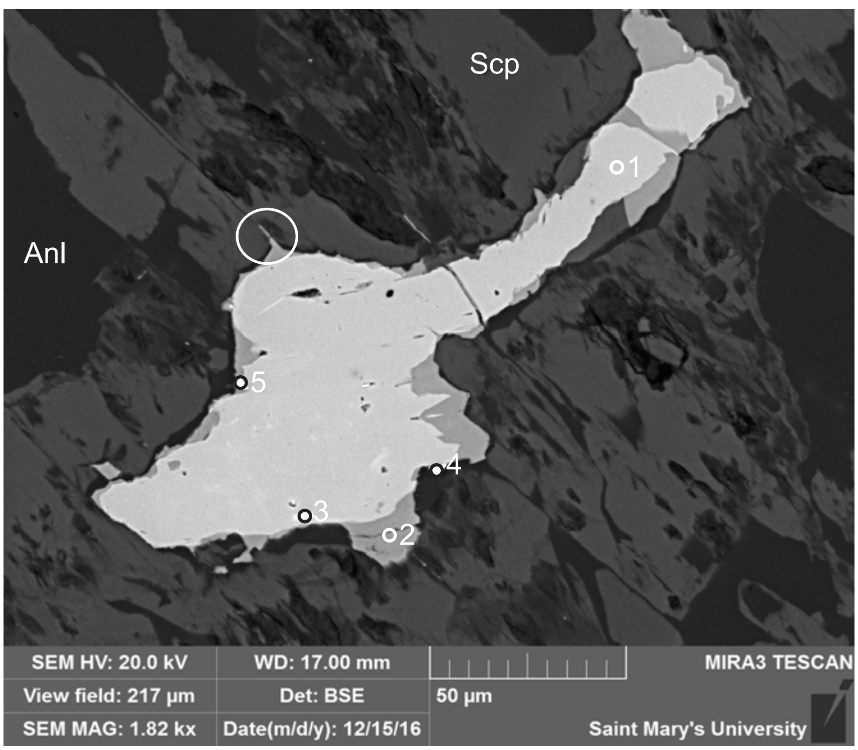



Figure 1-1.25: Sample 9956a (SEM).



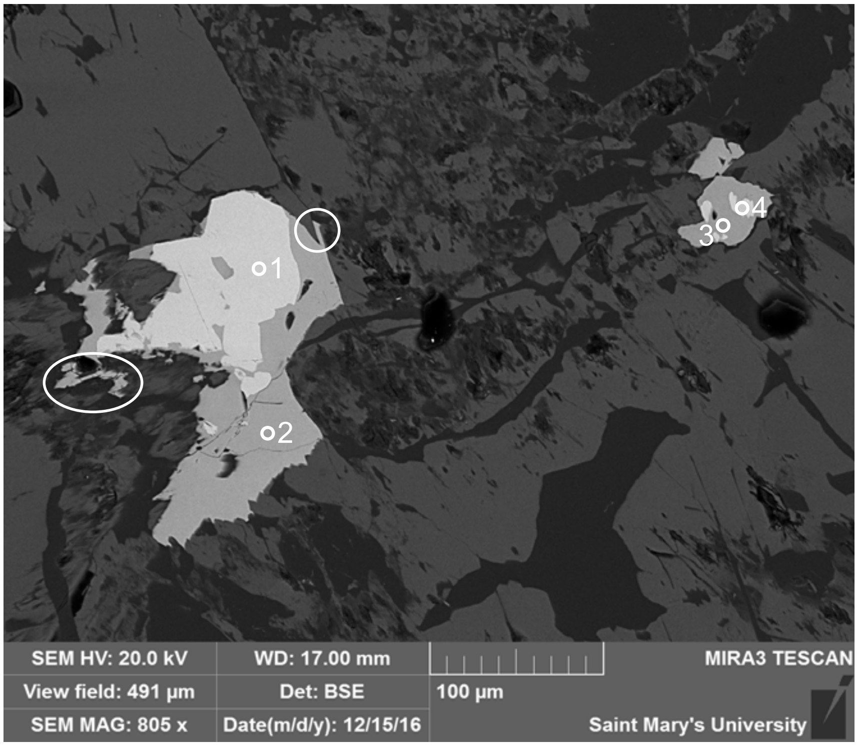

1:Rutile
2:Rutile
3:Rutile
4:Titanite
5:Goethite
6:Titanite

Figure 1-1.26: Sample 9956a site 16 (SEM). This site consists of rutile (1-3), with equant overgrowth of titanite (4,6), which is then overgrown by Fe-oxides/hydroxides (position a). This mineral assemblage appears to partially fill a void that contains analcime.



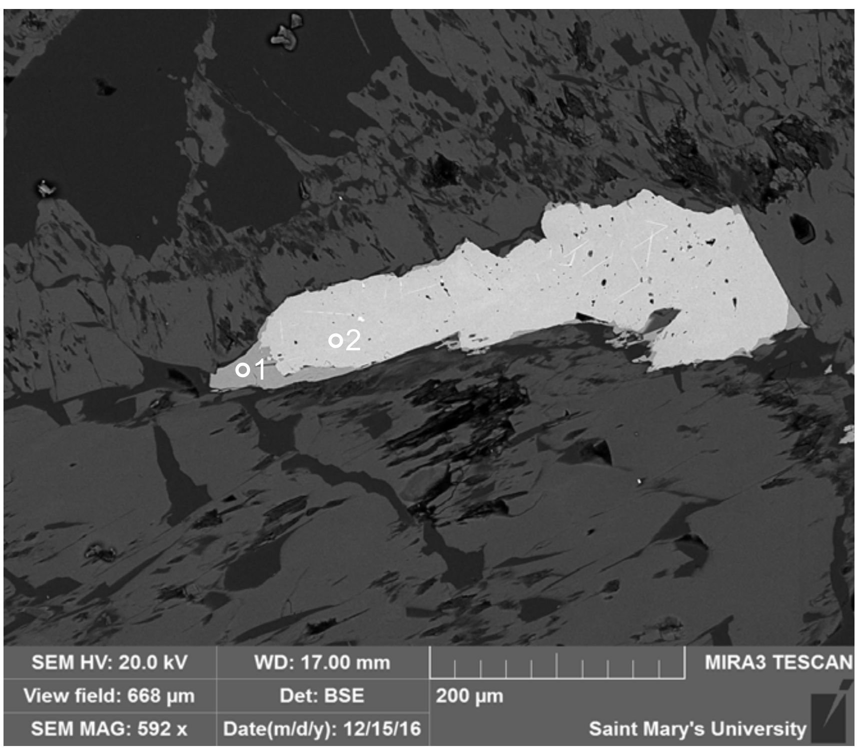

1:Rutile
2:Titanite
3:Mix?
4:Ti-Magnetite
5:Altered Ilmenite

Figure 1-1.27: Sample 9956a site 17 (SEM). Large anhedral rutile (1) crystal contains equant overgrowths of titanite (2). The titanite overgrowth also appears to be minor interstitial (circle). Small crystals of Fe-oxides/hydroxides (3-5) are found in the titanite and rutile.




1:Rutile
2:Titanite
3:Titanite
4:Rutile

Figure 1-1.28: Sample 9956a site 18 (SEM). Anhedral rutile (1,4) has equant overgrowths of titanite (2-3). Titanite also is minor interstitial (circles).




1:Titanite
2:Rutile

Figure 1-1.29: Sample 9956a site 19 (SEM). Rutile (2) with exsolution lamallae and lots of voids is subequantly overgrown by titanite (2).

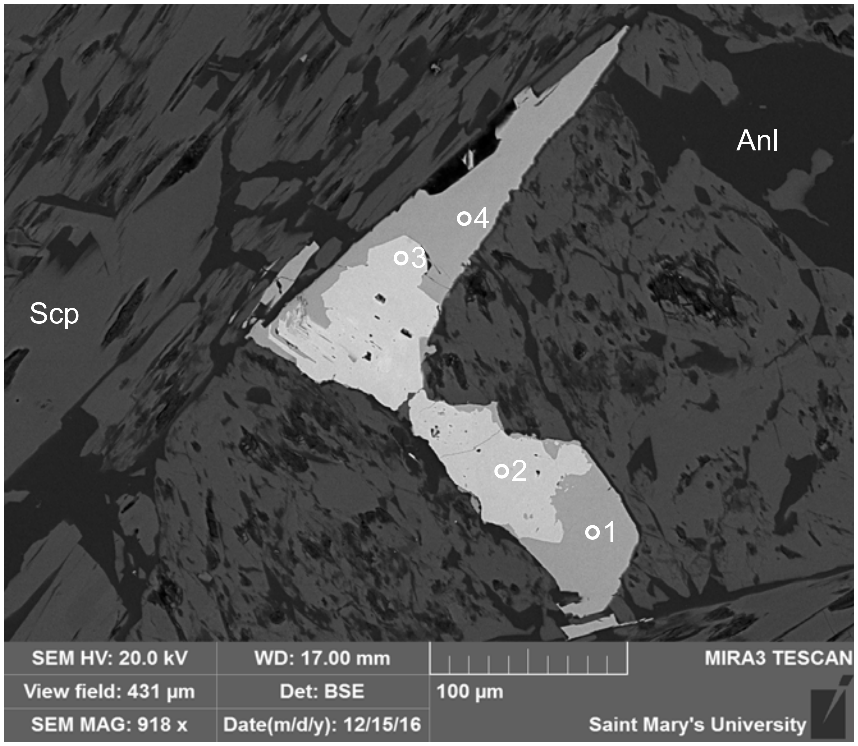



Figure 1-1.30: Sample 9956a site 20 (SEM). Large >250µm anhedral rutile (2,3) grain has subequant overgrowth of titanite (1,4) but appears to have formed in the interstitial space between grains.

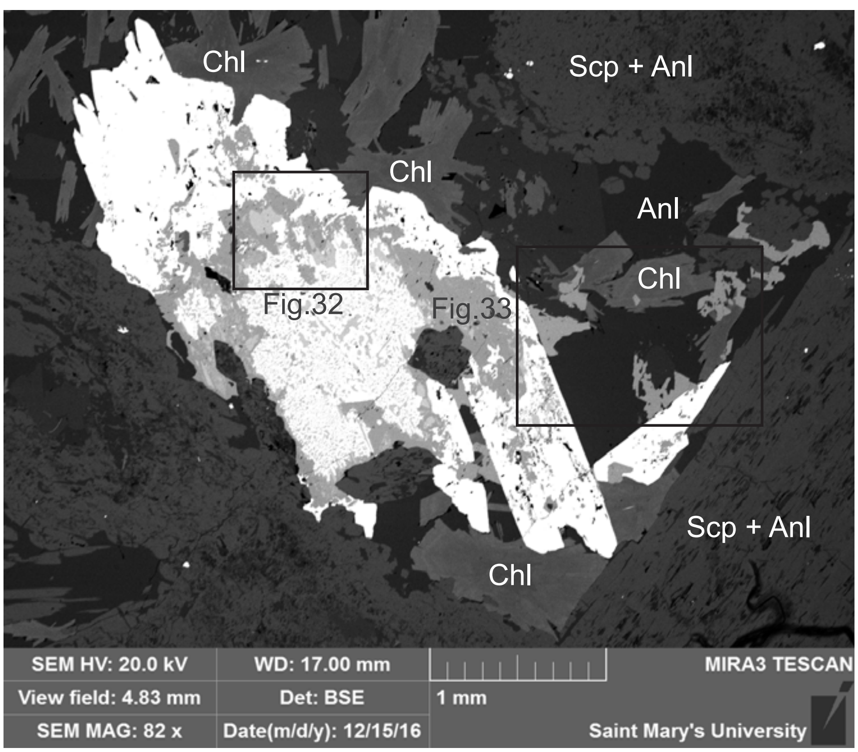
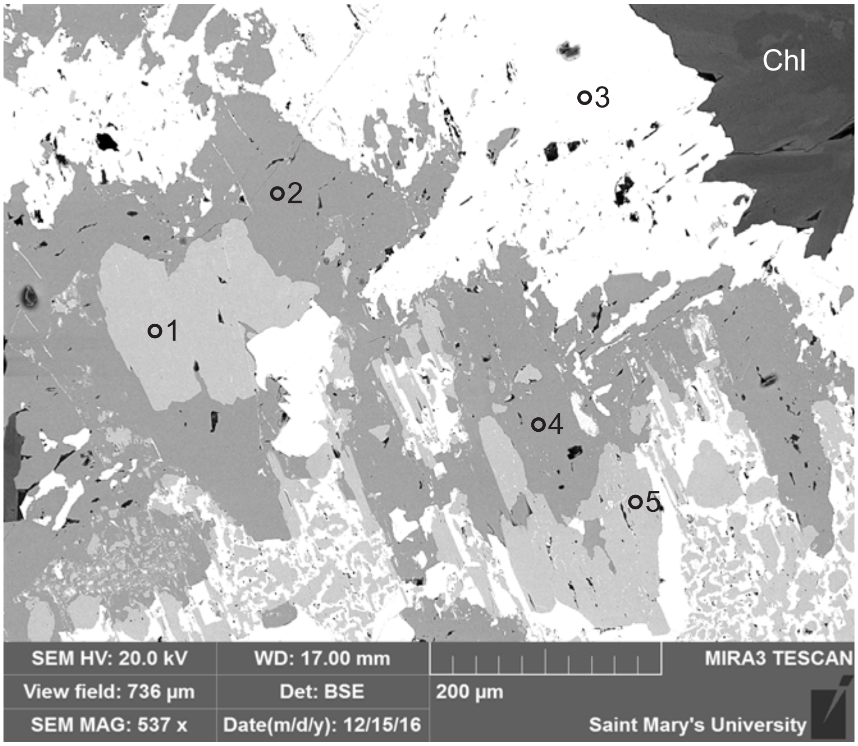
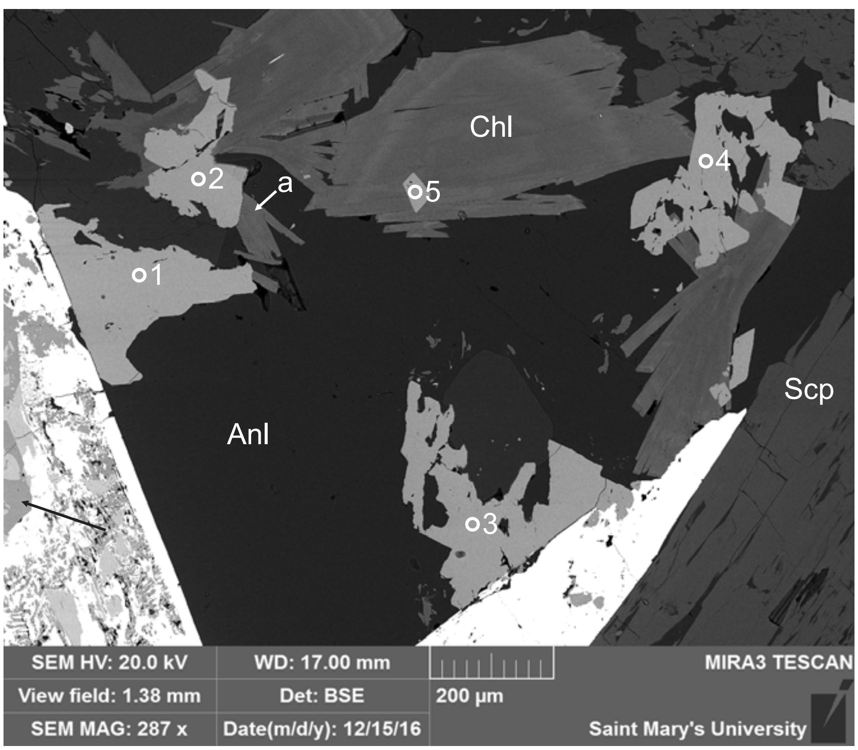



Figure 1-1.31: Sample 9956a (SEM).




1:Rutile
2:Titanite
3:Ti-Magnetite
4:Titanite
5:Rutile

Figure 1-1.32: Sample 9956a site 21 (SEM). Large crystal of rutile (1,5) with equant overgrowths of titanite (2,4), which is then overgrown by Fe-oxides (3).




1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Titanite

Figure 1-1.33: Sample 9956a site 22 (SEM). This generation of titanite (1-5) appears to be replacive or interstitial, it seems to postdate chlorite (position a) and the titanite overgrowths on rutile (note grey scale difference) (arrow).

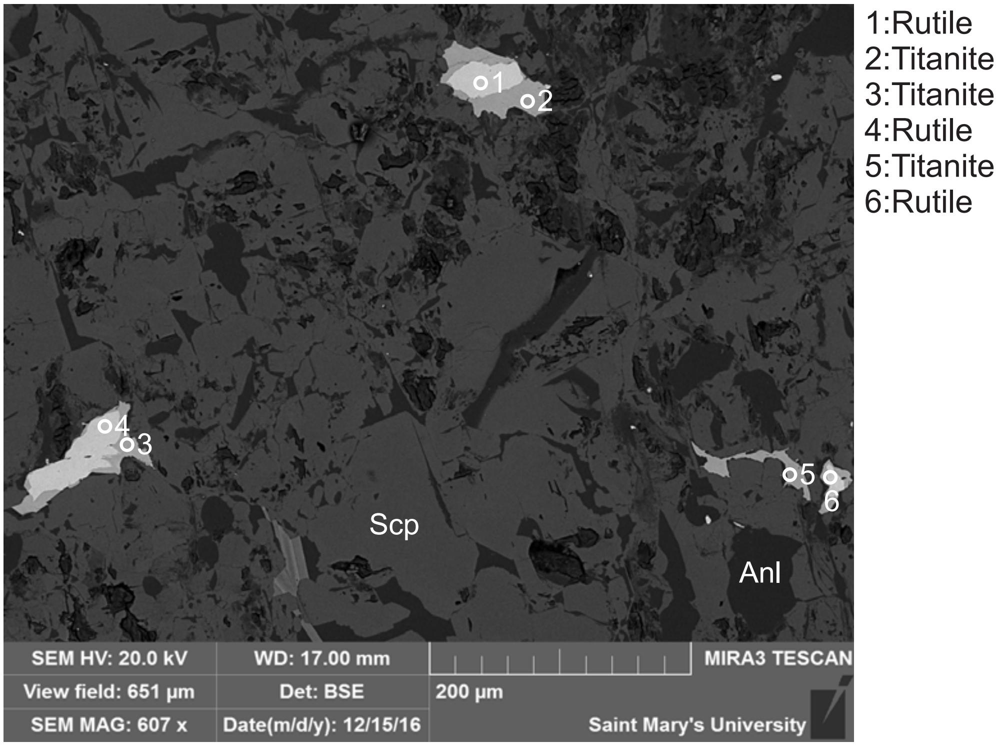



Figure 1-1.34: Sample 9956a site 23 (SEM). This site consists of small anhedral rutile (1,4) which has equant overgrowths of titanite (2-3), and a large interstitial crystal of titanite (5).

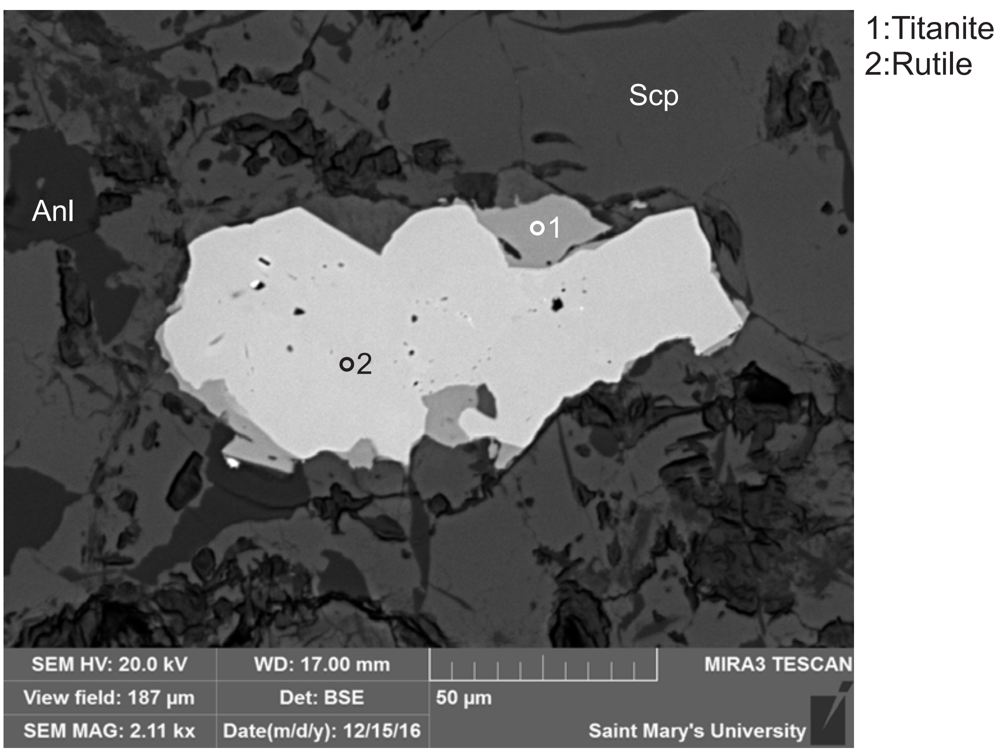
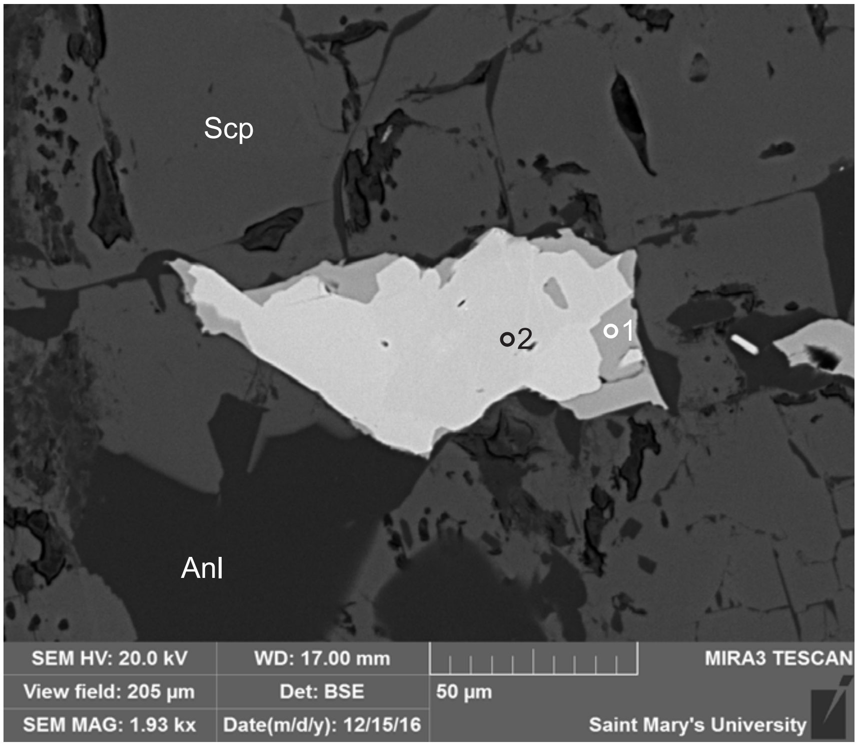
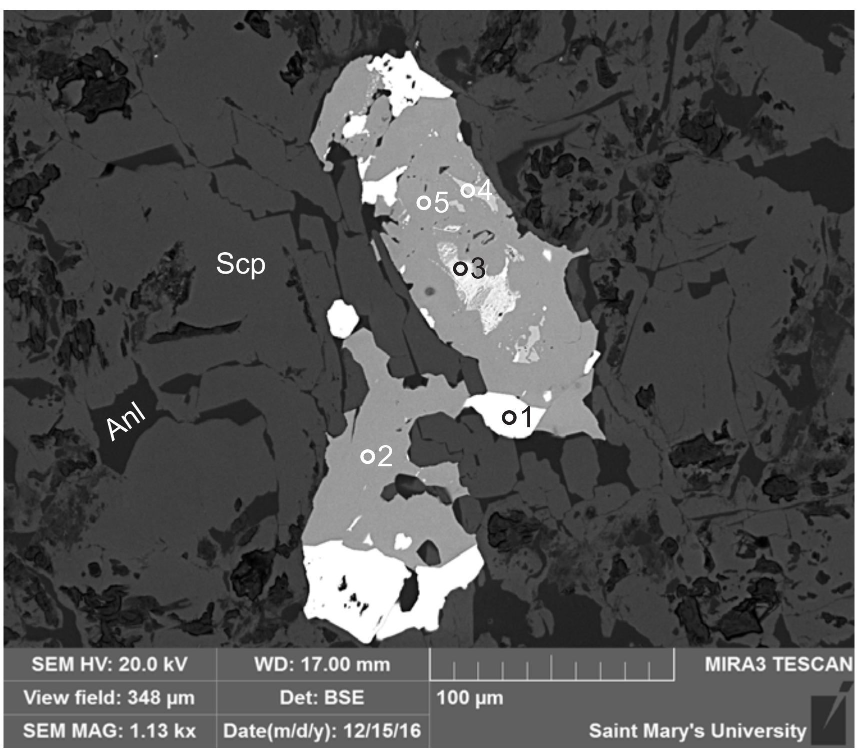



Figure 1-1.35: Sample 9956a site 24 (SEM). Small anhedral rutile (2) crystal with patchy overgrowth of titanite (1).



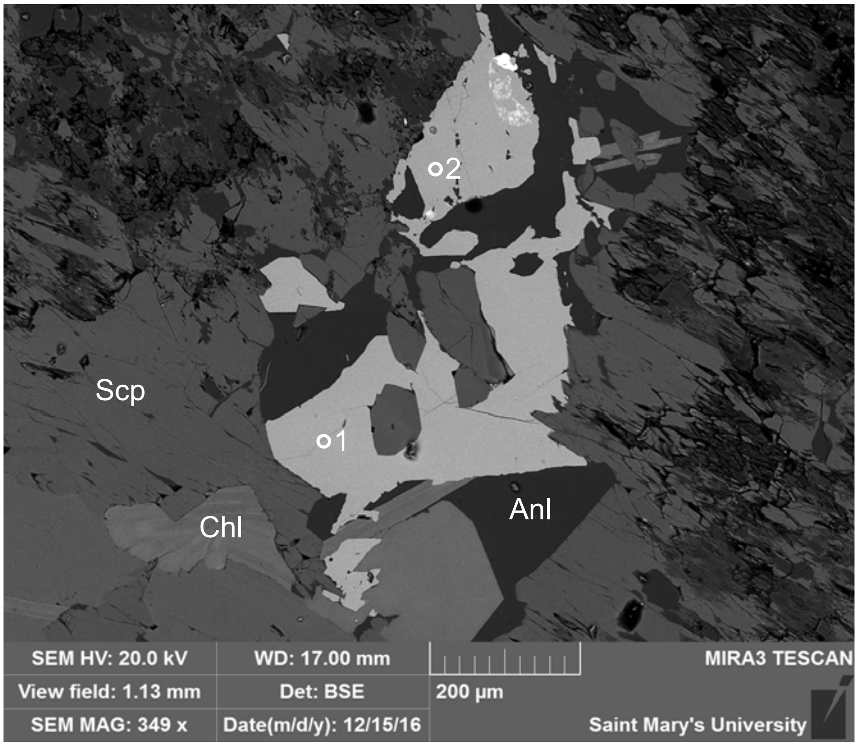

1:Titanite
2:Rutile

Figure 1-1.36: Sample 9956a site 25 (SEM). Small anhedral rutile (2) with patchy subequant overgrowth of titanite (1).



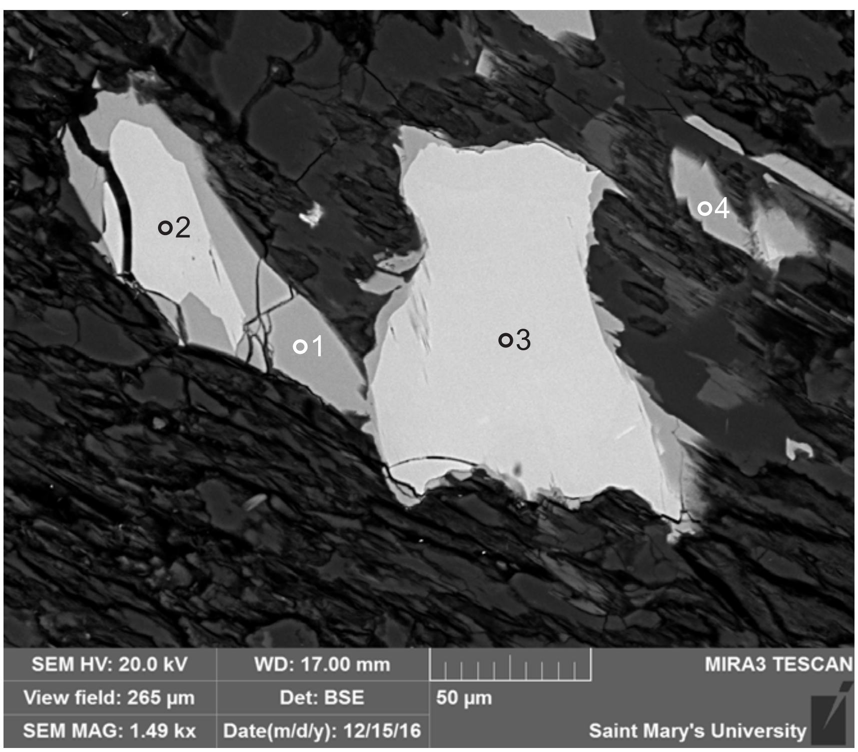

1:Limonite
2:Titanite
3:Altered Ilmenite
4:Rutile
5:Titanite

Figure 1-1.37: Sample 9956a site 26 (SEM). This site consists of interstitial titanite (2,5) with relics of rutile (4), and altered ilmenite (3).



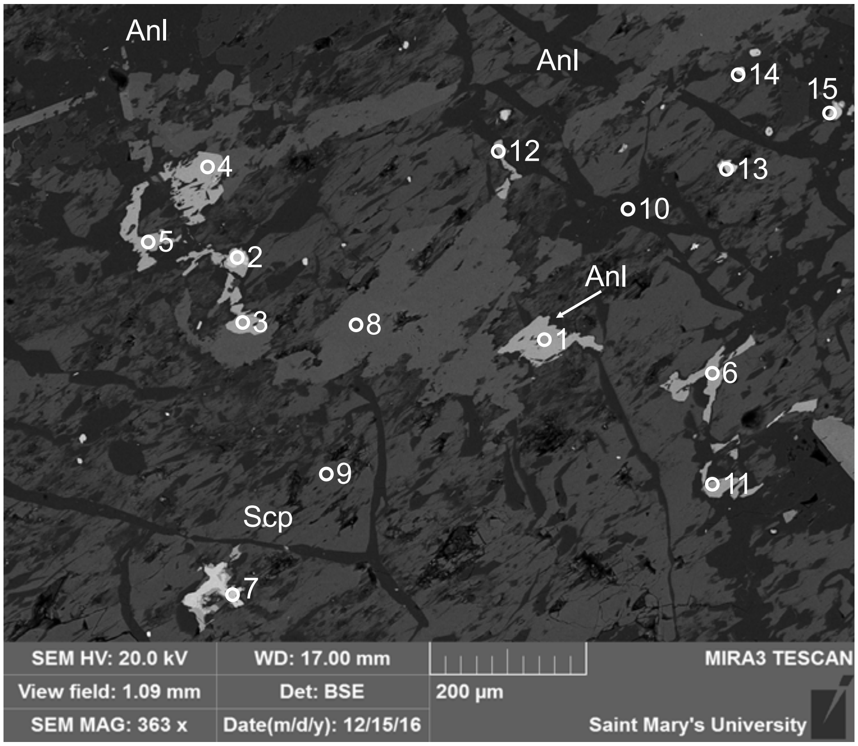

1:Titanite
2:Titanite

Figure 1-1.38: Sample 9956a site 27 (SEM). This site consists of large interstitial titanite crystals that cross-cut chlorite and probably analcime.



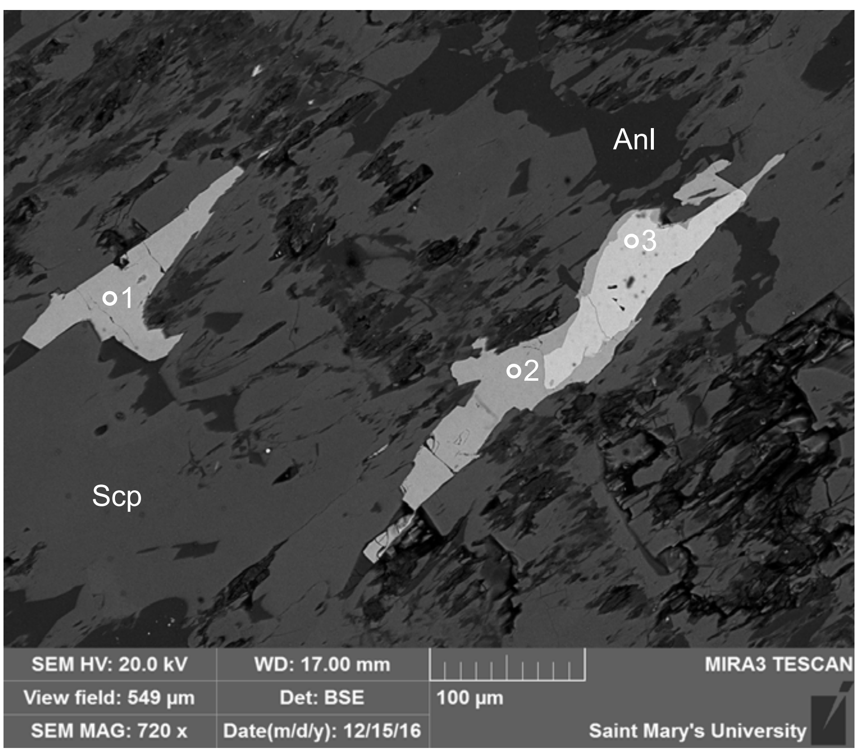

1:Titanite
2:Rutile
3:Rutile
4:Titanite

Figure 1-1.39: Sample 9956a site 28 (SEM). Anhedral crystals of rutile (2-3) are overgrown by equant titanite (1,4).



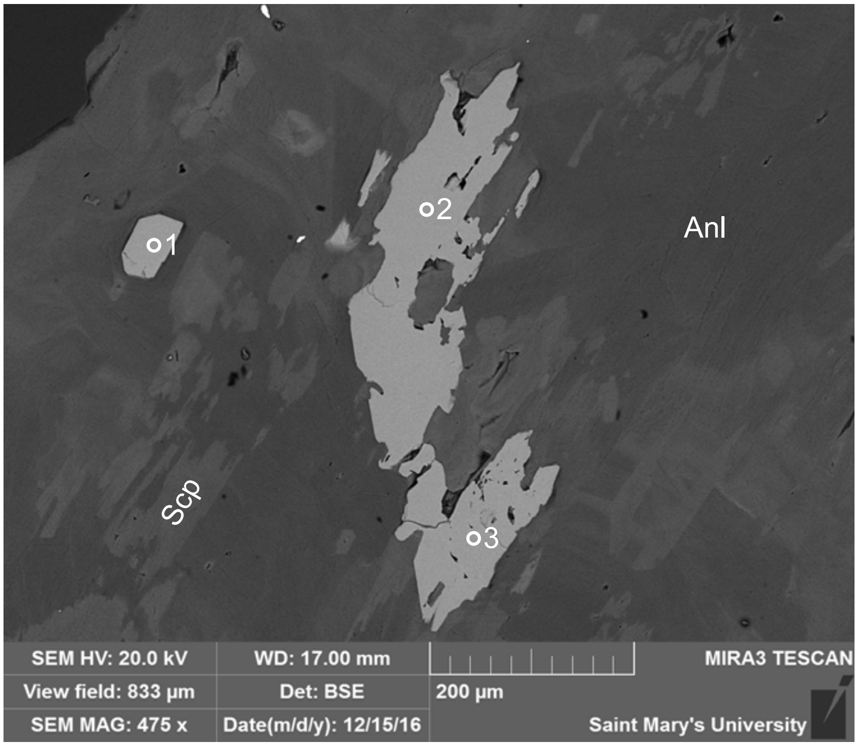

1:Titanite
2:Rutile
3:Titanite
4:Titanite
5:Titanite
6:Titanite
7:Rutile
8:K-feldspar
9:Scapolite
10:Analcime
11:Titanite +
12:Titanite
13:Rutile
14:Rutile
15:Rutile

Figure 1-1.40: Sample 9956a site 29 (SEM). Interstitial titanite (3-6,11-12) cross-cuts relic K-feldspar crystals that have been scapolitized and tends to form in areas with more abundant analcime. Titanite also equantly overgrows rutile (2,7,15). Some rutile crystals (13,14) appear to be precipitates.



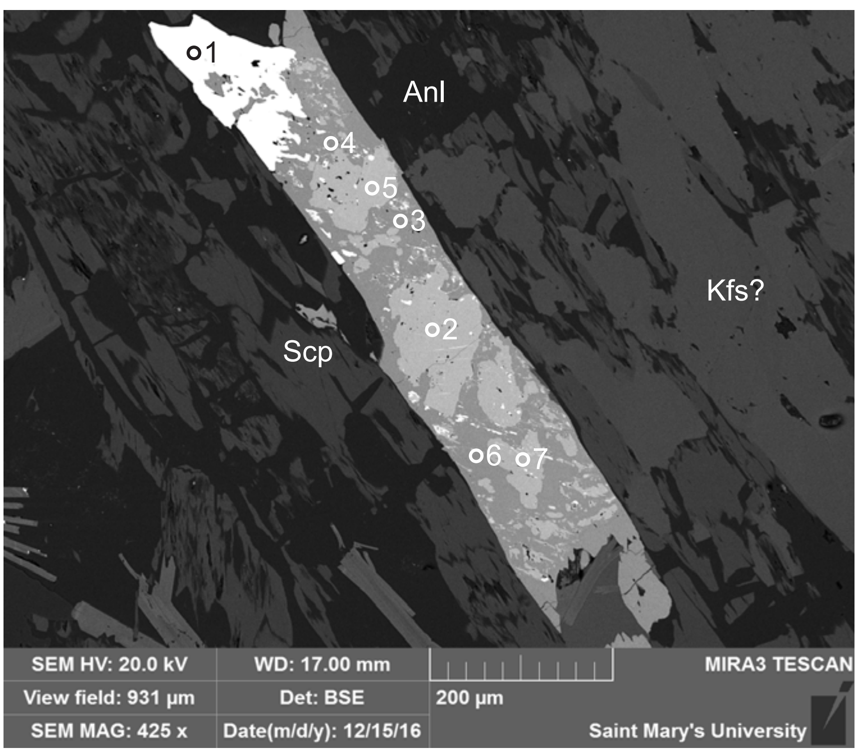

1:Titanite
2:Titanite
3:Rutile

Figure 1-1.41: Sample 9956a site 30 (SEM). Large ~100µm anhedral rutile (3) crystal with subequant overgrowth of titanite (2). Titanite (1,2) appears as interstitial grains.




1:Titanite
2:Titanite
3:Titanite

Figure 1-1.42: Sample 9956a site 31 (SEM). This site consists of ragged titanite (1-3) that appears to be subequant with minor interstital parts. The grain has some voids and is possibly filling a void.




1:Limonite
2:Rutile
3:Titanite
4:Titanite
5:Rutile
6:Titanite
7:Rutile

Figure 1-1.43: Sample 9956a site 32 (SEM). This site consists of equant titanite (3-4,6) overgrowths on rutile (2,5,7). Late Fe-oxides/hydroxides overgrow titanite and rutile. Tabular habit may suggest ilmentite origin.

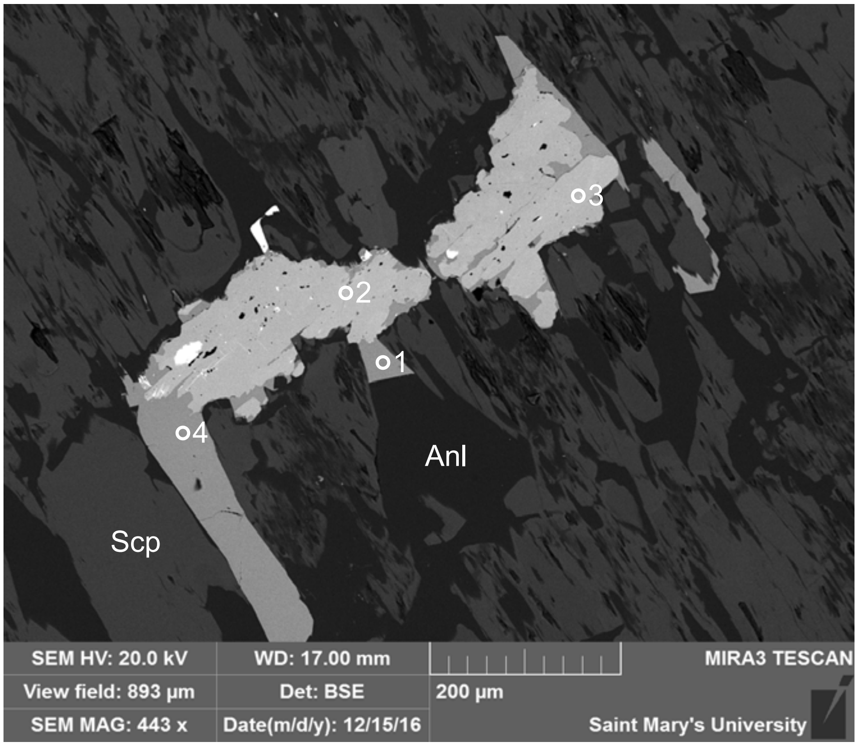



Figure 1-1.44: Sample 9956a site 33 (SEM). Subequant titanite (1) overgrows large anhedral rutile (2-3). The titanite (1,4) appears to be interstitial.

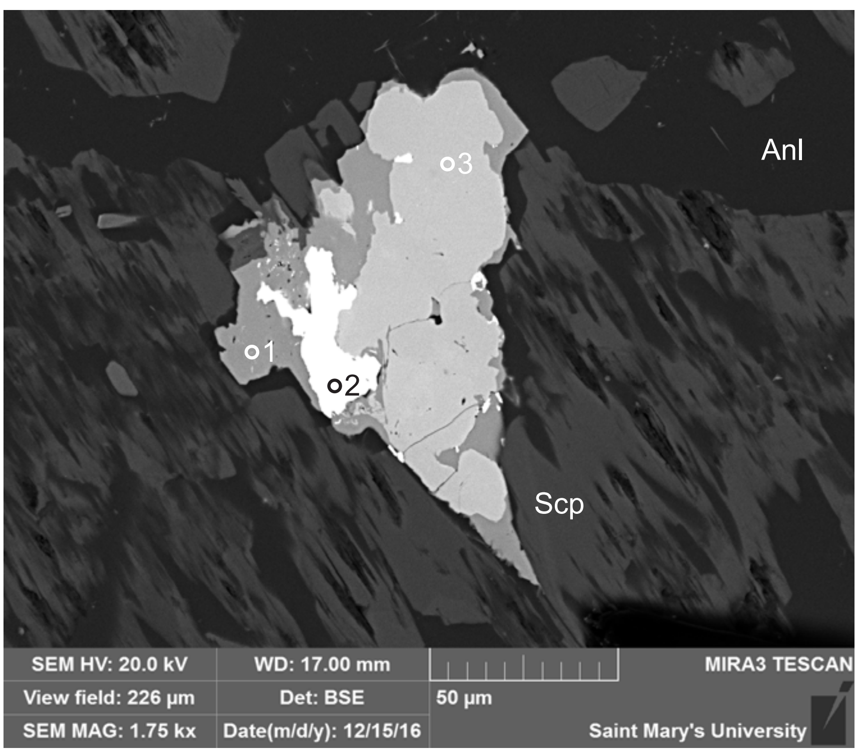



Figure 1-1.45: Sample 9956a site 34 (SEM). Equant titanite (1) overgrows small anhedral rutile (3), which is all overgrown by Fe-oxides/hydroxides (3).

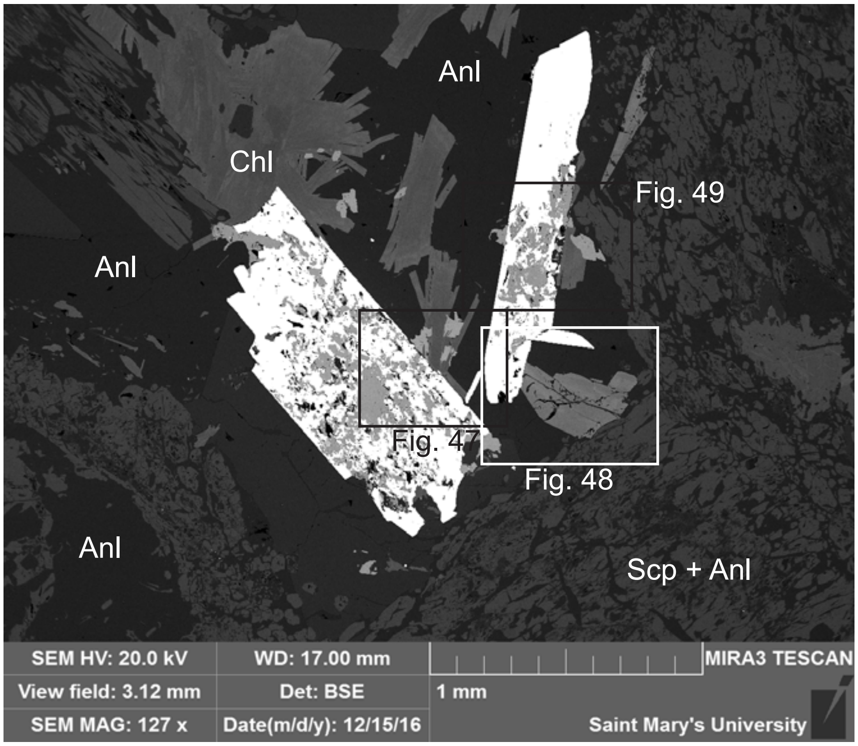
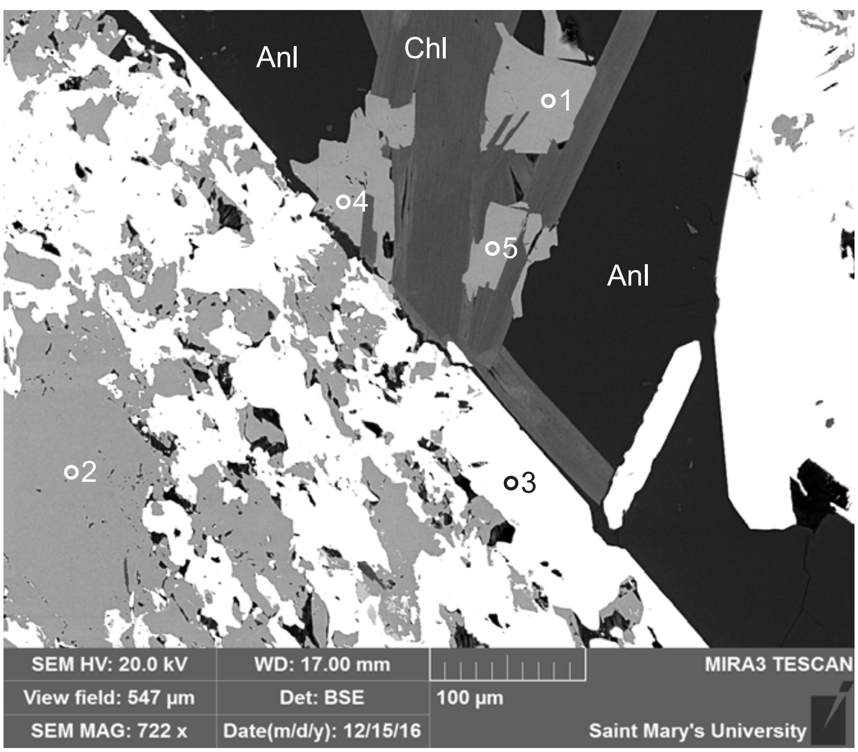



Figure 1-1.46: Sample 9956a (SEM).




1:Titanite
2:Titanite
3:Limonite
4:Titanite
5:Titanite

Figure 1-1.47: Sample 9956a site 35 (SEM). This site consists of two different generations of titanite. Titanite (1,4-5) appear as ?replacive-interstitial grains that postdate chlorite, and titanite (2) which probably is an equant overgrowth on rutile. This is all overgrown by Fe-oxides/hydroxides.

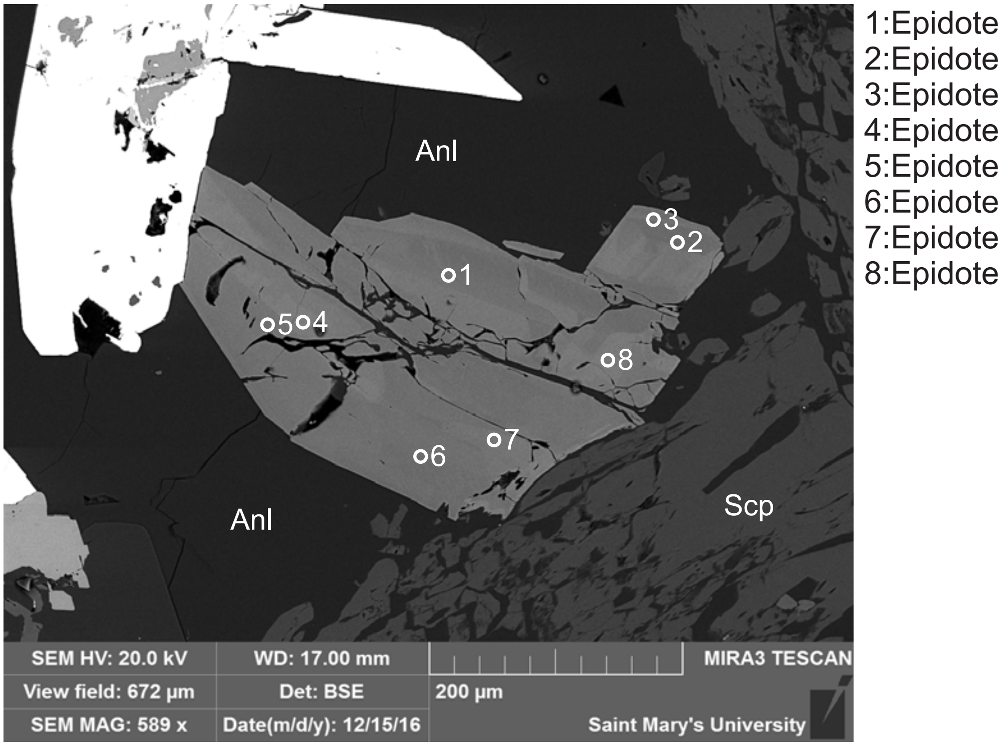



Figure 1-1.48: Sample 9956a site 36 (SEM). This site consists of zoned epidote (1-8).

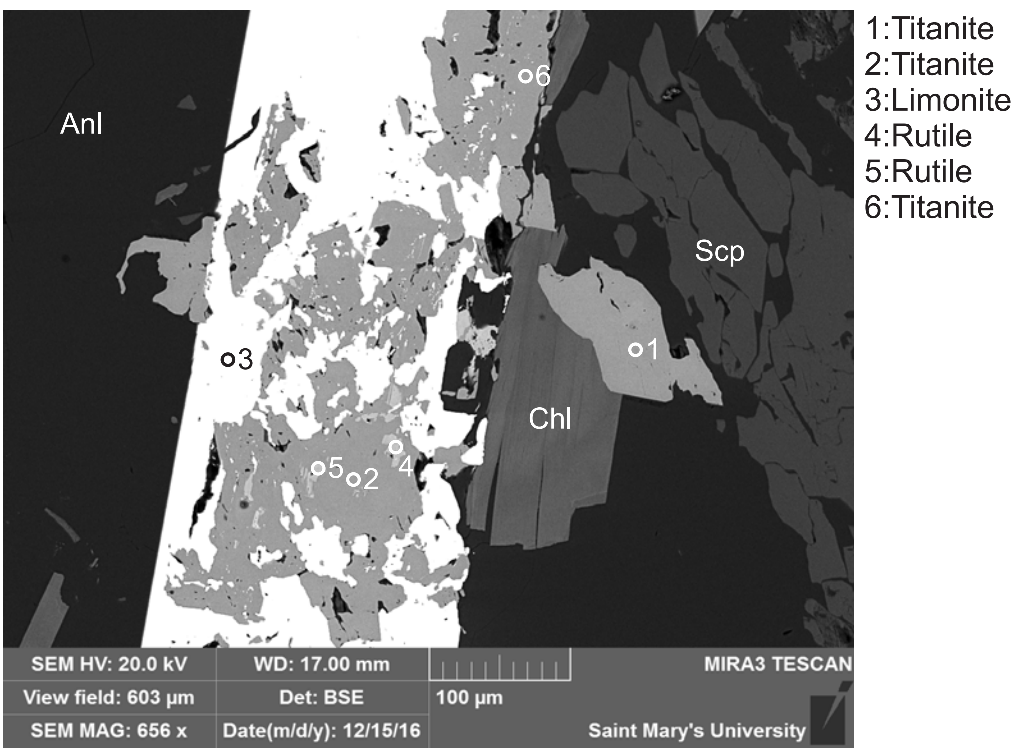
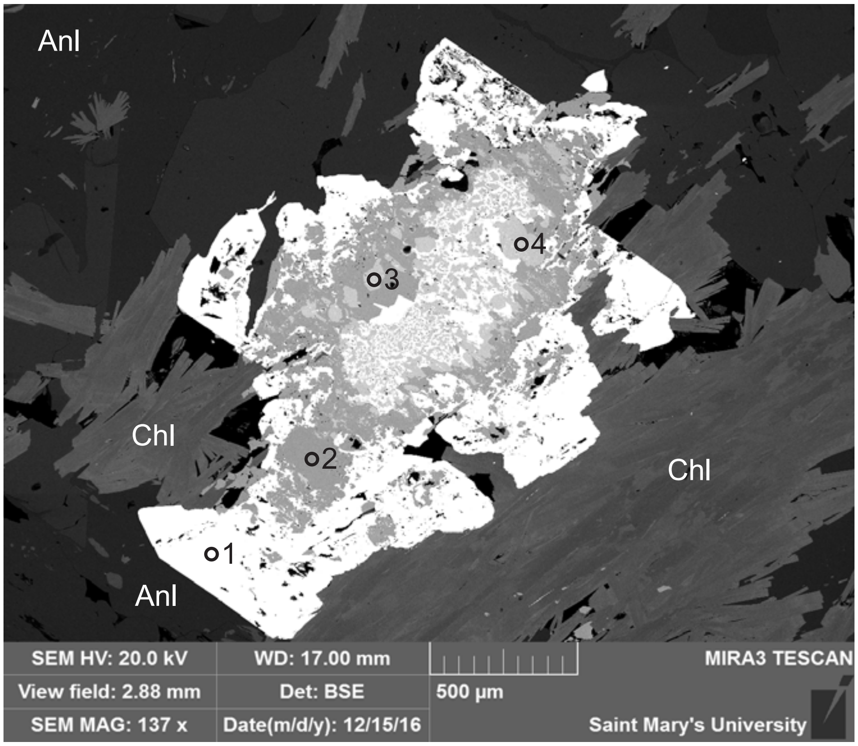



Figure 1-1.49: Sample 9956a site 37 (SEM). This site consists of ?replacive-interstitial titanite (1,6) and equant titanite (2) which overgrows rutile (4-5) and is all overgrown by Fe-oxides/hydroxides (3).




1:Limonite
2:Titanite
3:Rutile
4:Rutile + FeO

Figure 1-1.50: Sample 9956a site 38 (SEM). This site consists of equant titanite (2) which overgrows rutile (3,4) and is overgrown by Fe-oxides/hydroxides (1).

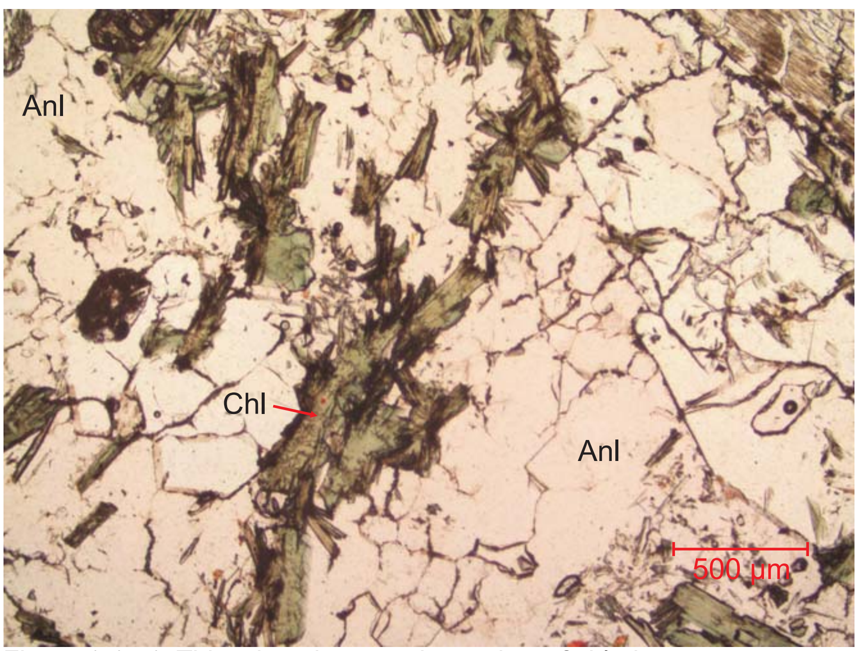



Figure 1-1.51: This microphotograph consists of chlorite veinlets/stringers cross-cutting analcime. 4x PPL.

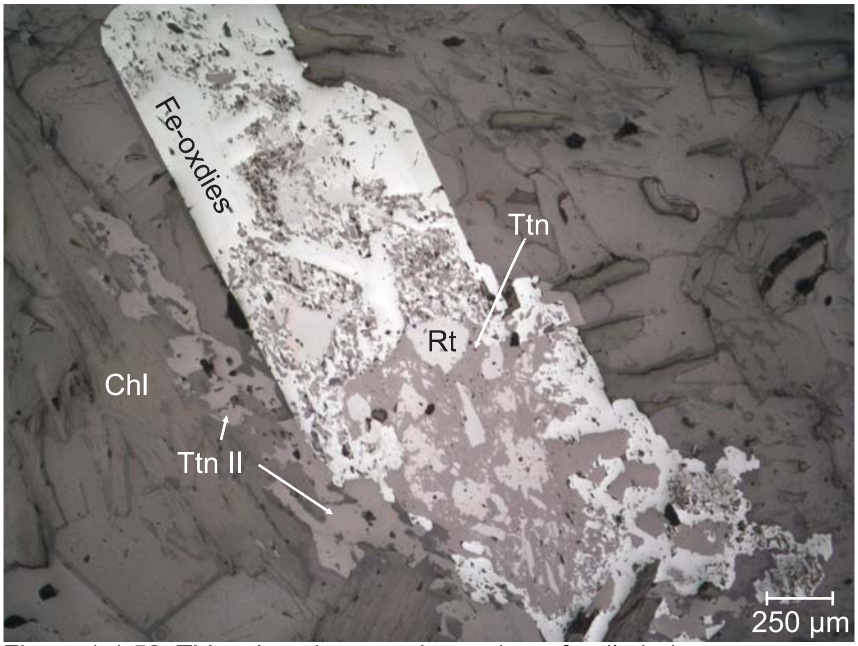


Figure 1-1.52: This microphotograph consists of rutile being overgrown by titanite and Fe-oxides. Secondary titanite (Ttn II) appears to slightly cross-cut the large grain. 4x RF.

Table 1-1.1: EDS analyses from sample 9956a. 

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 1 | 1 | Rt | | 99.09 | | | | | | | | | | | | | | 0.91 | | | | 100 | 106 | |
| 9956a | 1 | 2 | Ti-Mag | | 5.76 | | 93.10 | | | | | | | | | | | 0.50 | 0.63 | | | | 100 | 91 | |
| 9956a | 1 | 3 | Rt | | 99.50 | | 0.50 | | | | | | | | | | | | | | | | 100 | 105 | |
| 9956a | 1 | 4 | Anl | 60.08 | | 20.46 | | | | | 10.47 | | | | | | | | | | | | 91 | 96 | |
| 9956a | 1 | 5 | Scp | 57.55 | 0.25 | 22.07 | | | | 7.07 | 9.67 | 0.25 | | | | 3.13 | | | | | | | 100 | 113 | |
| 9956a | 2 | 1 | Rt | | 99.23 | | 0.33 | | | | | | | | | | | | 0.44 | | | | 100 | 106 | |
| 9956a | 2 | 2 | Ttn | 33.24 | 35.17 | 2.94 | 0.72 | | | 27.93 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 2 | 3 | Ttn | 33.28 | 35.10 | 2.70 | 0.82 | | | 28.10 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 2 | 4 | Rt | | 98.85 | | | | | 0.61 | | | | | | | | | 0.54 | | | | 100 | 107 | |
| 9956a | 2 | 5 | Rt | | 99.40 | | | | | | | | | | | | | | 0.60 | | | | 100 | 106 | |
| 9956a | 2 | 6 | Ttn | 33.35 | 34.87 | 2.92 | 0.65 | | | 28.22 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 2 | 7 | Ab | 68.98 | | 19.29 | | | | 0.69 | 11.04 | | | | | | | | | | | | 100 | 116 | |
| 9956a | 2 | 8 | Anl | 59.88 | 0.34 | 20.37 | | | | | 10.41 | | | | | | | | | | | | 91 | 95 | |
| 9956a | 2 | 9 | Scp | 57.09 | | 22.27 | | | | 7.06 | 9.90 | 0.31 | | | | 3.36 | | | | | | | 100 | 113 | |
| 9956a | 3 | 1 | Ttn | 32.26 | 37.38 | 2.99 | 0.25 | | | 27.13 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 3 | 2 | Rt + Ilm | | 86.08 | | 13.25 | | | | | | | | | | | | 0.67 | | | | 100 | 105 | |
| 9956a | 3 | 3 | Rt + Ilm | | 93.14 | | 6.26 | | | | | | | | | | | | 0.60 | | | | 100 | 106 | |
| 9956a | 3 | 4 | Rt | | 99.41 | | | | | | | | | | | | | | 0.59 | | | | 100 | 106 | |
| 9956a | 4 | 1 | Gth + Rt | | 2.16 | | 97.84 | | | | | | | | | | | | | | | | 100 | 90 | 79 |
| 9956a | 4 | 2 | Rt | | 99.05 | | 0.31 | | | 0.22 | | | | | | | | | 0.42 | | | | 100 | 107 | |
| 9956a | 4 | 3 | Ttn | 33.13 | 34.84 | 2.74 | 1.24 | | | 28.05 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 4 | 4 | Ttn | 33.41 | 34.75 | 2.52 | 1.28 | | | 28.04 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 4 | 5 | Ti-Mag | 0.56 | 7.14 | | 90.69 | | | 0.81 | | | | | | | | 0.47 | 0.33 | | | | 100 | 95 | 82 |
| 9956a | 4 | 6 | Rt | | 98.95 | | 0.29 | | | 0.29 | | | | | | | | | 0.47 | | | | 100 | 107 | |
| 9956a | 4 | 7 | Anl | 59.72 | 0.23 | 20.72 | | | | | 10.33 | | | | | | | | | | | | 91 | 93 | |
| 9956a | 4 | 8 | Scp | 56.92 | | 22.46 | | | | 7.45 | 9.74 | 0.17 | | | | 3.26 | | | | | | | 100 | 114 | |
| 9956a | 5 | 1 | Ttn | 33.70 | 34.66 | 2.51 | 0.86 | | | 27.63 | | | | | | | | 0.65 | | | | | 100 | 108 | |
| 9956a | 6 | 1 | Rt | 0.44 | 99.56 | | | | | | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 6 | 2 | Rt + FeO | 0.52 | 97.59 | | 1.89 | | | | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 6 | 3 | Rt + FeO | 0.46 | 93.48 | | 5.64 | | | | | | | | | | | | 0.42 | | | | 100 | 106 | |
| 9956a | 6 | 4 | Rt | 0.62 | 98.97 | | | | | | | | | | | | | | 0.41 | | | | 100 | 107 | |
| 9956a | 7 | 1 | Ttn | 33.53 | 35.10 | 2.22 | 1.21 | | | 27.94 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 7 | 2 | Ttn | 33.69 | 35.03 | 2.47 | 1.09 | | | 27.71 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 8 | 1 | Ttn | 33.65 | 33.09 | 3.57 | 1.39 | | | 28.30 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 8 | 2 | Rt | 0.77 | 98.62 | | | | | 0.23 | | | | | | | | | 0.39 | | | | 100 | 106 | |
| 9956a | 8 | 3 | Ttn | 33.59 | 35.49 | 2.25 | 0.80 | | | 27.88 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 9 | 1 | Rt | 0.49 | 98.70 | | | | | 0.31 | | | | | | | | | 0.49 | | | | 100 | 108 | |
| 9956a | 10 | 1 | Py | 0.25 | | | 28.23 | | | | | | | 71.52 | | | | | | | | | 100 | 228 | |

Table 1-1.1: EDS analyses from sample 9956a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 10 | 2 | Rt | 0.42 | 98.53 | | 0.51 | | | | | | | | | | | | 0.54 | | | | 100 | 108 | |
| 9956a | 10 | 3 | Ttn | 33.29 | 35.89 | 2.57 | 0.51 | | | 27.74 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 10 | 4 | Lm | 0.69 | 5.66 | | 93.65 | | | | | | | | | | | | | | | | 100 | 93 | 80 |
| 9956a | 10 | 5 | Mag | 4.24 | | 0.47 | 70.84 | | | 0.44 | | | | 23.74 | | 0.28 | | | | | | | 100 | 105 | 91 |
| 9956a | 10 | 6 | Lm | 5.02 | 0.52 | | 81.78 | | 0.56 | 0.72 | | | | 11.04 | | 0.36 | | | | | | | 100 | 92 | 80 |
| 9956a | 11 | 1 | Rt | 0.42 | 99.15 | | | | | | | | | | | | | | 0.42 | | | | 100 | 106 | |
| 9956a | 11 | 2 | Rt | 0.58 | 98.61 | | | | | 0.30 | | | | | | | | | 0.51 | | | | 100 | 106 | |
| 9956a | 11 | 3 | Rt | 1.40 | 97.54 | | 0.27 | | | 0.80 | | | | | | | | | | | | | 100 | 106 | |
| 9956a | 11 | 4 | Rt | 0.53 | 98.79 | | 0.26 | | | | | | | | | | | | 0.42 | | | | 100 | 106 | |
| 9956a | 12 | 1 | Rt | | 99.34 | | 0.31 | | | | | | | | | | | | 0.36 | | | | 100 | 107 | |
| 9956a | 12 | 2 | Lm | | 2.20 | | 97.80 | | | | | | | | | | | | | | | | 100 | 90 | 78 |
| 9956a | 12 | 3 | Ttn | 32.93 | 38.21 | 0.98 | | | | 27.89 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 12 | 4 | Rt | | 98.97 | | 0.24 | | | | | | | | | | | | 0.78 | | | | 100 | 110 | |
| 9956a | 12 | 5 | Ttn | 32.66 | 37.74 | 1.31 | 0.33 | | | 27.96 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 12 | 6 | Ti-Mag | | 10.06 | | 88.85 | | | 0.30 | | | | | | 0.27 | | | 0.51 | | | | 100 | 93 | |
| 9956a | 13 | 1 | Ttn | 32.98 | 36.09 | 1.82 | 0.99 | | | 28.13 | | | | | | | | | | | | | 100 | 112 | |
| 9956a | 13 | 2 | Ttn | 33.30 | 36.02 | 1.94 | 0.79 | | | 27.95 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 14 | 1 | Lm | | 1.28 | | 98.29 | | | | | | | | | | | 0.43 | | | | | 100 | 90 | 78 |
| 9956a | 14 | 2 | Rt | | 97.91 | | | | | 1.31 | | | | | | | | | 0.78 | | | | 100 | 110 | |
| 9956a | 14 | 3 | Ttn | 33.02 | 35.51 | 2.23 | 1.05 | | | 28.18 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 14 | 4 | Rt | 0.39 | 97.62 | | | | | 0.76 | | | | | | | | | 1.23 | | | | 100 | 105 | |
| 9956a | 14 | 5 | Ttn | 32.95 | 35.48 | 2.35 | 1.06 | | | 28.17 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 14 | 6 | Rt | | 96.41 | | 2.01 | | | 0.64 | | | | | | | | | 0.94 | | | | 100 | 109 | |
| 9956a | 14 | 7 | Ttn | 32.90 | 37.68 | 0.99 | 0.37 | | | 28.06 | | | | | | | | | | | | | 100 | 112 | |
| 9956a | 15 | 1 | Ttn | 32.86 | 38.42 | 0.59 | 0.28 | | | 27.85 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 15 | 2 | Rt | | 97.98 | | 1.73 | | | 0.30 | | | | | | | | | | | | | 100 | 104 | |
| 9956a | 15 | 3 | Ttn | 32.76 | 38.24 | 0.74 | 0.34 | | | 27.92 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 15 | 4 | Ttn | 32.96 | 38.15 | 0.64 | 0.30 | | | 27.95 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 15 | 5 | Ttn | 32.97 | 36.64 | 1.58 | 0.84 | | | 27.97 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 16 | 1 | Rt | 0.83 | 98.00 | | 0.58 | | | 0.32 | | | | | | | 0.27 | | | | | | 100 | 107 | |
| 9956a | 16 | 2 | Rt | | 99.40 | | 0.34 | | | 0.25 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 16 | 3 | Rt | 0.52 | 98.72 | | 0.36 | | | 0.40 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 16 | 4 | Ttn | 33.27 | 30.78 | 5.89 | 0.44 | | | 28.06 | | | | | 1.56 | | | | | | | | 100 | 112 | |
| 9956a | 16 | 5 | Gth | | 8.64 | | 91.34 | | | | | | | | | | | | | 0.01 | | | 100 | 94 | 82 |
| 9956a | 16 | 6 | Ttn | 32.84 | 36.65 | 2.41 | 0.33 | | | 27.77 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 17 | 1 | Rt | 0.42 | 98.83 | | 0.36 | | | 0.38 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 17 | 2 | Ttn | 33.18 | 31.26 | 4.96 | 0.85 | | | 27.65 | | | | | 2.10 | | | | | | | | 100 | 112 | |
| 9956a | 17 | 3 | Mix? | 16.47 | 45.83 | | | | | | | | | | | | | | | | 36.15 | 1.55 | 100 | 113 | |

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 17 | 4 | Ti-Mag | 1.86 | 11.19 | 1.07 | 85.30 | | | 0.36 | | | | | | | | | | 0.22 | | | 100 | 96 | |
| 9956a | 17 | 5 | "Ilm" | 2.25 | 34.08 | 0.61 | 61.40 | | | 0.84 | | | | | | | | | 0.43 | 0.37 | | | 100 | 104 | |
| 9956a | 18 | 1 | Rt | | 98.97 | | | | | 0.29 | | | | | | | | | 0.74 | | | | 100 | 106 | |
| 9956a | 18 | 2 | Ttn | 33.40 | 35.60 | 2.11 | 0.71 | | | 28.18 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 18 | 3 | Ttn | 33.05 | 32.39 | 4.56 | | | | 28.03 | | | | | 1.97 | | | | | | | | 100 | 111 | |
| 9956a | 18 | 4 | Rt | 1.61 | 95.73 | | | | | 2.66 | | | | | | | | | | | | | 100 | 106 | |
| 9956a | 19 | 1 | Ttn | 32.70 | 35.08 | 2.27 | 1.31 | | | 27.97 | | | 0.55 | | | | | | | 0.13 | | | 100 | 109 | |
| 9956a | 19 | 2 | Rt | | 99.32 | | 0.29 | | | | | | | | | | | | 0.39 | | | | 100 | 107 | |
| 9956a | 20 | 1 | Ttn | 33.45 | 34.30 | 2.91 | 1.25 | | | 28.09 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 20 | 2 | Rt | | 99.71 | | 0.29 | | | | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 20 | 3 | Rt | | 99.09 | | | | | 0.43 | | | | | | | | | 0.37 | 0.11 | | | 100 | 107 | |
| 9956a | 20 | 4 | Ttn | 33.18 | 35.24 | 2.16 | 1.04 | | | 28.38 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 21 | 1 | Rt | | 99.13 | | 0.35 | | | | | | | | | | | | 0.52 | | | | 100 | 107 | |
| 9956a | 21 | 2 | Ttn | 33.08 | 35.25 | 2.07 | 1.41 | | | 28.18 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 21 | 3 | Ti-Mag | | 3.71 | | 95.55 | | | | | | | | | | | 0.43 | 0.32 | | | | 100 | 91 | |
| 9956a | 21 | 4 | Ttn | 32.99 | 35.67 | 2.16 | 1.14 | | | 28.05 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 21 | 5 | Rt | | 97.91 | | 0.50 | | | | | | | | | | | | 1.59 | | | | 100 | 109 | |
| 9956a | 22 | 1 | Ttn | 32.84 | 37.75 | 1.08 | 0.34 | | | 27.99 | | | | | | | | | | | | | 100 | 106 | |
| 9956a | 22 | 2 | Ttn | 33.01 | 38.12 | 0.67 | 0.30 | | | 27.90 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 22 | 3 | Ttn | 32.93 | 38.03 | 0.81 | 0.29 | | | 27.94 | | | | | | | | | | | | | 100 | 112 | |
| 9956a | 22 | 4 | Ttn | 32.70 | 38.24 | 0.83 | 0.33 | | | 27.91 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 22 | 5 | Ttn | 32.82 | 37.73 | 0.88 | 0.69 | | | 27.89 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 23 | 1 | Rt | 0.37 | 99.03 | | 0.29 | | | 0.31 | | | | | | | | | | | | | 100 | 104 | |
| 9956a | 23 | 2 | Ttn | 33.53 | 34.17 | 3.11 | 0.93 | | | 28.26 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 23 | 3 | Ttn | 33.68 | 34.33 | 3.02 | 0.84 | | | 28.14 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 23 | 4 | Rt | 0.44 | 98.95 | | 0.34 | | | 0.26 | | | | | | | | | | | | | 100 | 106 | |
| 9956a | 23 | 5 | Ttn | 33.14 | 36.15 | 2.28 | 0.49 | | | 27.94 | | | | | | | | | | | | | 100 | 112 | |
| 9956a | 23 | 6 | Rt | 0.59 | 98.19 | | 0.32 | | | 0.53 | | | | | | | | | 0.36 | | | | 100 | 108 | |
| 9956a | 24 | 1 | Ttn | 33.05 | 31.74 | 5.33 | | | | 27.88 | | | | | 2.00 | | | | | | | | 100 | 113 | |
| 9956a | 24 | 2 | Rt | | 99.64 | | 0.36 | | | | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 25 | 1 | Ttn | 33.22 | 34.59 | 3.03 | 1.34 | | | 27.82 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 25 | 2 | Rt | | 99.32 | | 0.29 | | | | | | | | | | | | 0.39 | | | | 100 | 109 | |
| 9956a | 26 | 1 | Lm | | 2.83 | | 96.68 | | | | | | | | | | | 0.49 | | | | | 100 | 92 | 80 |
| 9956a | 26 | 2 | Ttn | 33.00 | 36.38 | 1.53 | 0.69 | | | 27.75 | | | | | | | | 0.66 | | | | | 100 | 111 | |
| 9956a | 26 | 3 | "Ilm" | 0.55 | 72.16 | | 26.13 | | | 1.16 | | | | | | | | | | | | | 100 | 102 | |
| 9956a | 26 | 4 | Rt | 1.01 | 97.17 | | 0.33 | | | 1.49 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 26 | 5 | Ttn | 32.81 | 37.72 | 1.05 | 0.40 | | | 28.02 | | | | | | | | | | | | | 100 | 110 | |
| 9956a | 27 | 1 | Ttn | 32.79 | 35.24 | 1.98 | 0.82 | | | 27.76 | | | | | | | | | | 1.40 | | | 100 | 114 | |

Table 1-1.1: EDS analyses from sample 9956a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 27 | 2 | Ttn | 33.08 | 33.86 | 2.79 | 1.09 | | | 27.93 | | | | | | | | | | 1.26 | | | 100 | 110 | |
| 9956a | 28 | 1 | Ttn | 32.98 | 34.67 | 2.62 | 0.68 | | | 27.88 | | | | | | | | | | 1.18 | | | 100 | 113 | |
| 9956a | 28 | 2 | Rt | | 98.27 | | 0.30 | | | 0.22 | | | | | | | | | | 1.21 | | | 100 | 108 | |
| 9956a | 28 | 3 | Rt | | 97.90 | | 0.29 | | | | | | | | | | | | 0.41 | 1.40 | | | 100 | 109 | |
| 9956a | 28 | 4 | Ttn | 32.64 | 34.19 | 3.05 | 0.74 | | | 28.15 | | | | | | | | | | 1.23 | | | 100 | 111 | |
| 9956a | 29 | 1 | Ttn | 33.12 | 34.94 | 2.10 | 0.86 | | | 27.80 | | | | | | | | | | 1.17 | | | 100 | 110 | |
| 9956a | 29 | 2 | Rt | 0.45 | 97.01 | | 0.30 | | | 0.33 | | | | | | | | | 0.42 | 1.49 | | | 100 | 105 | |
| 9956a | 29 | 3 | Ttn | 32.94 | 36.77 | 1.20 | 0.28 | | | 27.58 | | | | | | | | | | 1.23 | | | 100 | 109 | |
| 9956a | 29 | 4 | Ttn | 32.99 | 33.68 | 2.97 | 0.83 | | | 27.49 | | | | | 0.91 | | | | | 1.13 | | | 100 | 107 | |
| 9956a | 29 | 5 | Ttn | 33.19 | 35.15 | 2.33 | 0.48 | | | 27.66 | | | | | | | | | | 1.20 | | | 100 | 106 | |
| 9956a | 29 | 6 | Ttn | 32.96 | 32.90 | 3.43 | 1.32 | | | 28.08 | | | | | | | | | | 1.30 | | | 100 | 110 | |
| 9956a | 29 | 7 | Rt | 0.67 | 96.60 | | | | | 0.49 | | | | | | | | | 0.44 | 1.80 | | | 100 | 109 | |
| 9956a | 29 | 8 | Kfs | 65.60 | | 17.77 | | | | | | 15.75 | | | | | | | | 0.88 | | | 100 | 115 | |
| 9956a | 29 | 9 | Scp | 58.50 | | 20.48 | | | | 3.91 | 11.86 | 0.21 | | | | 4.17 | | | | 0.86 | | | 100 | 118 | |
| 9956a | 29 | 10 | Anl | 58.13 | | 19.96 | | | | | 12.07 | | | | | | | | | 0.85 | | | 91 | 103 | |
| 9956a | 29 | 11 | Ttn + | 40.39 | 23.41 | 8.72 | 0.41 | | | 20.11 | 5.91 | | | | | | | | | 1.04 | | | 100 | 111 | |
| 9956a | 29 | 12 | Ttn | 33.36 | 34.57 | 2.73 | 0.46 | | | 27.65 | | | | | | | | | | 1.23 | | | 100 | 107 | |
| 9956a | 29 | 13 | Rt | 0.57 | 97.25 | | 0.26 | | | | | | | | | | | | 0.46 | 1.46 | | | 100 | 105 | |
| 9956a | 29 | 14 | Rt | 0.58 | 97.53 | | | | | | | | | | | | | | 0.47 | 1.42 | | | 100 | 103 | |
| 9956a | 29 | 15 | Rt | 1.16 | 96.28 | 0.35 | | | | 0.80 | | | | | | | | | | 1.41 | | | 100 | 104 | |
| 9956a | 30 | 1 | Ttn | 33.33 | 34.08 | 3.04 | 0.86 | | | 28.23 | | | | | | | | | | 0.45 | | | 100 | 108 | |
| 9956a | 30 | 2 | Ttn | 33.01 | 34.69 | 2.97 | 0.66 | | | 28.00 | | | | | | | | | | 0.66 | | | 100 | 110 | |
| 9956a | 30 | 3 | Rt | | 98.66 | | 0.34 | | | | | | | | | | | | 0.39 | 0.62 | | | 100 | 107 | |
| 9956a | 31 | 1 | Ttn | 32.77 | 37.39 | 1.12 | 0.64 | | | 27.81 | | | | | | | | | | 0.28 | | | 100 | 107 | |
| 9956a | 31 | 2 | Ttn | 32.81 | 36.76 | 1.37 | 0.76 | | | 27.91 | | | | | | | | | | 0.38 | | | 100 | 107 | |
| 9956a | 31 | 3 | Ttn | 32.63 | 36.66 | 1.52 | 0.79 | | | 27.95 | | | | | | | | | | 0.46 | | | 100 | 109 | |
| 9956a | 32 | 1 | Lm | | 1.79 | | 97.58 | | | | | | | | | | | | 0.62 | | | | 100 | 85 | 74 |
| 9956a | 32 | 2 | Rt | | 99.16 | | 0.35 | | | | | | | | | | | | 0.49 | | | | 100 | 103 | |
| 9956a | 32 | 3 | Ttn | 32.93 | 37.97 | 0.87 | 0.43 | | | 27.80 | | | | | | | | | | | | | 100 | 105 | |
| 9956a | 32 | 4 | Ttn | 32.86 | 37.54 | 1.41 | 0.32 | | | 27.87 | | | | | | | | | | | | | 100 | 104 | |
| 9956a | 32 | 5 | Rt | | 99.28 | | 0.35 | | | | | | | | | | | | 0.37 | | | | 100 | 101 | |
| 9956a | 32 | 6 | Ttn | 32.67 | 38.06 | 0.58 | 0.88 | | | 27.82 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 32 | 7 | Rt | | 98.80 | | 0.26 | | | | | | | | | | | | 0.94 | | | | 100 | 104 | |
| 9956a | 33 | 1 | Ttn | 33.49 | 34.30 | 3.01 | 1.03 | | | 28.17 | | | | | | | | | | | | | 100 | 104 | |
| 9956a | 33 | 2 | Rt | | 99.24 | | 0.30 | | | | | | | | | | | | 0.46 | | | | 100 | 102 | |
| 9956a | 33 | 3 | Rt | | 99.08 | | 0.27 | | | | | | | | | 0.22 | | | 0.43 | | | | 100 | 101 | |
| 9956a | 33 | 4 | Ttn | 33.37 | 35.70 | 2.00 | 0.82 | | | 28.12 | | | | | | | | | | | | | 100 | 104 | |
| 9956a | 34 | 1 | Ttn | 33.00 | 36.36 | 1.82 | 0.92 | | | 27.90 | | | | | | | | | | | | | 100 | 111 | |

Table 1-1.1: EDS analyses from sample 9956a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 34 | 2 | Lm | 0.58 | 0.90 | | 98.52 | | | | | | | | | | | | | | | | 100 | 92 | 80 |
| 9956a | 34 | 3 | Rt | | 100.00 | | | | | | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 35 | 1 | Ttn | 33.00 | 37.79 | 0.88 | 0.49 | | | 27.84 | | | | | | | | | | | | | 100 | 107 | |
| 9956a | 35 | 2 | Ttn | 33.28 | 35.60 | 2.19 | 1.00 | | | 27.94 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 35 | 3 | Lm | | 2.83 | | 97.17 | | | | | | | | | | | | | | | | 100 | 92 | 80 |
| 9956a | 35 | 4 | Ttn | 32.90 | 36.52 | 1.37 | 0.84 | | | 27.71 | | | | | | | | 0.66 | | | | | 100 | 107 | |
| 9956a | 35 | 5 | Ttn | 32.89 | 37.90 | 0.82 | 0.75 | | | 27.64 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 36 | 1 | Ep | 40.01 | | 24.61 | 9.89 | | | 22.49 | | | | | | | | | | | | | 97 | 107 | |
| 9956a | 36 | 2 | Ep | 40.03 | | 26.03 | 8.04 | 0.50 | | 22.39 | | | | | | | | | | | | | 97 | 107 | |
| 9956a | 36 | 3 | Ep | 40.25 | | 24.90 | 9.21 | 0.74 | | 21.91 | | | | | | | | | | | | | 97 | 106 | |
| 9956a | 36 | 4 | Ep | 40.00 | | 21.48 | 13.15 | | | 22.37 | | | | | | | | | | | | | 97 | 107 | |
| 9956a | 36 | 5 | Ep | 40.14 | | 25.89 | 8.59 | | | 22.38 | | | | | | | | | | | | | 97 | 106 | |
| 9956a | 36 | 6 | Ep | 40.16 | | 26.16 | 7.86 | 0.25 | | 22.57 | | | | | | | | | | | | | 97 | 109 | |
| 9956a | 36 | 7 | Ep | 39.96 | | 23.02 | 11.17 | | | 22.85 | | | | | | | | | | | | | 97 | 108 | |
| 9956a | 36 | 8 | Ep | 40.06 | | 21.57 | 13.10 | | | 22.27 | | | | | | | | | | | | | 97 | 107 | |
| 9956a | 37 | 1 | Ttn | 33.03 | 36.64 | 1.34 | 0.54 | | | 27.72 | | | | | | | | 0.74 | | | | | 100 | 108 | |
| 9956a | 37 | 2 | Ttn | 33.24 | 35.02 | 2.54 | 1.10 | | | 28.10 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 37 | 3 | Lm | | 1.45 | | 98.10 | | | | | | | | | | | | 0.45 | | | | 100 | 91 | 79 |
| 9956a | 37 | 4 | Rt | 0.94 | 96.19 | | 0.74 | | | 2.13 | | | | | | | | | | | | | 100 | 108 | |
| 9956a | 37 | 5 | Rt | 3.37 | 91.58 | | 0.51 | | | 4.54 | | | | | | | | | | | | | 100 | 109 | |
| 9956a | 37 | 6 | Ttn | 32.83 | 36.75 | 1.62 | 0.76 | | | 28.03 | | | | | | | | | | | | | 100 | 107 | |

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | Sc2O3 | V2O5 | Cr2O3 | ZnO | ZrO2 | HfO2 | Total | Acual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 38 | 1 | Lm | | 6.66 | | 92.84 | | | | | | | | | | | 0.51 | | | | | 100 | 91 | 79 |
| 9956a | 38 | 2 | Ttn | 33.16 | 35.09 | 2.47 | 1.00 | | | 28.28 | | | | | | | | | | | | | 100 | 111 | |
| 9956a | 38 | 3 | Rt | | 99.25 | | | | | | | | | | | | | | 0.75 | | | | 100 | 107 | |
| 9956a | 38 | 4 | Rt + FeO | | 93.41 | | 6.08 | | | | | | | | | | | | 0.52 | | | | 100 | 104 | |

Oxide total

Mag = >90%

Hem = 85-89%

Gth = 80-84%

Lm = <80%

Average scapolite total = 115

Oxide total = (wt % oxide / Avg. Scp total) * 100

Notes

1 + = indicates other minerals present

2 Rt + FeO = Rt that contains more than 2wt% FeO

3 "Ilm" = altered ilmenite

# Appendix 1-2: SEM-BSE images and EDS mineral analyses for sample 9956b.

**Sample 9956b**

**Host: Scapolitized analcime syenite**

Magmatic minerals: Analcime, albite, K-feldspar, quartz, rutile, titanite

Secondary Minerals: Analcime, calcite, Fe-oxides/hydroxides, rutile, scapolite, titanite, zircon

**Notes:**

1. Patches of rutile crystals (Figures 1-2.5,1-2.12).

2. Dark brown patches in light brown patches of rutile (Figure 1-2.20).

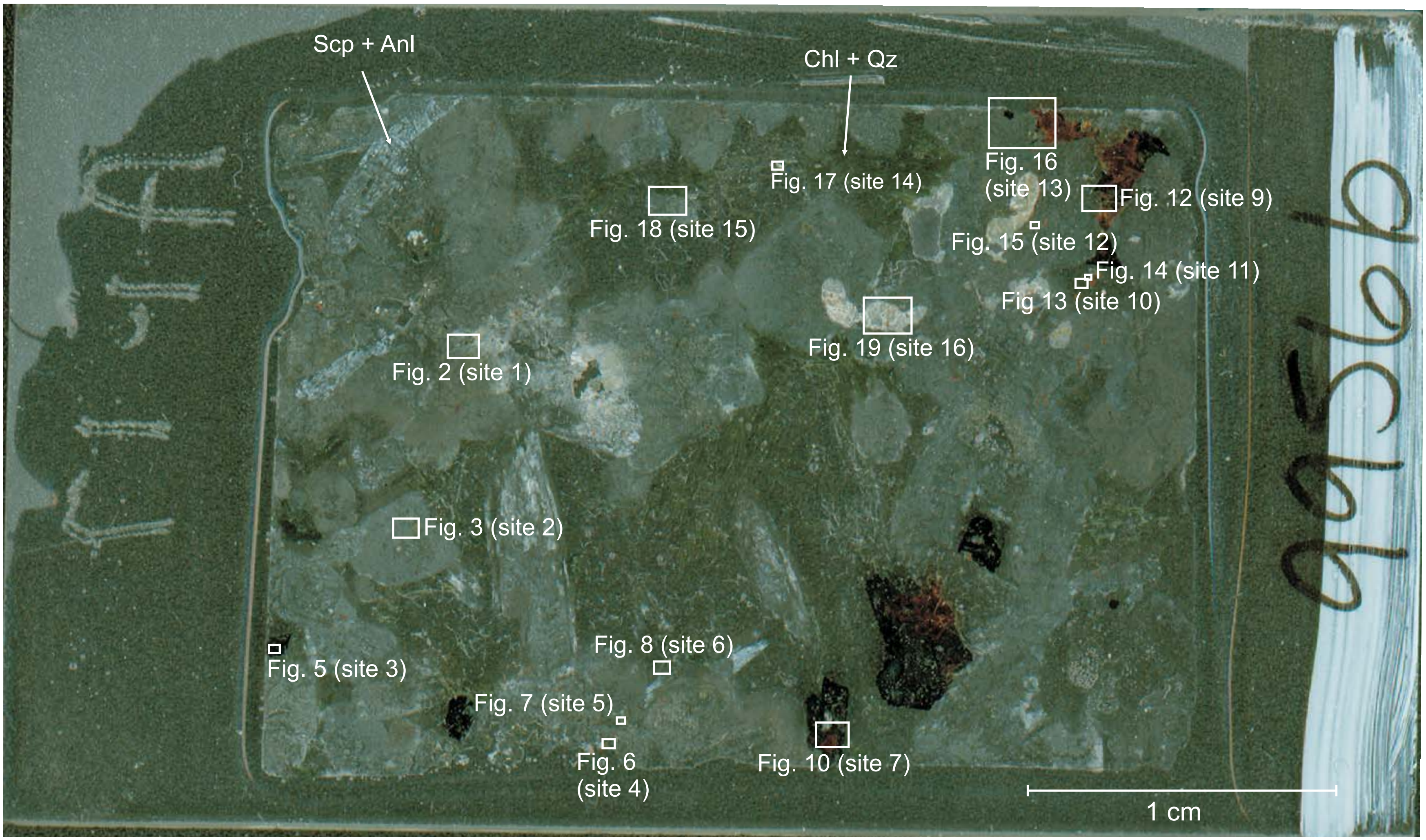
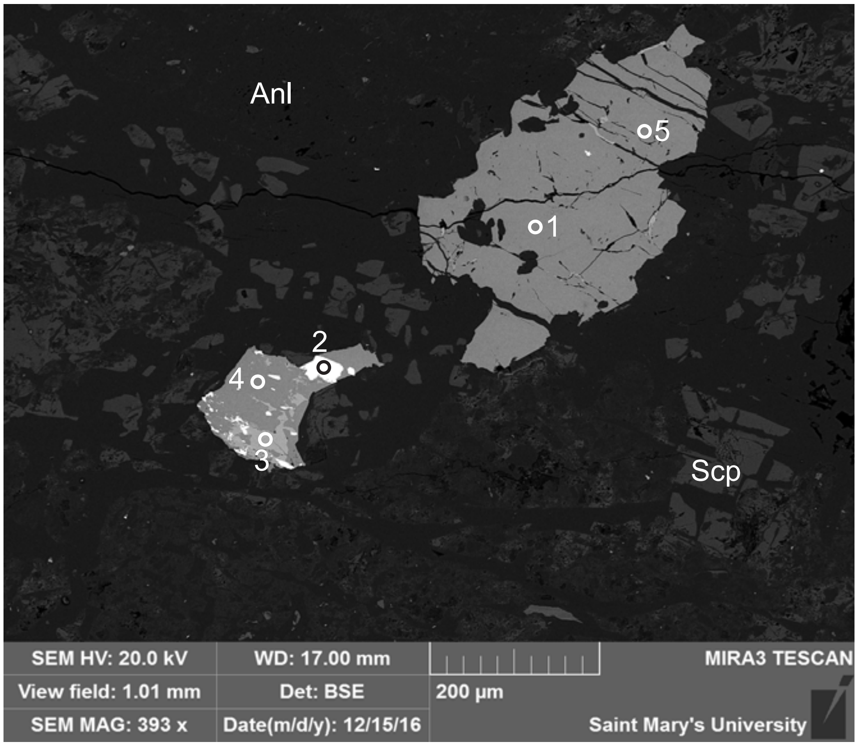
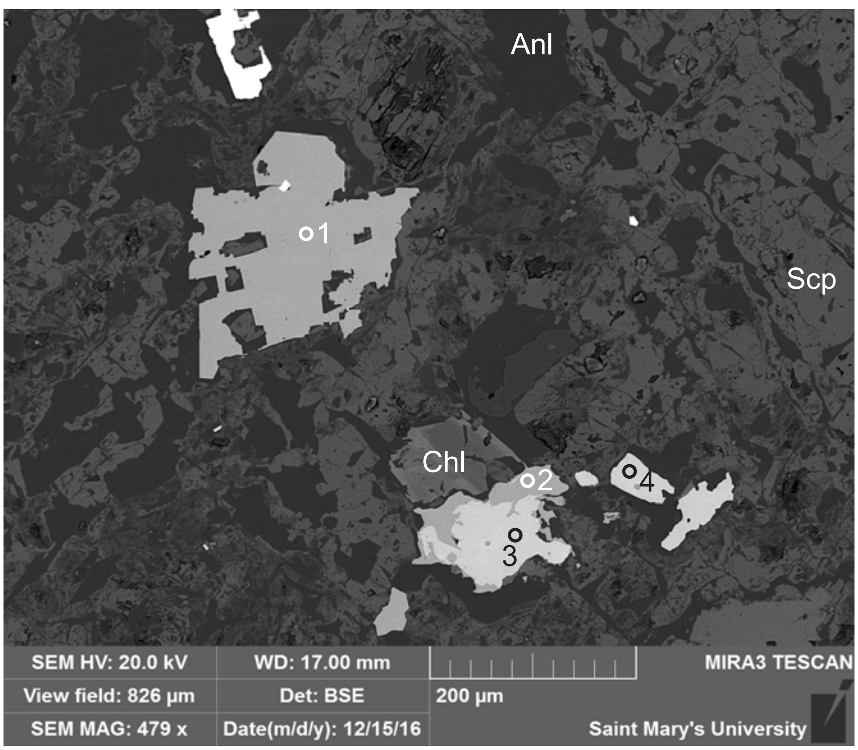



Figure 1-2.1: Scanned thin section of sample of 9956b showing the location of analyzed sites. This sample comes from a coarse-grained syenite with dark minerals (sites 3,7,9-13).




1:Titanite
2:Ti-Magnetite
3:Rutile
4:Titanite
5:Titanite

Figure 1-2.2: Sample 9956b site 1 (SEM). Large grain of anhedral rutile (3) has an equant overgrowth of titanite (4). Large grain of fractured equant titanite (1,5).




1:Titanite
2:Titanite
3:Rutile
4:Rutile

Figure 1-2.3: Sample 9956b site 2 (SEM). Small ~50-75μm anhedral rutile (3) crystal is overgrown by discontinuous equant titanite (2). Titanite (1) has smooth crystal faces and scapolite and analcime ?inclusions.

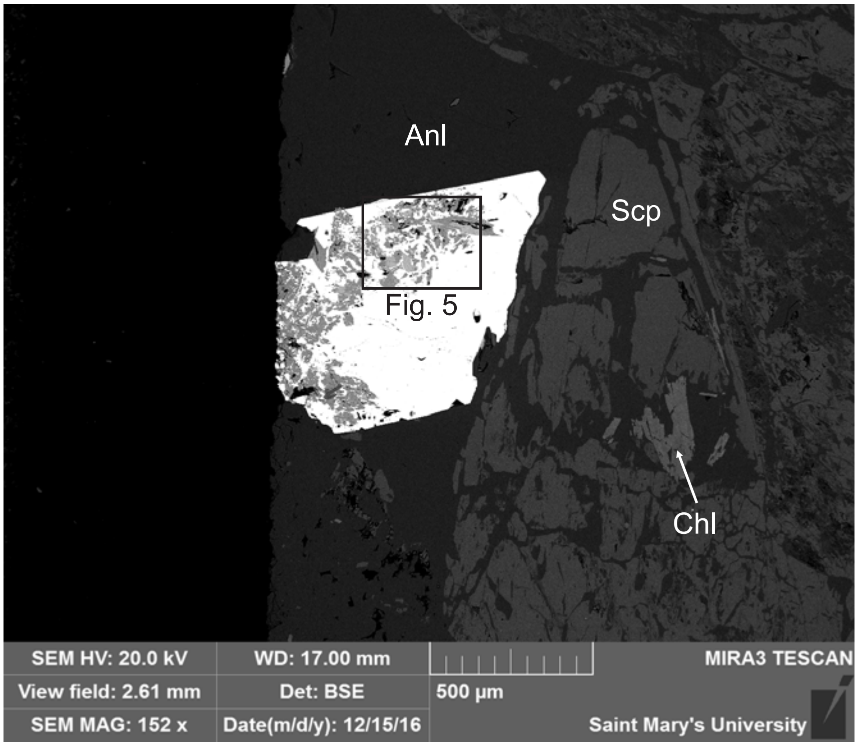



Figure 1-2.4: Sample 9956b (SEM).

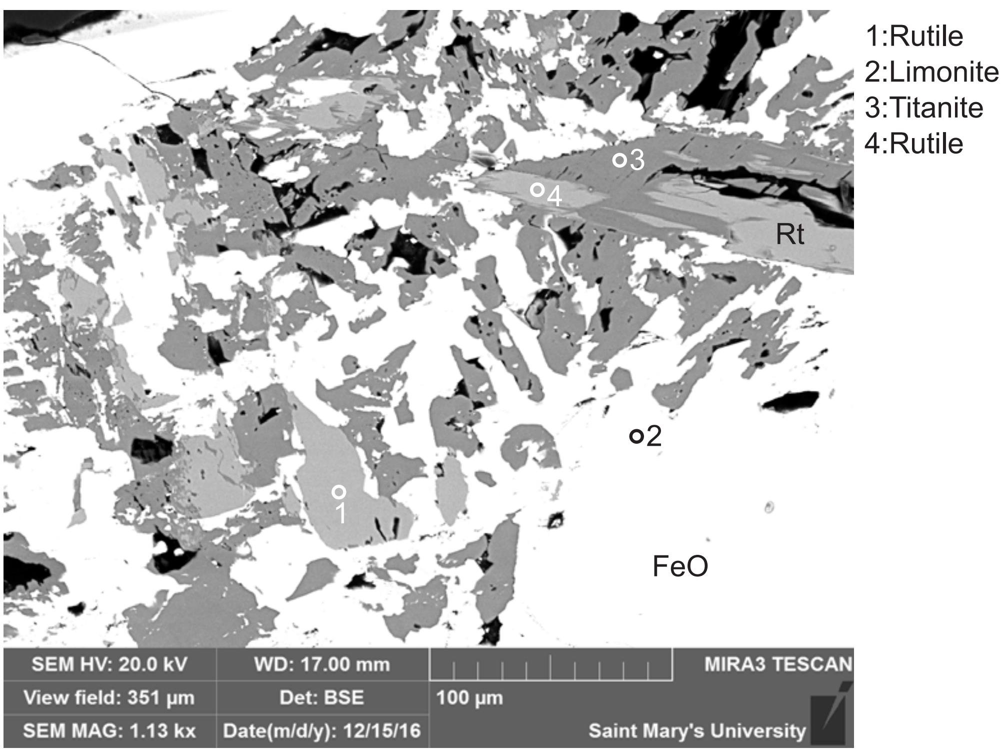
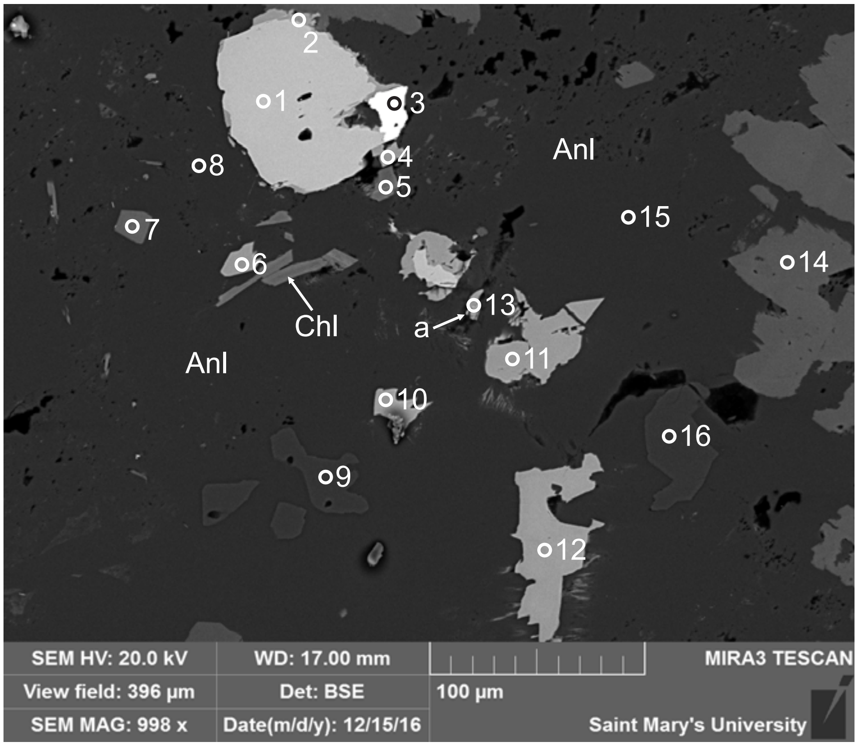
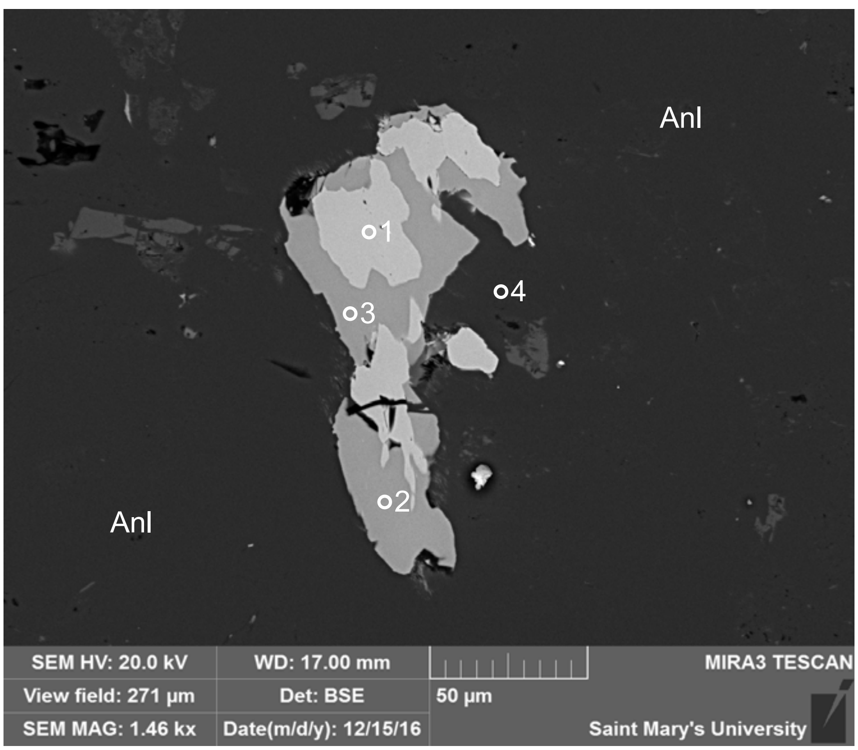



Figure 1-2.5: Sample 9956b site 3 (SEM). This site consists of a small patche of rutile (1,4). The rutile crystals in this patch have equant overgrowths of titanite (3) and Fe-oxides/hydroxides (2).



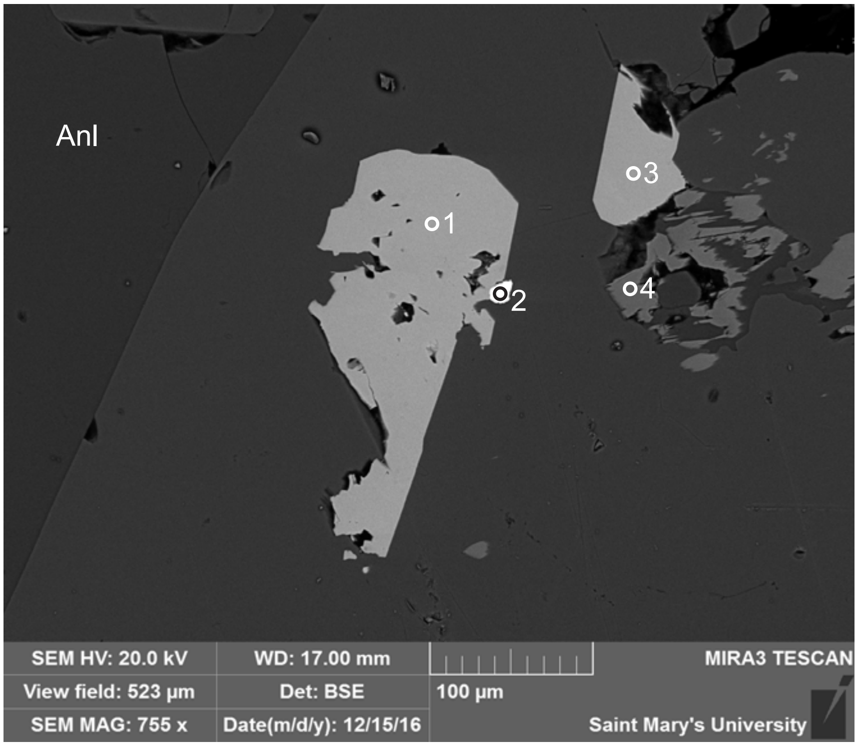

1:Rutile
2:Titanite
3:Ti-Magnetite
4:Titanite
5:Titanite
6:Titanite
7:Calcite
8:Analcime
9:Quartz
10:Titanite
11:Titanite
12:Titanite
13:Titanite
14:K-feldspar
15:Analcime
16:Quartz

Figure 1-2.6: Sample 9956b site 4 (SEM). A large crystal of rutile (1) with sub-equant titanite (2) overgrowth is within a mat of analcime (8,15), minor quartz (9,16) and K-feldspar (14). Titanite (4-6,10-13) appears as discrete grains and may fill voids in the analcime (position a). Titanite (12) is an sub-equant crystal.




1:Rutile
2:Titanite
3:Titanite
4:Analcime

Figure 1-2.7: Sample 9956b site 5 (SEM). This site consists of small crystal fragments of rutile (1) that have equant overgrowths of titanite (2-3).




1:Titanite
2:Zircon
3:Titanite
4:Scapolite

Figure 1-2.8: Sample 9956b site 6 (SEM). This site consists of a large anhedral interstitial grains of titanite (1-3) with some voids. The titanite may be filling void.

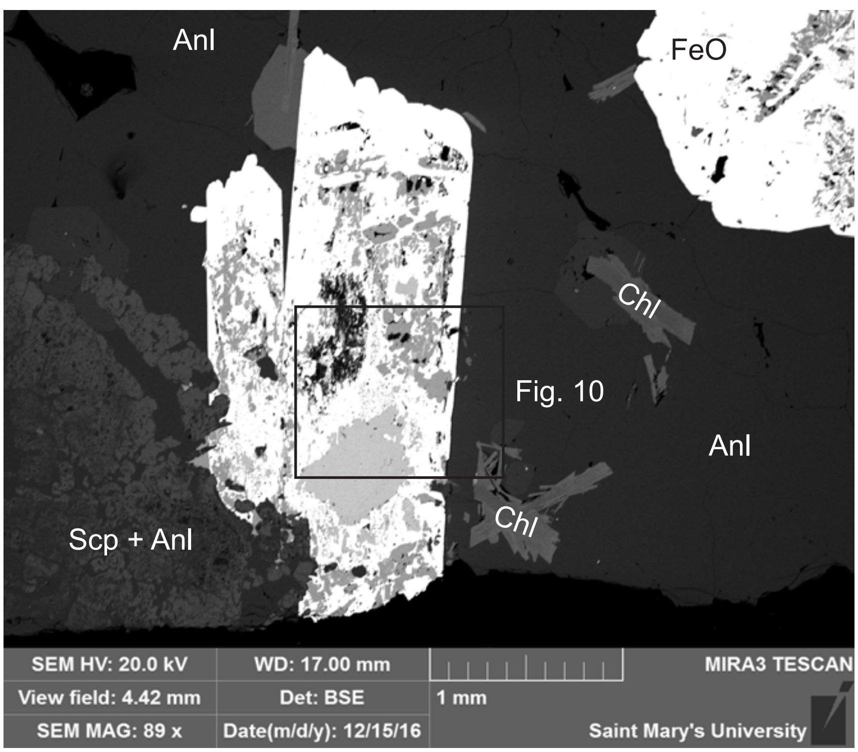



Figure 1-2.9: Sample 9956b (SEM).

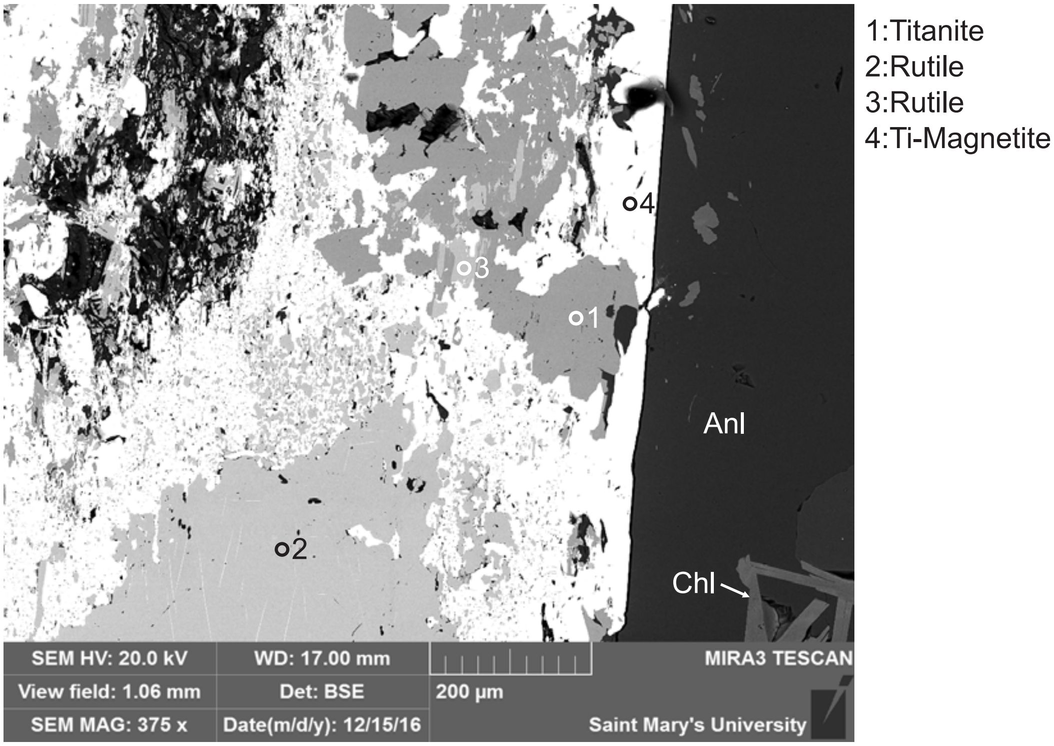



Figure 1-2.10: Sample 9956b site 7 (SEM). This site consists of a large tabular rutile (2-3) crystal that has equant overgrowths of titanite (1) and Fe-oxides.

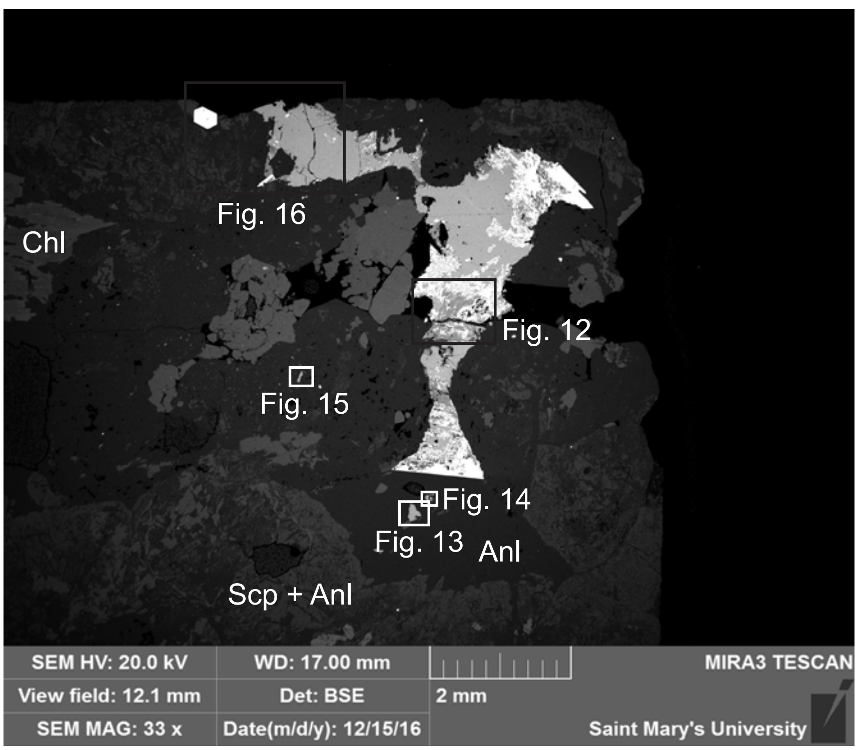
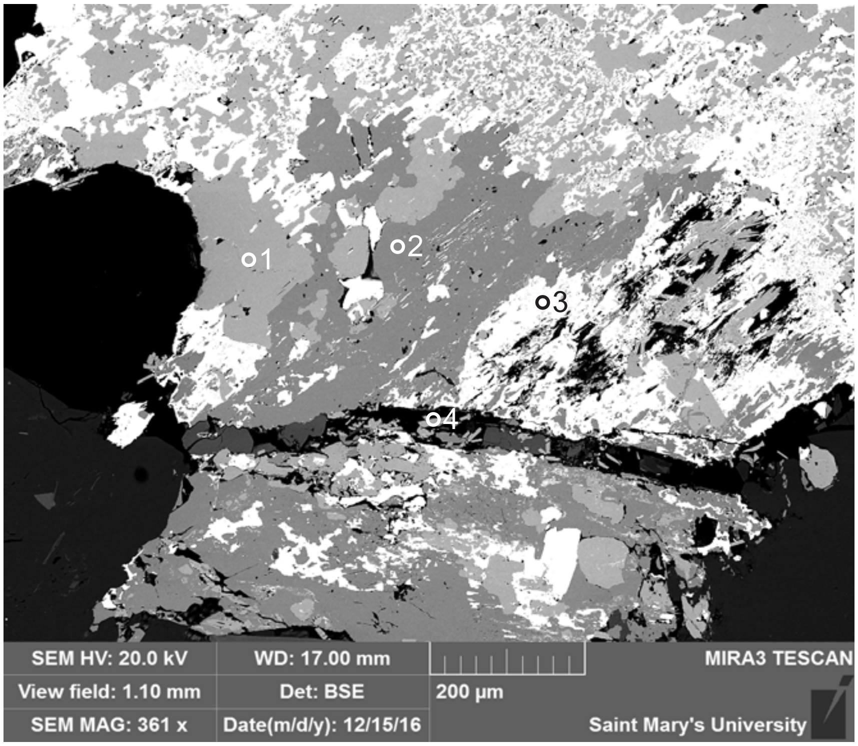
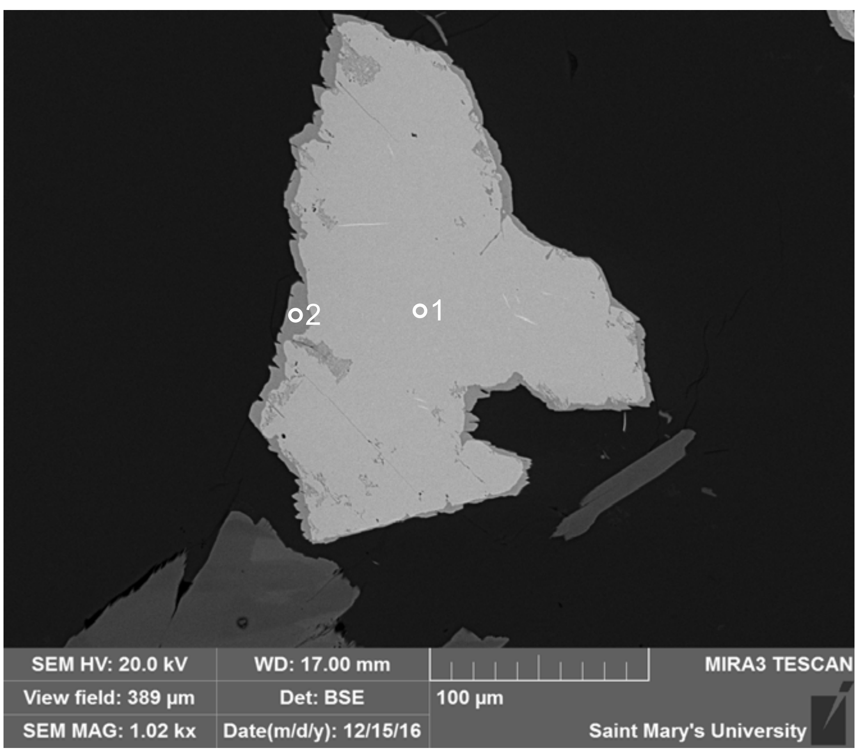



Figure 1-2.11: Sample 9956b (SEM).



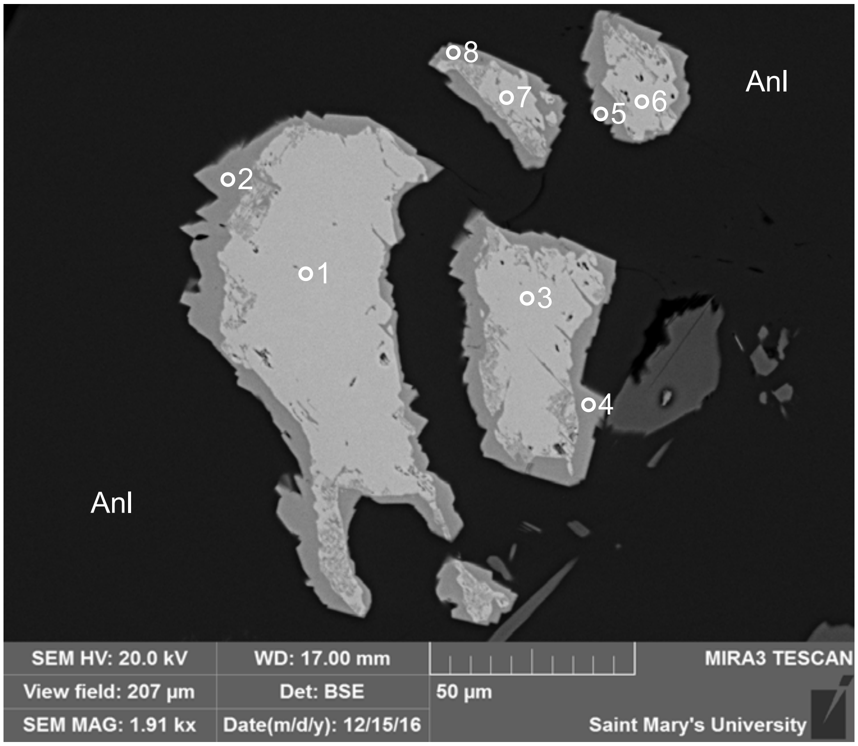

1:Rutile
2:Titanite
3:Ti-Magnetite
4:Rutile + FeO

Figure 1-2.12: Sample 9956b site 9 (SEM). Rutile (1,4) grains partially bound a void and are overgrown by sub-equant of titanite (2) and Fe-oxides (3). These rutile crystals may be relics of an original large rutile grain.



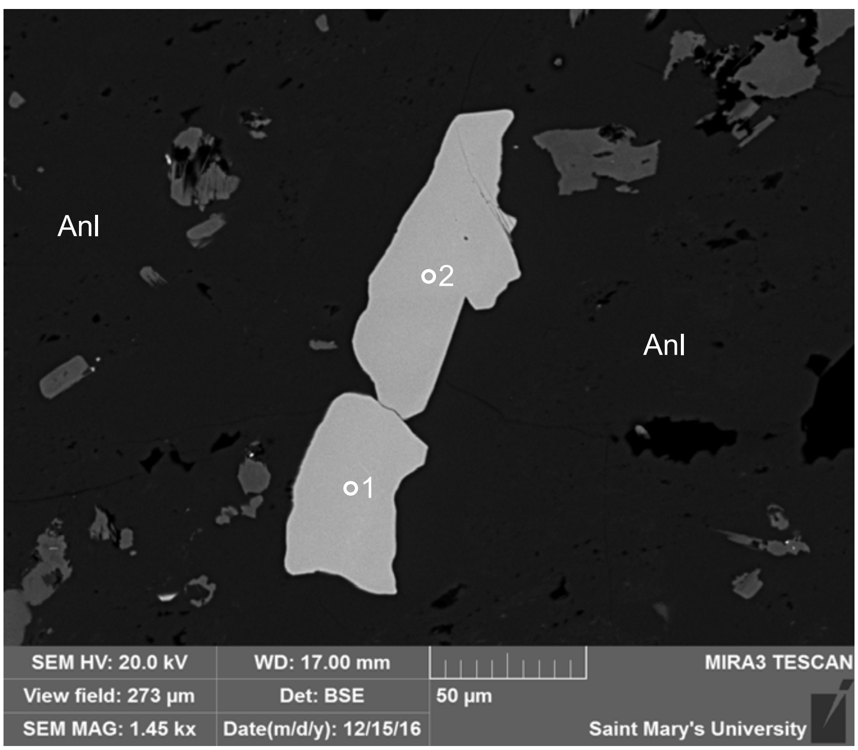

1:Rutile
2:Titanite

Figure 1-2.13: Sample 9956b site 10 (SEM). Large anhedral rutile (1) crystal has equant overgrowths of titanite (2).




1:Rutile
2:Titanite
3:Rutile
4:Titanite
5:Titanite
6:Rutile
7:Rutile
8:Titanite

Figure 1-2.14: Sample 9956b site 11 (SEM). Small-large anhedral rutile (1,3,6-7) crystals contain titanite (2,4-5,8) overgrowths.




1:Rutile
2:Rutile

Figure 1-2.15: Sample 9956b site 12 (SEM). Large discrete subhedral rutile (1-2) crystals.

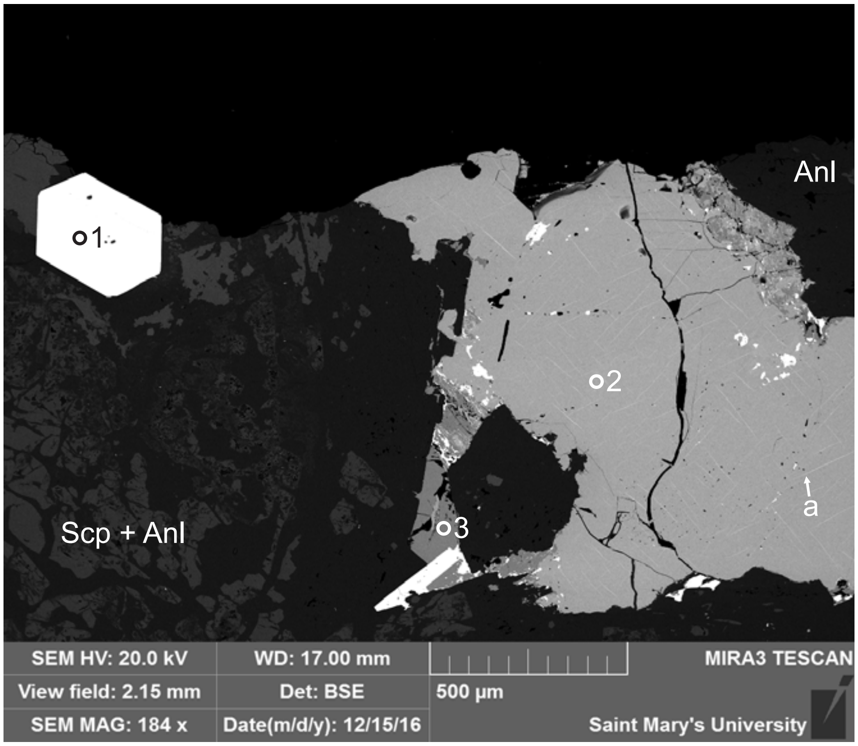



Figure 1-2.16: Sample 9956b site 13 (SEM). Large rutile (2) with Fe-oxide trellis exsolution lamellae (position a) and some voids have sub-equant titanite (3) overgrowths. Titanite (3) may also be interstitial.

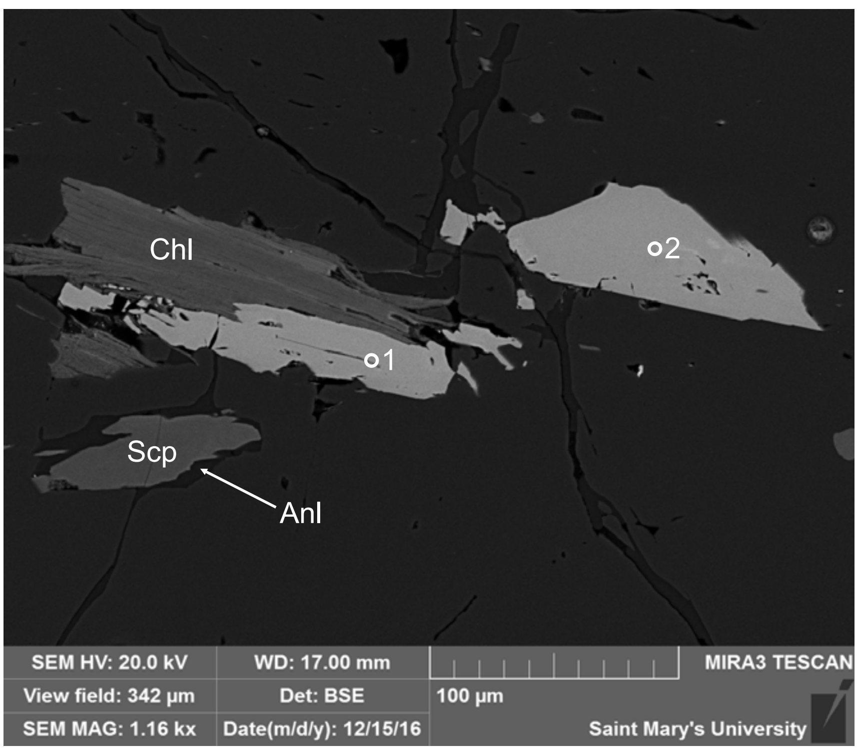



Figure 1-2.17: Sample 9956b site 14 (SEM). This site consists of titanite (1-2) that is ?replacive-interstitial and contains some voids.

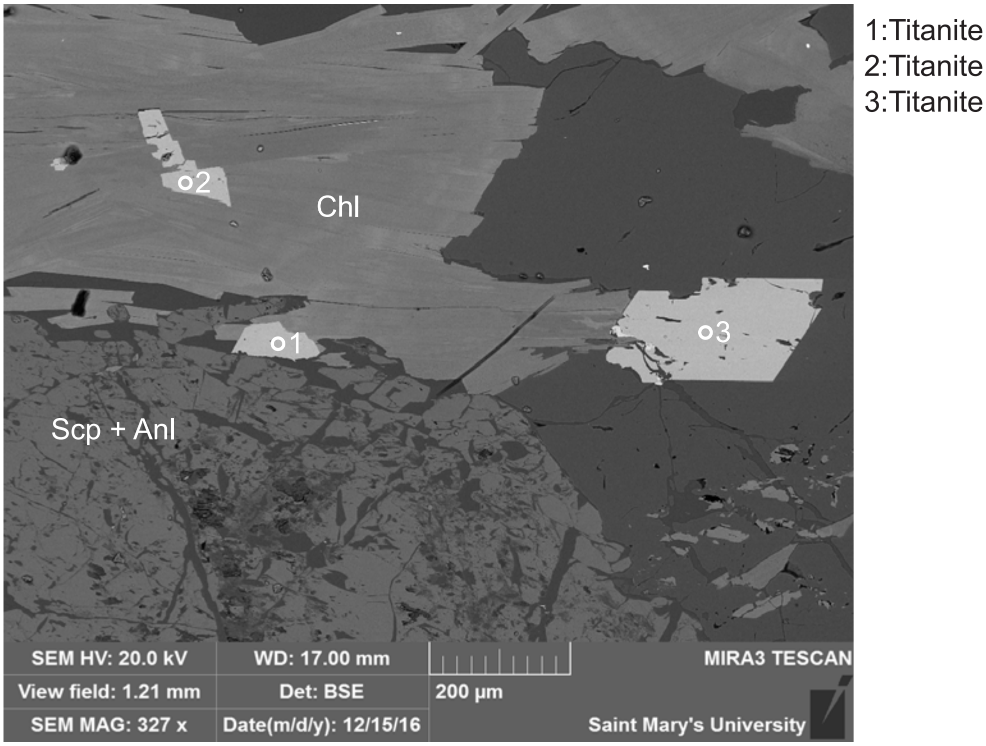



Figure 1-2.18: Sample 9956b site 15 (SEM). Large titanite (1-3) crystals cross-cut chlorite and appear to be ?replacive-interstitial.

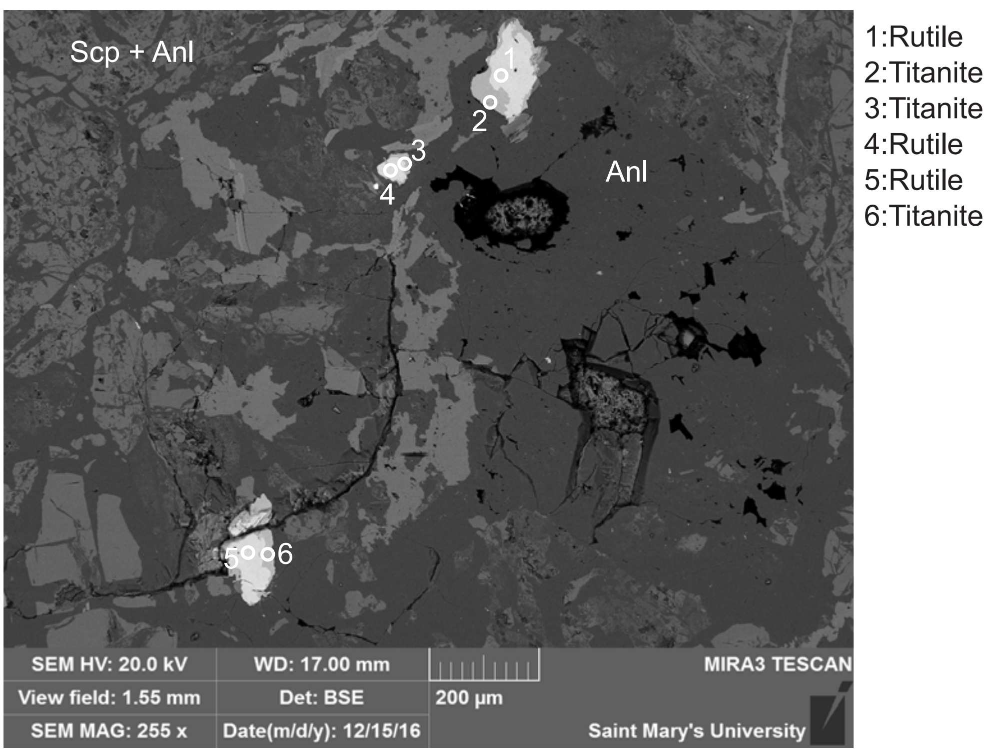



Figure 1-2.19: Sample 9956b site 16 (SEM). Large ~75-125μm rutile (1,4-5) grains are overgrown by equant titanite (2-3,6). Later fracture cuts through rutile (5) and titanite (6).

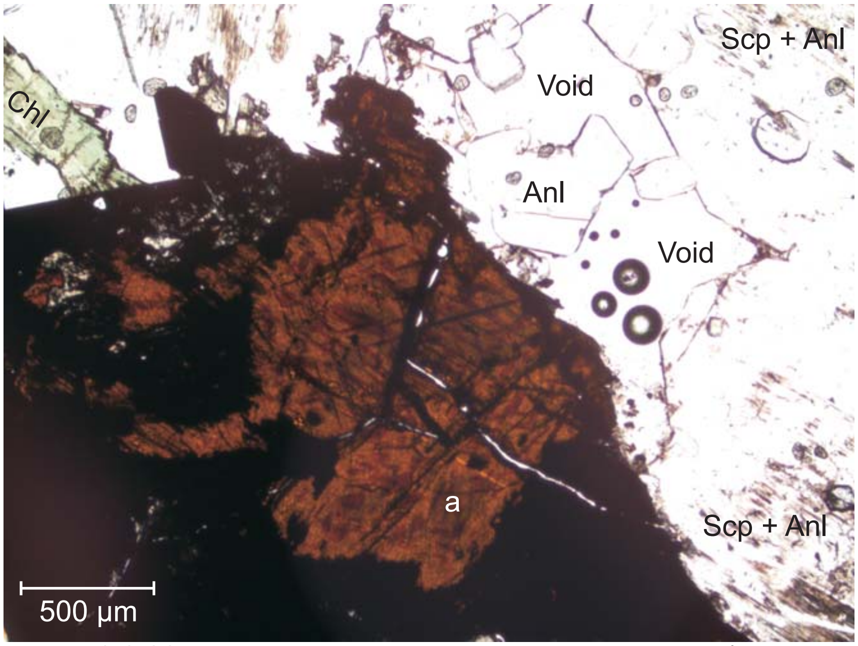


Figure 1-2.20: Large rutile grain with some red patches (position a). 4x PPL.

Table 1-2.1: EDS analyses from sample 9956b.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | ZrO2 | HfO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 1 | 1 | Ttn | 33.09 | 37.91 | 0.94 | 0.29 |  | 27.77 |  |  |  |  |  |  |  |  |  |  |  | 100 | 111 |  |
| 9956b | 1 | 2 | Ti-Mag |  | 6.29 |  | 92.32 |  |  |  |  |  |  |  | 0.65 | 0.75 |  |  |  |  | 100 | 94 |  |
| 9956b | 1 | 3 | Rt |  | 98.87 |  | 0.28 |  | 0.33 |  |  |  |  |  |  | 0.51 |  |  |  |  | 100 | 109 |  |
| 9956b | 1 | 4 | Ttn | 33.10 | 36.66 | 1.43 | 0.76 |  | 28.06 |  |  |  |  |  |  |  |  |  |  |  | 100 | 111 |  |
| 9956b | 1 | 5 | Ttn | 33.50 | 35.81 | 1.98 | 0.63 |  | 28.08 |  |  |  |  |  |  |  |  |  |  |  | 100 | 109 |  |
| 9956b | 2 | 1 | Ttn | 33.07 | 35.58 | 2.48 | 0.77 |  | 28.10 |  |  |  |  |  |  |  |  |  |  |  | 100 | 112 |  |
| 9956b | 2 | 2 | Ttn | 33.40 | 34.29 | 2.83 | 1.18 |  | 28.29 |  |  |  |  |  |  |  |  |  |  |  | 100 | 113 |  |
| 9956b | 2 | 3 | Rt |  | 99.15 |  | 0.28 |  |  |  |  |  |  |  |  | 0.57 |  |  |  |  | 100 | 111 |  |
| 9956b | 2 | 4 | Rt |  | 99.37 |  |  |  |  |  |  |  |  |  |  | 0.63 |  |  |  |  | 100 | 110 |  |
| 9956b | 3 | 1 | Rt |  | 98.73 |  | 0.87 |  |  |  |  |  |  |  |  | 0.40 |  |  |  |  | 100 | 110 |  |
| 9956b | 3 | 2 | Lm |  | 1.69 |  | 98.31 |  |  |  |  |  |  |  |  |  |  |  |  |  | 100 | 94 | 77 |
| 9956b | 3 | 3 | Ttn | 33.18 | 34.67 | 2.92 | 1.12 |  | 28.11 |  |  |  |  |  |  |  |  |  |  |  | 100 | 111 |  |
| 9956b | 3 | 4 | Rt |  | 98.15 |  | 0.73 |  | 0.64 |  |  |  |  |  |  | 0.47 |  |  |  |  | 100 | 109 |  |
| 9956b | 4 | 1 | Rt |  | 98.43 |  | 0.29 |  |  |  |  |  |  |  |  | 0.77 |  | 0.51 |  |  | 100 | 106 |  |
| 9956b | 4 | 2 | Ttn | 32.47 | 34.49 | 4.40 | 1.43 |  | 26.80 |  |  |  |  |  |  |  |  | 0.40 |  |  | 100 | 110 |  |
| 9956b | 4 | 3 | Ti-Mag |  | 5.16 |  | 93.76 |  |  |  |  |  |  |  |  | 0.30 |  | 0.78 |  |  | 100 | 93 |  |
| 9956b | 4 | 4 | Ttn | 33.36 | 30.54 | 5.67 | 0.67 |  | 27.51 |  |  |  | 1.97 |  |  |  |  | 0.28 |  |  | 100 | 111 |  |
| 9956b | 4 | 5 | Ttn | 32.37 | 0.48 | 22.63 | 24.02 | 19.89 |  |  |  |  |  |  |  |  |  | 0.61 |  |  | 100 | 101 |  |
| 9956b | 4 | 6 | Ttn | 33.99 | 31.77 | 4.45 | 1.43 |  | 27.87 |  |  |  |  |  |  |  |  | 0.49 |  |  | 100 | 110 |  |
| 9956b | 4 | 7 | Cal | 1.34 |  | 0.60 | 1.37 | 0.44 | 51.93 |  |  |  |  |  |  |  |  | 0.31 |  |  | 56 | 58 |  |
| 9956b | 4 | 8 | Anl | 59.33 |  | 20.51 |  |  | 0.23 | 10.73 |  |  |  | 0.20 |  |  |  |  |  |  | 91 | 98 |  |
| 9956b | 4 | 9 | Qz | 99.66 |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.34 |  |  | 100 | 122 |  |
| 9956b | 4 | 10 | Ttn | 33.69 | 33.75 | 2.82 | 1.25 |  | 28.02 |  |  |  |  |  |  |  |  | 0.49 |  |  | 100 | 111 |  |
| 9956b | 4 | 11 | Ttn | 33.18 | 33.35 | 3.69 | 0.63 |  | 27.69 |  |  |  | 1.01 |  |  |  |  | 0.45 |  |  | 100 | 113 |  |
| 9956b | 4 | 12 | Ttn | 33.16 | 36.27 | 1.78 | 0.45 |  | 27.85 |  |  |  |  |  |  |  |  | 0.49 |  |  | 100 | 112 |  |
| 9956b | 4 | 13 | Ttn | 36.67 | 34.14 | 4.70 | 0.60 |  | 22.49 | 0.84 |  |  |  |  |  |  |  | 0.57 |  |  | 100 | 106 |  |
| 9956b | 4 | 14 | Kfs | 66.08 |  | 17.76 |  |  |  |  | 15.73 |  |  |  |  |  |  | 0.43 |  |  | 100 | 117 |  |
| 9956b | 4 | 15 | Anl | 59.60 |  | 20.28 |  |  |  | 10.77 |  |  |  |  |  |  |  | 0.35 |  |  | 91 | 100 |  |
| 9956b | 4 | 16 | Qz | 99.62 |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.38 |  |  | 100 | 123 |  |
| 9956b | 5 | 1 | Rt |  | 98.66 |  |  |  | 0.51 |  |  |  |  |  |  | 0.47 |  | 0.36 |  |  | 100 | 108 |  |
| 9956b | 5 | 2 | Ttn | 33.76 | 34.05 | 3.02 | 1.01 |  | 27.92 |  |  |  |  |  |  |  |  | 0.24 |  |  | 100 | 110 |  |
| 9956b | 5 | 3 | Ttn | 33.30 | 34.60 | 2.77 | 1.23 |  | 27.87 |  |  |  |  |  |  |  |  | 0.24 |  |  | 100 | 110 |  |
| 9956b | 5 | 4 | Anl | 59.30 |  | 20.80 |  |  |  | 10.90 |  |  |  |  |  |  |  |  |  |  | 91 | 100 |  |

Table 1-2.1: EDS analyses from sample 9956b. 

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | ZrO2 | HfO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 6 | 1 | Ttn | 33.01 | 37.81 | 0.88 | | | 27.91 | | | | | | | 0.39 | | | | | 100 | 114 | |
| 9956b | 6 | 2 | Zrn | 31.27 | | | | | | | | | | | | | | | 67.16 | 1.57 | 100 | 125 | |
| 9956b | 6 | 3 | Ttn | 33.03 | 37.19 | 1.20 | 0.37 | | 28.21 | | | | | | | | | | | | 100 | 113 | |
| 9956b | 6 | 4 | Scp | 58.65 | | 2.97 | 6.91 | 19.39 | 11.40 | 0.68 | | | | | | | | | | | 100 | 109 | |
| 9956b | 7 | 1 | Ttn | 32.83 | 37.08 | 1.25 | 0.68 | | 27.93 | | | | | | | | | 0.24 | | | 100 | 115 | |
| 9956b | 7 | 2 | Rt | | 98.58 | | 0.30 | | | | | | | | | 0.57 | | 0.55 | | | 100 | 111 | |
| 9956b | 7 | 3 | Rt | | 98.13 | | 0.73 | | 0.75 | | | | | | | | | 0.40 | | | 100 | 111 | |
| 9956b | 7 | 4 | Ti-Mag | | 9.21 | | 89.28 | | | | | | | | 0.60 | 0.49 | | 0.42 | | | 100 | 95 | |
| 9956b | 9 | 1 | Rt | | 97.64 | | 1.42 | | | | | | | | | 0.94 | | | | | 100 | 107 | |
| 9956b | 9 | 2 | Ttn | 32.69 | 37.89 | 1.11 | 0.45 | | 27.86 | | | | | | | | | | | | 100 | 112 | |
| 9956b | 9 | 3 | Ti-Mag | | 6.42 | | 93.58 | | | | | | | | | | | | | | 100 | 95 | |
| 9956b | 9 | 4 | Rt + FeO | | 97.40 | | 2.08 | | 0.52 | | | | | | | | | | | | 100 | 109 | |
| 9956b | 10 | 1 | Rt | | 99.67 | | 0.33 | | | | | | | | | | | | | | 100 | 108 | |
| 9956b | 10 | 2 | Ttn | 32.91 | 37.25 | 1.63 | 0.45 | | 27.76 | | | | | | | | | | | | 100 | 111 | |
| 9956b | 11 | 1 | Rt | 0.39 | 98.96 | | | | | | | | | | | 0.65 | | | | | 100 | 110 | |
| 9956b | 11 | 2 | Ttn | 32.88 | 36.60 | 1.76 | 0.45 | | 27.49 | | | | 0.82 | | | | | | | | 100 | 115 | |
| 9956b | 11 | 3 | Rt | 0.37 | 98.74 | | | | 0.31 | | | | | | | 0.58 | | | | | 100 | 111 | |
| 9956b | 11 | 4 | Ttn | 33.74 | 36.00 | 2.14 | 0.59 | | 27.52 | | | | | | | | | | | | 100 | 113 | |
| 9956b | 11 | 5 | Ttn | 33.26 | 37.16 | 1.56 | 0.35 | | 27.66 | | | | | | | | | | | | 100 | 113 | |
| 9956b | 11 | 6 | Rt | 0.43 | 98.62 | | | | 0.41 | | | | | | | 0.54 | | | | | 100 | 111 | |
| 9956b | 11 | 7 | Rt | | 99.00 | | | | 0.56 | | | | | | | 0.44 | | | | | 100 | 110 | |
| 9956b | 11 | 8 | Ttn | 33.17 | 36.44 | 2.64 | 0.60 | | 26.72 | 0.44 | | | | | | | | | | | 100 | 114 | |
| 9956b | 12 | 1 | Rt | | 99.66 | | 0.34 | | | | | | | | | | | | | | 100 | 106 | |
| 9956b | 12 | 2 | Rt | | 99.62 | | 0.38 | | | | | | | | | | | | | | 100 | 105 | |
| 9956b | 13 | 1 | Py | 0.18 | | | 27.52 | | | | | 71.19 | | | | | 1.11 | | | | 100 | 215 | |
| 9956b | 13 | 2 | Rt | | 99.28 | | | | | | | | | | | 0.72 | | | | | 100 | 107 | |
| 9956b | 13 | 3 | Ttn | 33.15 | 36.21 | 2.03 | 0.58 | | 28.02 | | | | | | | | | | | | 100 | 114 | |
| 9956b | 14 | 1 | Ttn | 33.89 | 34.86 | 2.31 | 1.92 | 1.20 | 25.81 | | | | | | | | | | | | 100 | 111 | |
| 9956b | 14 | 2 | Ttn | 33.52 | 36.38 | 1.22 | 0.58 | | 27.41 | | | | | | 0.89 | | | | | | 100 | 110 | |
| 9956b | 15 | 1 | Ttn | 32.89 | 37.56 | 1.13 | 0.45 | | 27.97 | | | | | | | | | | | | 100 | 113 | |
| 9956b | 15 | 2 | Ttn | 33.02 | 37.39 | 1.01 | 0.74 | | 27.85 | | | | | | | | | | | | 100 | 110 | |
| 9956b | 15 | 3 | Ttn | 33.08 | 36.17 | 1.92 | 0.70 | | 28.13 | | | | | | | | | | | | 100 | 114 | |
| 9956b | 16 | 1 | Rt | | 99.05 | | 0.34 | | | | | | | | | 0.60 | | | | | 100 | 105 | |

Table 1-2.1: EDS analyses from sample 9956b.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | SO3 | F | Cl | V2O5 | Cr2O3 | CoO | ZnO | ZrO2 | HfO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 16 | 2 | Ttn | 33.39 | 34.41 | 2.96 | 0.92 | | 28.32 | | | | | | | | | | | | 100 | 108 | |
| 9956b | 16 | 3 | Ttn | 33.53 | 34.58 | 2.93 | 1.10 | | 27.86 | | | | | | | | | | | | 100 | 109 | |
| 9956b | 16 | 4 | Rt | | 99.21 | | | | | | | | | | | 0.79 | | | | | 100 | 105 | |
| 9956b | 16 | 5 | Rt | | 99.24 | | 0.30 | | | | | | | | | 0.46 | | | | | 100 | 111 | |
| 9956b | 16 | 6 | Ttn | 33.45 | 34.48 | 3.02 | 1.23 | | 27.83 | | | | | | | | | | | | 100 | 113 | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Oxide total | | | | | | | | | | | | | | | | | | | |
| | | | Mag = | >90% | | | | | | | Average quartz total = 122.5 | | | | | | | | | | | | |
| | | | Hem = | 85-89% | | | | | | | | | | | | | | | | | | | |
| | | | Gth = | 80-84% | | | | | | | Oxide total = (wt % oxide / Avg. Qz total) * 100 | | | | | | | | | | | | |
| | | | Lm = | <80% | | | | | | | | | | | | | | | | | | | |
| | | | | Notes | | | | | | | | | | | | | | | | | | | |
| | | 1 | + = indicates other minerals present | | | | | | | | | | | | | | | | | | | | |
| | | 2 | Rt + FeO = Rutile that contains more than 2wt% FeO | | | | | | | | | | | | | | | | | | | | |

# Appendix 1-3: SEM-BSE images and EDS mineral analyses for sample 9956c.

**Sample 9956c**

**Host: Scapolitized analcime syenite**

Magmatic minerals: K-feldspar, analcime, rutile, titanite

Secondary Minerals: Chlorite, Fe-oxides/hydroxides, rutile, scapolite, analcime, titanite

**Notes:**

1. This sample contains megacrysts of rutile (up to ~6mm) that have been overgrown and/or partially replaced by titanite and Fe-oxides/hydroxides (Figures 1-3.2,1-3.11,1-3.16,1-3.36,1-3.38).

2. There is more than one generation of titanite (see grey-scale difference Figure 1-3.5).

3. The replacement of rutile by titanite is very clear in Figure 1-3.13.

4. The chlorite appears to postdate a titanite generation and predate Fe-oxide (Figure 1-3.13).

5. A large rutile crystal appears to have exsolution lamellae of Fe-oxide (Figure 1-3.4).

6. The titanite overgrowths on rutile can be equant, subequant, irregular, continuous or discontinuous.

7. Epidote appears to postdate scapolite, analcime, and chlorite (Figure 1-3.43).

8. Strongly zoned large crystals of rutile (dark brown cores and light brown rims) are present in this sample. Such crystals are further overgrown by Fe-oxide and titanite (Figure 1-3.42).

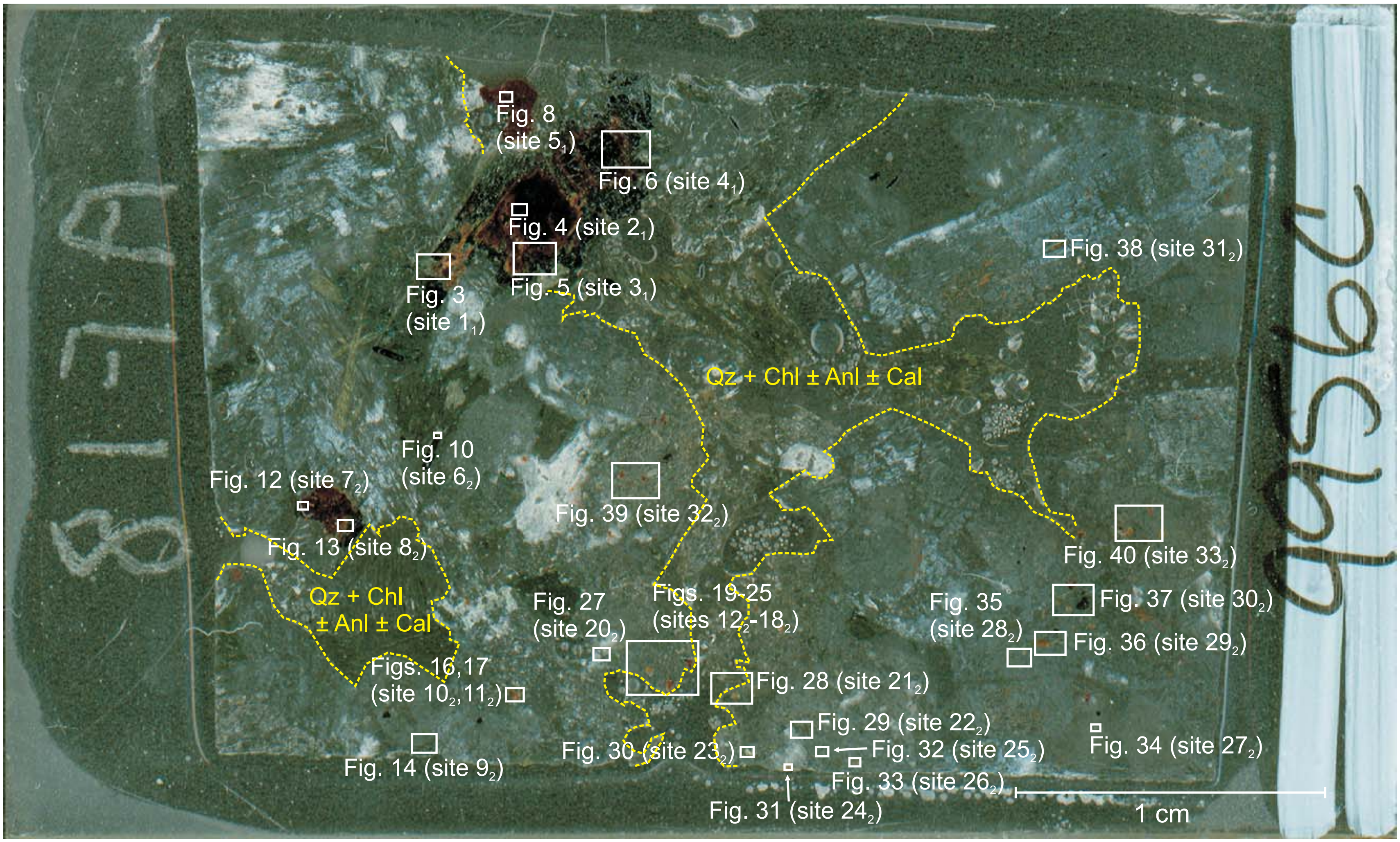



Figure 1-3.1: Scanned thin section of sample 9956c showing the location of analyzed sites. This sample comes from a coarse-grained syenite with dark minerals (sites 1-4,6-8,12-18,29-33). The subscripts indicate where the table can be found 1 = 1-3.1, 2 = 1-3.2.

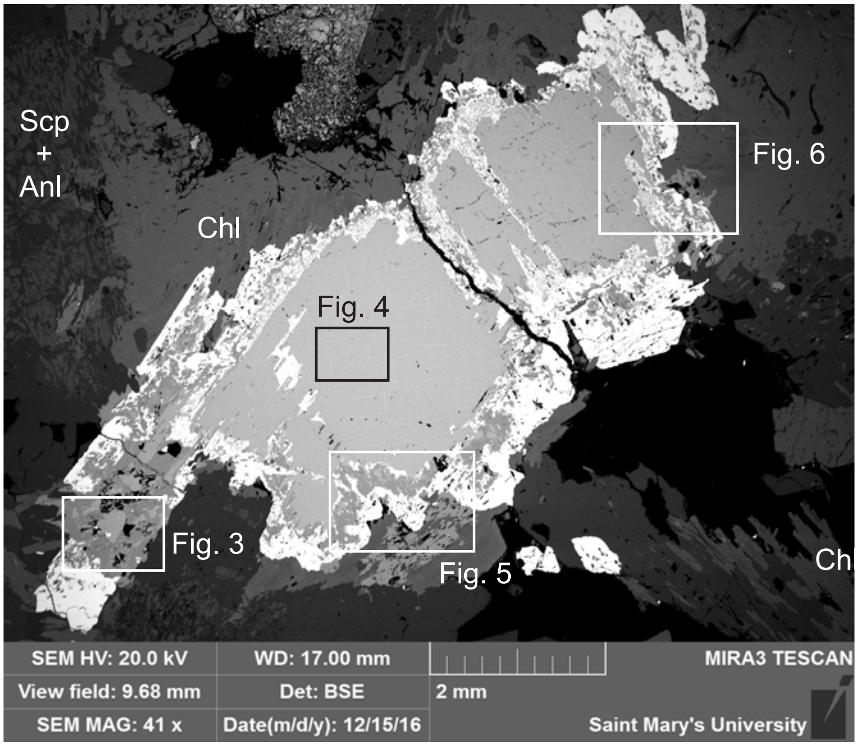
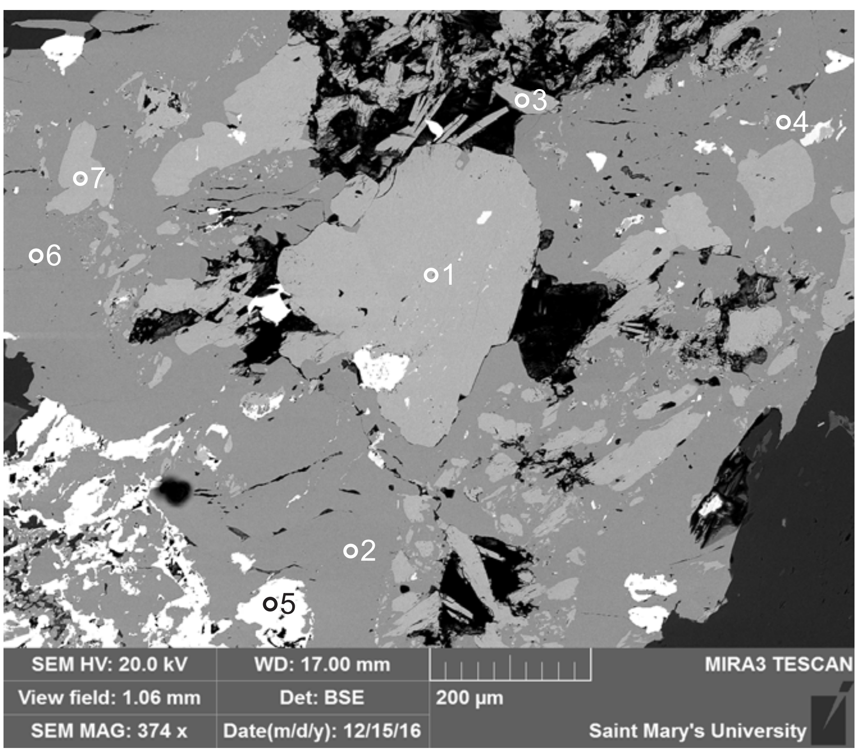
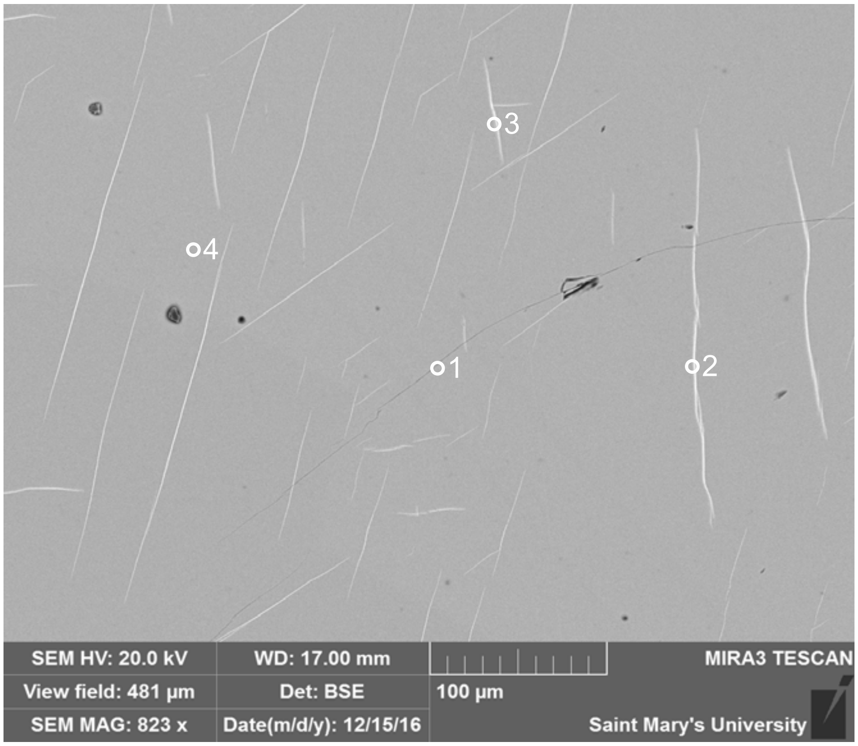



Figure 1-3.2: Sample 9956c (SEM).



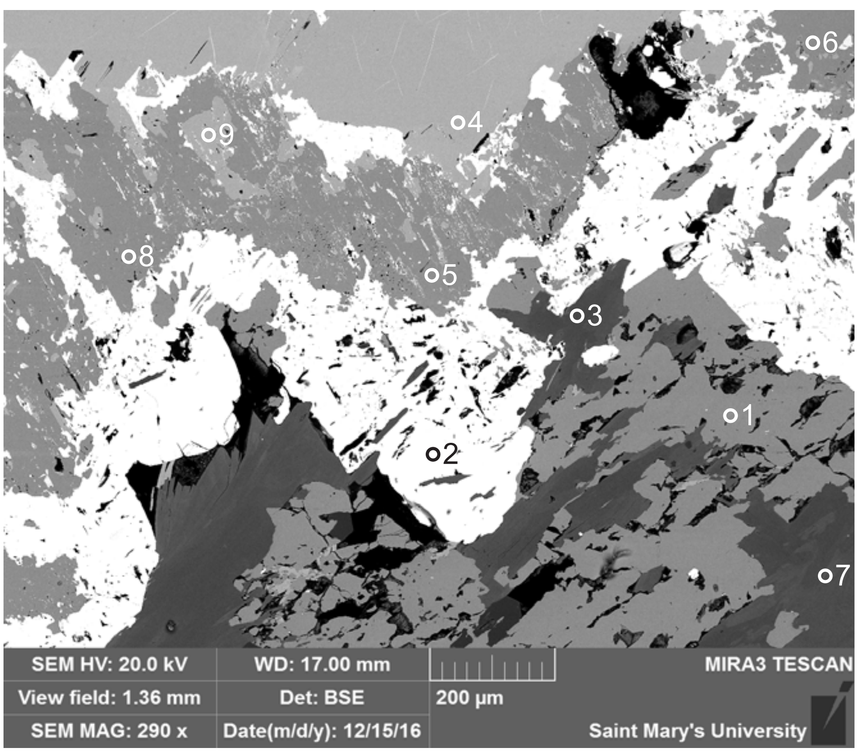

1:Rutile
2:Titanite
3:Rutile
4:Titanite
5:Magnetite
6:Titanite
7:Rutile

Figure 1-3.3: Sample 9956c site 1 (SEM). (Table 1-3.1). Large rutile (1,3,7) grain with equant overgrowths of titanite (2,4,6) and Fe-oxides (5) and contains Fe-oxide exsolution.



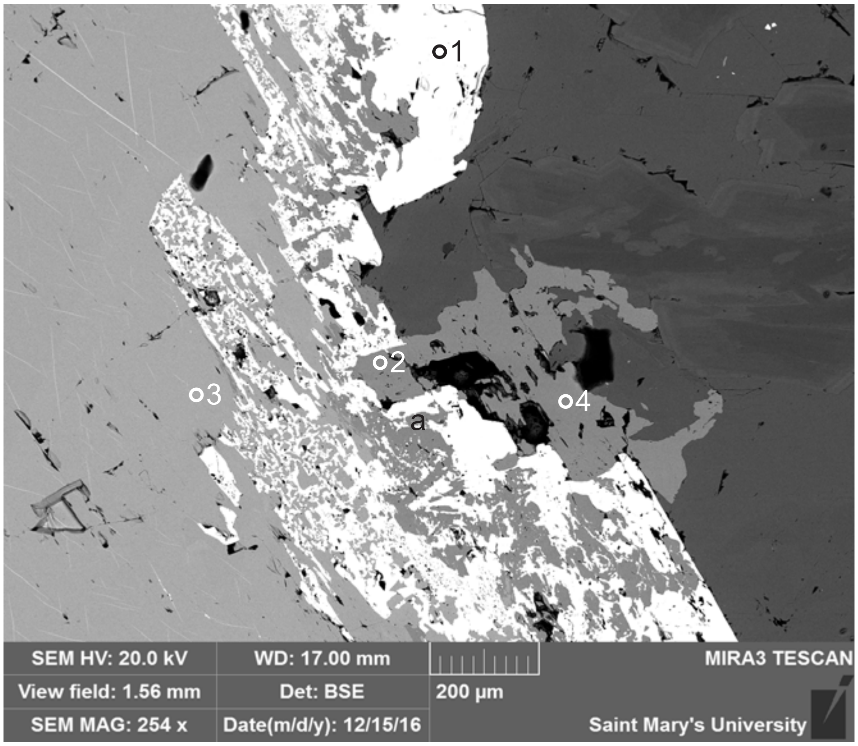

1:Rutile
2:Rutile + Ilm
3:Rutile + Ilm
4:Rutile

Figure 1-3.4: Sample 9956c site 2 (SEM). (Table 1-3.1). Exsolution of probably ilmenite in rutile (1,4).




1:Titanite
2:Ti-Magnetite
3:Chlorite
4:Rutile
5:Titanite
6:Titanite
7:Chlorite
8:Titanite
9:Rutile

Figure 1-3.5: Sample 9956c site 3 (SEM). (Table 1-3.1). Titanite (5,8) are equant overgrowths on rutile (4,9) with Fe-oxide overgrowing both. This large crystal appears to predate a different generation of titanite (1), which appears to be ?replacive-interstitial (note grey scale difference, but it is hard to tell).




1:Goethite
2:Titanite
3:Rutile
4:Titanite

Figure 1-3.6: Sample 9956c site 4 (SEM). (Table 1-3.1). Fe-oxides (1) overgrow a large rutile (3) crystal and appear to have partly replaced irregular titanite (2,4) (position a).

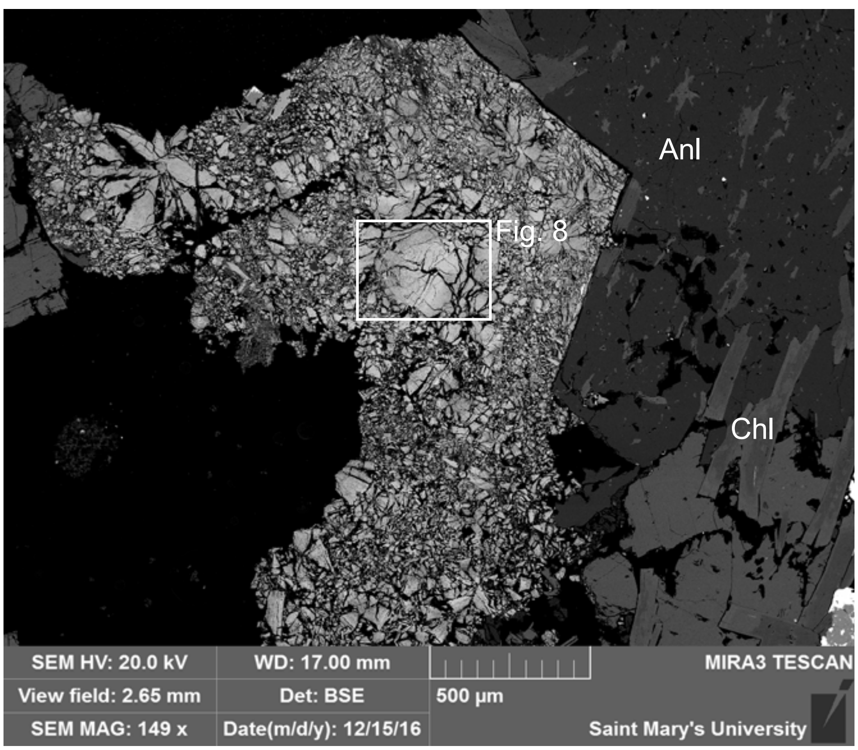
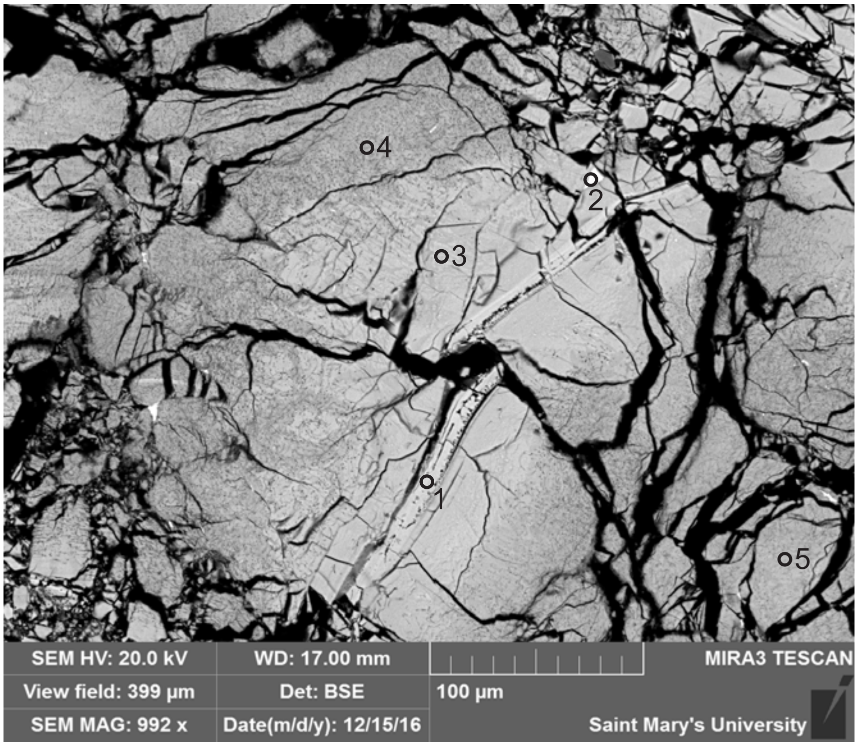



Figure 1-3.7: Sample 9956c (SEM).




1:Mixture (mainly FeO)
2:Mixture (mainly FeO)
3:Mixture (mainly FeO)
4:Mixture (mainly FeO)
5:Mixture (mainly FeO)

Figure 1-3.8: Sample 9956c site 5 (SEM). (Table 1-3.1). This site consists of a very fractured crystal of Fe-oxide/hydroxide.

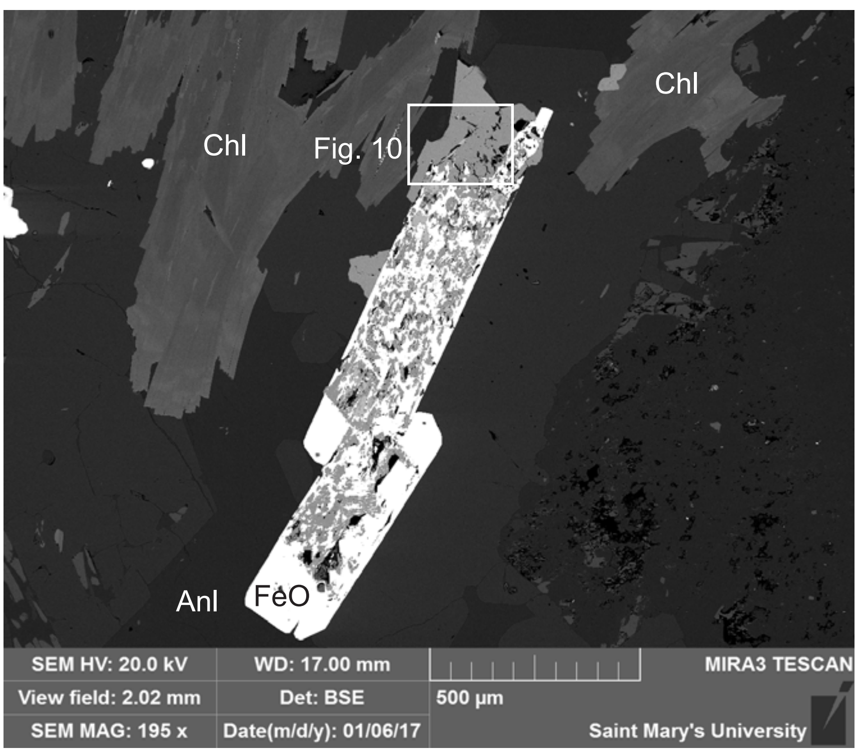
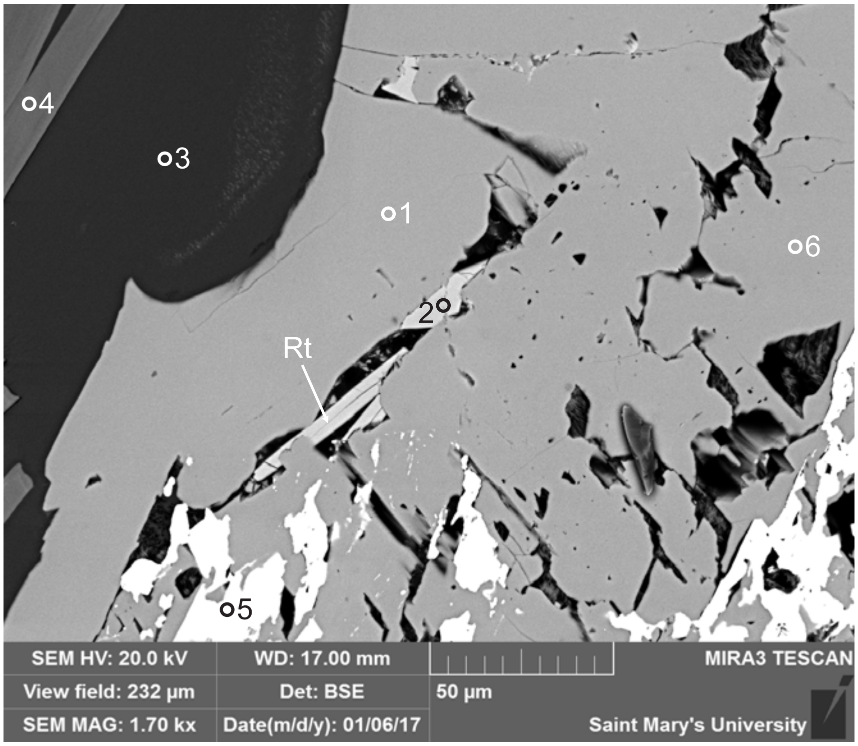



Figure 1-3.9: Sample 9956c (SEM).




1:Titanite
2:Rutile
3:Analcime?
4:Chlorite
5:Ti-Magnetite
6:Titanite

Figure 1-3.10: Sample 9956c site 6 (SEM). (Table 1-3.2). Very small ?bladed rutile (2) grain is being overprinted by? interstitial titanite (1,6). (Texture in Figure 1-3.9).

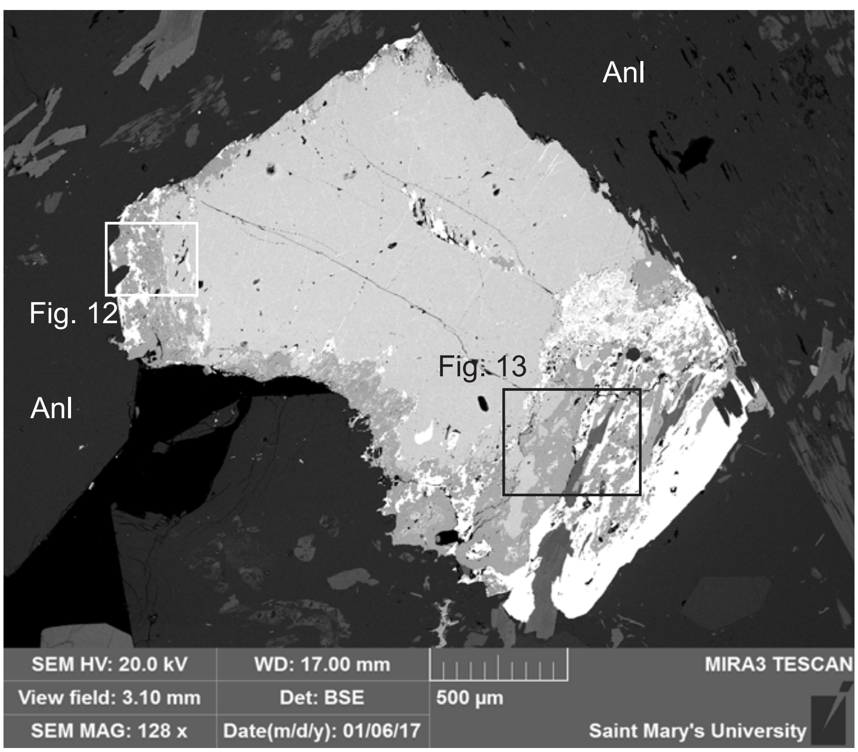



Figure 1-3.11: Sample 9956c (SEM).

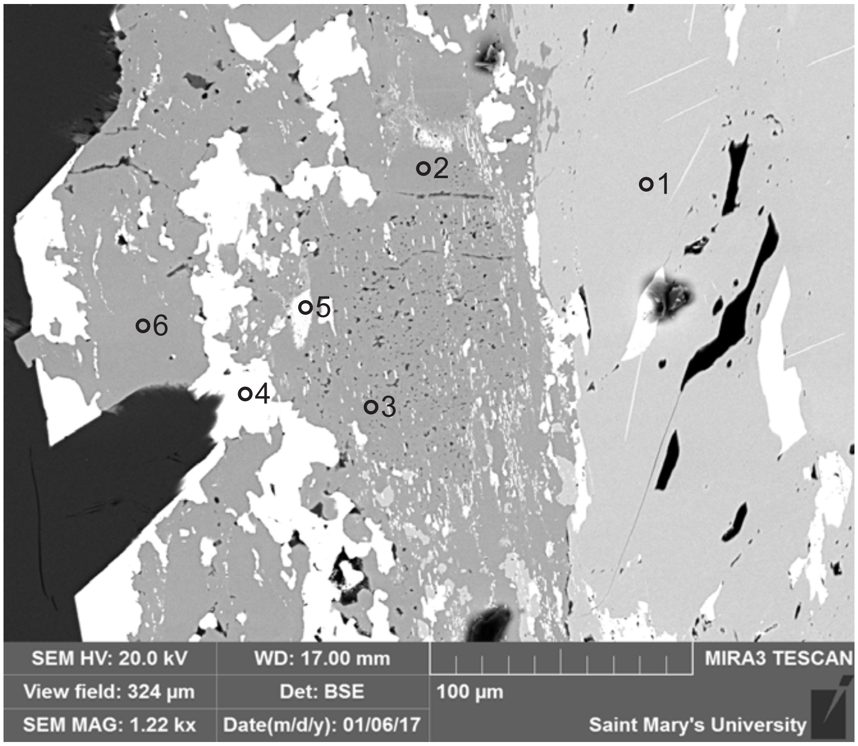



Figure 1-3.12: Sample 9956c site 7 (SEM). (Table 1-3.2). This site consists of rutile (1) with eqant overgrowth of titanite (2-3,6) and Fe-oxides (4). The titanite contains a lot of small voids, whereas the rutile contains a few larger voids.

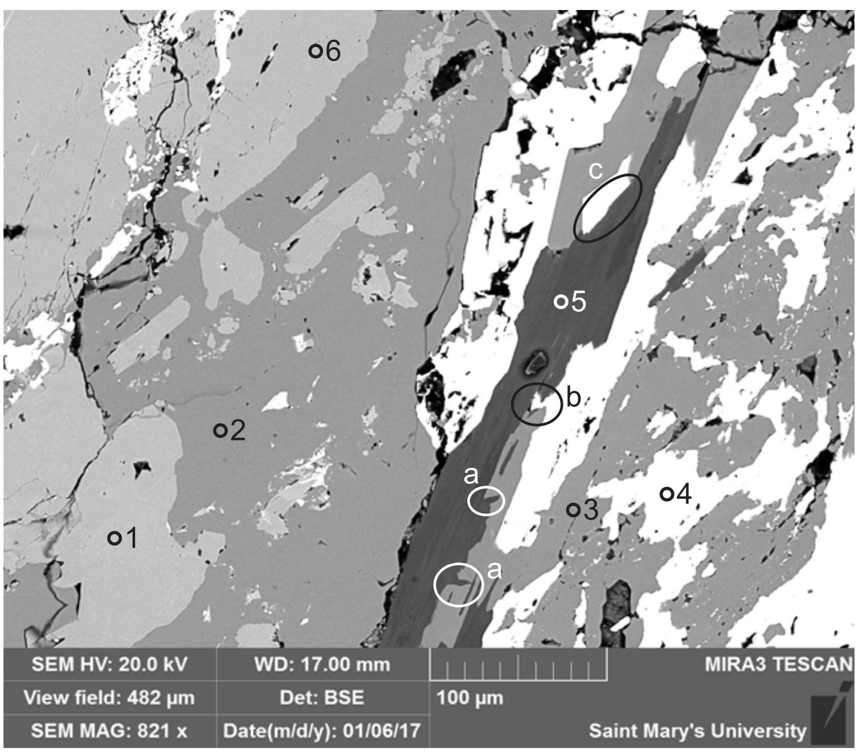



Figure 1-3.13: Sample 9956c site 8 (SEM). (Table 1-3.2). The large rutile (1,6) crystal is replaced by titanite (2) and titanite (3) by Fe-oxides (4). Chlorite (5) postdates titanite (position a). Fe-oxide postdates chlorite (positions b,c).

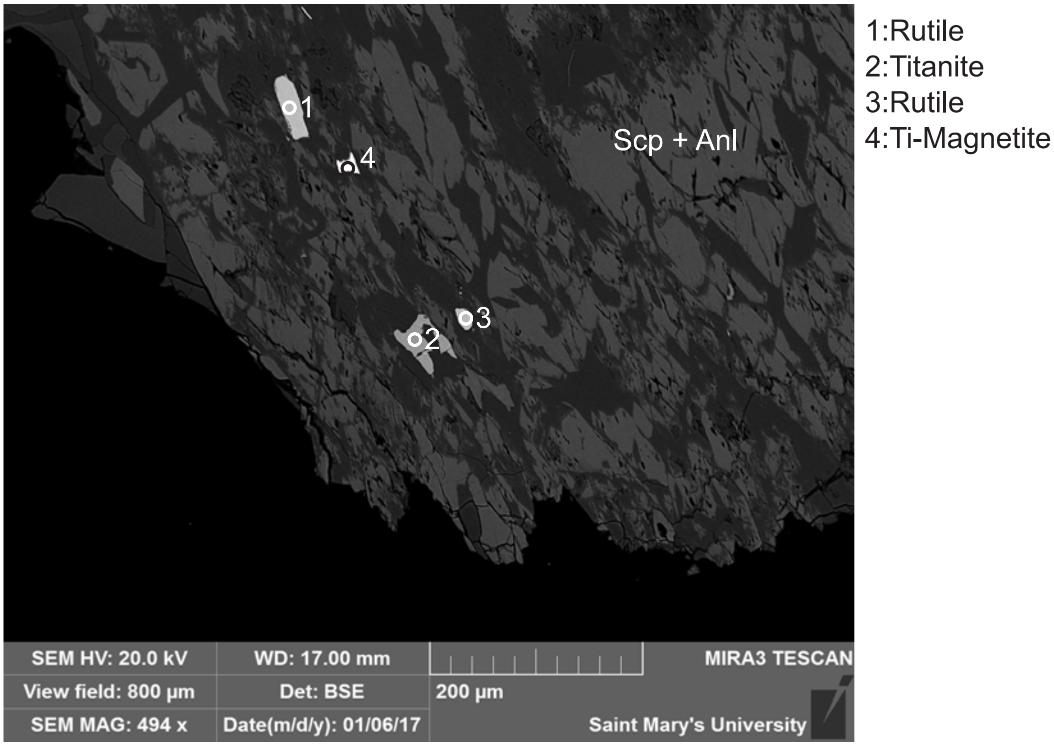



Figure 1-3.14: Sample 9956c site 9 (SEM). (Table 1-3.2). This site consists of small ~50-100μm crystals of euhedral-subhedral rutile (1,3), and a equant titanite (2) crystal in a mat of scapolite and analcime.

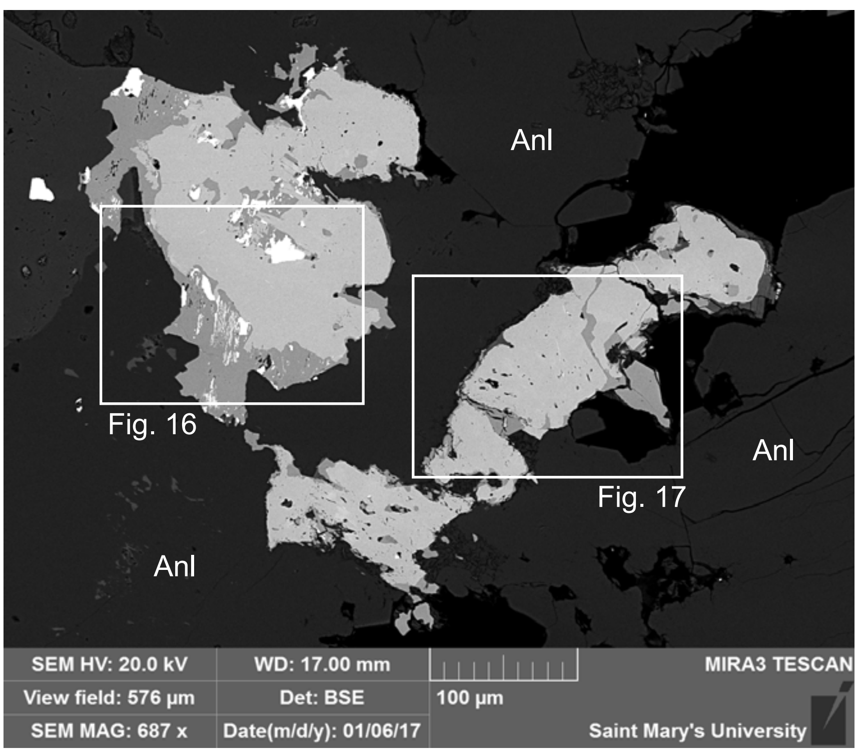



Figure 1-3.15: Sample 9956c (SEM).

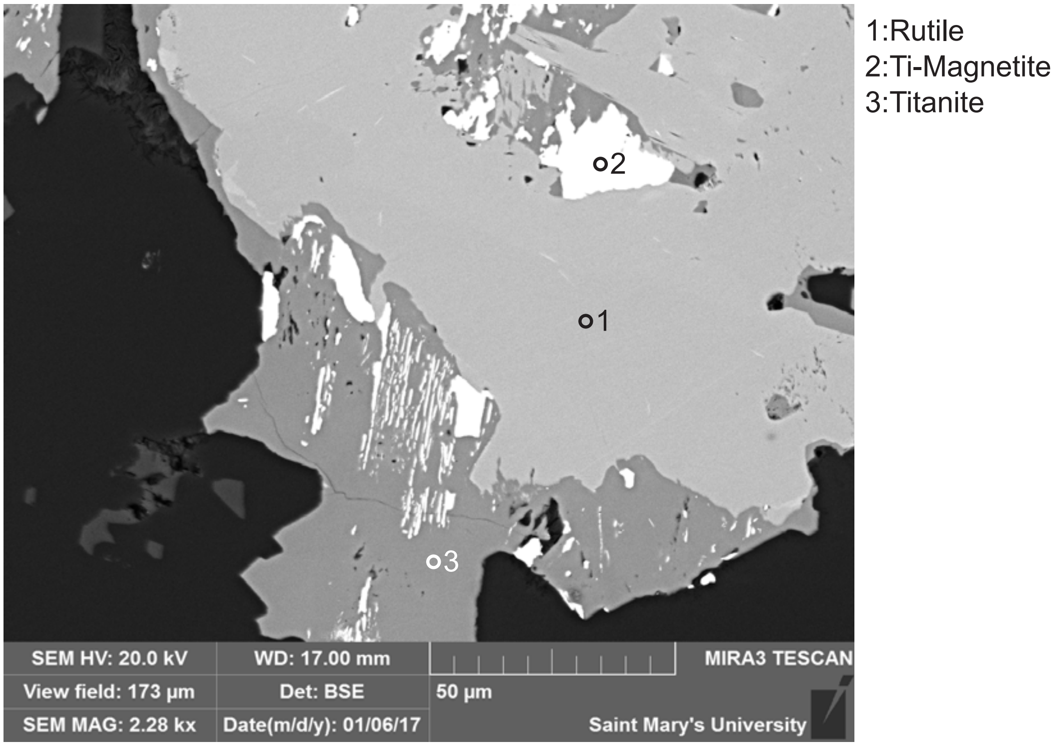



Figure 1-3.16: Sample 9956c site 10 (SEM). (Table 1-3.2). Large rutile (1) crystal is overgrown and replaced by equant titanite (3) and Fe-oxides (2). The whole crystal appears to be interstitial.

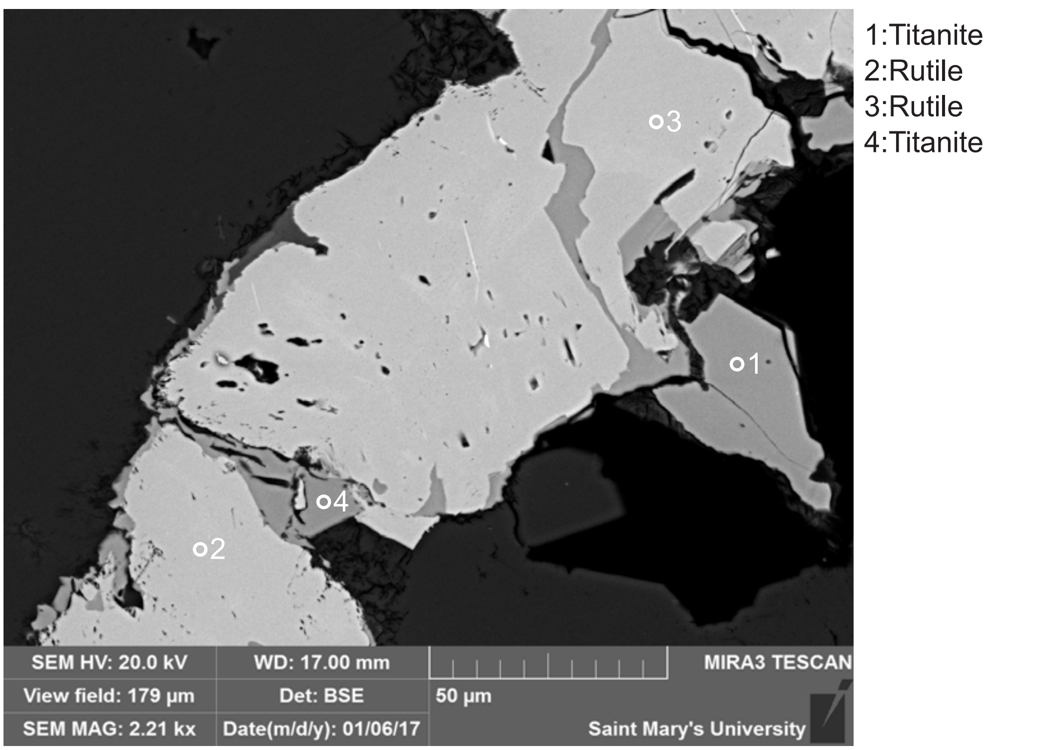



Figure 1-3.17: Sample 9956c site 11 (SEM). (Table 1-3.2). Large anhedral rutile (2-3) grain with some voids is overgrown by equant titanite (1,4). The whole crystal appears to be interstitial.

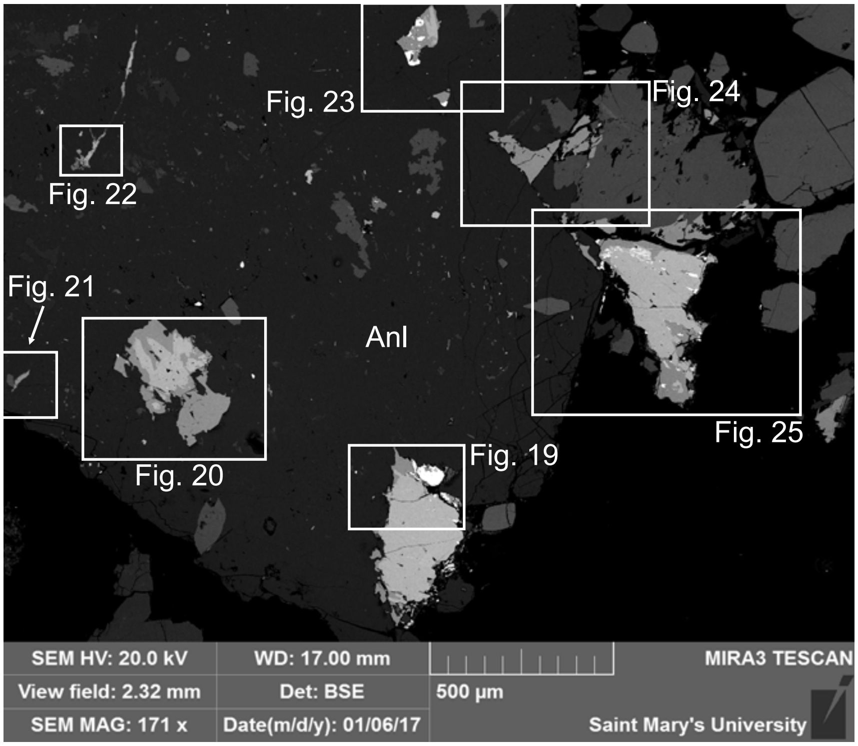



Figure 1-3.18: Sample 9956c (SEM).

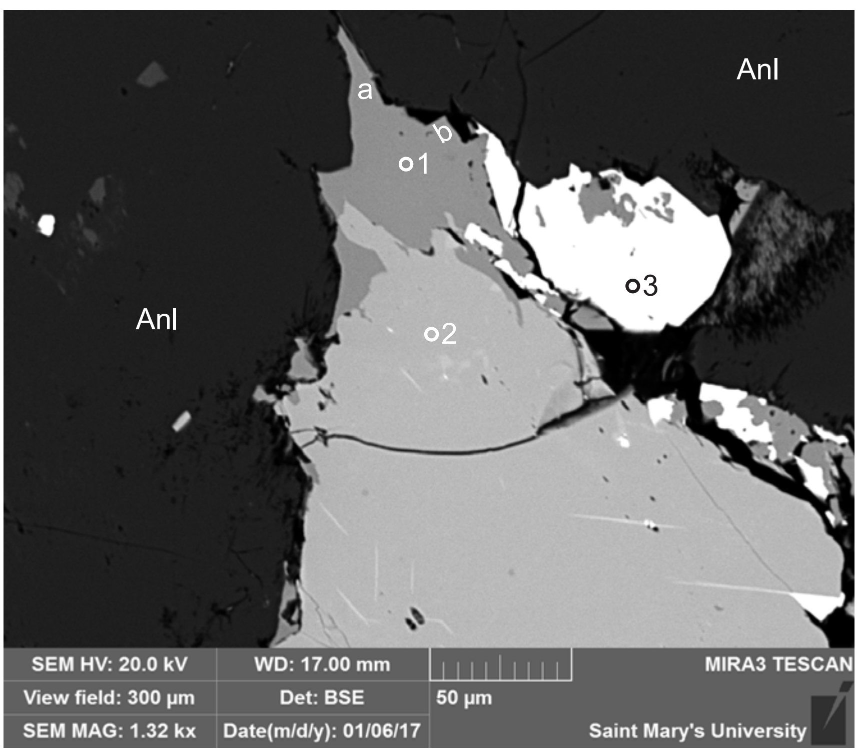
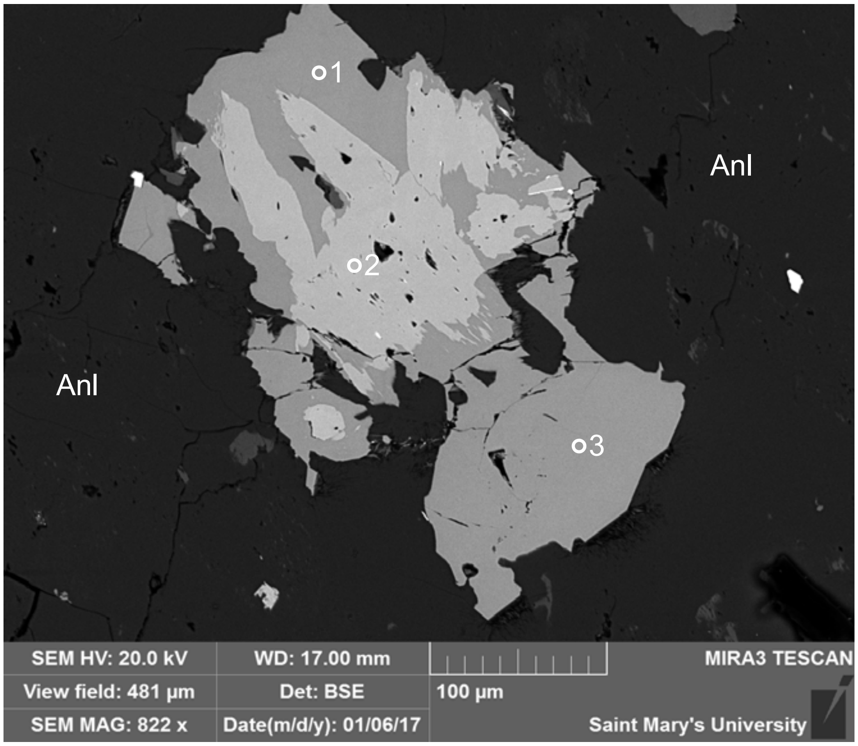
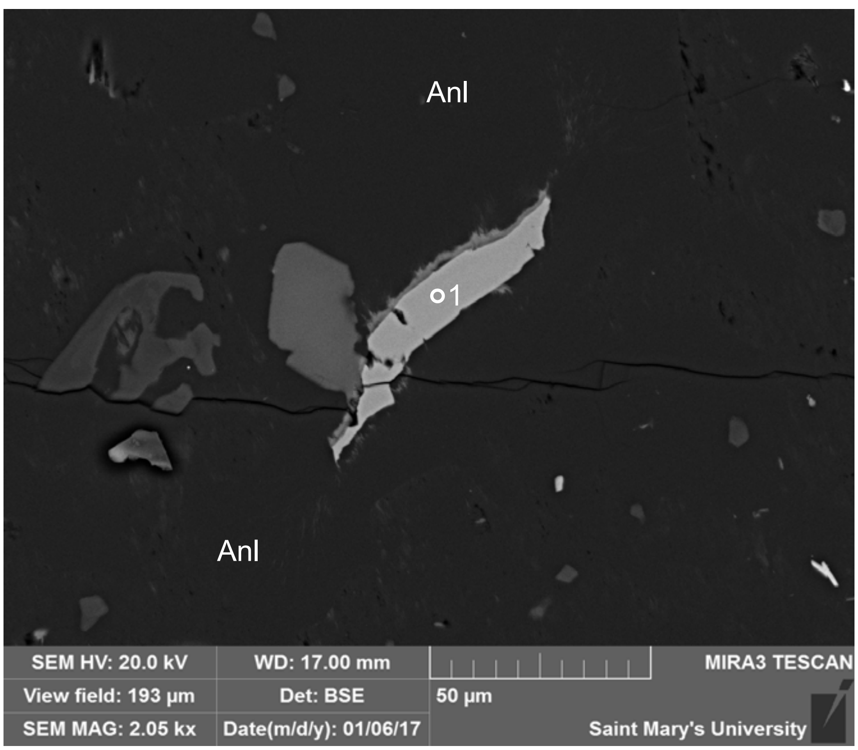



Figure 1-3.19: Sample 9956c site 12 (SEM). (Table 1-3.2). Large rutile (2) grain appears to fill voids and has equant overgrowths of titanite (1). The edge of the overgrowth appears to be interstitial at one point (a) and it also has euhedral margin against the void (position b).



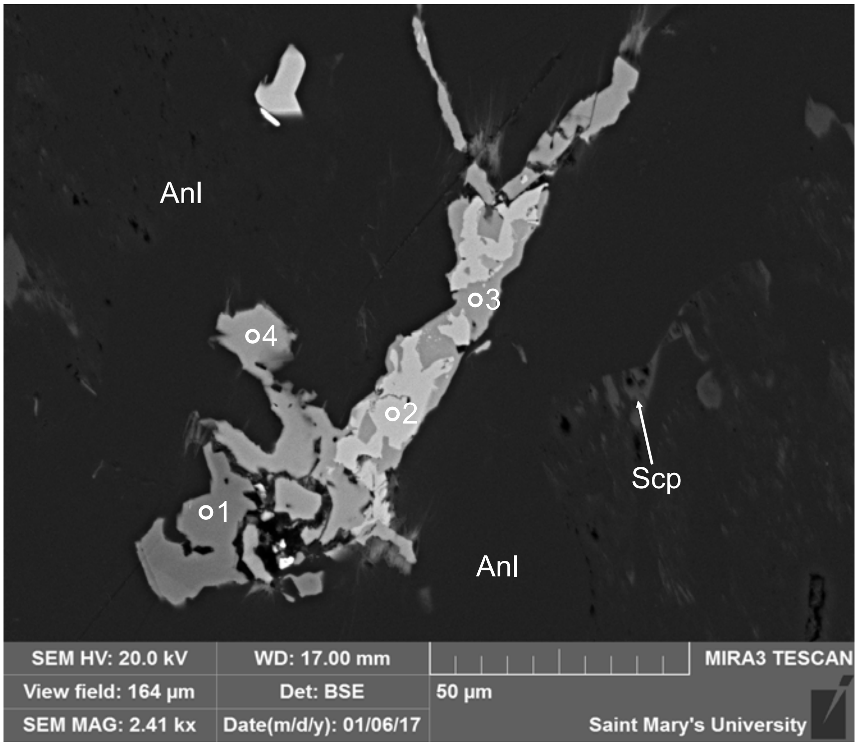

1:Titanite
2:Rutile
3:Titanite

Figure 1-3.20: Sample 9956c site 13 (SEM). (Table 1-3.2). Large anhedral rutile (2) crystal with some voids is overgrown by equant titanite (1,3). The grain appears to be interstitial.



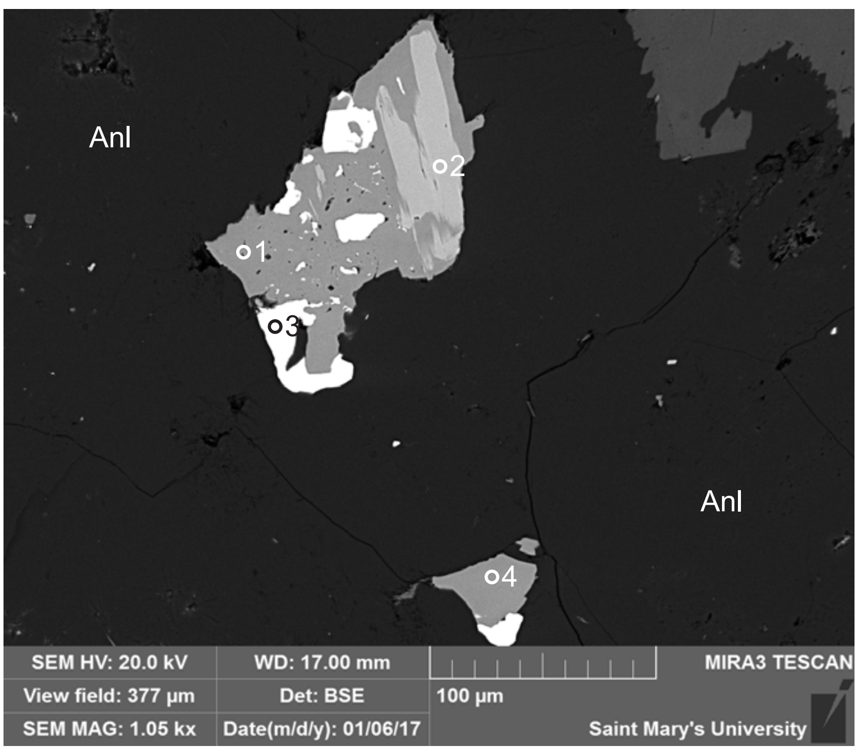

1:Titanite

Figure 1-3.21: Sample 9956c site 14 (SEM). (Table 1-3.2). This site consists of a small interstitial titanite (1) crystal that contains rare voids.



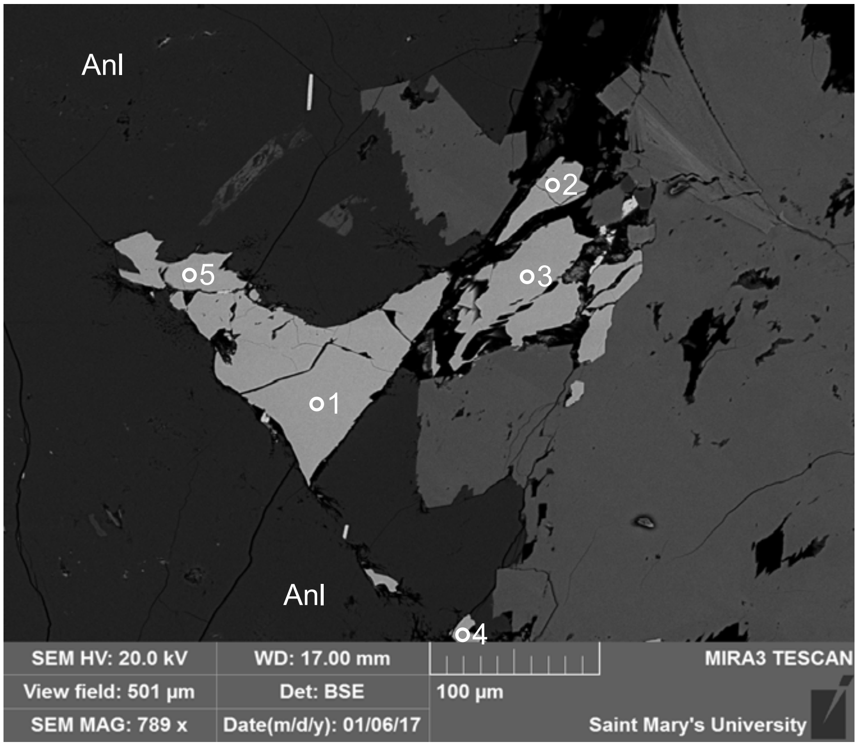

1:Epidote
2:Rutile
3:Titanite
4:Titanite

Figure 1-3.22: Sample 9956c site 15 (SEM). (Table 1-3.2). Small ~ 50µm anhedral rutile (2) grain with rare voids is replaced by titanite (3,4). This grain appears to be interstitial.



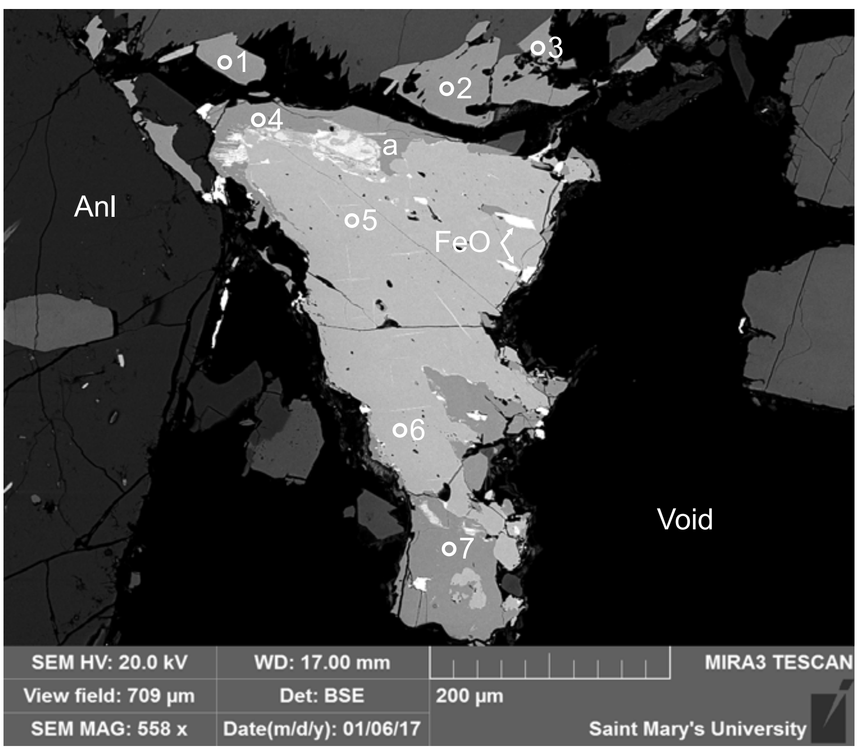

1:Titanite
2:Rutile
3:Hematite
4:Titanite

Figure 1-3.23: Sample 9956c site 16 (SEM). (Table 1-3.2). Large anhedral rutile (2) grain, possibly filling a void, is replaced and perhaps overgrown by equant titanite (1).



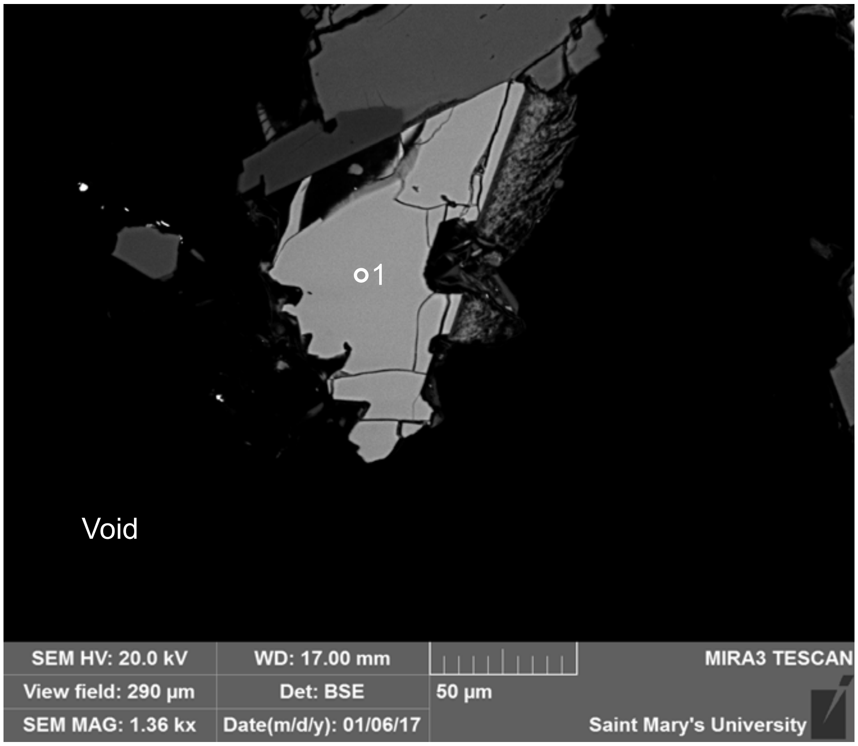

1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Titanite

Figure 1-3.24: Sample 9956c site 17 (SEM). (Table 1-3.2). Interstitial titanite (1-5) appears to partially fill a void.



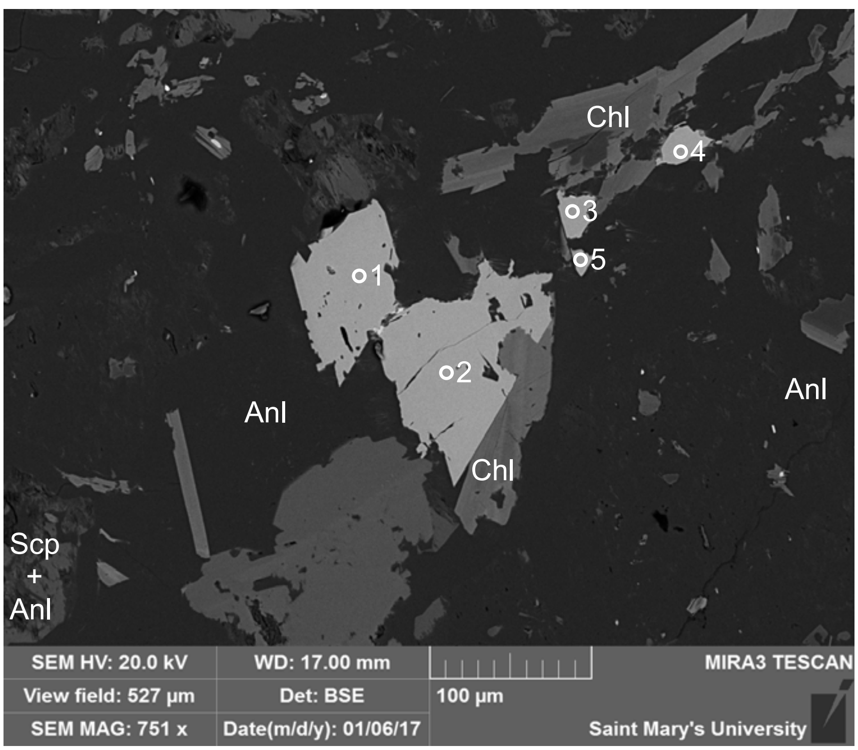

1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Rutile
6:Rutile
7:Titanite

Figure 1-3.25: Sample 9956c site 18 (SEM). (Table 1-3.2). Large anhedral >200µm interstitial rutile (5-6) grain is overgrown by equant and discontinuous (position a) titanite (1-4,7).



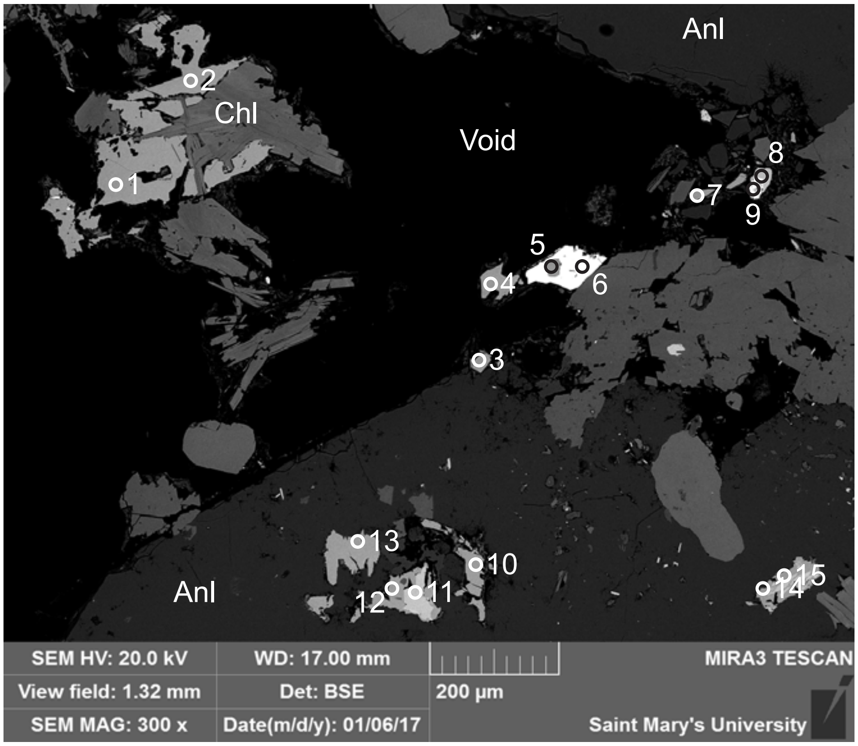

1:Titanite

Figure 1-3.26: Sample 9956c site 19 (SEM). (Table 1-3.2). Anhedral interstitial titanite (1) appears to partially fill a void.



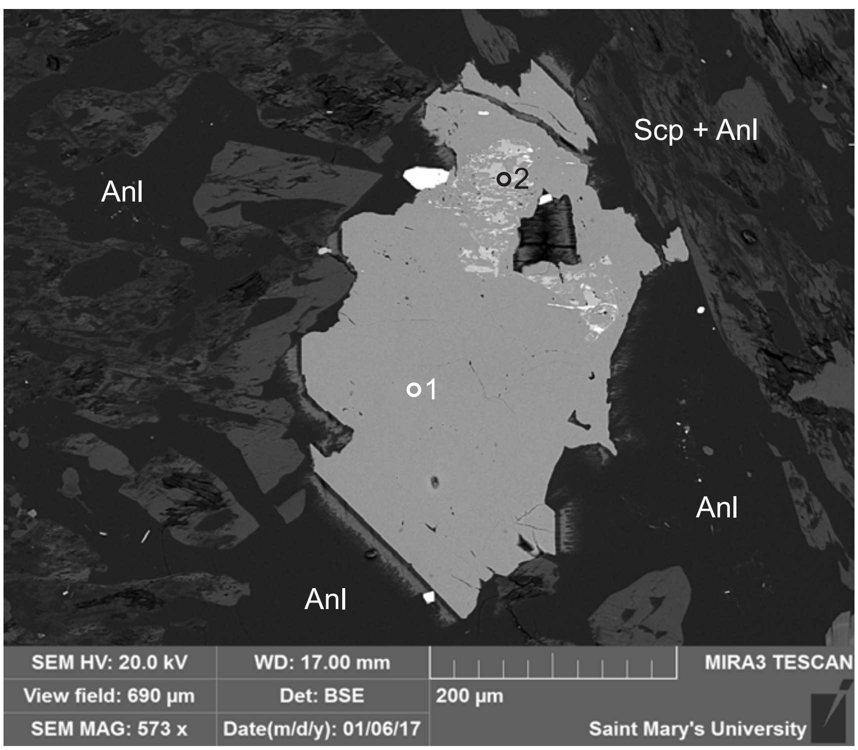

1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Titanite

Figure 1-3.27: Sample 9956c site 20 (SEM). (Table 1-3.2). Equant titanite (1-5) appears to fill voids and contains some voids. Some titanite (2-3,5) is in contact with chlorite. The titanite in this site is replacive-interstitial.



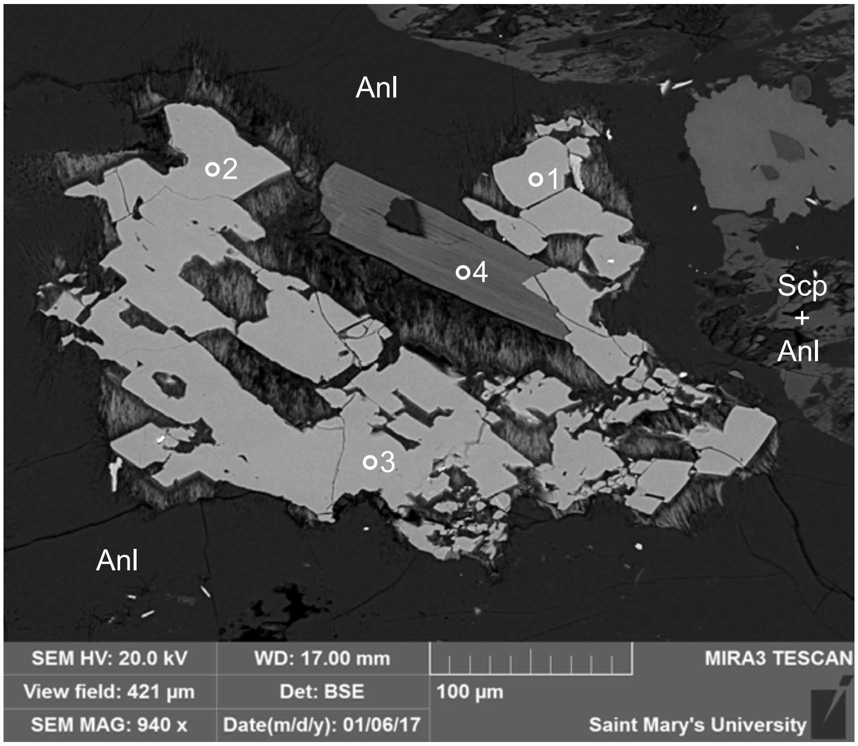

1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Titanite
6:Ti-Magnetite
7:Titanite
8:Rutile
9:Ti-Magnetite
10:Titanite
11:Rutile
12:Titanite
13:Titanite
14:Mixture
15:Rutile

Figure 1-3.28: Sample 9956c site 21 (SEM). (Table 1-3.2). Small anhedral rutile (8,11,15) crystals are overgrown by titanite. Large diamond shaped crystal with small patch of titanite (5) appears to have been overgrown by Fe-oxides (6). Most titanite grains appear to be interstitial.



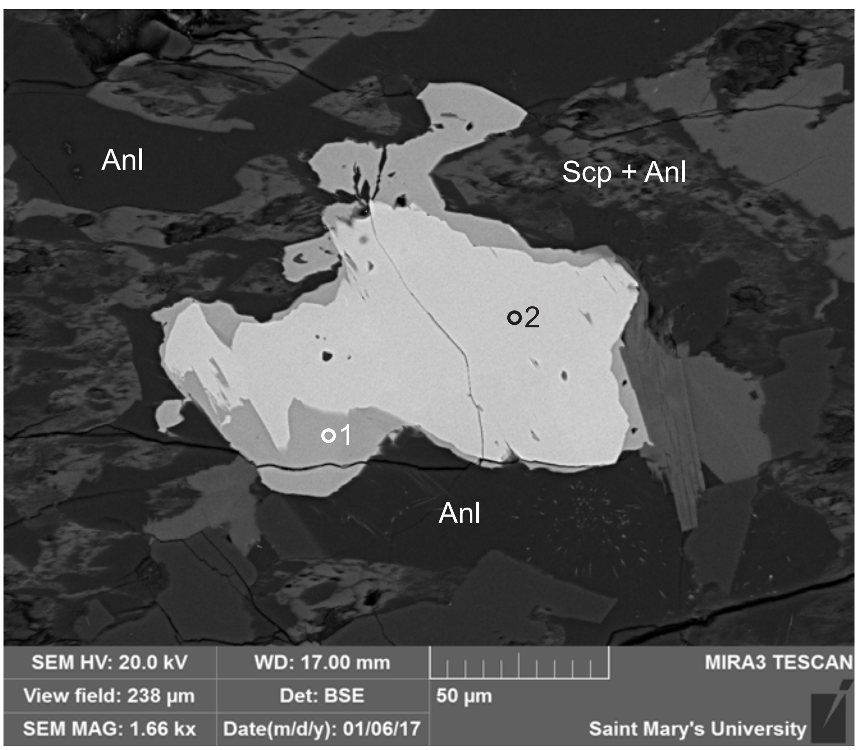

1:Titanite
2:Rutile

Figure 1-3.29: Sample 9956c site 22 (SEM). (Table 1-3.2). Large subhedral titanite (1) crystal that appears to be exsolving rutile (2).



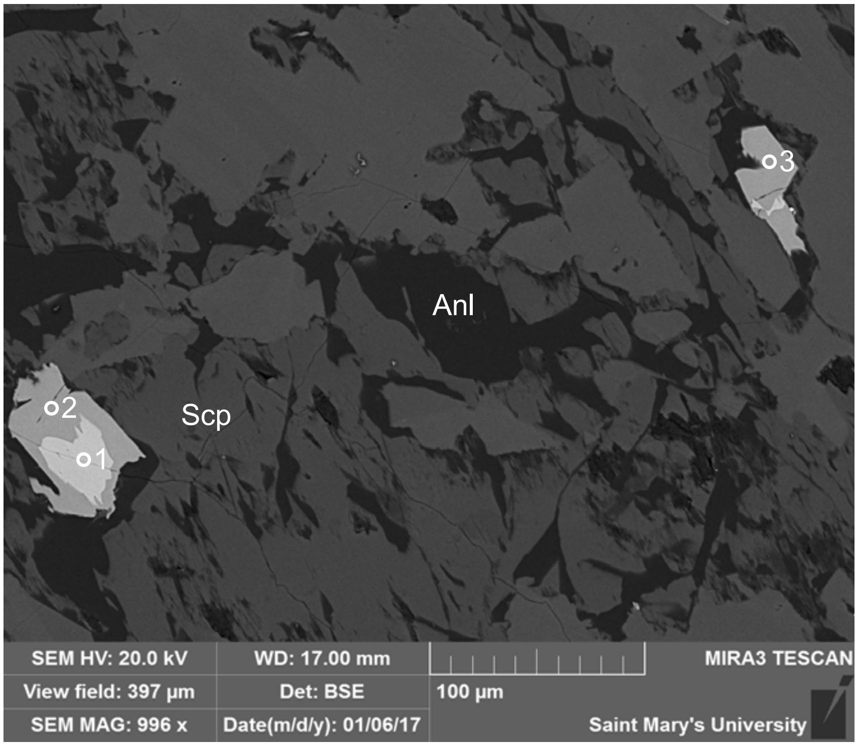

1:Titanite
2:Titanite
3:Titanite
4:Chlorite

Figure 1-3.30: Sample 9956c site 23 (SEM). (Table 1-3.2). Ragged titanite (1-3) with some voids, appears to predate chlorite (4).



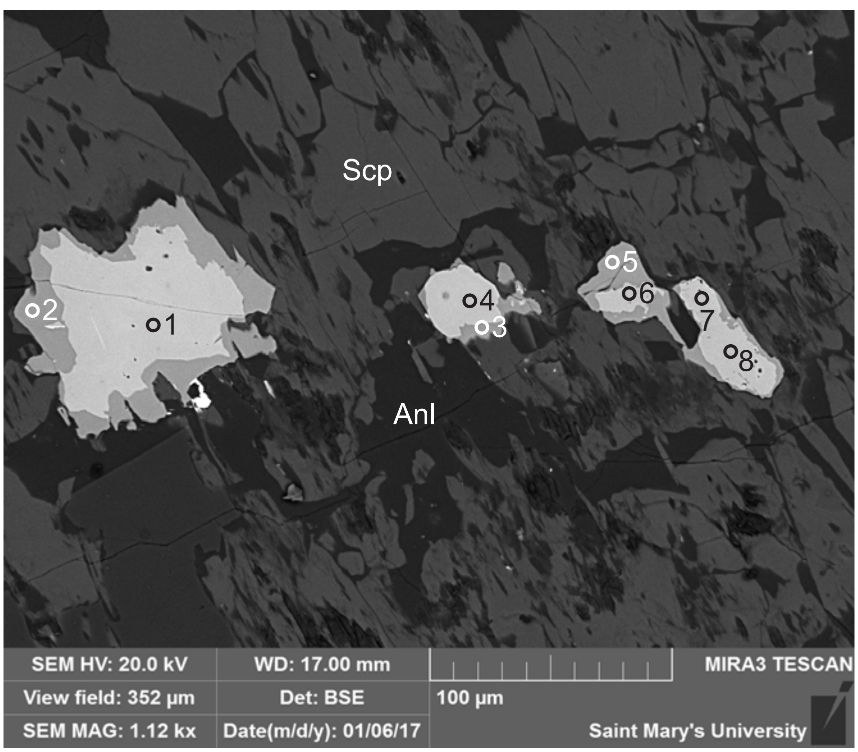

1:Titanite
2:Rutile

Figure 1-3.31: Sample 9956c site 24 (SEM). (Table 1-3.2). Large anhedral rutile (2) grain with few voids has equant and discontinuous overgrowths of titanite (1).



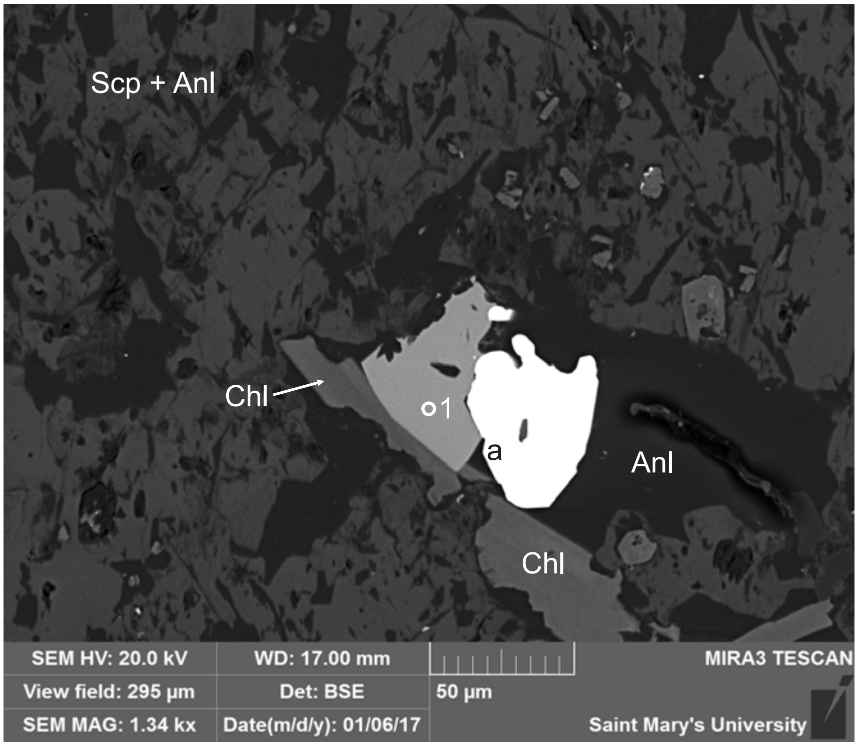

1:Rutile
2:Titanite
3:Titanite

Figure 1-3.32: Sample 9956c site 25 (SEM). (Table 1-3.2). Small anhedral rutile (1) grain is overgrown by titanite (2-3). The grains in this site appear to be interstitial.



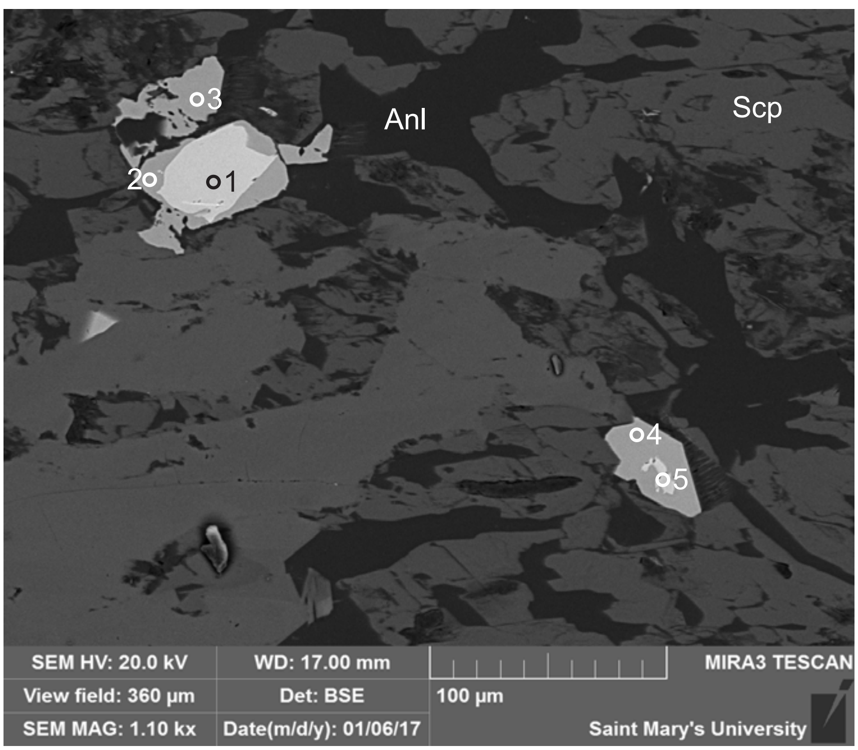

1:Rutile
2:Titanite
3:Titanite
4:Rutile
5:Titanite
6:Rutile
7:Rutile
8:Rutile

Figure 1-3.33: Sample 9956c site 26 (SEM). (Table 1-3.2). Small-large anhedral rutile (1,4,6-8) grains are overgrown by continuous titanite (2-3,5).



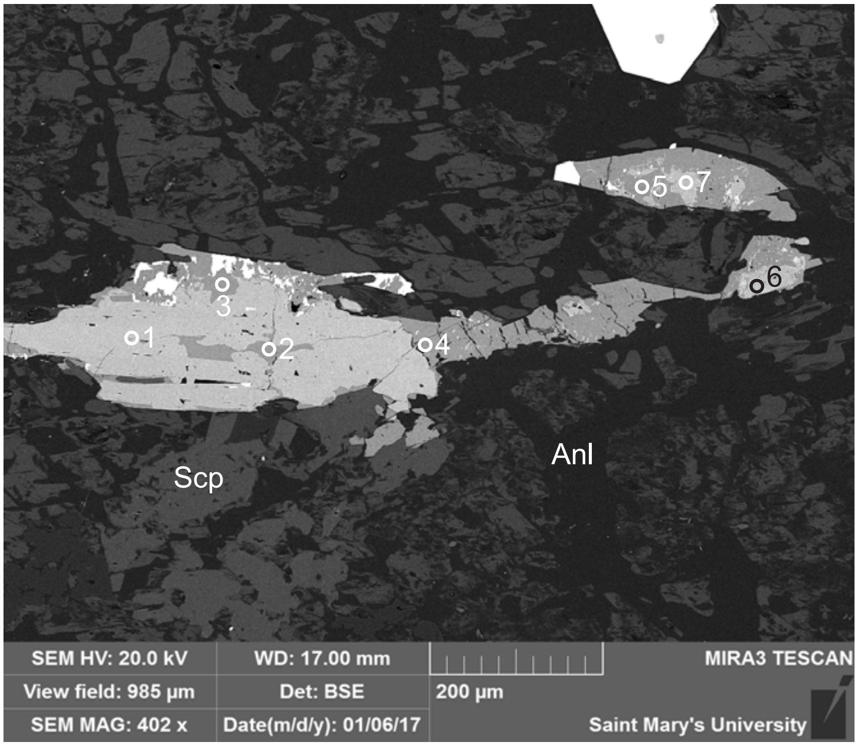

1:Titanite

Figure 1-3.34: Sample 9956c site 27 (SEM). (Table 1-3.2). A small grain of equant titanite (1) appears with analcime and Fe-oxide/hydroxide. The titanite appears to be in contact with chlorite. Both titanite and Fe-oxide/hydroxide appear to postdate analcime (position a).



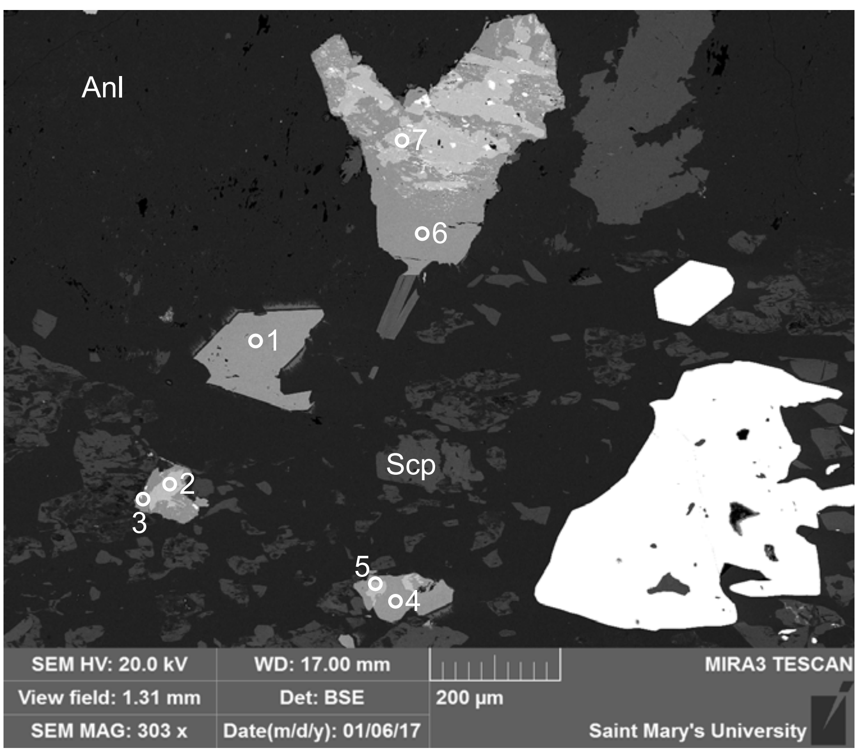

1:Rutile
2:Titanite
3:Titanite
4:Titanite
5:Rutile

Figure 1-3.35: Sample 9956c site 28 (SEM). (Table 1-3.2). Small subhedral rutile (1,5) grains are overgrown by equant titanite (2-4).




1:Rutile
2:Titanite
3:Titanite +
4:Titanite
5:Titanite
6:Rutile
7:Rutile

Figure 1-3.36: Sample 9956c site 29 (SEM). (Table 1-3.2). Large subhedral rutile (1,6-7) crystal is partly replaced by titanite (2-5) and Fe-oxides. All appear to be interstitial.




1:Titanite
2:Rutile
3:Titanite
4:Titanite
5:Rutile
6:Titanite
7:Rutile + FeO

Figure 1-3.37: Sample 9956c site 30 (SEM). (Table 1-3.2). Small-large anhedral rutile (2,5,7) crystals with few voids are replaced and locally overgrown by titanite (3,4,6). Titanite (1) is an equant crystal.

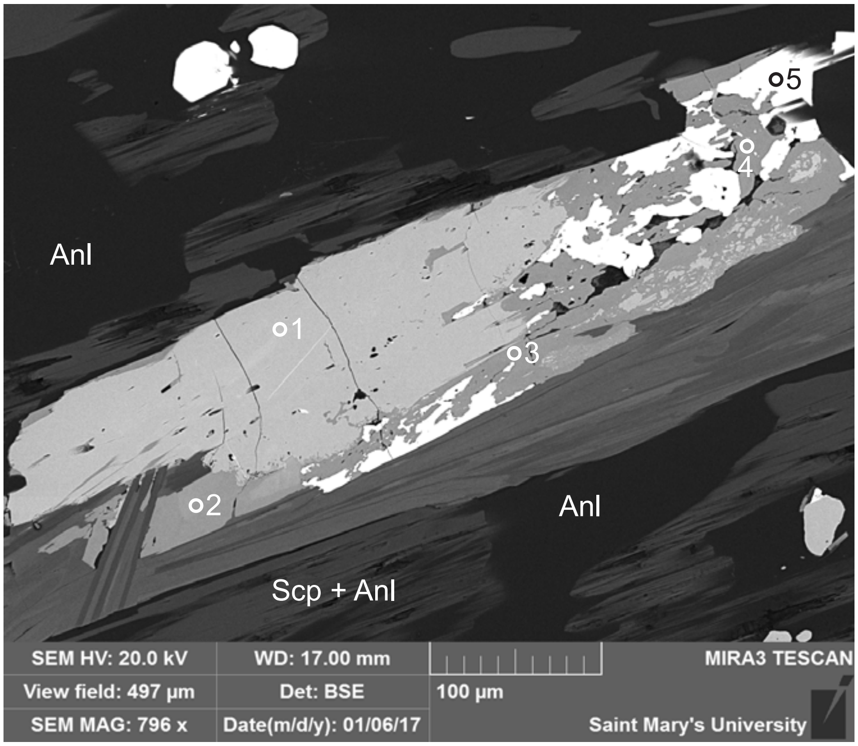



Figure 1-3.38: Sample 9956c site 31 (SEM). (Table 1-3.2). Large ~200μm rutile (1) crystal with replacement (4) and possibly equant overgrowth (2) of titanite and Fe-oxides (5).

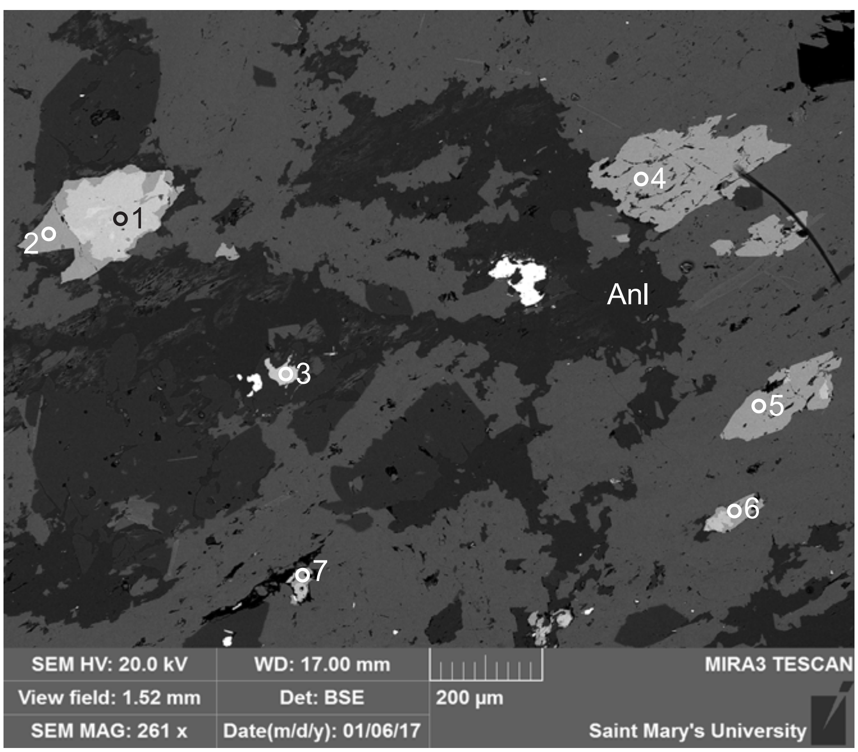



Figure 1-3.39: Sample 9956c site 32 (SEM). (Table 1-3.2). This site consists of rutile (1,3) with equant overgrowths of titanite (2), and titanite (4) which is an equant crystal. Some of the titanite crystals contain many voids and/or rutile relics (4,5,6).

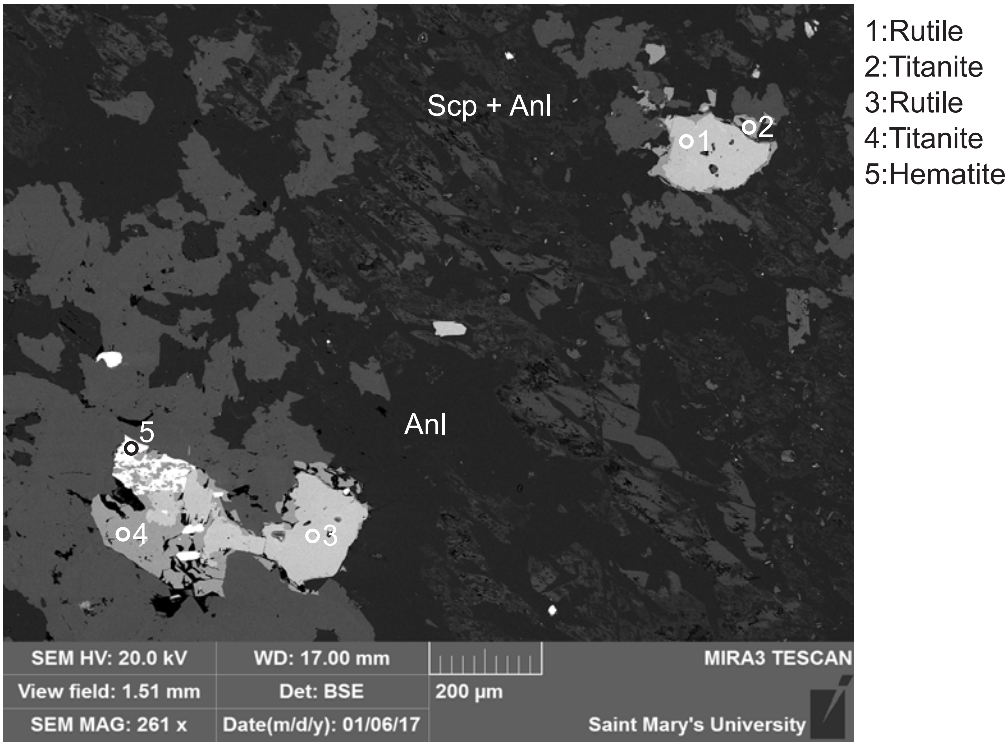



Figure 1-3.40: Sample 9956c site 33 (SEM). (Table 1-3.2). This site consists of large rutile (1,3) crystals with equant overgrowth of titanite (2,4) and Fe-oxides (5). The large grain (3-5) appears to be interstitial.

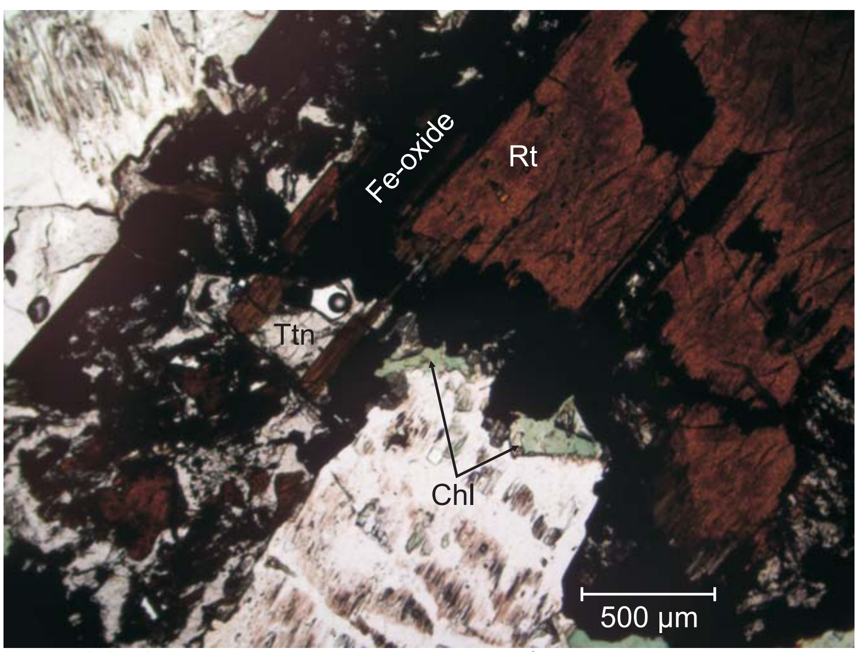



Figure 1-3.41: This microphotograph consists of rutile with some zoning (light orange vs dark red/brown), and titanite and Fe-oxide overgrowths. 4x PPL.

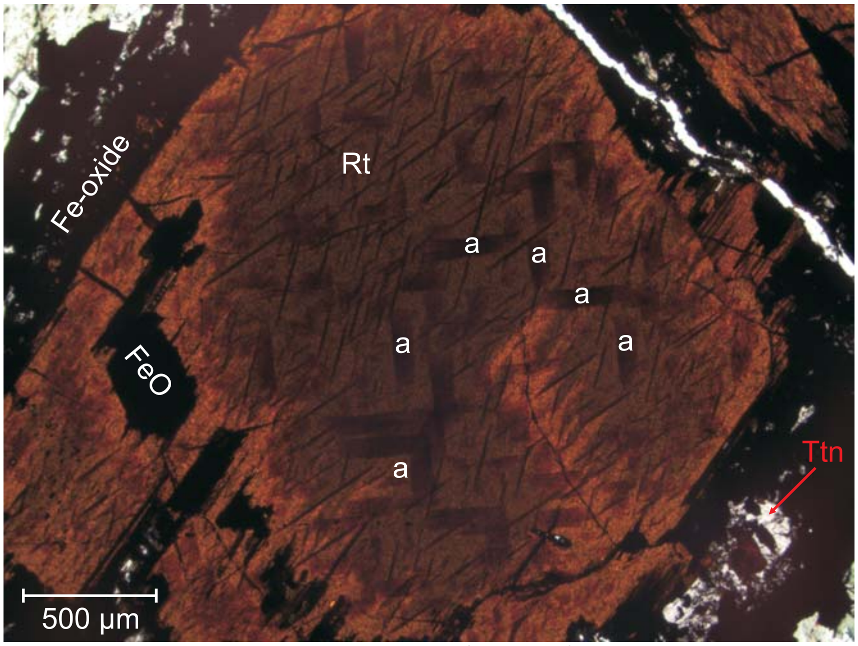


Figure 1-3.42: Large rutile grain with zoning (light-dark) and dark red lines (positions a). These lines cannot be seen under reflected light microscope. They may thus be just striation lines. The grain is then overgrown by titanite and Fe-oxide. 4x PPL.

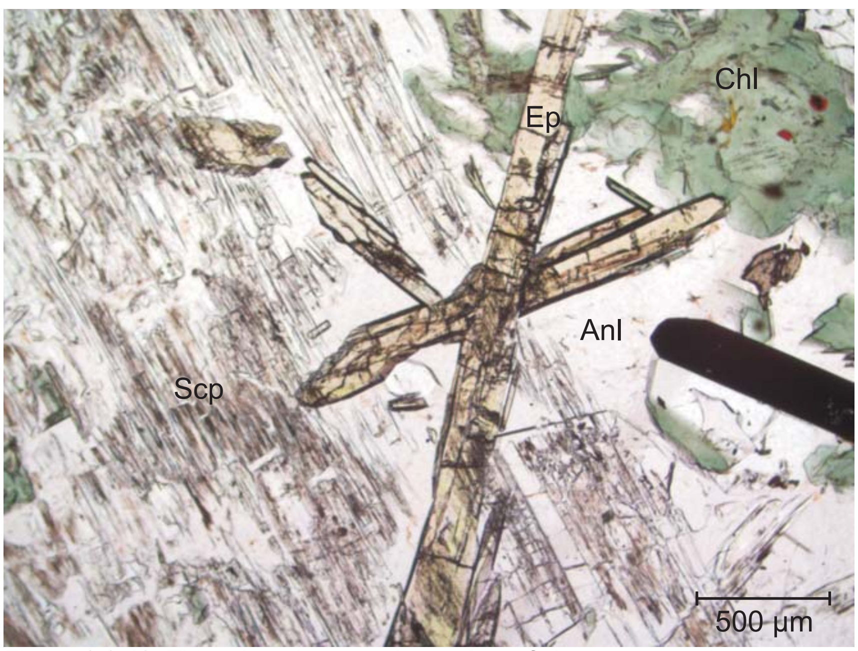


Figure 1-3.43: This microphotograph consists of chlorite, scapolite, analcime, and probably later epidote. 4x PPL.

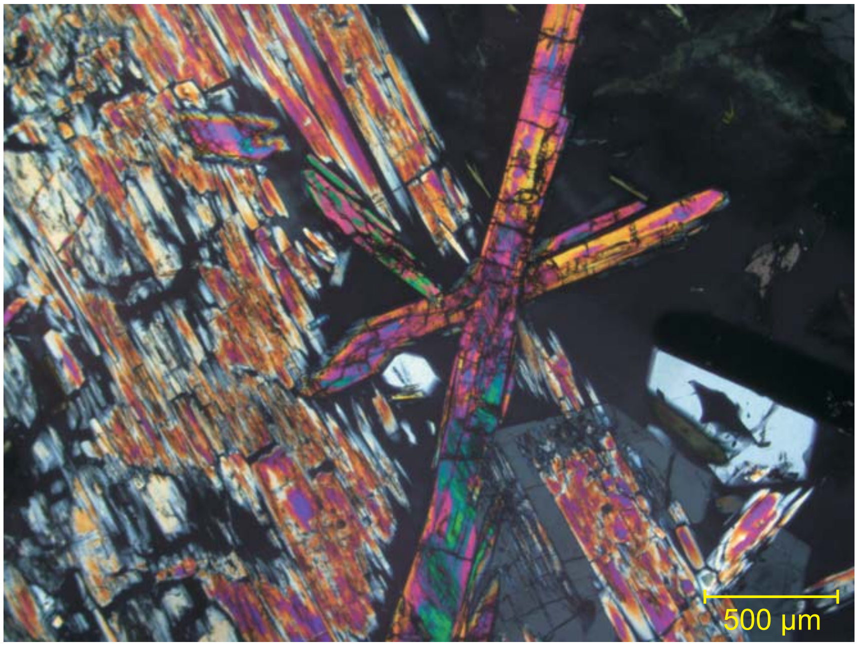


Figure 1-3.44: Same as in Figure 1-3.43 except XPL.

Table 1-3.1: EDS analyses from sample 9956c.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | Cl | V2O5 | Cr2O3 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 1 | 1 | Rt | 1.01 | 97.71 | | 1.09 | | 0.20 | | | | | 100 | 106 | |
| 9956c | 1 | 2 | Ttn | 33.25 | 35.32 | 2.29 | 1.00 | | 28.14 | | | | | 100 | 114 | |
| 9956c | 1 | 3 | Rt | | 98.47 | | 1.53 | | | | | | | 100 | 105 | |
| 9956c | 1 | 4 | Ttn | 32.98 | 36.50 | 1.75 | 0.69 | | 28.08 | | | | | 100 | 110 | |
| 9956c | 1 | 5 | Mag | | 2.30 | | 96.99 | | | | | 0.41 | 0.30 | 100 | 95 | 91 |
| 9956c | 1 | 6 | Ttn | 33.22 | 35.66 | 2.12 | 0.90 | | 28.11 | | | | | 100 | 109 | |
| 9956c | 1 | 7 | Rt | | 98.13 | | 1.62 | | 0.25 | | | | | 100 | 106 | |
| 9956c | 2 | 1 | Rt | | 99.03 | | 0.29 | | | | | | 0.68 | 100 | 106 | |
| 9956c | 2 | 2 | Rt + Ilm | | 78.74 | | 20.53 | | | | | | 0.72 | 100 | 105 | |
| 9956c | 2 | 3 | Rt + Ilm | | 86.33 | | 12.88 | | | | | | 0.79 | 100 | 104 | |
| 9956c | 2 | 4 | Rt | | 99.18 | | | | | | | | 0.82 | 100 | 105 | |
| 9956c | 3 | 1 | Ttn | 33.05 | 36.90 | 1.37 | 0.55 | | 28.14 | | | | | 100 | 113 | |
| 9956c | 3 | 2 | Ti-Mag | | 3.19 | | 96.16 | | | | | 0.65 | | 100 | 96 | |
| 9956c | 3 | 3 | Chl | 28.60 | | 19.27 | 15.47 | 21.37 | | | | | 0.29 | 85.00 | 100 | |
| 9956c | 3 | 4 | Rt | | 98.86 | | 0.33 | | | | | | 0.81 | 100 | 105 | |
| 9956c | 3 | 5 | Ttn | 33.06 | 37.91 | 0.86 | 0.40 | | 27.76 | | | | | 100 | 111 | |
| 9956c | 3 | 6 | Ttn | 33.30 | 35.29 | 2.04 | 1.38 | | 27.98 | | | | | 100 | 105 | |
| 9956c | 3 | 7 | Chl | 28.29 | | 19.24 | 17.66 | 19.81 | | | | | | 85.00 | 103 | |
| 9956c | 3 | 8 | Ttn | 32.67 | 37.92 | 1.11 | 0.45 | | 27.86 | | | | | 100 | 109 | |
| 9956c | 3 | 9 | Rt | | 99.24 | | | | | | | | 0.76 | 100 | 104 | |
| 9956c | 4 | 1 | Gth | | | | 100.00 | | | | | | | 100 | 85 | 81 |
| 9956c | 4 | 2 | Ttn | 33.30 | 36.80 | 1.37 | 0.71 | | 27.83 | | | | | 100 | 109 | |
| 9956c | 4 | 3 | Rt | | 99.03 | | 0.30 | | | | | | 0.67 | 100 | 103 | |

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | Cl | V2O5 | Cr2O3 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 4 | 4 | Ttn | 33.29 | 36.81 | 1.28 | 0.76 | | 27.87 | | | | | 100 | 111 | |
| 9956c | 5 | 1 | Mix | 8.58 | | 0.86 | 88.04 | 1.78 | 0.74 | | | | | 100 | 77 | |
| 9956c | 5 | 2 | Mix | 4.97 | | | 93.37 | 0.88 | 0.78 | | | | | 100 | 80 | |
| 9956c | 5 | 3 | Mix | 14.18 | | | 80.85 | 1.45 | 2.42 | 0.79 | 0.31 | | | 100 | 78 | |
| 9956c | 5 | 4 | Mix | 17.51 | | | 77.02 | 1.68 | 2.84 | 0.60 | 0.35 | | | 100 | 74 | |
| 9956c | 5 | 5 | Mix | 18.54 | | | 75.00 | 1.88 | 3.05 | 1.15 | 0.39 | | | 100 | 80 | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | Oxide total | | | | | | | | | | | | | | |
| | Mag = | >90% | | | | | | | Average rutile total = | | | | 105 | | | |
| | Hem = | 85-89% | | | | | | | | | | | | | | |
| | Gth = | 80-84% | | | | | | | Oxide total = (wt % oxide / Avg. Rt total) * 100 | | | | | | | |
| | Lm = | <80% | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | Notes | | | | | | | | | | | | | | |
| 1 | + = indicates other minerals present | | | | | | | | | | | | | | | |
| 2 | Rt + FeO = Rt that contains more than 2wt% FeO | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

# Appendix 1-4: SEM-BSE images and EDS mineral analyses for sample 9956d.

**Sample 9956d**

**Host: Scapolitized syenite**

Magmatic minerals: Analcime, quartz, rutile, titanite

Secondary Minerals: Chlorite, Fe-oxides/hydroxides, rutile, scapolite, analcime, titanite

**Notes:**

1. Titanite commonly overgrows and replaces rutile (Figures 1-4.4,1-4.5). Fe-oxide is doing the same, but the Fe-oxide overgrowths are better expressed because the Fe-oxide precipitation appears to be later (Figures 1-4.30,1-4.31).

2. Titanite has often been seen cross-cutting the scapolite and analcime mat (Figure 1-4.6).

3. Titanite in this sample appears to postdate chlorite, and analcime (Figures 1-4.6,1-4.7).

4. Titanite and rutile appear to occur also commonly as late interstitial grains (Figures 1-4.12,1-4.24,1-4.26,1-4.32).

5. The Fe-oxides have been seen not only replacing both rutile and titanite relics, but rimming individual relics of rutile (Figure 1-4.10).

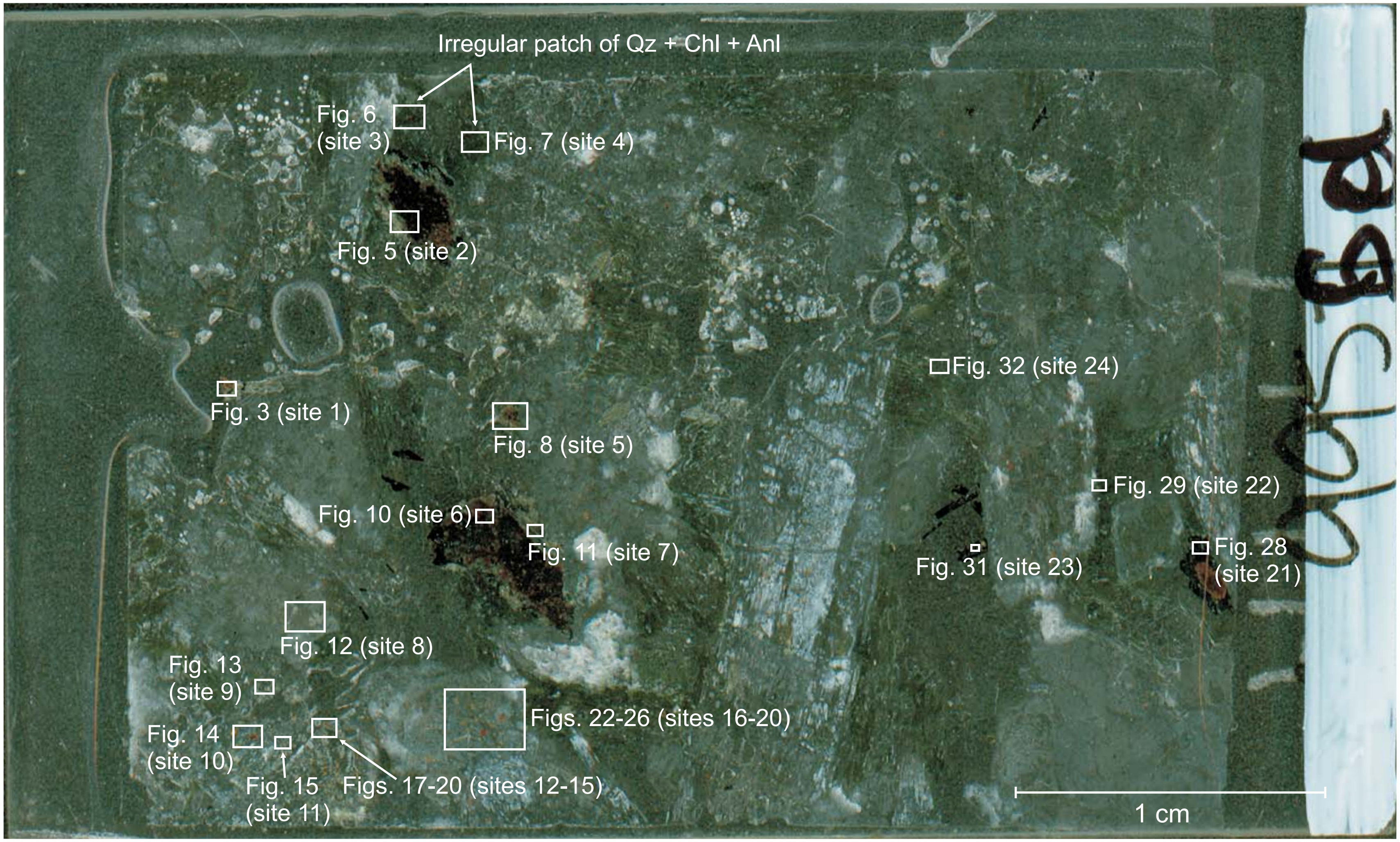



Figure 1-4.1: Scanned thin section of sample 9956d showing the location of analyzed sites. This sample comes from a coarse-grained syenite with dark minerals (sites 2-3,5-7,22-26,21,23).

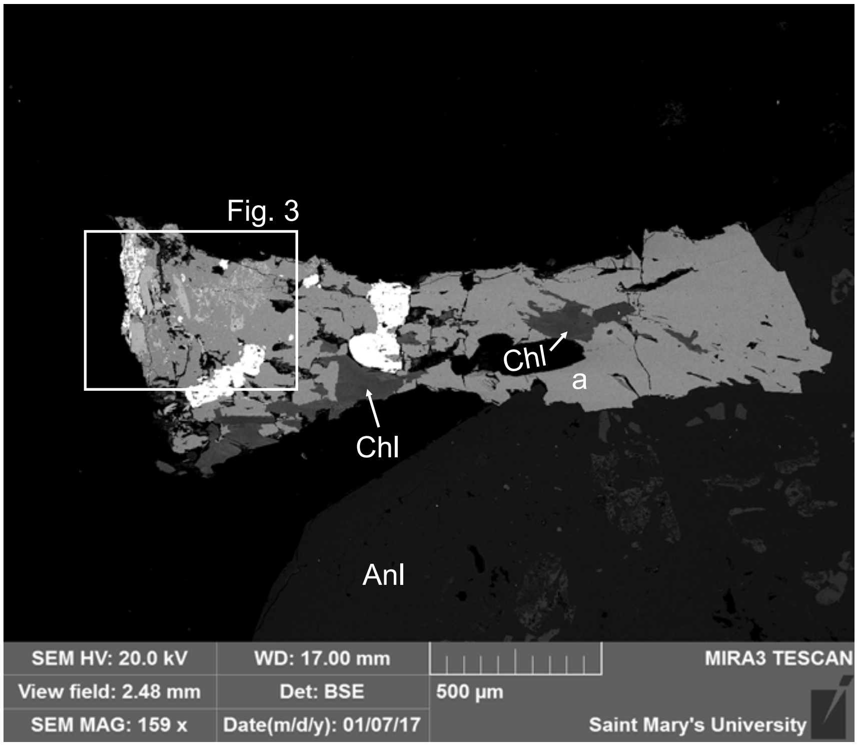
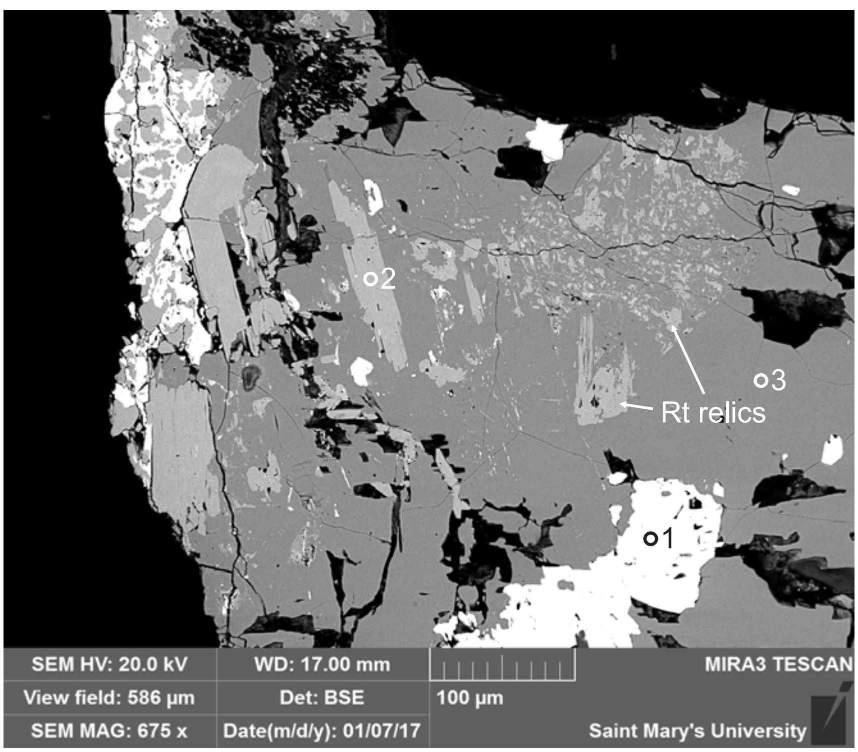



Figure 1-4.2: Sample 9956d (SEM).




1:Ti-Magnetite
2:Rutile
3:Titanite

Figure 1-4.3: Sample 9956d site 1 (SEM). Large anhedral-subhedral rutile (2) crystal or rutile crystal aggregate that is replaced by equant titanite (3) and Fe-oxides (1). The titanite appears to be replacing chlorite (see Figure 1-4.2, position a).

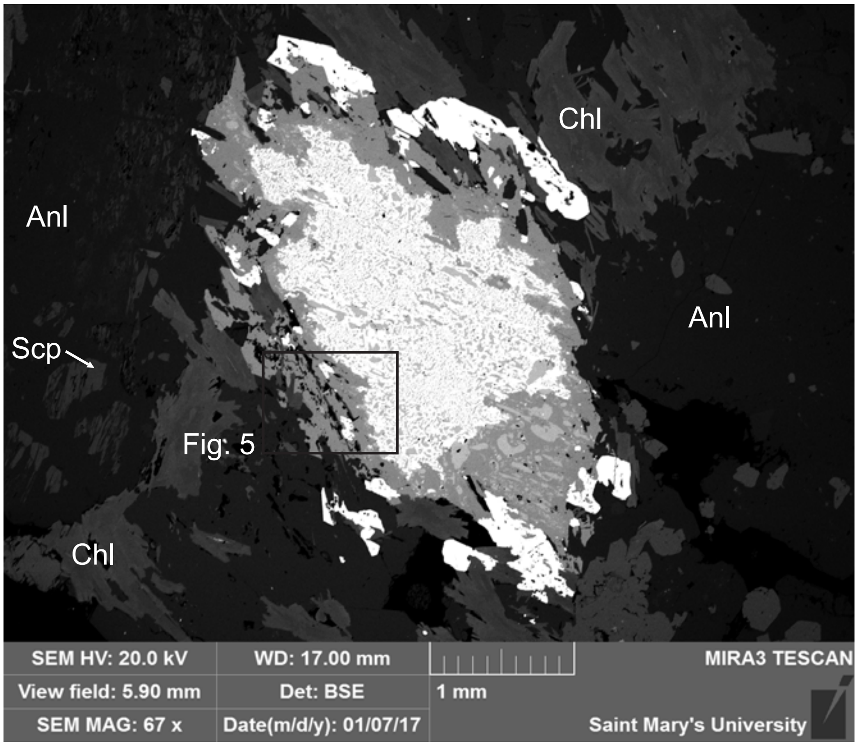
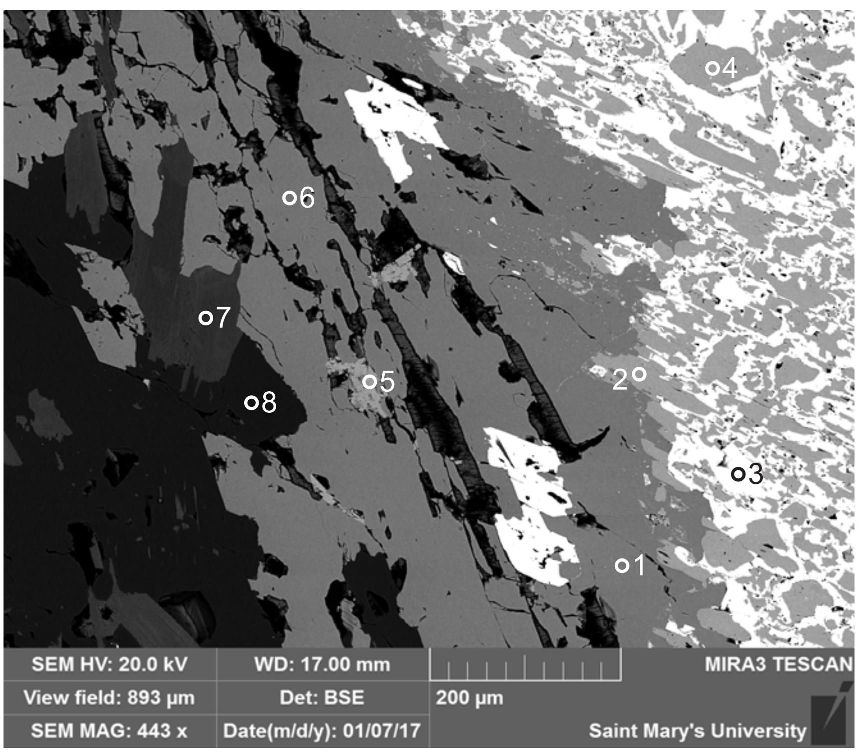
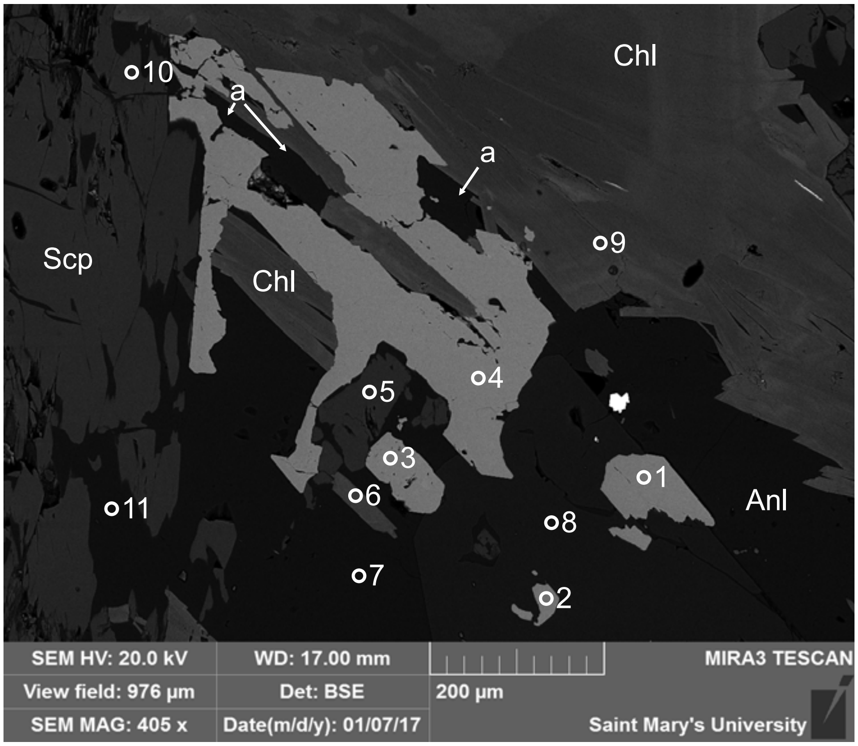



Figure 1-4.4: Sample 9956d (SEM).



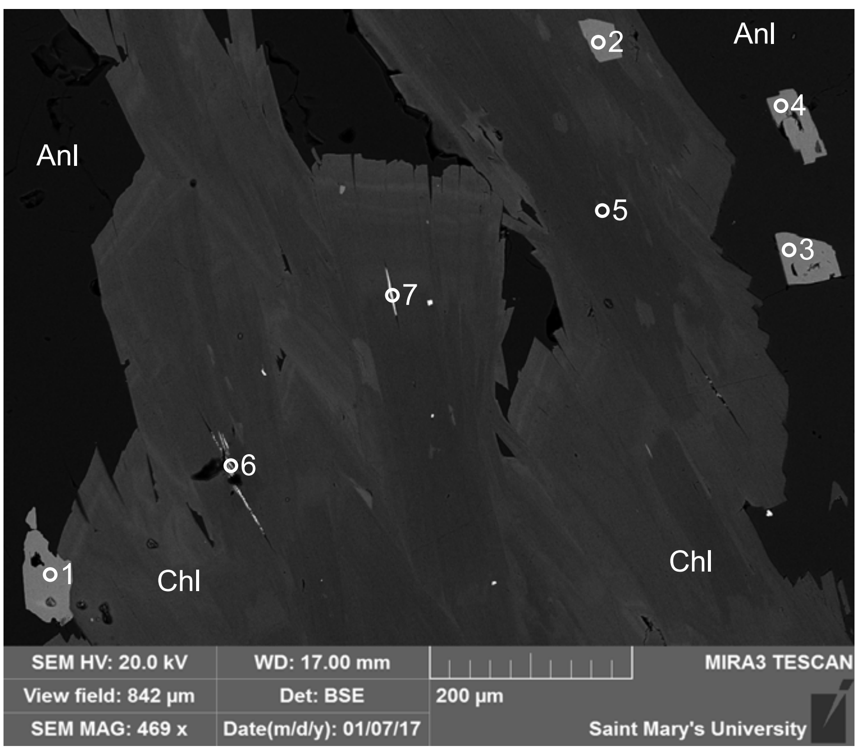

1:Titanite
2:Rutile
3:Goethite
4:Rutile
5:Rutile
6:Titanite
7:Chlorite
8:Quartz

Figure 1-4.5: Sample 9956d site 2 (SEM). Large rutile (2,4-5) crystal or aggregate with equant overgrowth of titanite (1,6), and Fe-oxides and a lot of replacement (5). Chlorite (7) and quartz (8) appear to occur around the grain boundaries.




1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Scapolite
6:Chlorite
7:Analcime
8:Quartz
9:Chlorite
10:Scapolite
11:Analcime

Figure 1-4.6: Sample 9956d site 3 (SEM). Titanite (4) appears to cross-cut scapolite (5) and analcime (7), and also occur as discrete grains (1-3). Chlorite (9) appears to postdate titanite (corroded) and it is probably synchronous with analcime (positions a).




1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Chlorite
6:Chlorite + FeO
7:Chlorite + FeO

Figure 1-4.7: Sample 9956d site 4 (SEM). This site consists of small grains of titanite (1-4) and large grains of chlorite (5-7). The titanite (1) appears to predate chlorite. The chlorite grain has Fe-oxide exsolutions (6,7).

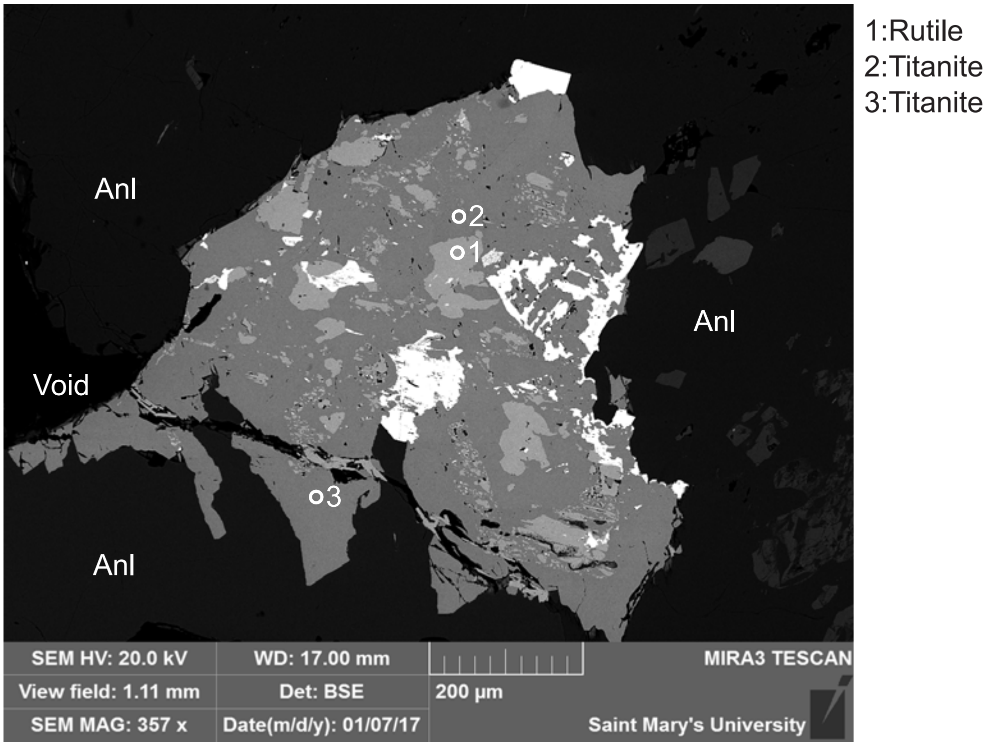



Figure 1-4.8: Sample 9956d site 5 (SEM). Large anhedral rutile (1) is replaced and probably overgrown by equant titanite (2-3), and Fe-oxides. Fractures cut both titanite and rutile.

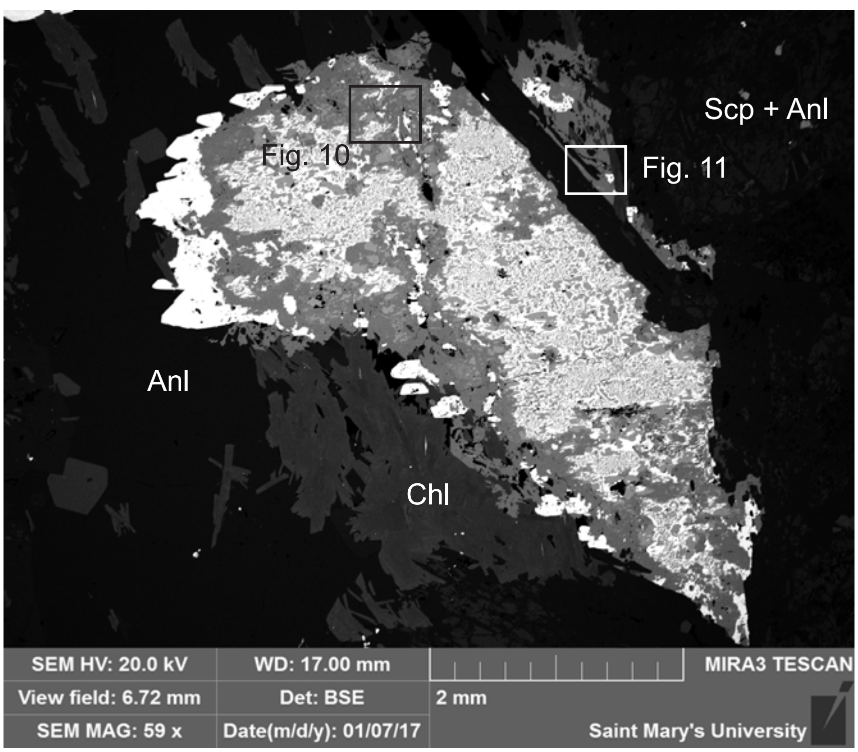



Figure 1-4.9: Sample 9956d (SEM).

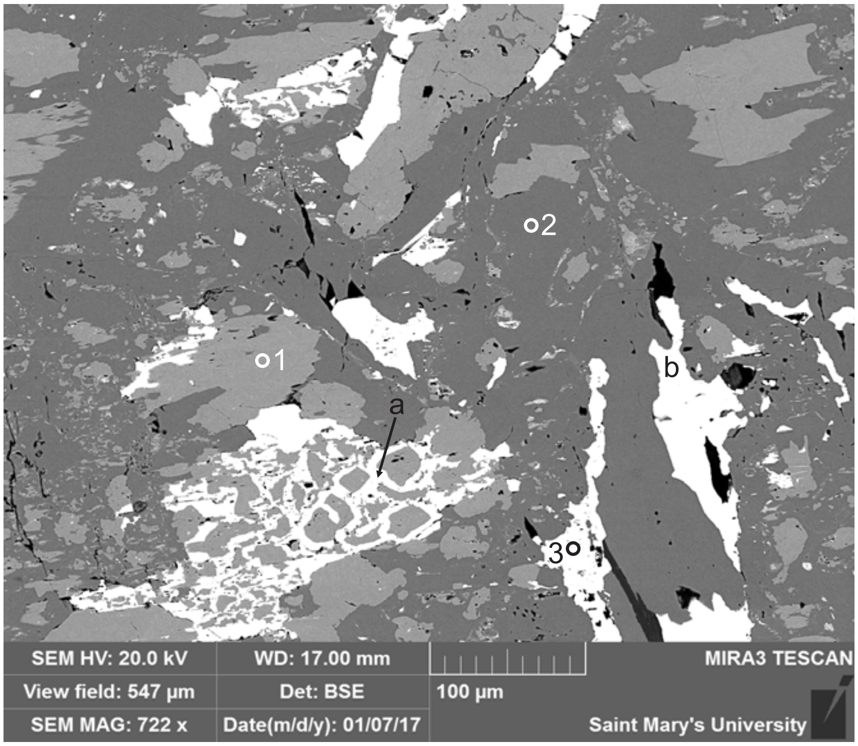



Figure 1-4.10: Sample 9956d site 6 (SEM).Very large rutile (1) crystal or crystal aggregate is replaced and overgrown by equant titanite (2), and later Fe-oxides (3) (position a). The Fe-oxides also appear to fill voids (position b). Titanite and rutile contain some voids.

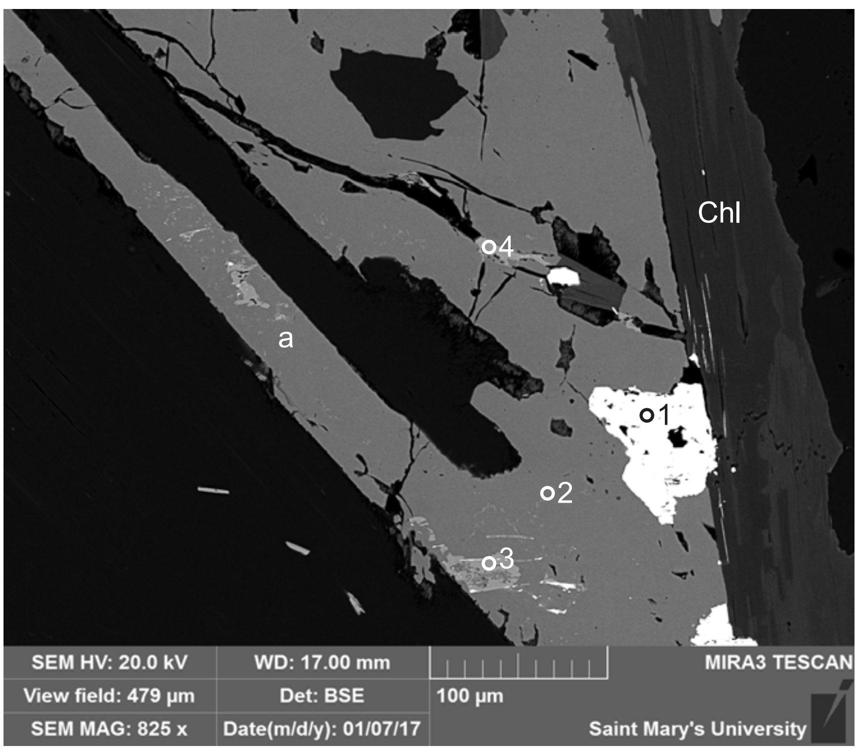
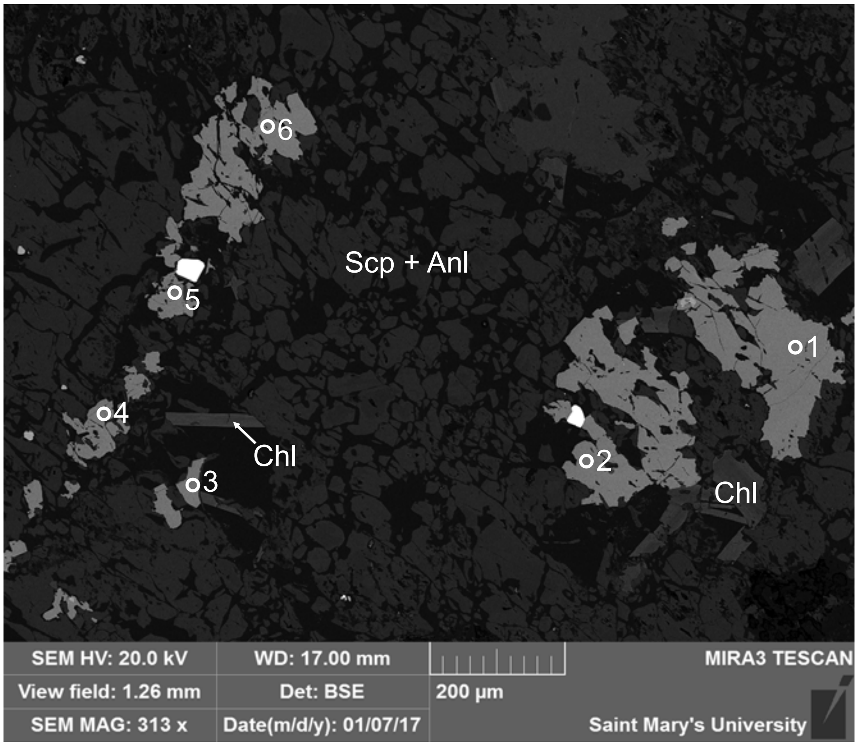
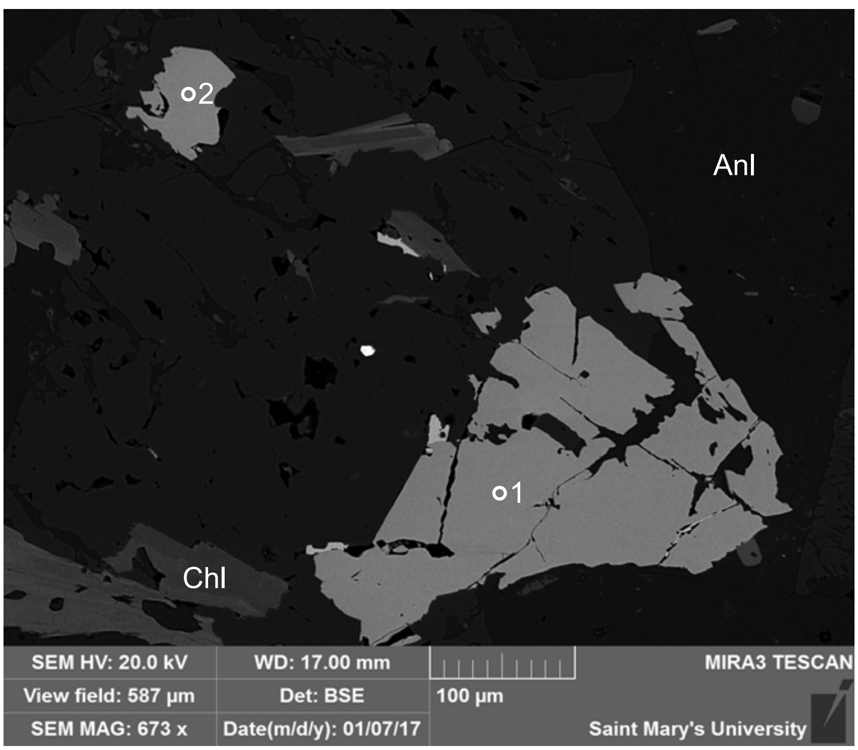



Figure 1-4.11: Sample 9956d site 7 (SEM). This site consists of small rutile (4) that appears to fill a fracture through a titanite (2) crystal. Rutile (3, position a) are probably relics in the titanite (2). Fe-oxides (1) appear to fill voids.




1:Titanite
2:Titanite
3:Titanite
4:Titanite
5:Titanite
6:Titanite

Figure 1-4.12: Sample 9956d site 8 (SEM). Ragged interstitial titanite (1-6) appears to cross-cut the host (scapolite and analcime).




1:Titanite
2:Titanite

Figure 1-4.13: Sample 9956d site 9 (SEM). This site consists of titanite (1-2) with some voids. The titanite appears to partially fill voids.

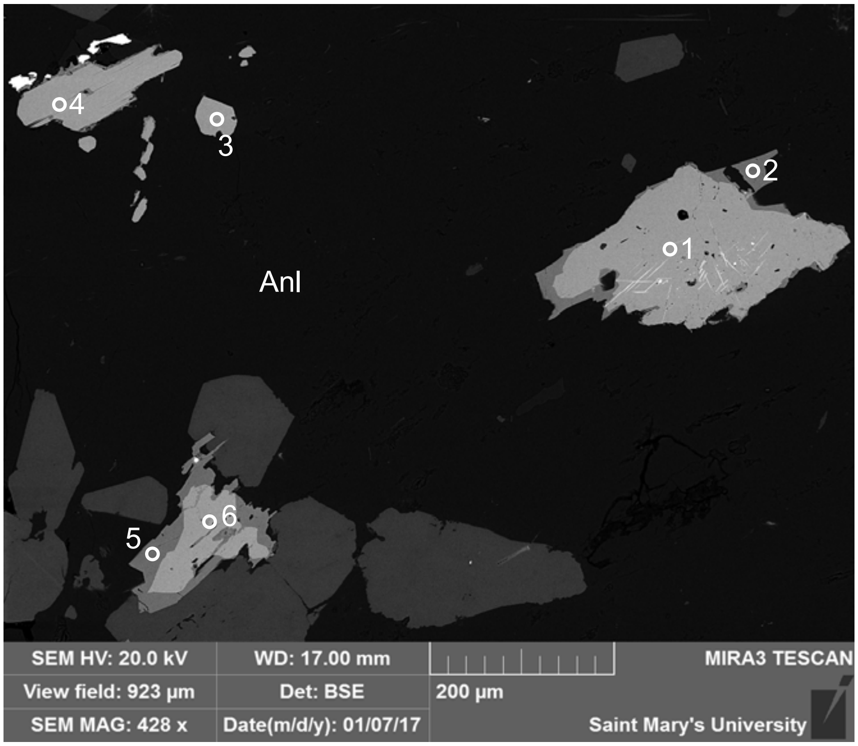



Figure 1-4.14: Sample 9956d site 10 (SEM). Large rutile (1,4,6) grains with equant and discontinuous overgrowths of titanite (2,5). A small rutile (3) grain appears to have precipitated later.

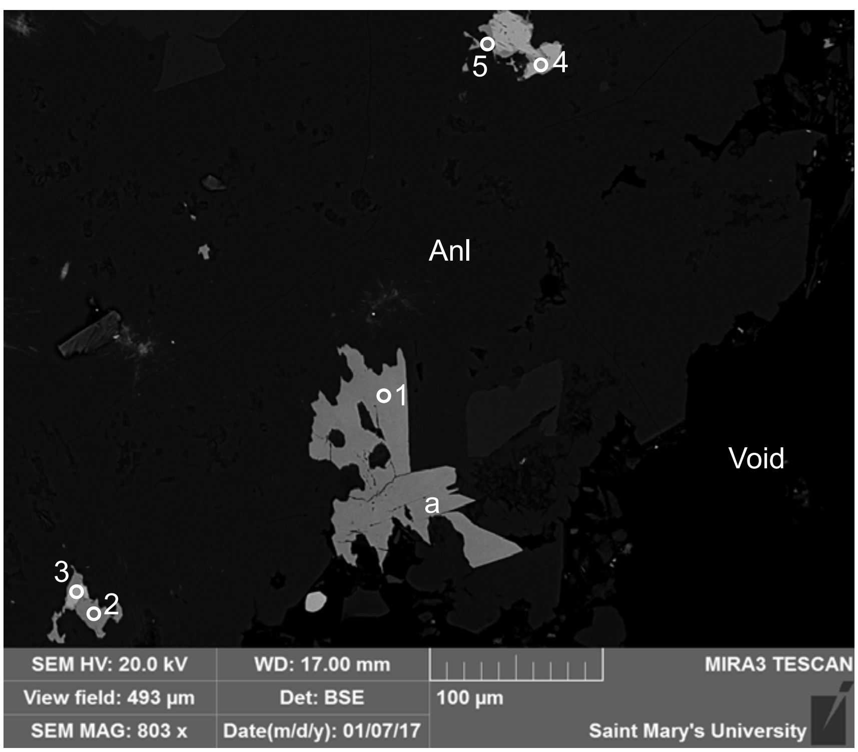



Figure 1-4.15: Sample 9956d site 11 (SEM). Small rutile (3-4) grains are overgrown by large discontinuous titanite (2,5). A large ragged titanite (1) crystal contains some inclusions of analcime and appears to be replacive (position a).

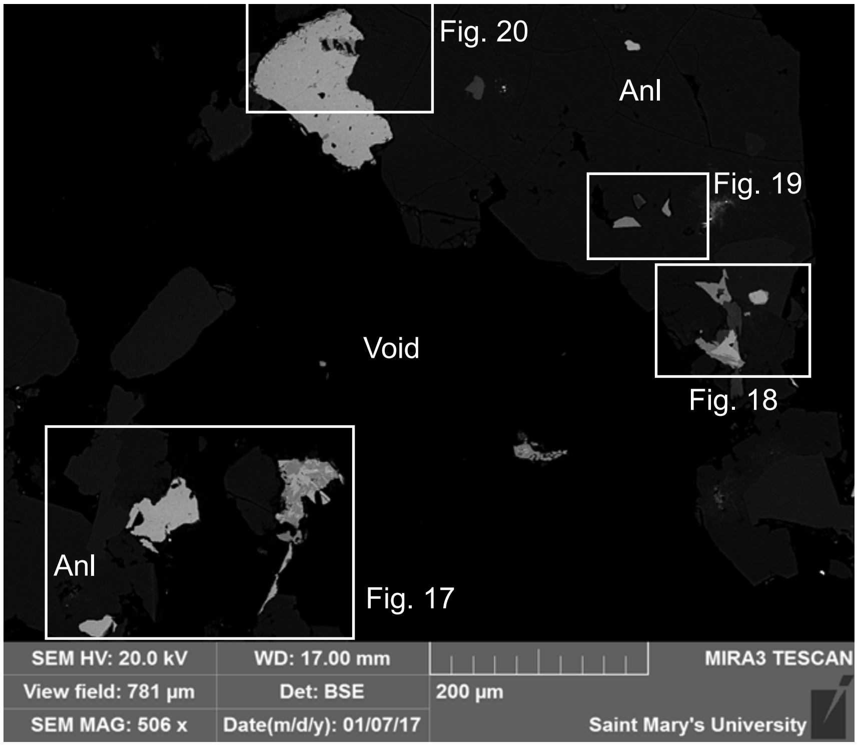
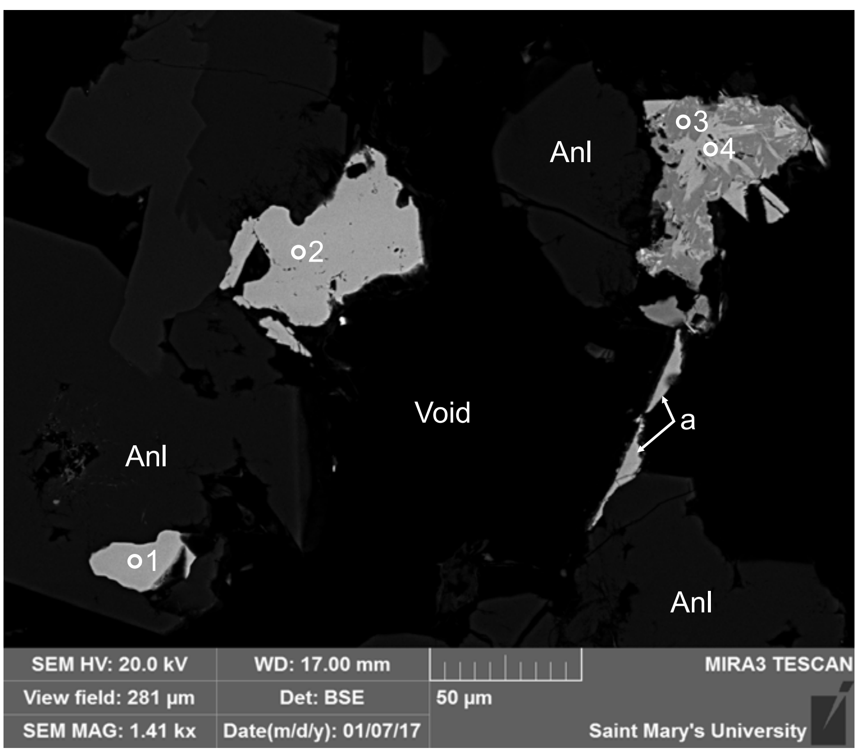
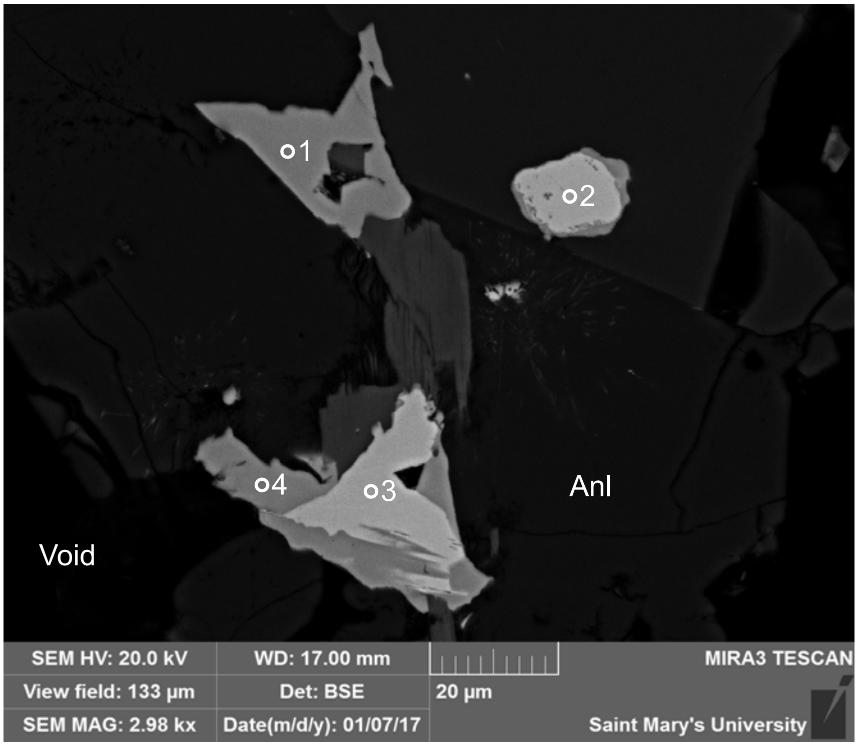



Figure 1-4.16: Sample 9956d (SEM).



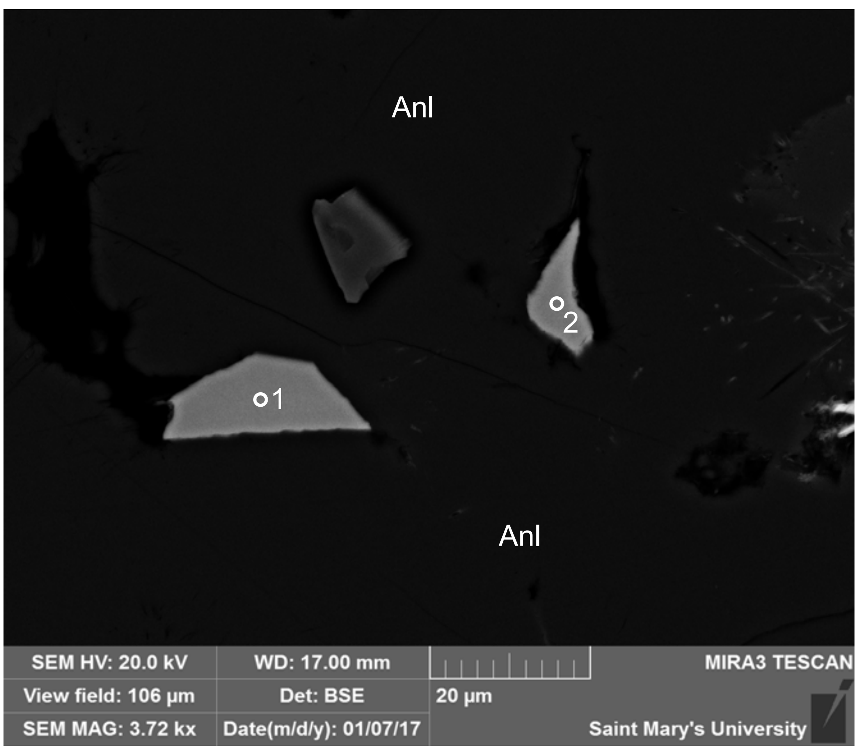

1:Rutile
2:Rutile
3:Titanite
4:Rutile

Figure 1-4.17: Sample 9956d site 12 (SEM).Titanite (3) appears to have partly replaced rutile (4). Other rutile (1-2) crystals appear to be partially filling a large void. The rutile (2, position a) grains in this site appear to be interstitial.



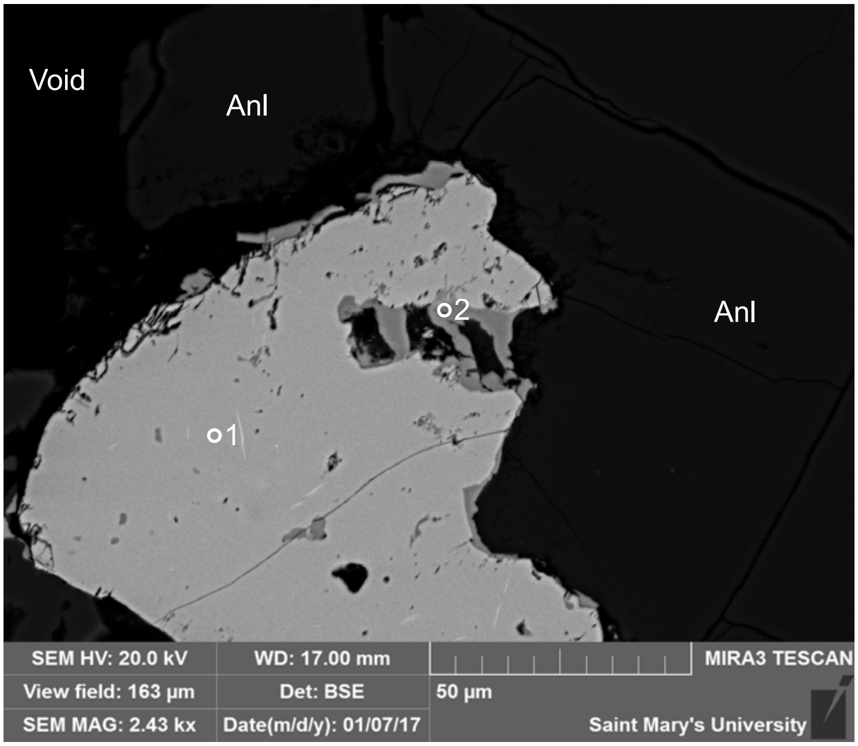

1:Titanite
2:Rutile
3:Rutile
4:Titanite

Figure 1-4.18: Sample 9956d site 13 (SEM). Small anhedral rutile (2-3) grains are overgrown by subequant titanite (4). Titanite (1) appears to be an subequant crystal.




1:Titanite
2:Titanite

Figure 1-4.19: Sample 9956d site 14 (SEM). Small subhedral titanite (1-2) crystals appear to be interstitial.




1:Rutile
2:Titanite

Figure 1-4.20: Sample 9956d site 15 (SEM). Large anhedral ragged rutile (1) crystal is overgrown by discontinuous titanite (2).

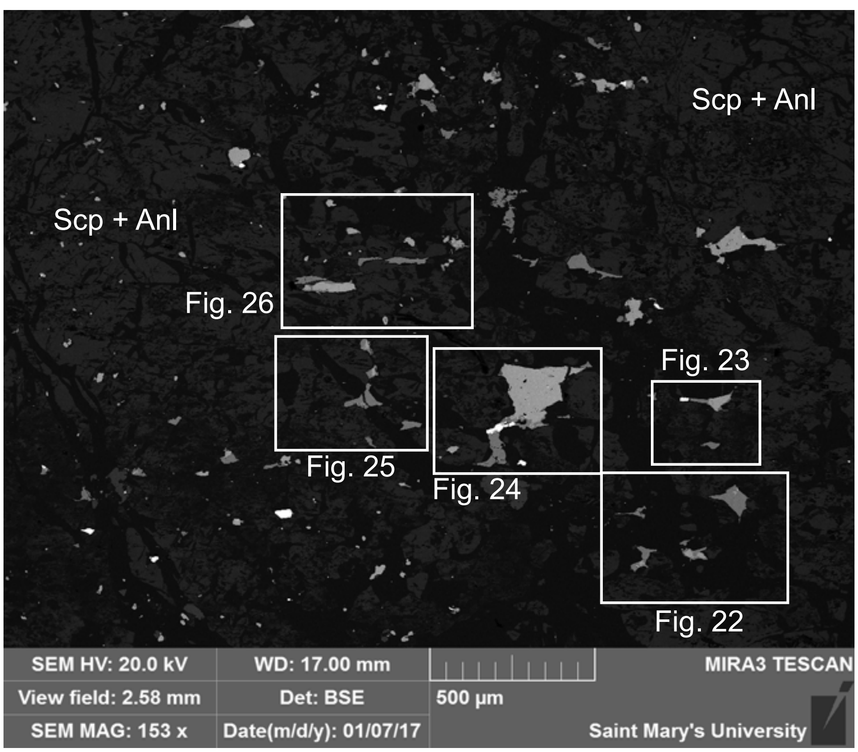
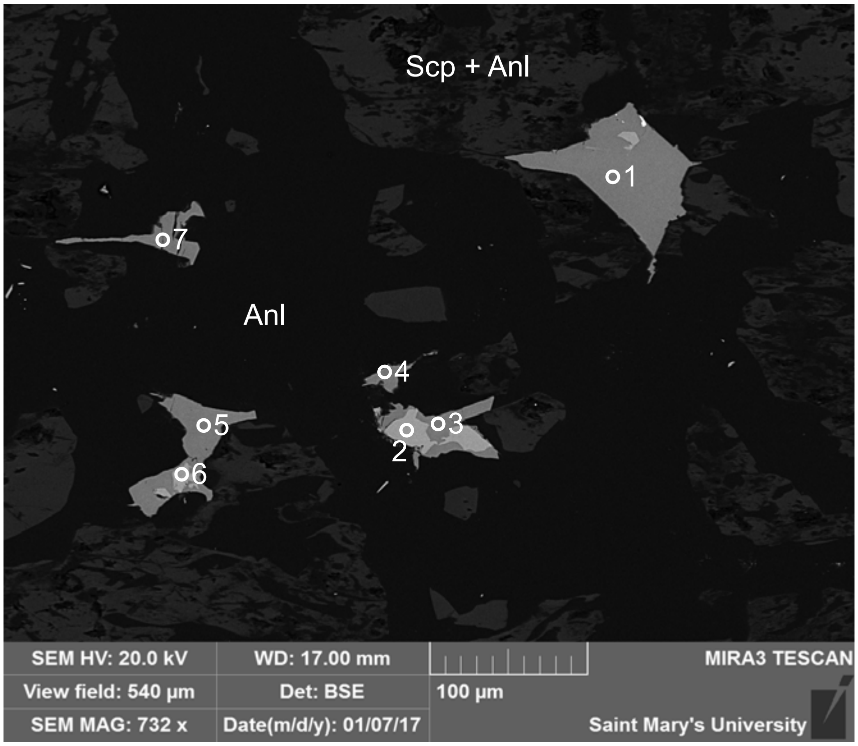
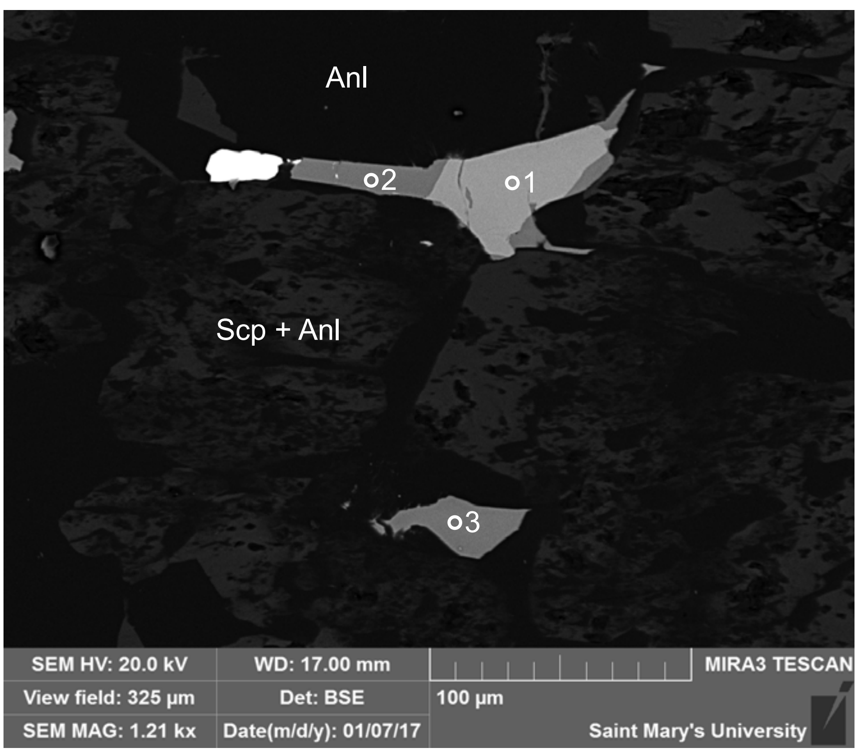



Figure 1-4.21: Sample 9956d (SEM).




1:Titanite
2:Rutile
3:Titanite
4:Titanite
5:Titanite
6:Rutile
7:Titanite

Figure 1-4.22: Sample 9956d site 16 (SEM). Small anhedral rutile (2,6) is overgrown by subequant titanite (3,4,5). All grains appear to be interstitial.




1:Rutile
2:Titanite
3:Titanite

Figure 1-4.23: Sample 9956d site 17 (SEM). Large subhedral rutile (1) crystal is overgrown by titanite (2). Titanite (3) also occurs as a discrete grain.

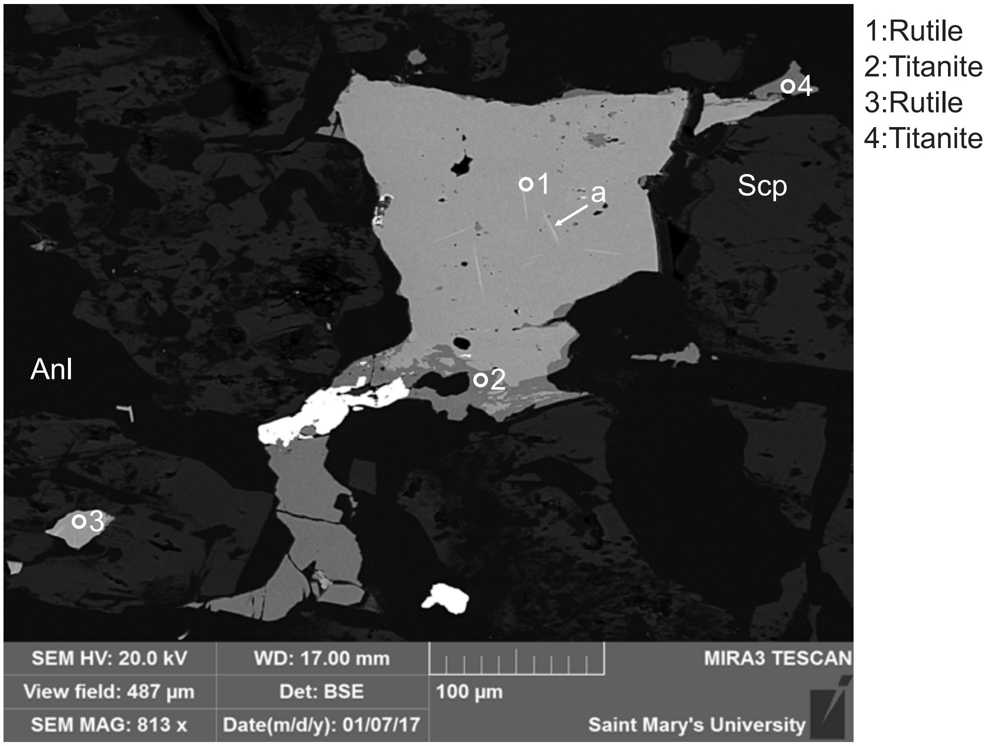



Figure 1-4.24: Sample 9956d site 18 (SEM). A large anhedral rutile (1) crystal is overgrown by discontinuous titanite (2,4). Other smaller rutile (3) crystals occur as discrete grains cross-cuting scapolite and analcime. The titanite appears to be interstitial. Rutil contains ilmenite exsolution (position a).

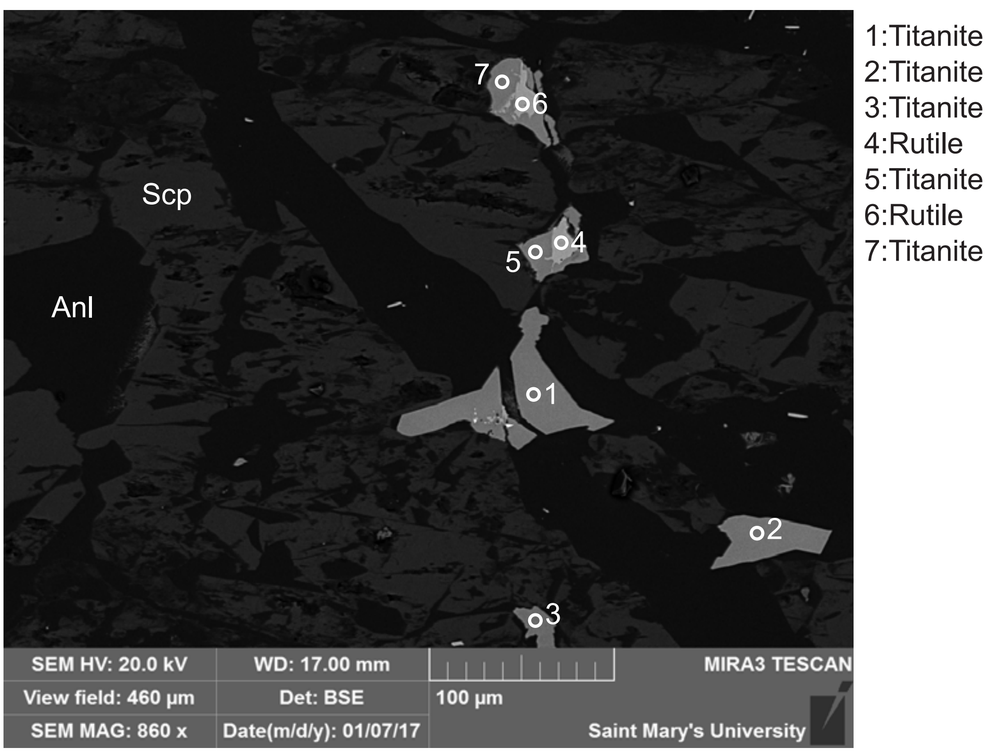
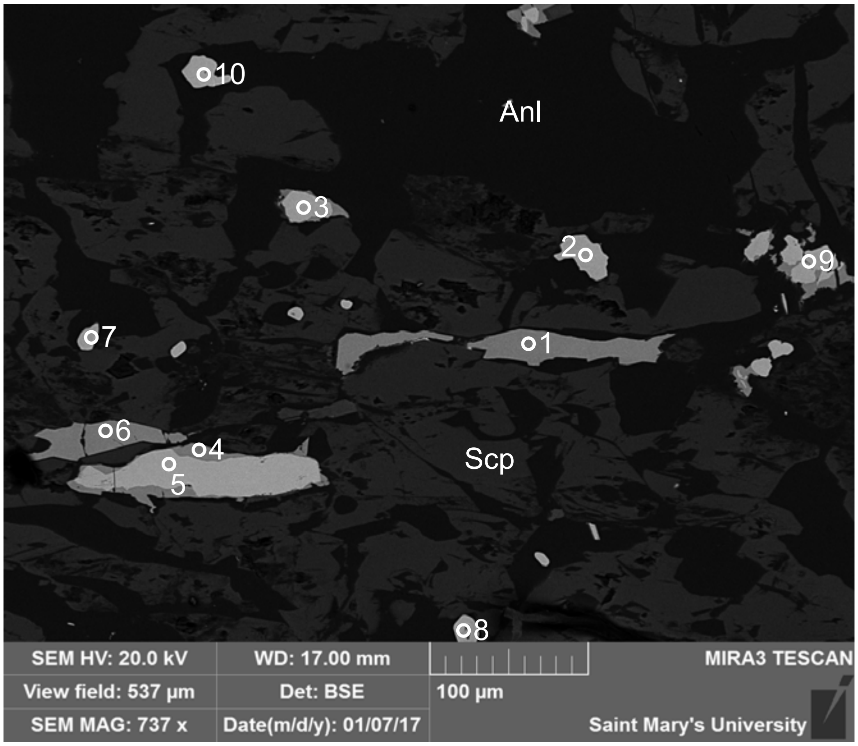



Figure 1-4.25: Sample 9956d site 19 (SEM).Small rutile (4,6) grains with eqant overgrowths of titanite (5,7). Titanite (1-3) also occurs as subequant crystals.




1:Titanite
2:Rutile
3:Rutile
4:Titanite
5:Rutile
6:Titanite
7:Rutile
8:Rutile +
9:Rutile
10:Rutile

Figure 1-4.26: Sample 9956d site 20 (SEM). Small-large rutile (3,5,9) grains are overgrown by interstitial titanite (4). Other smaller rutile (2,7,10) and titanite (1) appear as interstitial grains.

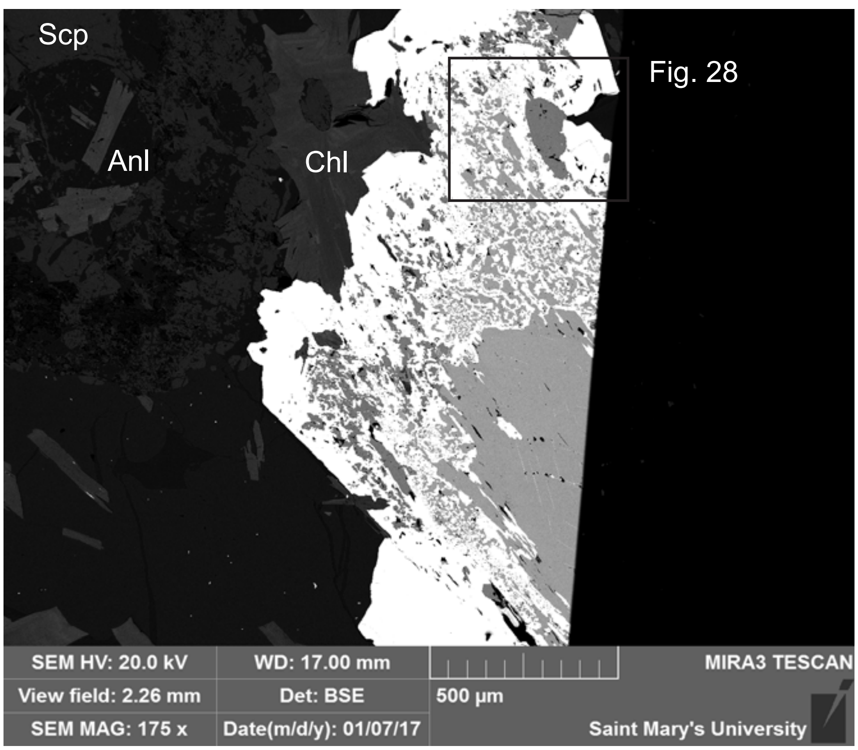



Figure 1-4.27: Sample 9956d (SEM).

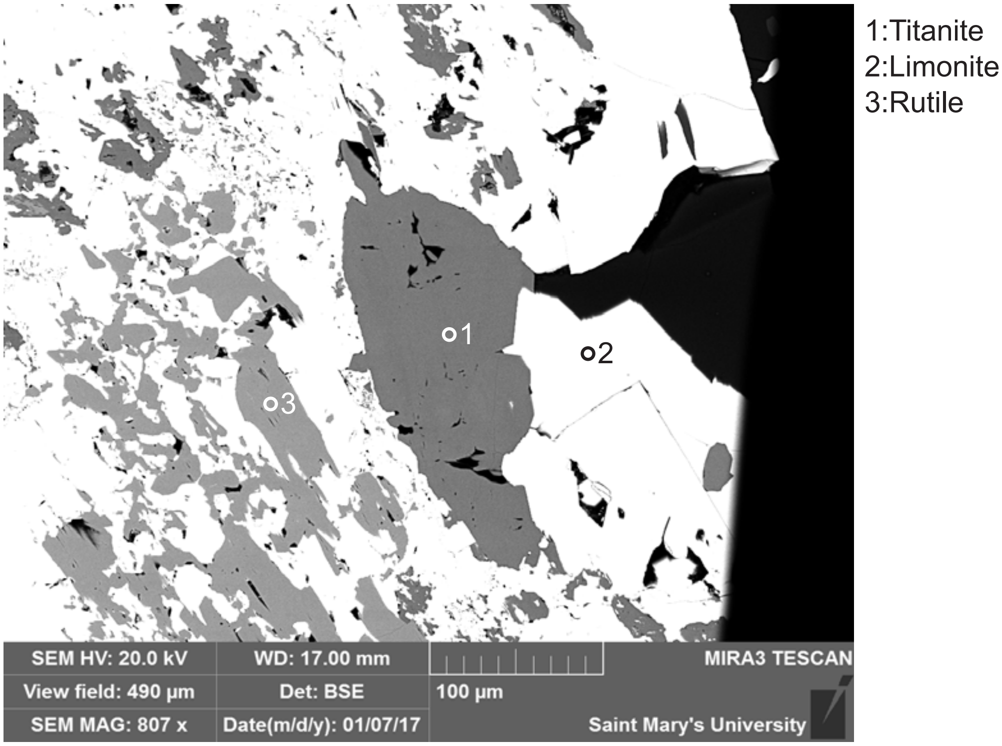



Figure 1-4.28: Sample 9956d site 21 (SEM). Large rutile (3) crystal (texture Figure 1-4.27) is replaced and probably overgrown by titanite (1) and Fe-oxides/hydroxides (2). All minerals contain lots of voids.

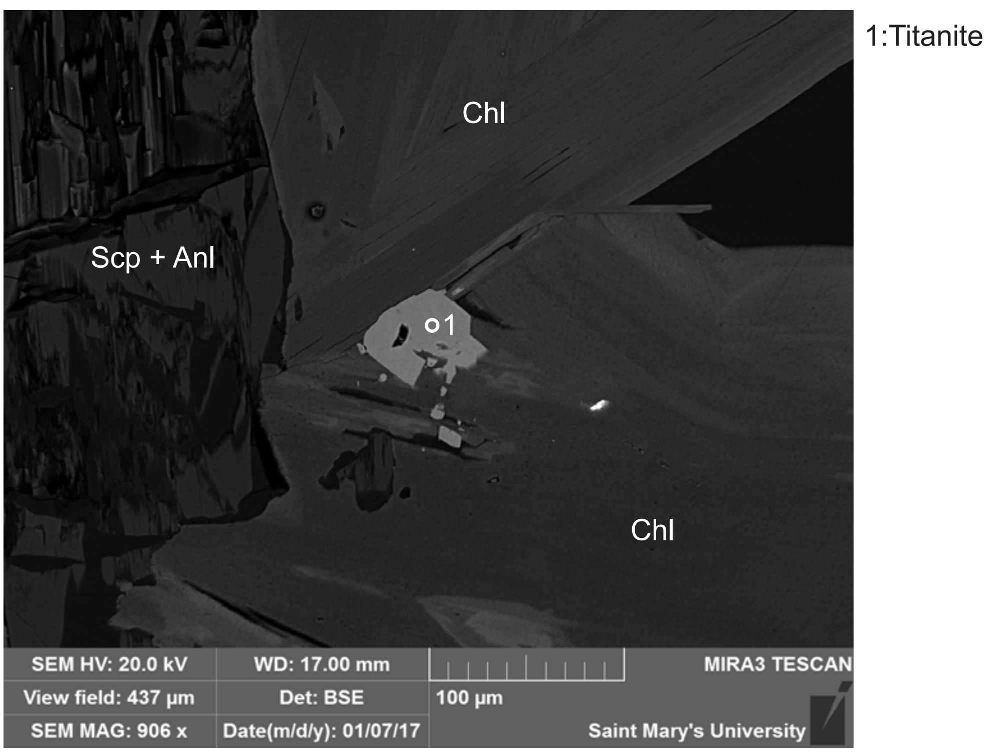



Figure 1-4.29: Sample 9956d site 22 (SEM). Titanite (1) appears to be replacive-interstitial.

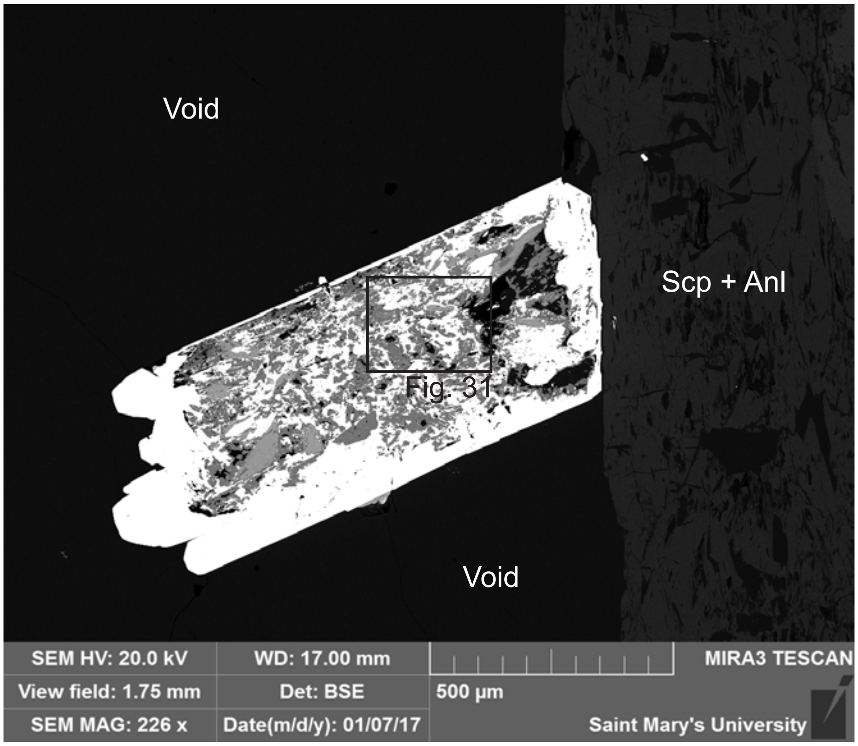
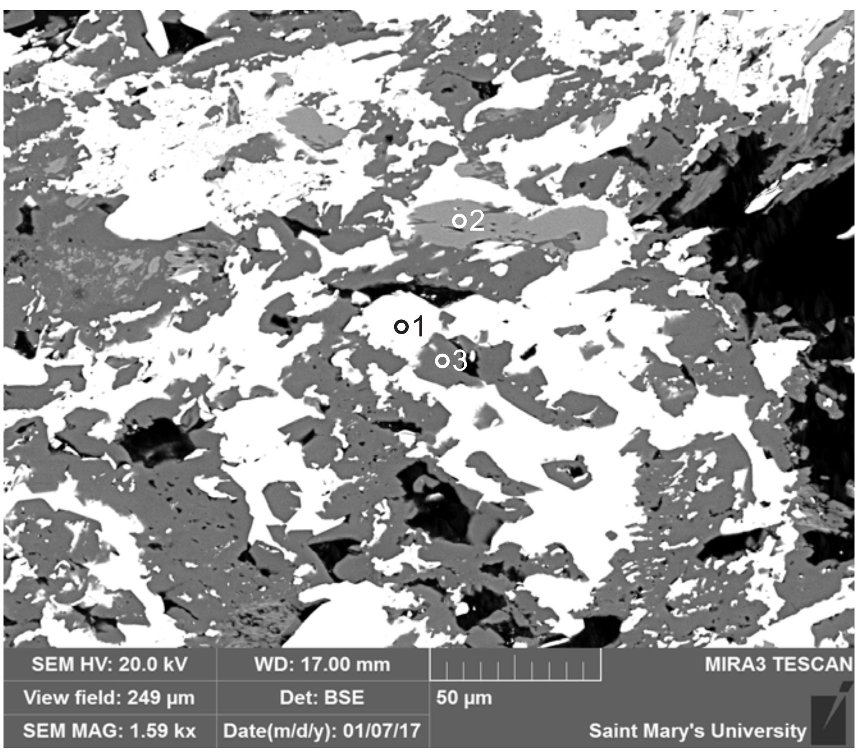



Figure 1-4.30: Sample 9956d (SEM). Fe-oxide/hydroxide overgrowths, and replacement by titanite and Fe-oxide/hydroxide of rutile.




1:Limonite
2:Rutile
3:Titanite

Figure 1-4.31: Sample 9956d site 23 (SEM). Large rutile (2) crystal appears to have been almost fully replaced and probably overgrown by titanite (3) and Fe-oxides/hydroxides (1) (only the Fe-oxide/hydroxide (Fig. 1-4.30) overgrowths are clear). Lots of voids are present in this site.

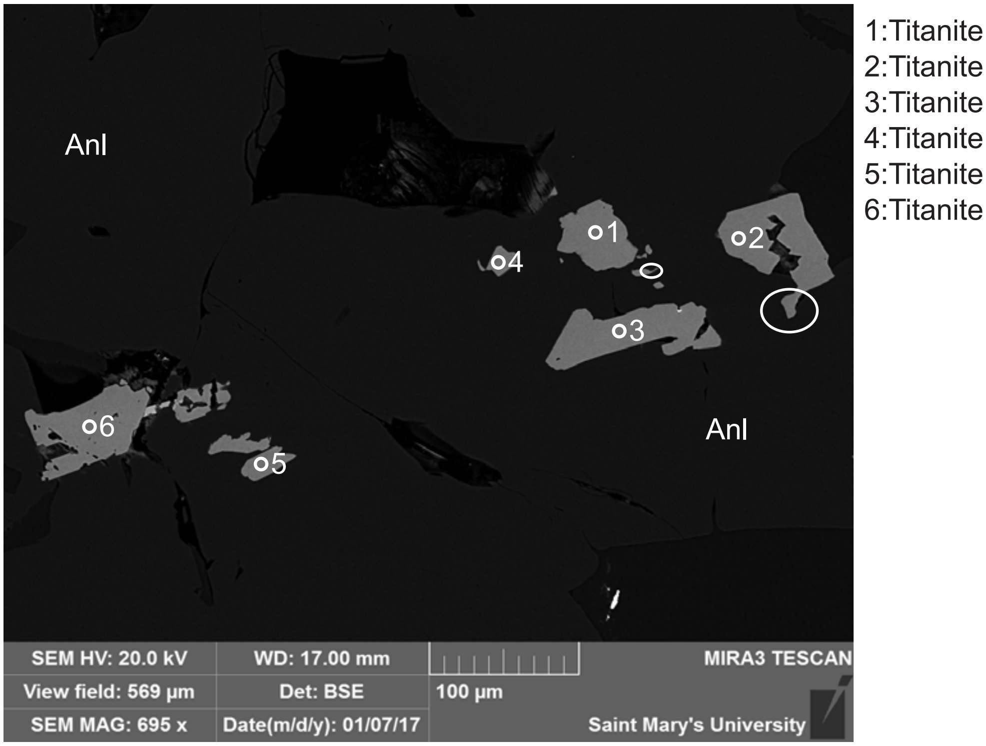



Figure 1-4.32: Sample 9956d site 24 (SEM). This site shows another mode of occurrence of titanite. Titanite (1-6) appear as equant crystals, some of which appear to fill voids. Some titanite crystals appear to be minor interstitial grains (circles).

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | F | Cl | V2O5 | Cr2O3 | ZnO | ZrO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 1 | 1 | Ti-Mag | | 3.51 | | 96.06 | | | | | | | | | 0.43 | | | 100 | 96 | |
| 9956d | 1 | 2 | Rt | | 98.60 | | 0.30 | | | 0.54 | | | | | | 0.56 | | | 100 | 109 | |
| 9956d | 1 | 3 | Ttn | 33.24 | 35.33 | 2.23 | 0.95 | | | 28.26 | | | | | | | | | 100 | 113 | |
| 9956d | 2 | 1 | Ttn | 33.31 | 36.88 | 1.27 | 0.70 | | | 27.84 | | | | | | | | | 100 | 116 | |
| 9956d | 2 | 2 | Rt | | 98.55 | | 0.54 | | | | | | | | | 0.91 | | | 100 | 111 | |
| 9956d | 2 | 3 | Gth | 0.53 | 1.53 | | 97.95 | | | | | | | | | | | | 100 | 100 | 80 |
| 9956d | 2 | 4 | Rt | | 97.66 | | 1.32 | | | | | | | | | 1.02 | | | 100 | 108 | |
| 9956d | 2 | 5 | Rt | 0.84 | 95.10 | | 1.50 | | | 1.17 | | | | | | | | 1.39 | 100 | 110 | |
| 9956d | 2 | 6 | Ttn | 33.43 | 35.67 | 2.11 | 0.81 | | | 27.97 | | | | | | | | | 100 | 112 | |
| 9956d | 2 | 7 | Chl | 28.42 | | 18.89 | 16.99 | | 20.46 | | | | | | | 0.25 | | | 85 | 100 | |
| 9956d | 2 | 8 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 123 | |
| 9956d | 3 | 1 | Ttn | 33.30 | 37.19 | 1.16 | 0.48 | | | 27.87 | | | | | | | | | 100 | 116 | |
| 9956d | 3 | 2 | Ttn | 33.47 | 35.54 | 2.12 | 1.02 | | | 27.86 | | | | | | | | | 100 | 116 | |
| 9956d | 3 | 3 | Ttn | 33.31 | 37.48 | 1.05 | 0.36 | | | 27.80 | | | | | | | | | 100 | 115 | |
| 9956d | 3 | 4 | Ttn | 33.29 | 37.89 | 0.81 | 0.28 | | | 27.73 | | | | | | | | | 100 | 115 | |
| 9956d | 3 | 5 | Scp | 56.70 | | 22.44 | | | | 7.50 | 9.87 | 0.18 | | 3.30 | | | | | 100 | 120 | |
| 9956d | 3 | 6 | Chl | 27.29 | | 20.35 | 20.80 | | 16.56 | | | | | | | | | | 85 | 102 | |
| 9956d | 3 | 7 | Anl | 60.10 | | 19.92 | | | | | 10.98 | | | | | | | | 91 | 108 | |
| 9956d | 3 | 8 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 127 | |
| 9956d | 3 | 9 | Chl | 27.96 | | 19.53 | 18.74 | | 18.63 | | | | | 0.14 | | | | | 85 | 100 | |
| 9956d | 3 | 10 | Scp | 57.77 | | 21.74 | | | | 6.64 | 10.27 | 0.31 | | 3.28 | | | | | 100 | 117 | |
| 9956d | 3 | 11 | Anl | 59.65 | | 20.17 | | | | | 11.17 | | | | | | | | 91 | 106 | |
| 9956d | 4 | 1 | Ttn | 33.01 | 37.09 | 1.21 | 0.69 | | | 28.00 | | | | | | | | | 100 | 112 | |
| 9956d | 4 | 2 | Ttn | 33.03 | 37.65 | 0.98 | 0.73 | | | 27.61 | | | | | | | | | 100 | 113 | |
| 9956d | 4 | 3 | Ttn | 33.35 | 36.56 | 1.62 | 0.58 | | | 27.89 | | | | | | | | | 100 | 114 | |
| 9956d | 4 | 4 | Ttn | 33.08 | 37.51 | 1.05 | 0.56 | | | 27.81 | | | | | | | | | 100 | 111 | |
| 9956d | 4 | 5 | Chl | 28.63 | | 19.26 | 14.89 | | 21.95 | | | | | | | 0.27 | | | 85 | 101 | |
| 9956d | 4 | 6 | Chl + FeO | 26.86 | | 18.91 | 34.16 | | 20.07 | | | | | | | | | | 100 | 103 | |
| 9956d | 4 | 7 | Chl + FeO | 26.15 | | 13.70 | 29.97 | | 15.17 | | | | | | | | | | 85 | 84 | |
| 9956d | 5 | 1 | Rt | | 99.41 | | 0.36 | | | 0.23 | | | | | | | | | 100 | 110 | |
| 9956d | 5 | 2 | Ttn | 32.95 | 37.64 | 0.87 | 0.43 | | | 28.11 | | | | | | | | | 100 | 112 | |

Table 1-4.1: EDS analyses from sample 9956d.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | F | Cl | V2O5 | Cr2O3 | ZnO | ZrO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 5 | 3 | Ttn | 33.51 | 37.23 | 1.03 | 0.40 | | | 27.84 | | | | | | | | | 100 | 114 | |
| 9956d | 6 | 1 | Rt | | 99.05 | | 0.95 | | | | | | | | | | | | 100 | 108 | |
| 9956d | 6 | 2 | Ttn | 32.81 | 38.18 | 0.53 | 0.68 | | | 27.81 | | | | | | | | | 100 | 112 | |
| 9956d | 6 | 3 | Ti-Mag | | 8.52 | | 88.12 | 0.37 | | 0.69 | 0.65 | | | 0.69 | | 0.96 | | | 100 | 96 | |
| 9956d | 7 | 1 | Ti-Mag | | 4.14 | | 95.38 | | | | | | | | | 0.48 | | | 100 | 93 | |
| 9956d | 7 | 2 | Ttn | 33.35 | 35.47 | 2.13 | 0.96 | | | 28.10 | | | | | | | | | 100 | 113 | |
| 9956d | 7 | 3 | Rt | | 99.02 | | | | | 0.98 | | | | | | | | | 100 | 110 | |
| 9956d | 7 | 4 | Rt + FeO | 0.61 | 95.81 | | 2.25 | | | 1.32 | | | | | | | | | 100 | 108 | |
| 9956d | 8 | 1 | Ttn | 33.08 | 35.93 | 2.09 | 0.78 | | | 28.11 | | | | | | | | | 100 | 114 | |
| 9956d | 8 | 2 | Ttn | 33.26 | 35.21 | 2.40 | 0.78 | | | 28.35 | | | | | | | | | 100 | 115 | |
| 9956d | 8 | 3 | Ttn | 33.37 | 35.01 | 2.53 | 1.10 | | | 27.99 | | | | | | | | | 100 | 112 | |
| 9956d | 8 | 4 | Ttn | 33.13 | 36.41 | 1.46 | 0.47 | | | 27.63 | | | | | 0.89 | | | | 100 | 112 | |
| 9956d | 8 | 5 | Ttn | 32.98 | 34.15 | 2.53 | 1.14 | | | 27.70 | | | 1.50 | | | | | | 100 | 113 | |
| 9956d | 8 | 6 | Ttn | 33.72 | 34.28 | 3.06 | 0.93 | | 0.41 | 27.31 | 0.29 | | | | | | | | 100 | 109 | |
| 9956d | 9 | 1 | Ttn | 33.01 | 34.51 | 2.58 | 0.86 | | | 27.76 | | | 1.27 | | | | | | 100 | 116 | |
| 9956d | 9 | 2 | Ttn | 33.13 | 34.56 | 2.36 | 1.03 | | | 27.71 | | | 1.21 | | | | | | 100 | 112 | |
| 9956d | 10 | 1 | Rt | | 99.22 | | | | | | | | | | | 0.38 | 0.40 | | 100 | 109 | |
| 9956d | 10 | 2 | Ttn | 32.92 | 31.84 | 4.61 | 0.40 | | | 27.57 | | | 2.43 | | | | 0.22 | | 100 | 114 | |
| 9956d | 10 | 3 | Rt | | 99.07 | | | | | | | | | | | 0.54 | 0.39 | | 100 | 106 | |
| 9956d | 10 | 4 | Rt | | 99.13 | | | | | | | | | | | 0.57 | 0.29 | | 100 | 105 | |
| 9956d | 10 | 5 | Ttn | 32.85 | 30.61 | 5.62 | 0.39 | | | 27.50 | | | 2.81 | | | | 0.22 | | 100 | 116 | |
| 9956d | 10 | 6 | Rt | | 98.37 | | | | | 0.45 | | | | | | 0.58 | 0.59 | | 100 | 110 | |
| 9956d | 11 | 1 | Ttn | 32.93 | 33.10 | 3.18 | 0.77 | | | 27.75 | | | 1.81 | | | | 0.48 | | 100 | 114 | |
| 9956d | 11 | 2 | Ttn | 32.81 | 29.12 | 5.71 | 1.30 | | | 27.28 | | | 3.43 | | | | 0.35 | | 100 | 115 | |
| 9956d | 11 | 3 | Rt | 0.45 | 97.91 | | 0.28 | | | 0.63 | | | | | | | 0.73 | | 100 | 110 | |
| 9956d | 11 | 4 | Rt + | 3.74 | 91.62 | 0.67 | | | | 2.24 | 0.61 | | | 0.63 | | | 0.48 | | 100 | 108 | |
| 9956d | 11 | 5 | Ttn | 34.66 | 32.95 | 3.95 | 0.52 | | | 25.78 | | | 1.71 | | | | 0.43 | | 100 | 110 | |
| 9956d | 12 | 1 | Rt | 0.38 | 98.72 | | | | | | | | | | | 0.53 | 0.37 | | 100 | 109 | |
| 9956d | 12 | 2 | Rt | | 99.11 | | | | | | | | | | | 0.53 | 0.36 | | 100 | 109 | |
| 9956d | 12 | 3 | Ttn | 32.57 | 38.54 | 0.56 | 0.91 | | | 27.13 | | | | | | | 0.28 | | 100 | 114 | |
| 9956d | 12 | 4 | Rt | 0.46 | 96.05 | | 1.55 | | | 1.00 | | | | | | 0.60 | 0.33 | | 100 | 111 | |

Table 1-4.1: EDS analyses from sample 9956d.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | F | Cl | V2O5 | Cr2O3 | ZnO | ZrO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 13 | 1 | Ttn | 33.45 | 37.30 | 1.37 | | | | 27.51 | | | | | | | 0.36 | | 100 | 113 | |
| 9956d | 13 | 2 | Rt | 0.42 | 98.40 | | | | | 0.23 | | | | | | 0.58 | 0.37 | | 100 | 108 | |
| 9956d | 13 | 3 | Rt | | 98.44 | | 0.33 | | | 0.46 | | | | | | 0.53 | 0.25 | | 100 | 110 | |
| 9956d | 13 | 4 | Ttn | 33.28 | 34.91 | 2.59 | 0.42 | | | 27.38 | | | 1.17 | | | | 0.25 | | 100 | 114 | |
| 9956d | 14 | 1 | Ttn | 33.52 | 35.05 | 2.91 | 0.51 | | | 27.81 | | | | | | | 0.19 | | 100 | 112 | |
| 9956d | 14 | 2 | Ttn | 33.84 | 34.88 | 2.27 | 1.05 | | | 27.47 | | | | | | | 0.49 | | 100 | 112 | |
| 9956d | 15 | 1 | Rt | | 99.16 | | 0.28 | | | | | | | | | 0.38 | 0.17 | | 100 | 110 | |
| 9956d | 15 | 2 | Ttn | 32.59 | 35.74 | 2.64 | 0.50 | | | 26.63 | | | 1.60 | | | | 0.30 | | 100 | 115 | |
| 9956d | 16 | 1 | Ttn | 33.51 | 35.22 | 2.26 | 0.83 | | | 27.81 | | | | | | | 0.37 | | 100 | 112 | |
| 9956d | 16 | 2 | Rt | 0.39 | 98.31 | | 0.28 | | | 0.34 | | | | | | | 0.68 | | 100 | 111 | |
| 9956d | 16 | 3 | Ttn | 33.53 | 35.20 | 2.07 | 1.12 | | | 27.66 | | | | | | | 0.42 | | 100 | 113 | |
| 9956d | 16 | 4 | Ttn | 33.81 | 33.74 | 2.99 | 1.11 | | | 27.88 | | | | | | | 0.46 | | 100 | 112 | |
| 9956d | 16 | 5 | Ttn | 33.69 | 34.11 | 2.84 | 1.13 | | | 27.90 | | | | | | | 0.33 | | 100 | 112 | |
| 9956d | 16 | 6 | Rt | 0.56 | 97.39 | | 0.27 | | | 0.88 | | | | | | 0.60 | 0.29 | | 100 | 110 | |
| 9956d | 16 | 7 | Ttn | 34.50 | 33.58 | 3.24 | 1.21 | | | 27.10 | | | | | | | 0.36 | | 100 | 111 | |
| 9956d | 17 | 1 | Rt | | 98.85 | | 0.33 | | | | | | | | | 0.61 | 0.20 | | 100 | 108 | |
| 9956d | 17 | 2 | Ttn | 33.46 | 34.39 | 2.98 | 0.94 | | | 28.03 | | | | | | | 0.20 | | 100 | 110 | |
| 9956d | 17 | 3 | Ttn | 33.44 | 34.95 | 2.69 | 0.59 | | | 27.86 | | | | | | | 0.47 | | 100 | 111 | |
| 9956d | 18 | 1 | Rt | | 99.67 | | | | | | | | | | | | 0.33 | | 100 | 107 | |
| 9956d | 18 | 2 | Ttn | 33.22 | 35.95 | 2.02 | 0.69 | | | 27.68 | | | | | | | 0.45 | | 100 | 112 | |
| 9956d | 18 | 3 | Rt | | 99.09 | | | | | | | | | | | 0.53 | 0.38 | | 100 | 108 | |
| 9956d | 18 | 4 | Ttn | 35.00 | 33.69 | 3.44 | 0.75 | | | 26.83 | | | | | | | 0.30 | | 100 | 108 | |
| 9956d | 19 | 1 | Ttn | 33.21 | 33.95 | 2.80 | 1.08 | | | 27.56 | | | 1.06 | | | | 0.35 | | 100 | 112 | |
| 9956d | 19 | 2 | Ttn | 33.48 | 34.96 | 2.35 | 1.15 | | | 27.71 | | | | | | | 0.36 | | 100 | 112 | |
| 9956d | 19 | 3 | Ttn | 33.04 | 33.17 | 4.13 | 0.36 | | | 27.52 | | | 1.33 | | | | 0.45 | | 100 | 114 | |
| 9956d | 19 | 4 | Rt | 0.41 | 97.99 | | 0.33 | | | 0.44 | | | | | | 0.43 | 0.39 | | 100 | 109 | |
| 9956d | 19 | 5 | Ttn | 33.45 | 34.79 | 2.27 | 1.29 | | | 27.64 | | | | | | | 0.55 | | 100 | 110 | |
| 9956d | 19 | 6 | Rt | 0.66 | 97.60 | | | | | 0.79 | | | | | | 0.61 | 0.33 | | 100 | 108 | |
| 9956d | 19 | 7 | Ttn | 33.37 | 35.92 | 1.87 | 0.79 | | | 27.63 | | | | | | | 0.42 | | 100 | 110 | |
| 9956d | 20 | 1 | Ttn | 33.62 | 34.03 | 3.09 | 0.98 | | | 28.01 | | | | | | | 0.27 | | 100 | 111 | |
| 9956d | 20 | 2 | Rt | 0.42 | 98.66 | | | | | | | | | | | 0.68 | 0.23 | | 100 | 107 | |

Table 1-4.1: EDS analyses from sample 9956d.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | F | Cl | V2O5 | Cr2O3 | ZnO | ZrO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 20 | 3 | Rt | | 98.98 | | | | | 0.27 | | | | | | 0.51 | 0.24 | | 100 | 106 | |
| 9956d | 20 | 4 | Ttn | 33.29 | 36.08 | 1.87 | 0.76 | | | 27.71 | | | | | | | 0.29 | | 100 | 110 | |
| 9956d | 20 | 5 | Rt | | 98.59 | | | | | 0.35 | | | | | | 0.79 | 0.27 | | 100 | 108 | |
| 9956d | 20 | 6 | Ttn | 33.80 | 33.16 | 2.94 | 1.17 | | | 27.95 | | | | | 0.73 | | 0.25 | | 100 | 110 | |
| 9956d | 20 | 7 | Rt | 0.50 | 98.47 | | 0.28 | | | | | | | | | 0.42 | 0.33 | | 100 | 106 | |
| 9956d | 20 | 8 | Rt + | 5.47 | 90.05 | 0.72 | 0.99 | | 1.16 | 1.29 | | | | | | | 0.32 | | 100 | 106 | |
| 9956d | 20 | 9 | Rt | | 98.49 | | | | | 0.22 | 0.25 | | | | | 0.53 | 0.52 | | 100 | 108 | |
| 9956d | 20 | 10 | Rt | 0.47 | 98.68 | | | | | | | | | | | 0.48 | 0.37 | | 100 | 105 | |
| 9956d | 21 | 1 | Ttn | 33.39 | 35.20 | 2.14 | 1.36 | | | 27.91 | | | | | | | | | 100 | 111 | |
| 9956d | 21 | 2 | Lm | | 0.66 | | 99.34 | | | | | | | | | | | | 100 | 93 | 75 |
| 9956d | 21 | 3 | Rt | | 99.03 | | 0.97 | | | | | | | | | | | | 100 | 109 | |
| 9956d | 22 | 1 | Ttn | 32.67 | 35.49 | 2.00 | 0.89 | | | 27.91 | | | 1.02 | | | | | | 100 | 114 | |
| 9956d | 23 | 1 | Lm | | 2.90 | | 95.17 | | | 0.53 | | | | | 0.60 | 0.79 | | | 100 | 94 | 76 |
| 9956d | 23 | 2 | Rt | | 97.77 | | 1.33 | | | 0.38 | | | | | | 0.52 | | | 100 | 109 | |
| 9956d | 23 | 3 | Ttn | 32.64 | 31.67 | 3.06 | 2.04 | | | 27.02 | | | 1.69 | | 1.34 | 0.53 | | | 100 | 115 | |
| 9956d | 24 | 1 | Ttn | 33.71 | 35.90 | 1.91 | 0.72 | | | 27.75 | | | | | | | | | 100 | 112 | |
| 9956d | 24 | 2 | Ttn | 33.18 | 36.87 | 1.27 | 0.74 | | | 27.93 | | | | | | | | | 100 | 113 | |
| 9956d | 24 | 3 | Ttn | 33.14 | 38.61 | 0.50 | | | | 27.75 | | | | | | | | | 100 | 114 | |
| 9956d | 24 | 4 | Ttn | 33.63 | 37.92 | 0.79 | | | | 27.66 | | | | | | | | | 100 | 113 | |

Table 1-4.1: EDS analyses from sample 9956d. 

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | F | Cl | V2O5 | Cr2O3 | ZnO | ZrO2 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 24 | 5 | Ttn | 33.54 | 35.67 | 2.27 | 0.74 | | | 27.77 | | | | | | | | | 100 | 113 | |
| 9956d | 24 | 6 | Ttn | 33.31 | 36.82 | 1.43 | 0.45 | | | 27.99 | | | | | | | | | 100 | 113 | |

Oxide total

Mag = >90%

Hem = 85-89%

Gth = 80-84%

Lm = <80%

Average quartz total = 125

Oxide total = (wt % oxide / Avg. Qz total) * 100

Notes

1 + = indicates other minerals present

2 Rt + FeO = Rt that contians more than 2wt% FeO

# Appendix 2: Detailed SEM-BSE images and EDS mineral analyses for a large grain from sample 9956c to investigate Zr distribution in various mineral phases.

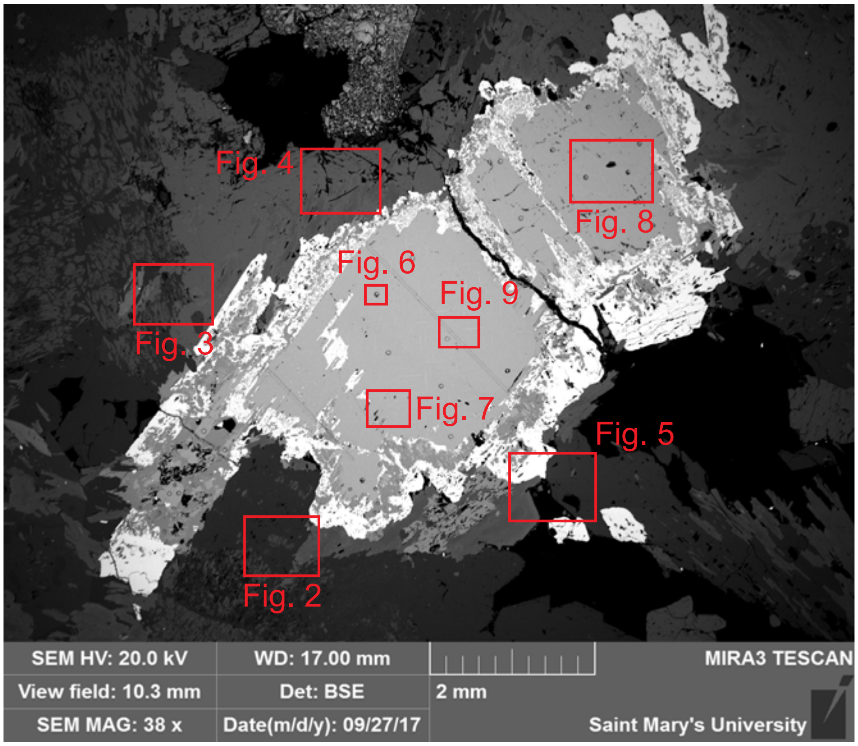



Figure 2.1: Sample 9956c (SEM).

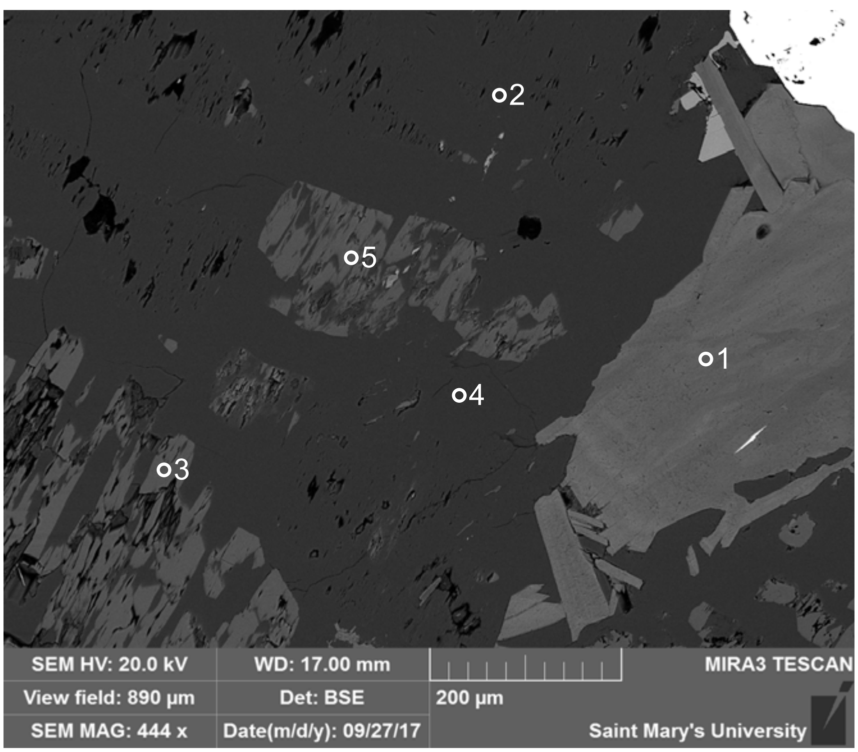
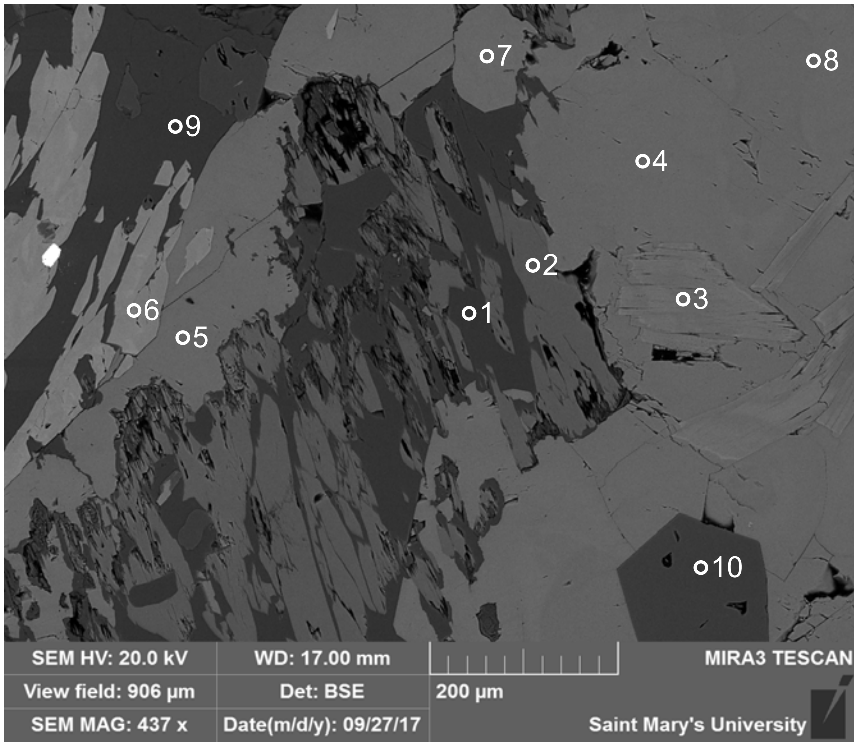
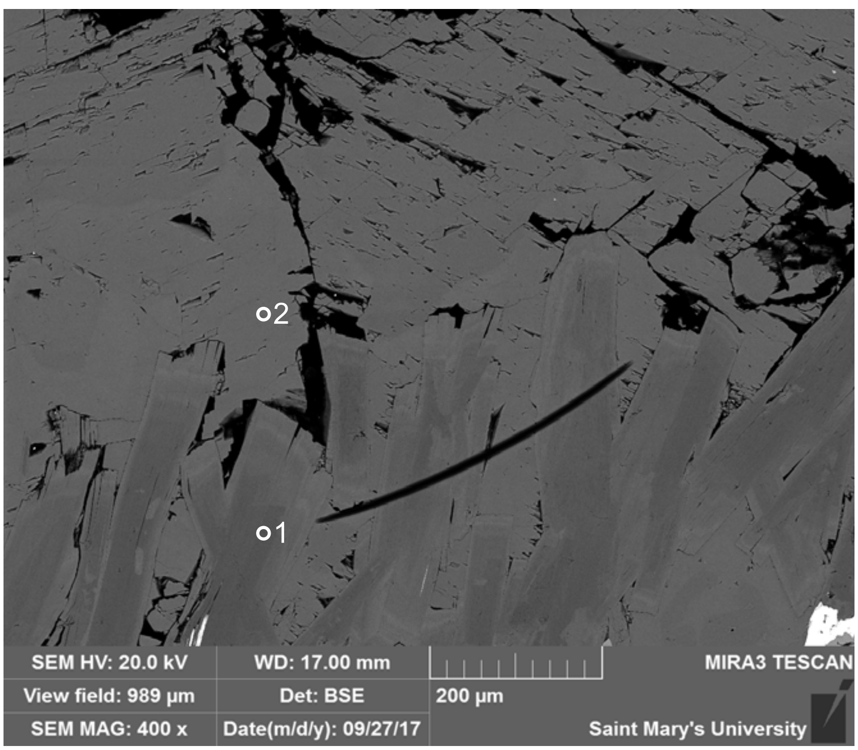



Figure 2.2: Sample 9956c site 1 (SEM).



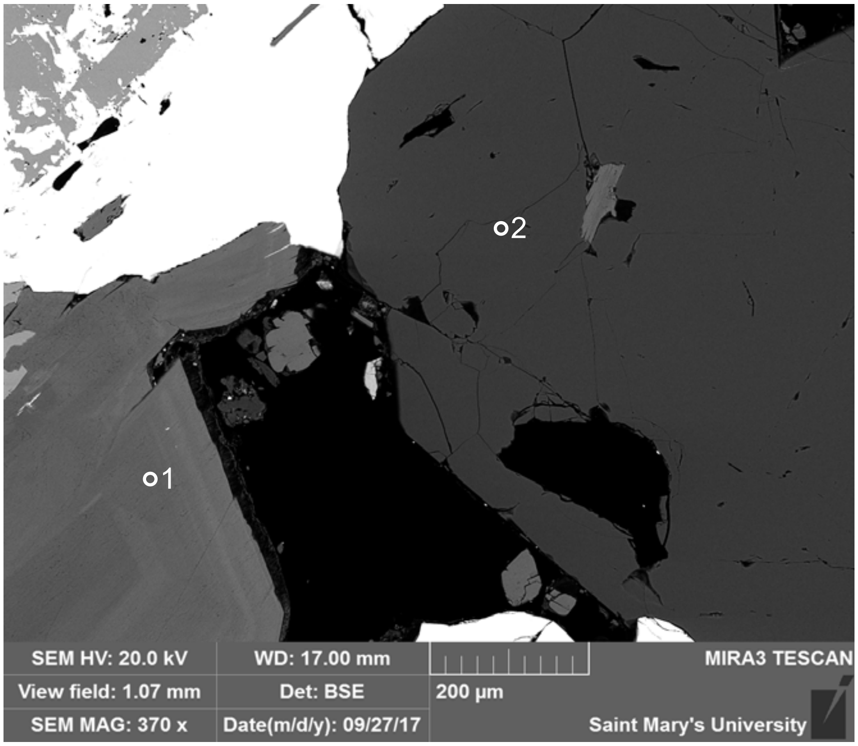

1:Analcime
2:Scapolite
3:Chlorite
4:Calcite
5:Calcite
6:Epidote
7:Calcite
8:Calcite
9:Analcime
10:Quartz

Figure 2.3: Sample 9956c site 2 (SEM).



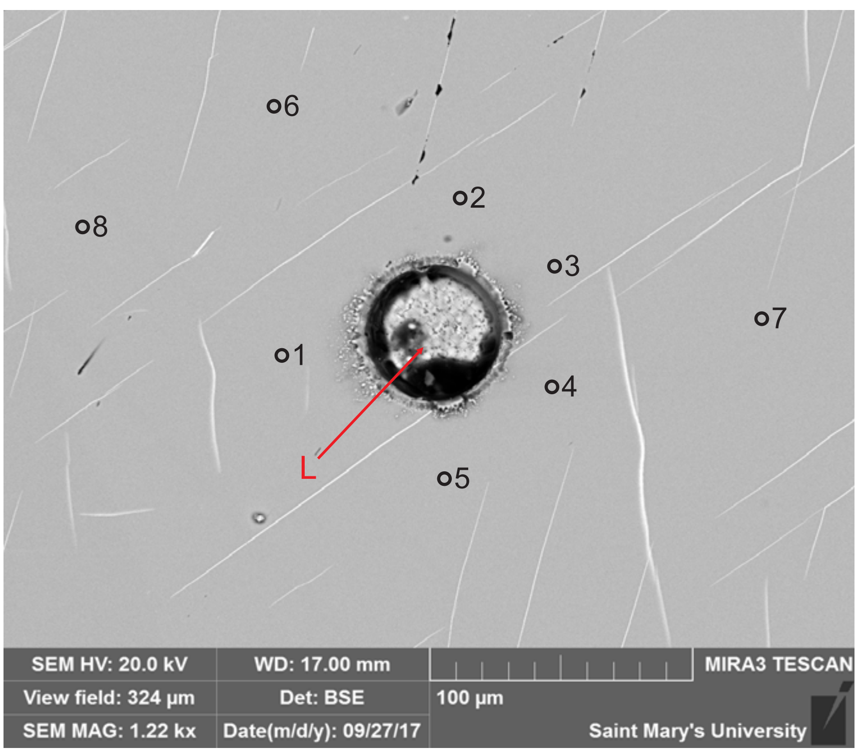

1:Chlorite
2:Calcite

Figure 2.4: Sample 9956c site 3 (SEM).




1:Chlorite
2:Quartz

Figure 2.5: Sample 9956c site 4 (SEM).




1:Rutile
2:Rutile
3:Rutile
4:Rutile
5:Rutile
6:Rutile
7:Rutile
8:Rutile

Figure 2.6: Sample 9956c site 5 (SEM) Spot L refers to geochronology analysis.

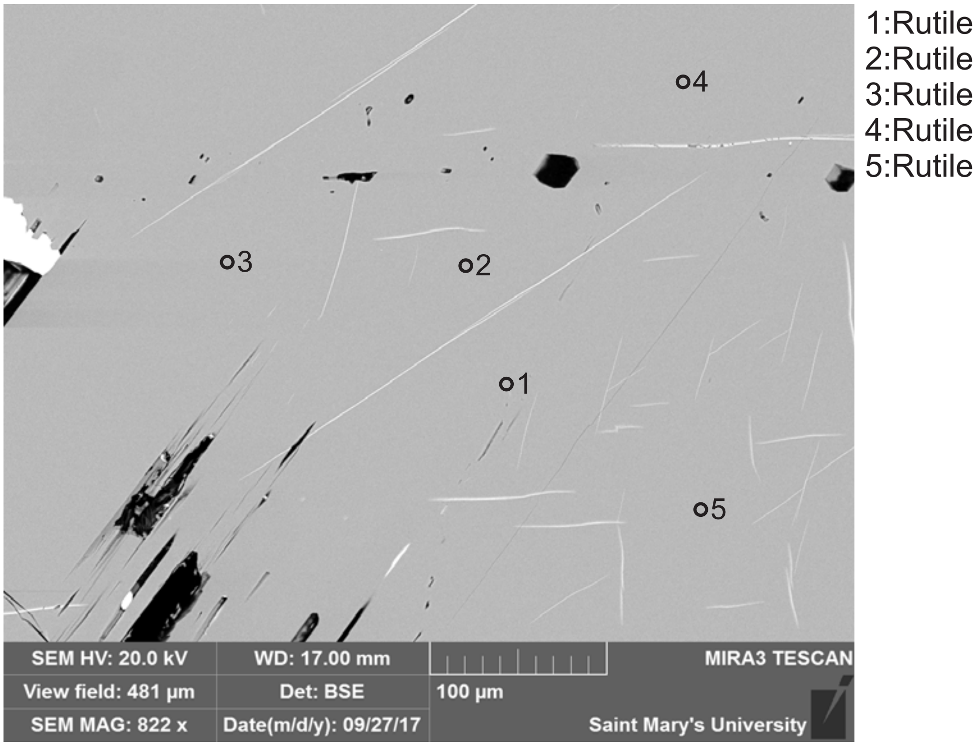



Figure 2.7: Sample 9956c site 6 (SEM).

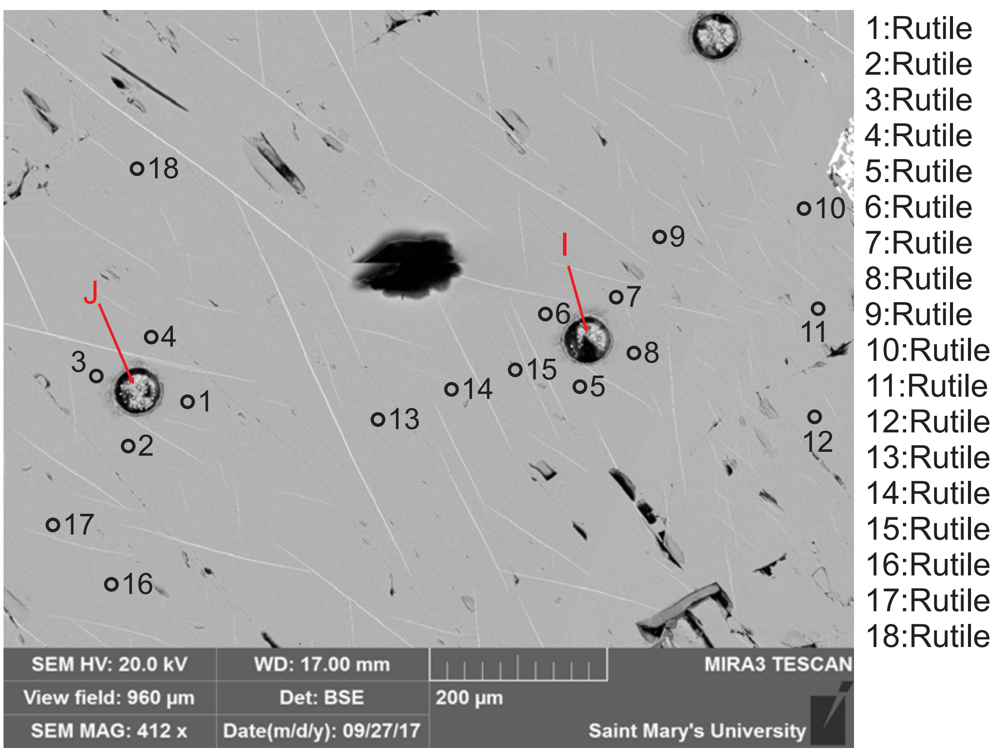
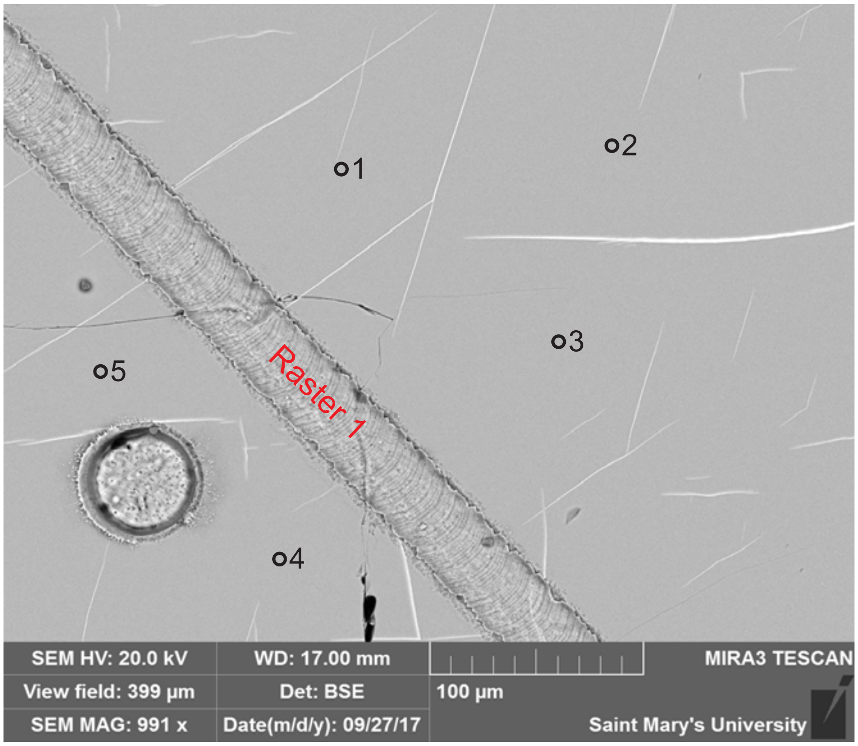



Figure 2.8: Sample 9956c site 7 (SEM). Spots I and J refer to geochronology analyses.




1:Rutile
2:Rutile
3:Rutile
4:Rutile
5:Rutile

Figure 2.9: Sample 9956c site 8 (SEM). Raster 1 refers to the raster 1 done in 9956c in Appendix 4.

Table 2.1: EDS analyses of a large grain from sample 9956c.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | SO3 | Cl | Cr2O3 | ZrO2 | Zr ppm | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 1 | 1 | Chl | 34.71 | | 20.35 | 21.83 | | 23.11 | | | | | | | | | 100 | 101 |
| 9956c | 1 | 2 | Anl | 59.82 | | 20.57 | | | | | 10.61 | | | | | | | 91 | 99 |
| 9956c | 1 | 3 | Scp | 56.70 | | 22.69 | | | | 7.34 | 9.85 | 0.16 | | 3.27 | | | | 100 | 116 |
| 9956c | 1 | 4 | Anl | 60.37 | | 20.26 | | | | | 10.37 | | | | | | | 91 | 99 |
| 9956c | 1 | 5 | Scp | 56.98 | | 22.43 | | | | 7.21 | 9.97 | 0.14 | | 3.27 | | | | 100 | 116 |
| 9956c | 2 | 1 | Anl | 60.35 | | 20.30 | | | | | 10.35 | | | | | | | 91 | 98 |
| 9956c | 2 | 2 | Scp | 57.74 | | 21.80 | | | | 6.31 | 10.50 | 0.30 | | 3.34 | | | | 100 | 116 |
| 9956c | 2 | 3 | Chl | 32.19 | | 23.25 | 24.26 | | 20.30 | | | | | | | | | 100 | 100 |
| 9956c | 2 | 4 | Cal | | | | 0.42 | 0.44 | 0.71 | 97.72 | | | 0.71 | | | | | 100 | 57 |
| 9956c | 2 | 5 | Cal | | | | | | 0.86 | 99.14 | | | | | | | | 100 | 56 |
| 9956c | 2 | 6 | Ep | 41.21 | | 24.04 | 11.32 | | | 23.43 | | | | | | | | 100 | 109 |
| 9956c | 2 | 7 | Cal | | | | 0.51 | 0.49 | 0.96 | 98.04 | | | | | | | | 100 | 55 |
| 9956c | 2 | 8 | Cal | | | | | 0.54 | 1.20 | 98.26 | | | | | | | | 100 | 55 |
| 9956c | 2 | 9 | Anl | 60.31 | | 20.37 | | | | | 10.31 | | | | | | | 91 | 97 |
| 9956c | 2 | 10 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 123 |
| 9956c | 3 | 1 | Chl | 33.54 | | 22.53 | 17.74 | | 25.67 | | | | | 0.14 | 0.38 | | | 100 | 100 |
| 9956c | 3 | 2 | Cal | | | | 0.74 | 0.44 | 1.73 | 97.09 | | | | | | | | 100 | 57 |
| 9956c | 4 | 1 | Chl | 33.48 | | 22.56 | 20.50 | | 22.71 | | 0.60 | | | 0.15 | | | | 100 | 101 |
| 9956c | 4 | 2 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 121 |
| 9956c | 5 | 1 | Rt | | 98.37 | | | | | | | | | | 0.77 | 0.86 | 6367 | 100 | 108 |
| 9956c | 5 | 2 | Rt | | 98.31 | | | | | | | | | | 0.70 | 1.00 | 7403 | 100 | 107 |
| 9956c | 5 | 3 | Rt | | 98.00 | | 0.26 | | | | | | | | 0.76 | 0.99 | 7329 | 100 | 109 |
| 9956c | 5 | 4 | Rt | | 98.24 | | | | | | | | | | 0.76 | 0.99 | 7329 | 100 | 109 |
| 9956c | 5 | 5 | Rt | | 98.32 | | | | | | | | | | 0.76 | 0.92 | 6811 | 100 | 108 |
| 9956c | 5 | 6 | Rt | | 98.01 | | 0.25 | | | | | | | | 0.70 | 1.04 | 7700 | 100 | 107 |

Table 2.1: EDS analyses of a large grain from sample 9956c.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | SO3 | Cl | Cr2O3 | ZrO2 | Zr ppm | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 5 | 7 | Rt | | 98.09 | | 0.28 | | | | | | | | 0.70 | 0.93 | 6885 | 100 | 108 |
| 9956c | 5 | 8 | Rt | | 98.13 | | 0.28 | | | | | | | | 0.71 | 0.89 | 6589 | 100 | 107 |
| 9956c | 6 | 1 | Rt | | 98.84 | | | | | | | | | | 0.73 | 0.43 | 3183 | 100 | 109 |
| 9956c | 6 | 2 | Rt | | 98.91 | | | | | | | | | | 0.76 | 0.33 | 2443 | 100 | 109 |
| 9956c | 6 | 3 | Rt | | 98.66 | | 0.29 | | | | | | | | 0.76 | 0.29 | 2147 | 100 | 109 |
| 9956c | 6 | 4 | Rt | | 99.00 | | | | | | | | | | 0.68 | 0.32 | 2369 | 100 | 107 |
| 9956c | 6 | 5 | Rt | | 98.89 | | | | | | | | | | 0.72 | 0.39 | 2887 | 100 | 110 |
| 9956c | 7 | 1 | Rt | | 98.83 | | | | | | | | | | 0.83 | 0.34 | 2517 | 100 | 106 |
| 9956c | 7 | 2 | Rt | | 98.95 | | | | | | | | | | 0.73 | 0.32 | 2369 | 100 | 106 |
| 9956c | 7 | 3 | Rt | | 98.68 | | 0.31 | | | | | | | | 0.75 | 0.26 | 1925 | 100 | 106 |
| 9956c | 7 | 4 | Rt | | 98.51 | | 0.30 | | | | | | | | 0.73 | 0.46 | 3406 | 100 | 106 |
| 9956c | 7 | 5 | Rt | | 98.62 | | 0.26 | | | | | | | | 0.69 | 0.43 | 3183 | 100 | 108 |
| 9956c | 7 | 6 | Rt | | 98.81 | | 0.30 | | | | | | | | 0.63 | 0.26 | 1925 | 100 | 107 |
| 9956c | 7 | 7 | Rt | | 98.99 | | | | | | | | | | 0.65 | 0.37 | 2739 | 100 | 107 |
| 9956c | 7 | 8 | Rt | | 98.73 | | 0.32 | | | | | | | | 0.62 | 0.33 | 2443 | 100 | 108 |
| 9956c | 7 | 9 | Rt | | 98.59 | | 0.30 | | | | | | | | 0.78 | 0.33 | 2443 | 100 | 107 |
| 9956c | 7 | 10 | Rt | | 97.94 | | 0.35 | | | | | | | | 0.70 | 1.00 | 7403 | 100 | 107 |
| 9956c | 7 | 11 | Rt | | 98.15 | | 0.25 | | | | | | | | 0.76 | 0.84 | 6219 | 100 | 108 |
| 9956c | 7 | 12 | Rt | | 98.34 | | 0.26 | | | | | | | | 0.69 | 0.72 | 5330 | 100 | 109 |
| 9956c | 7 | 13 | Rt | | 98.54 | | 0.30 | | | | | | | | 0.79 | 0.38 | 2813 | 100 | 108 |
| 9956c | 7 | 14 | Rt | | 98.83 | | | | | | | | | | 0.77 | 0.40 | 2961 | 100 | 108 |
| 9956c | 7 | 15 | Rt | | 98.58 | | 0.26 | | | | | | | | 0.73 | 0.43 | 3183 | 100 | 108 |
| 9956c | 7 | 16 | Rt | | 98.58 | | 0.31 | | | | | | | | 0.66 | 0.46 | 3406 | 100 | 107 |
| 9956c | 7 | 17 | Rt | | 98.57 | | 0.29 | | | | | | | | 0.74 | 0.40 | 2961 | 100 | 106 |
| 9956c | 7 | 18 | Rt | | 98.49 | | 0.31 | | | | | | | | 0.72 | 0.48 | 3554 | 100 | 105 |

Table 2.1: EDS analyses of a large grain from sample 9956c.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | SO3 | Cl | Cr2O3 | ZrO2 | Zr ppm | Total | Actual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956c | 8 | 1 | Rt | | 98.16 | | 0.24 | | | | | | | | 0.74 | 0.86 | 6367 | 100 | 107 |
| 9956c | 8 | 2 | Rt | | 97.99 | | 0.34 | | | | | | | | 0.77 | 0.90 | 6663 | 100 | 107 |
| 9956c | 8 | 3 | Rt | | 98.15 | | 0.33 | | | | | | | | 0.70 | 0.82 | 6071 | 100 | 108 |
| 9956c | 8 | 4 | Rt | | 98.24 | | 0.24 | | | | | | | | 0.70 | 0.81 | 5997 | 100 | 108 |
| 9956c | 8 | 5 | Rt | | 98.05 | | 0.28 | | | | | | | | 0.67 | 1.00 | 7403 | 100 | 107 |
| | | | | | | | | | | | | | | | | | | | |
| | | | Zr ppm | | | | | | | | | | | | | | | | |
| | | | = ZrO2 wt.% *(Zr/ZrO2)*10000 | | | | | | | | | | | | | | | | |

# Appendix 3: Normalized XRF maps of sample thin sections analyzed by laser ablation.

# Appendix 3-1: XRF thin section maps of sample 9927(1).

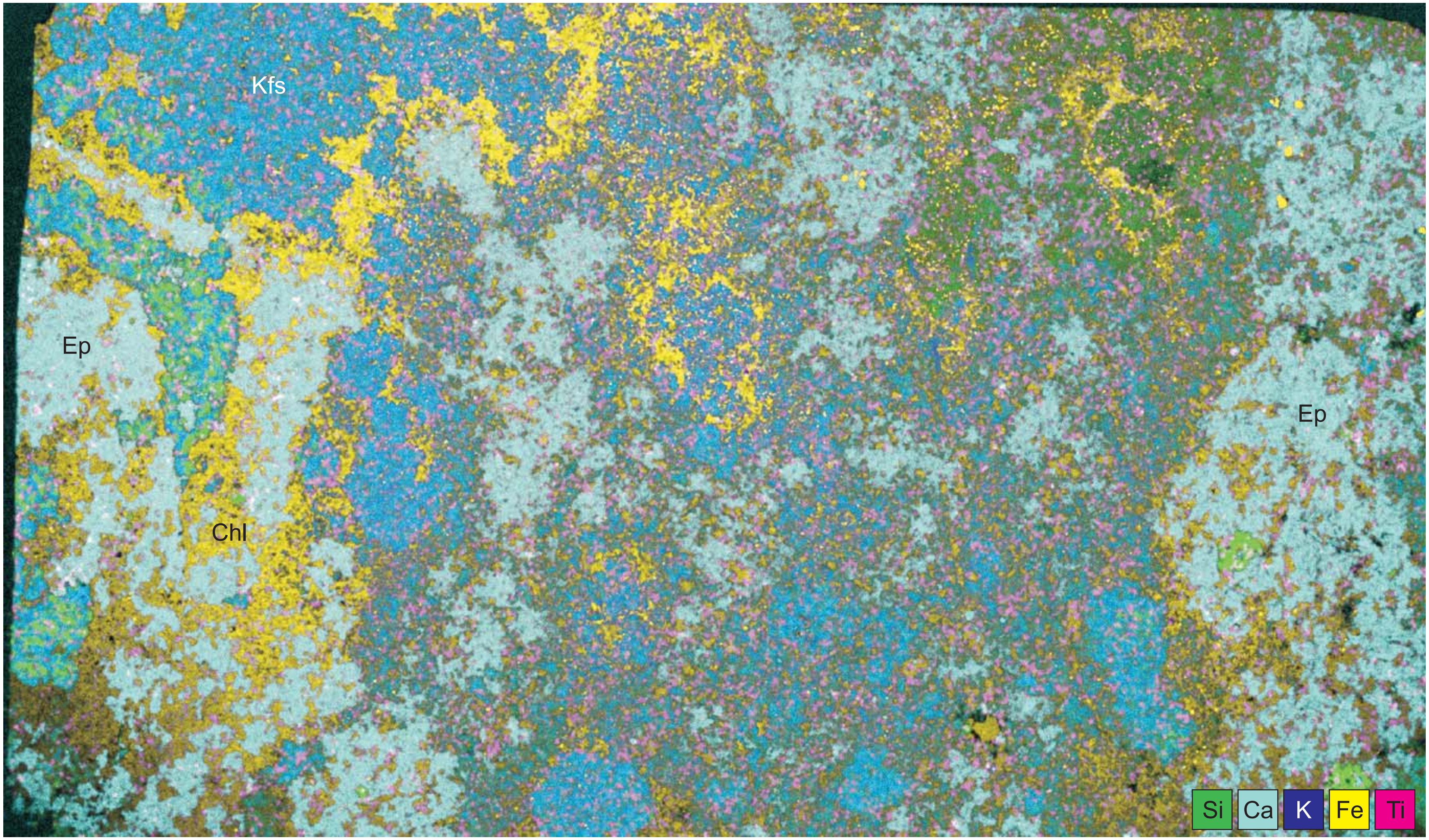



Figure 3-1.1: Sample 9927(1) XRF composite map of elements (Si, Ca, K, Fe, Ti).

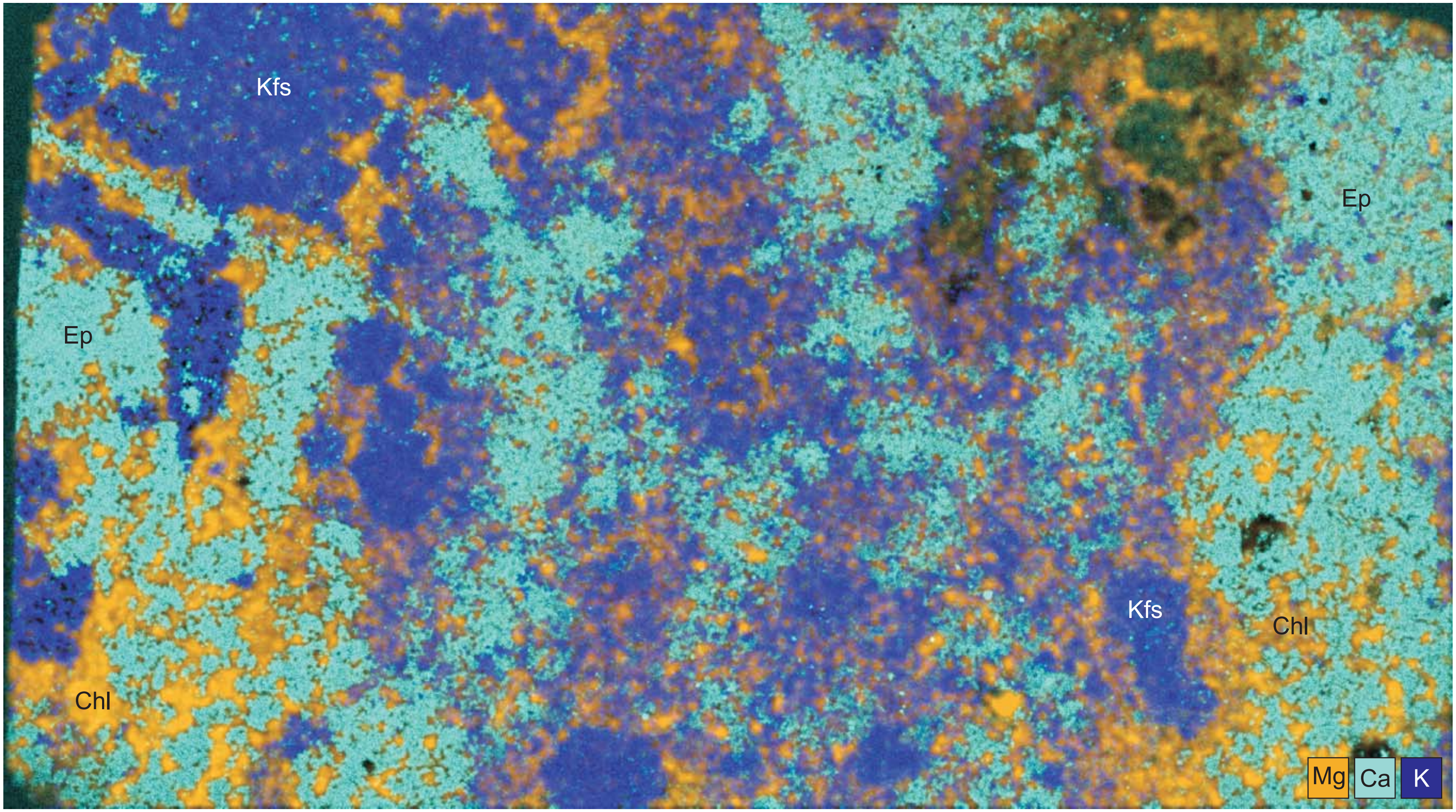



Figure 3-1.2: Sample 9927(1) XRF composite map of elements (Mg, Ca, K).

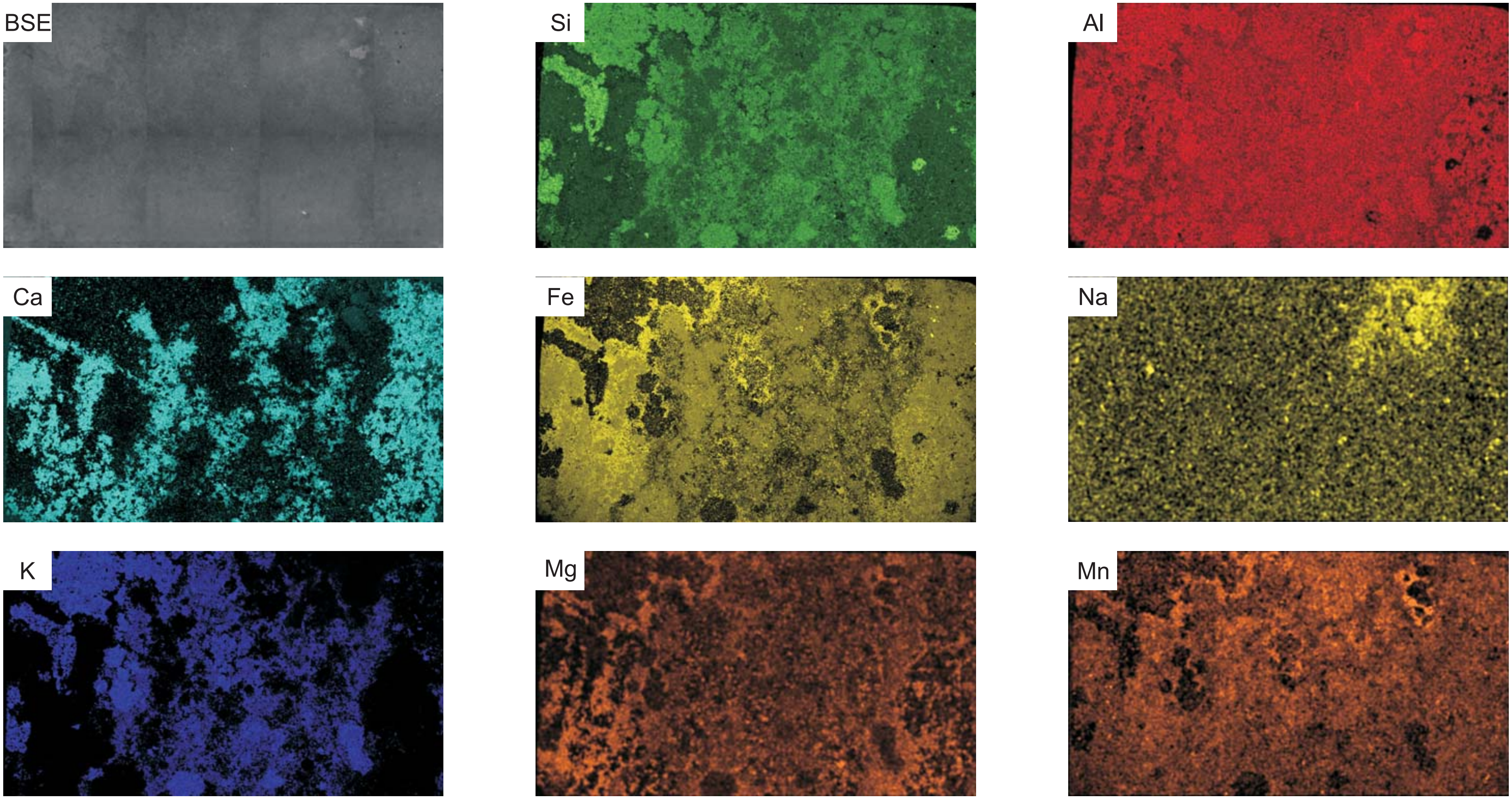



Figure 3-1.3: Sample 9927(1) XRF maps for individual elements..

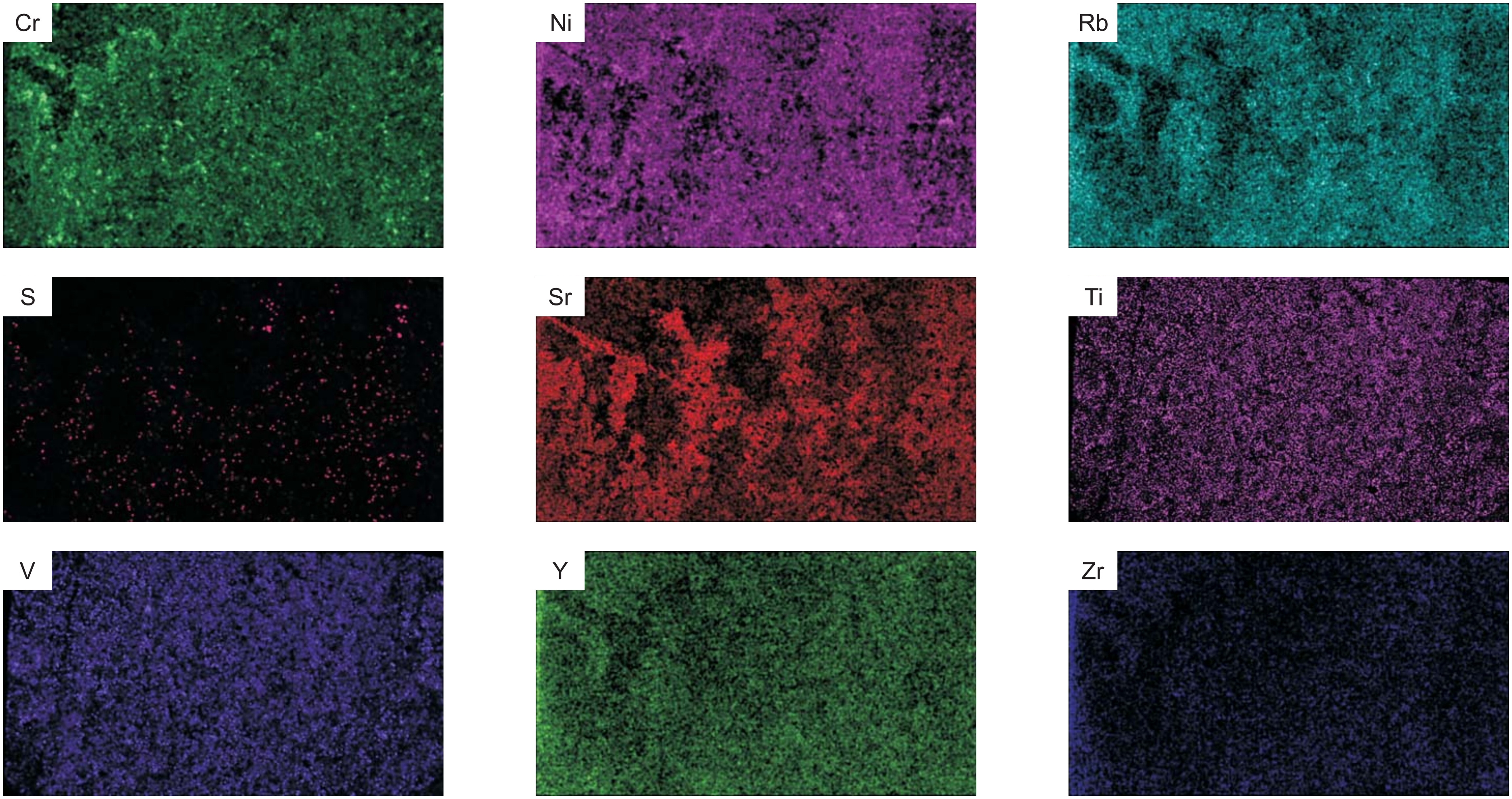



Figure 3-1.4: Sample 9927(1) XRF maps for individual elements.

# Appendix 3-2: XRF thin section maps of sample 9928a.

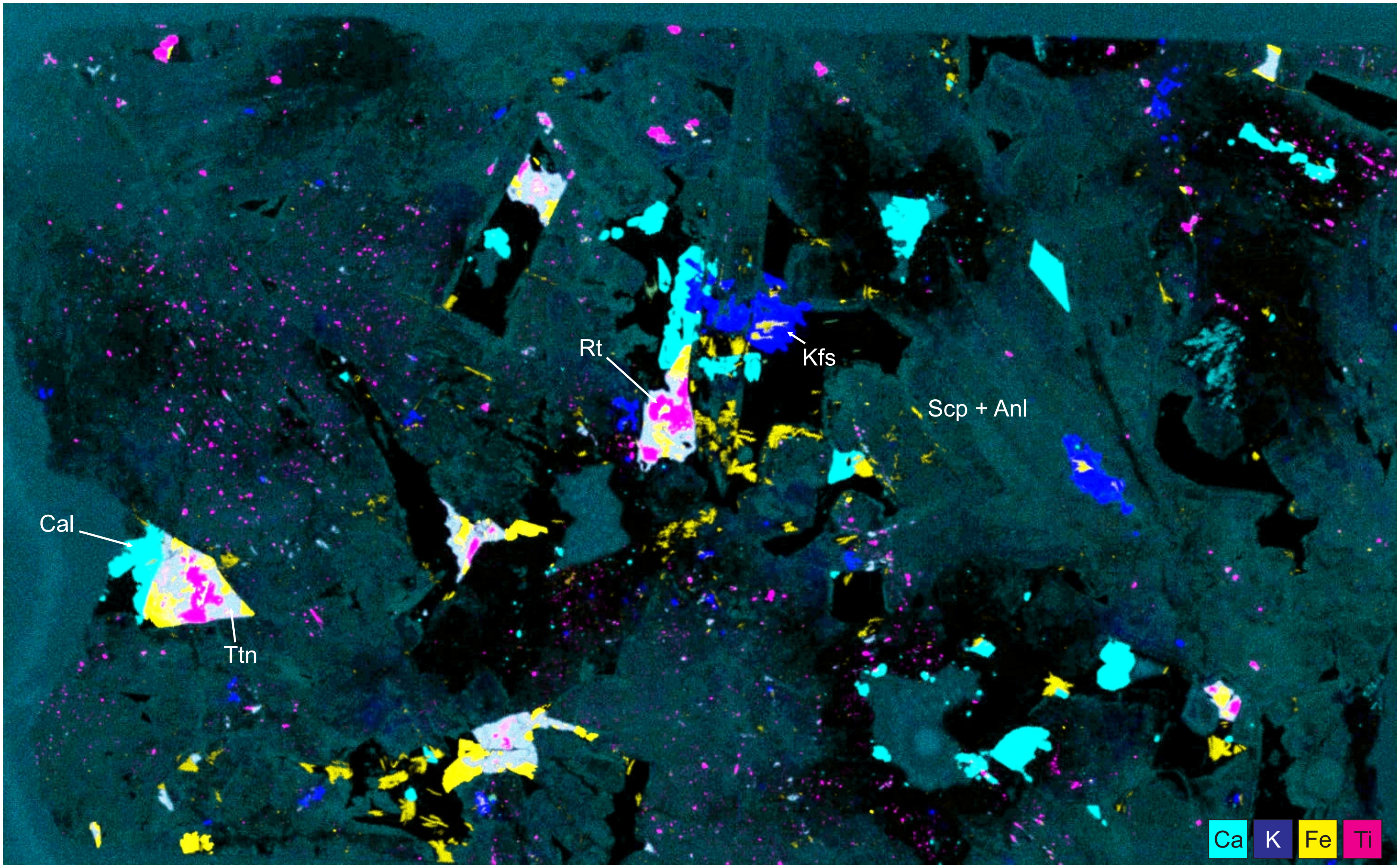



Figure 3-2.1: Sample 9928a XRF composite map of elements (Ca, K, Fe, Ti)..

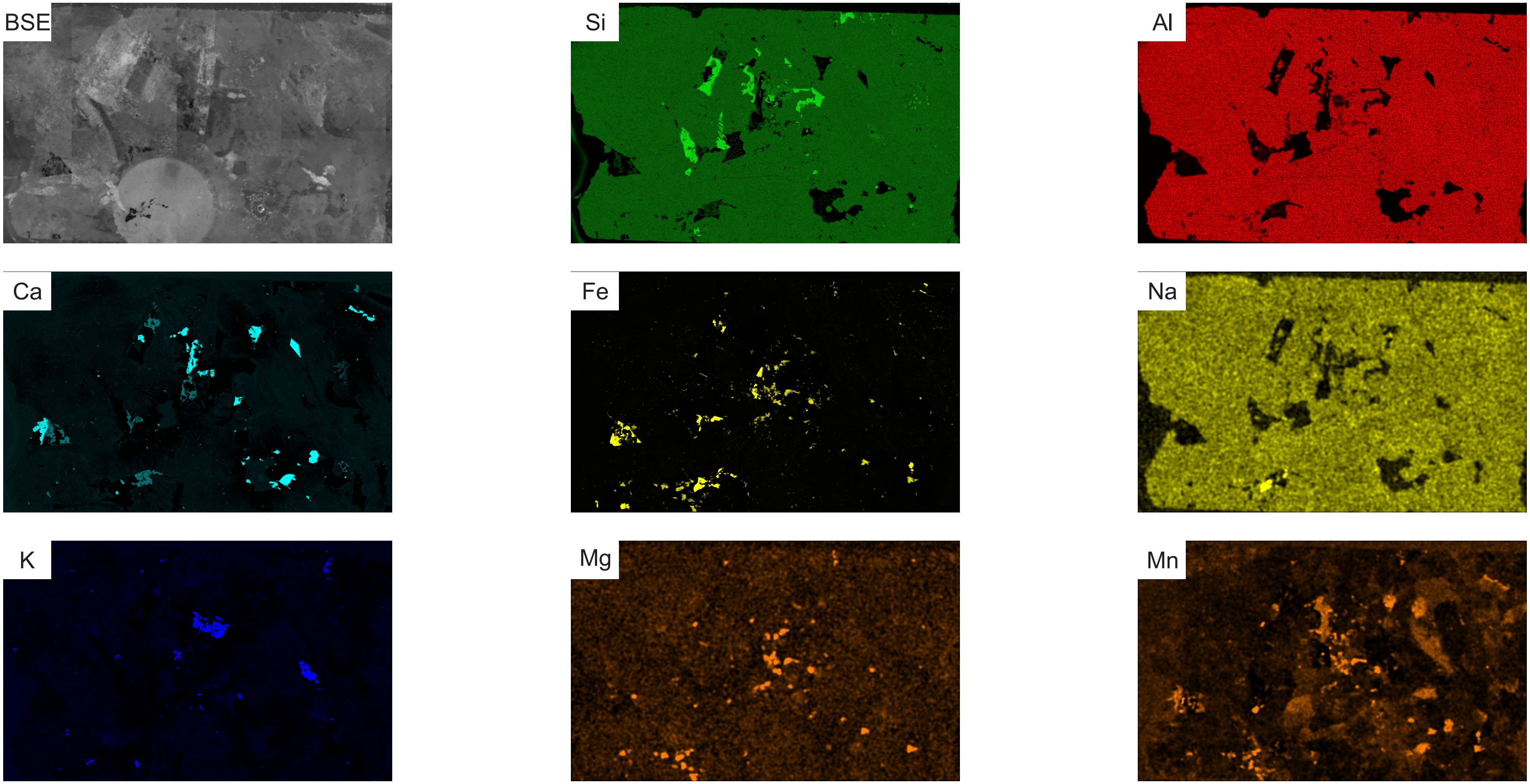



Figure 3-2.2: Sample 9928a XRF maps for individual elements.

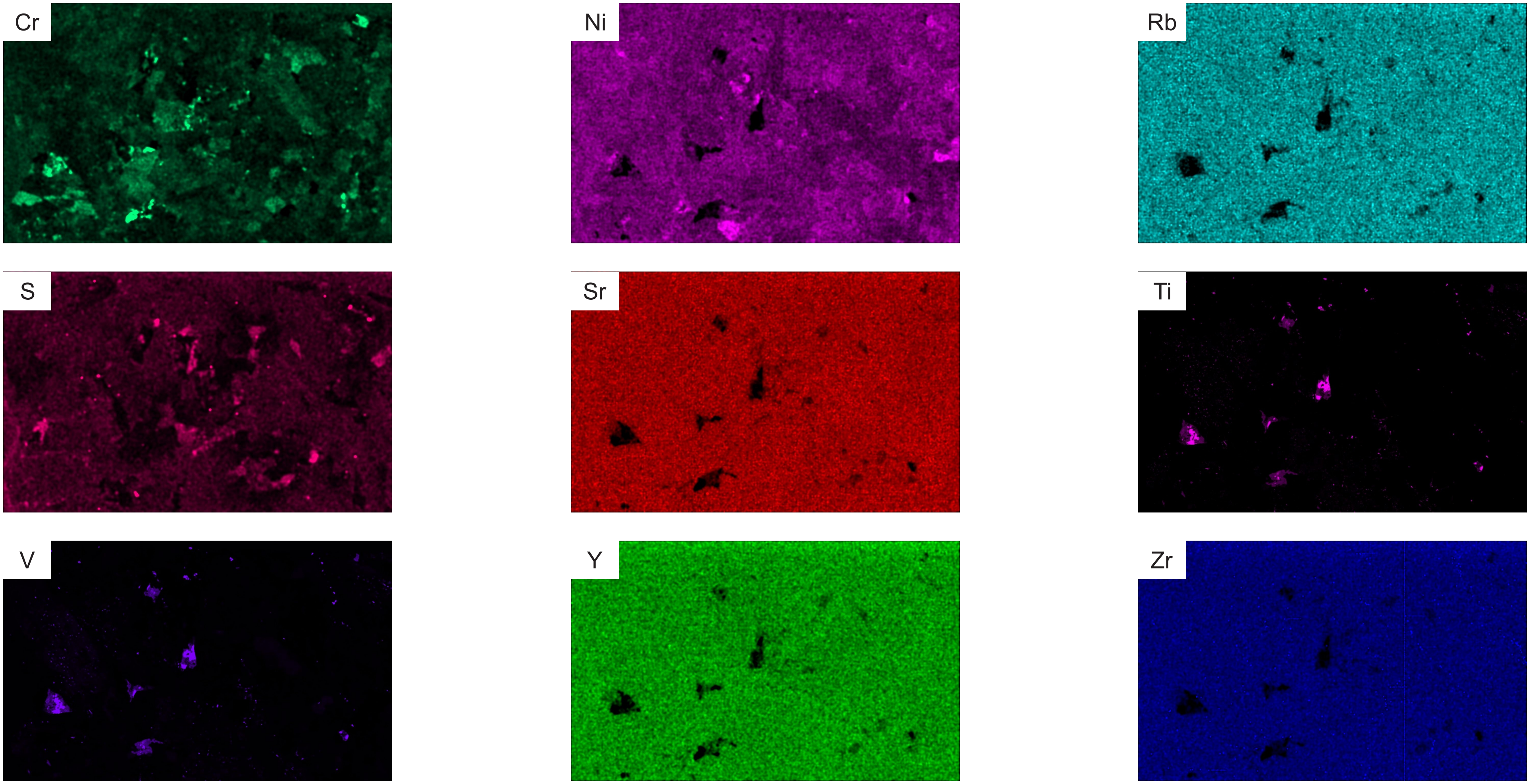



Figure 3-2.3: Sample 9928a XRF maps for individual elements.

# Appendix 3-3: XRF thin section maps of sample 9928b.

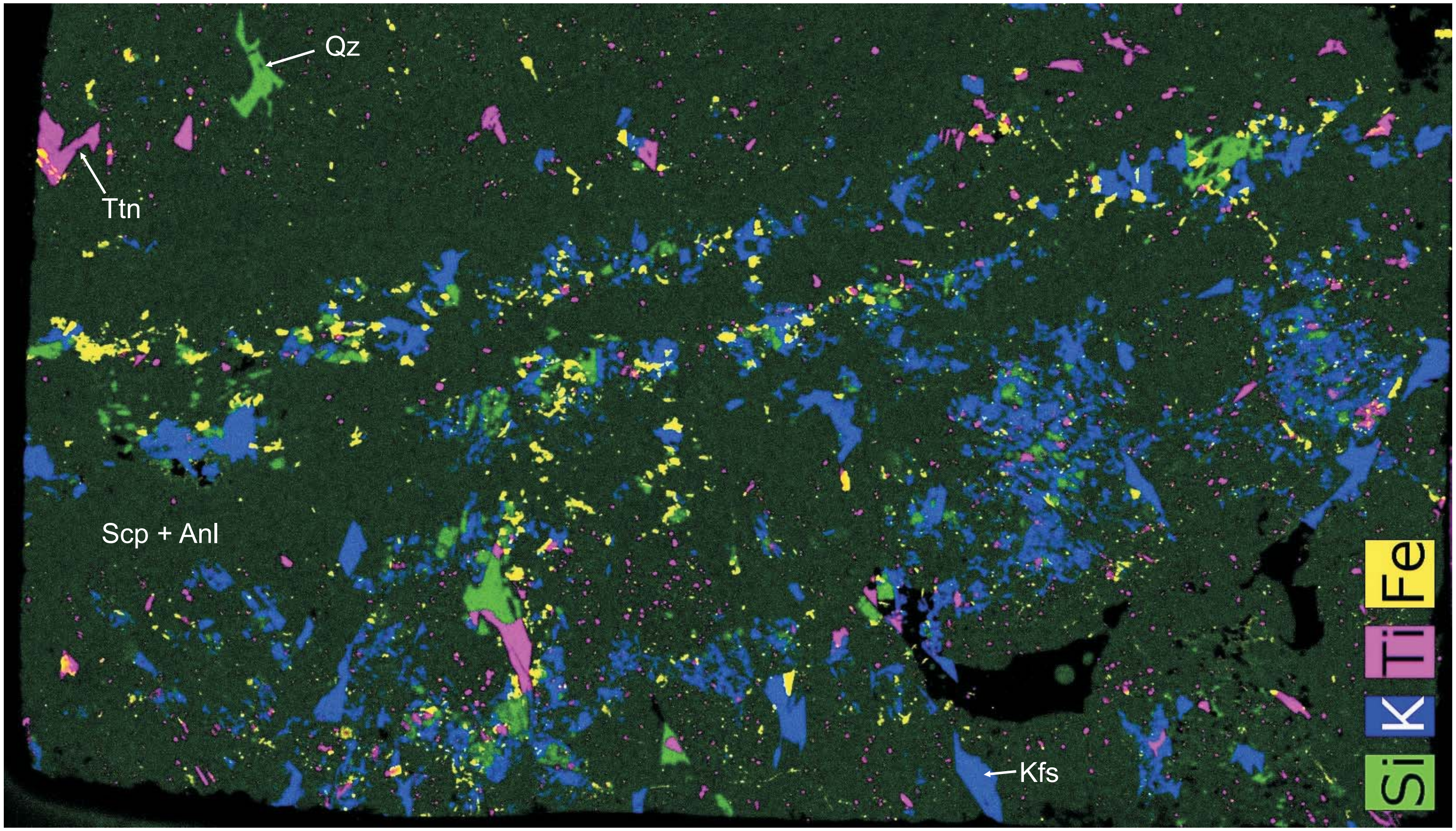


Figure 3-3.1: Sample 9928b XRF composite map of elements (Si, K, Ti, Fe).

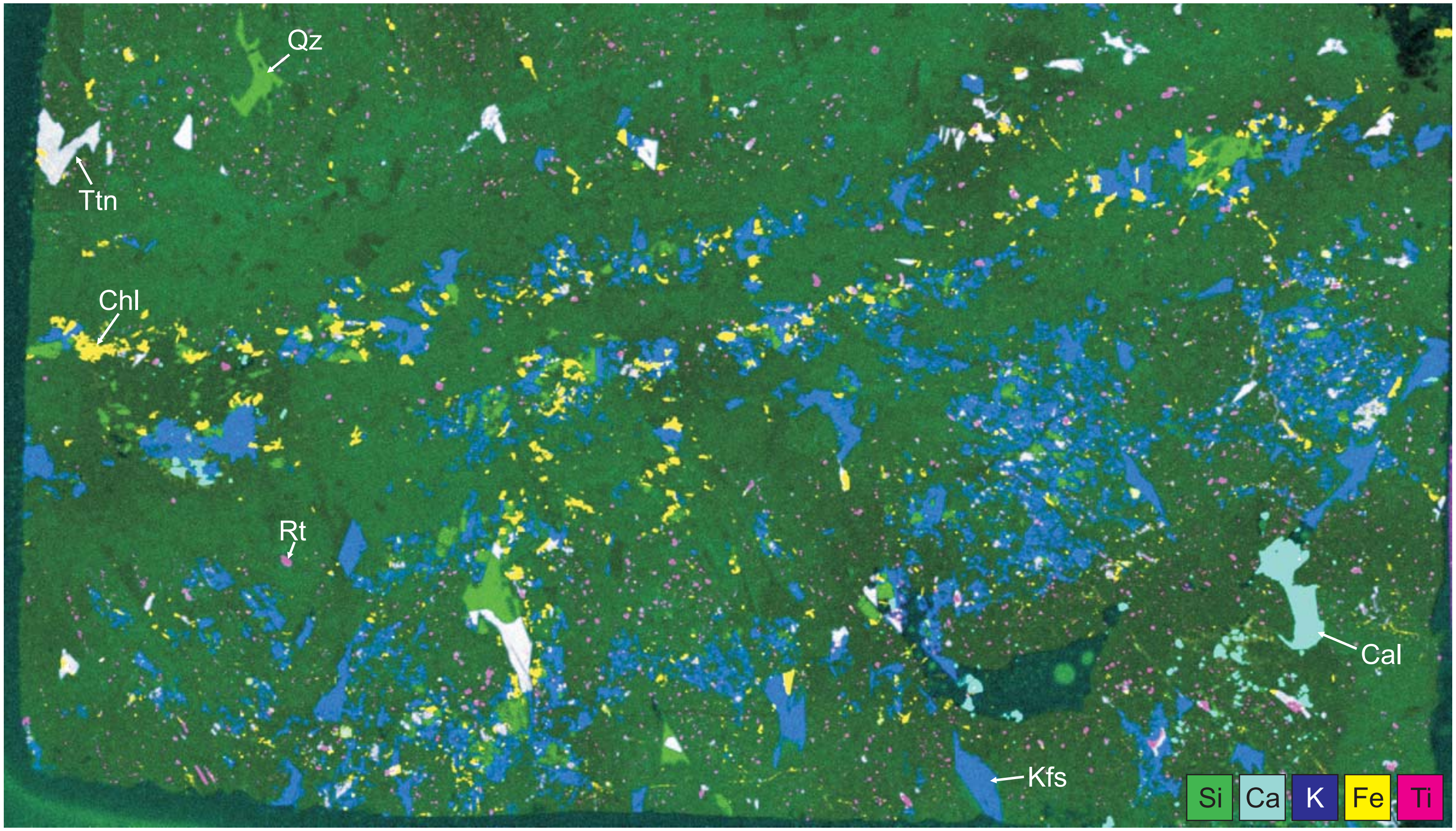



Figure 3-3.2: Sample 9928b XRF composite map of elements (Si, Ca, K, Fe, Ti).

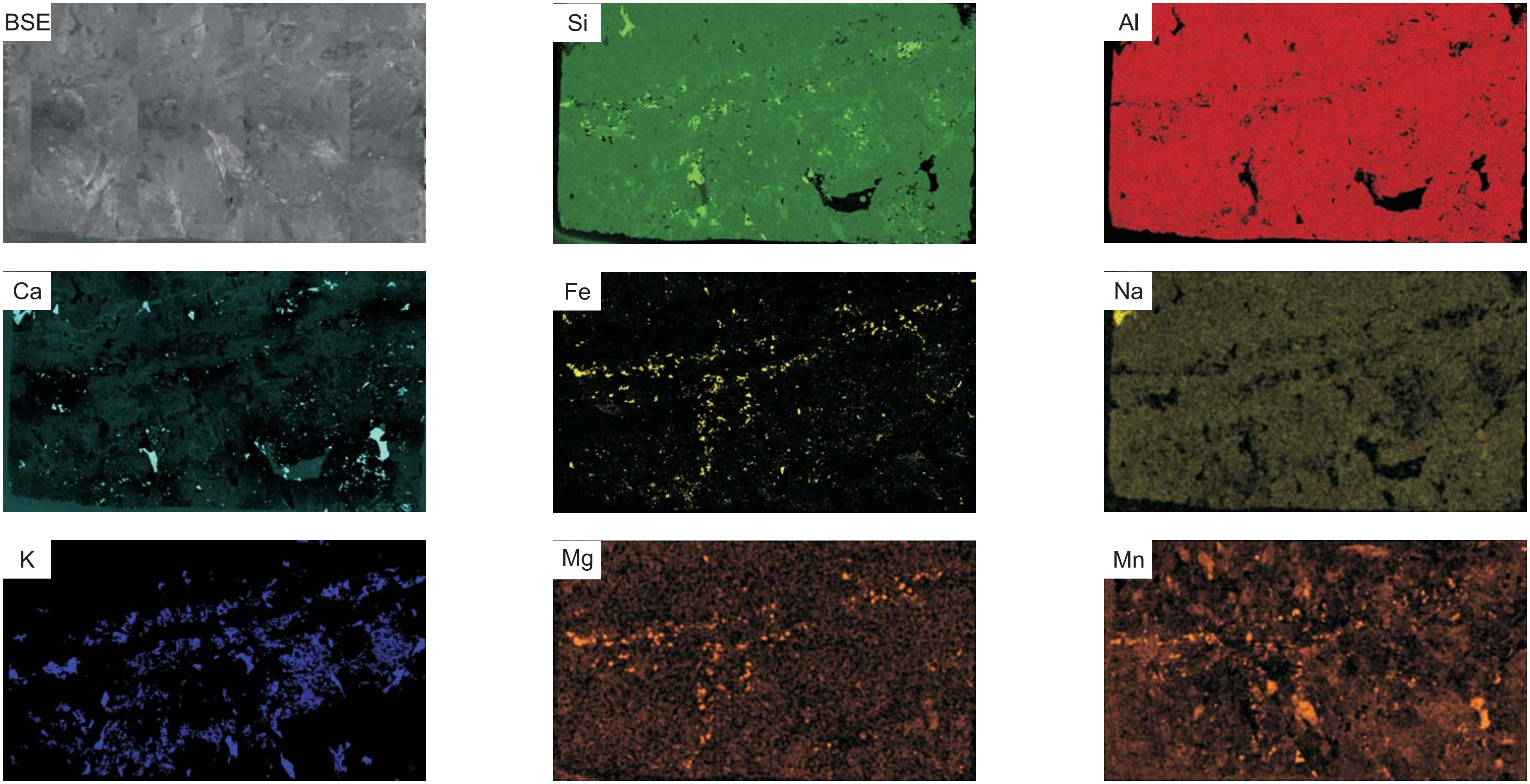



Figure 3-3.3: Sample 9928b XRF maps for individual elements.

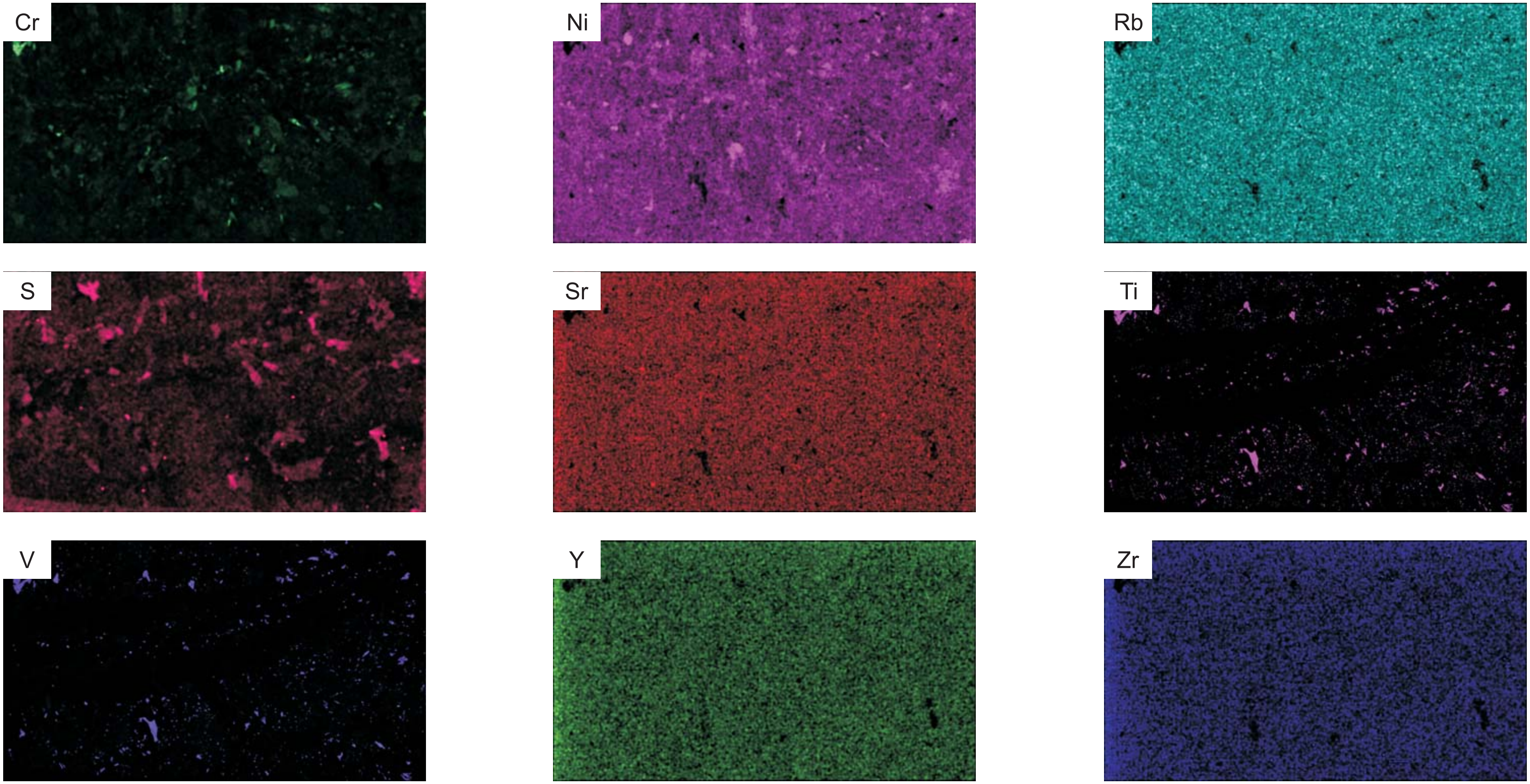



Figure 3-3.4: Sample 9928b XRF maps for individual elements.

# Appendix 3-4: XRF thin section maps of sample 9954a.

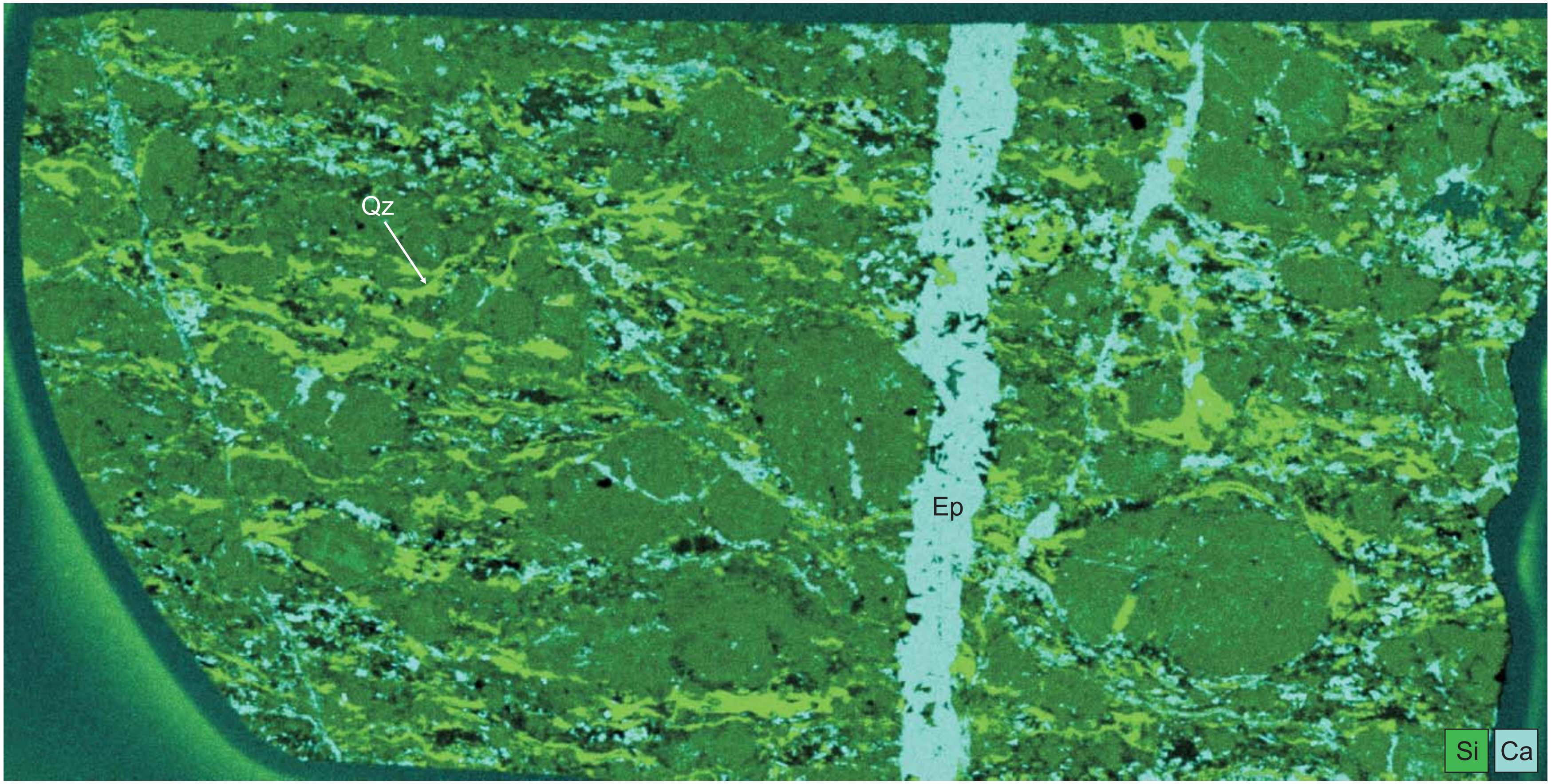


Figure 3-4.1: Sample 9954a XRF composite map of elements (Si, Ca).

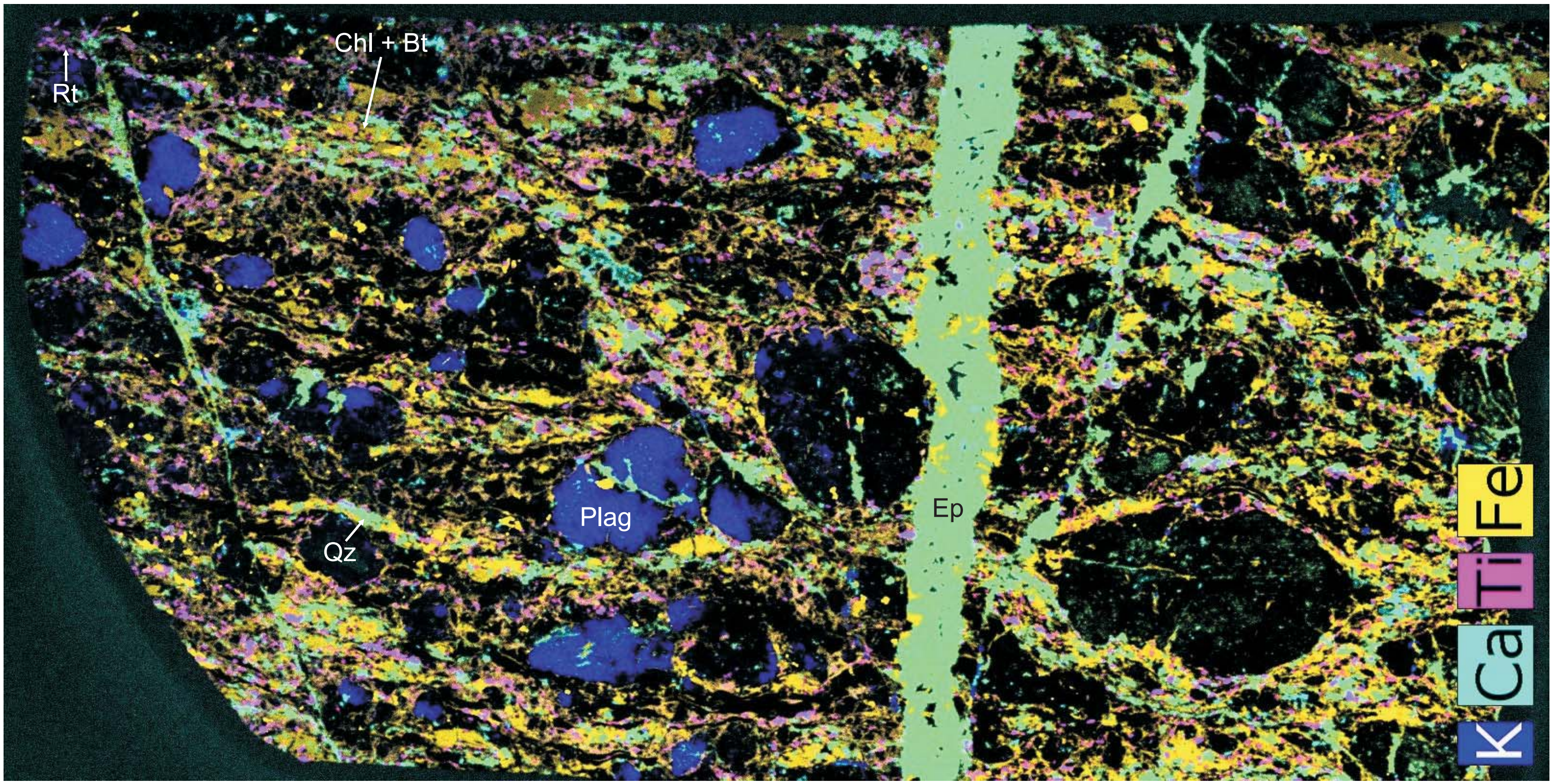


Figure 3-4.2: Sample 9954a XRF composite map of elements (K, Ca, Ti, Fe).

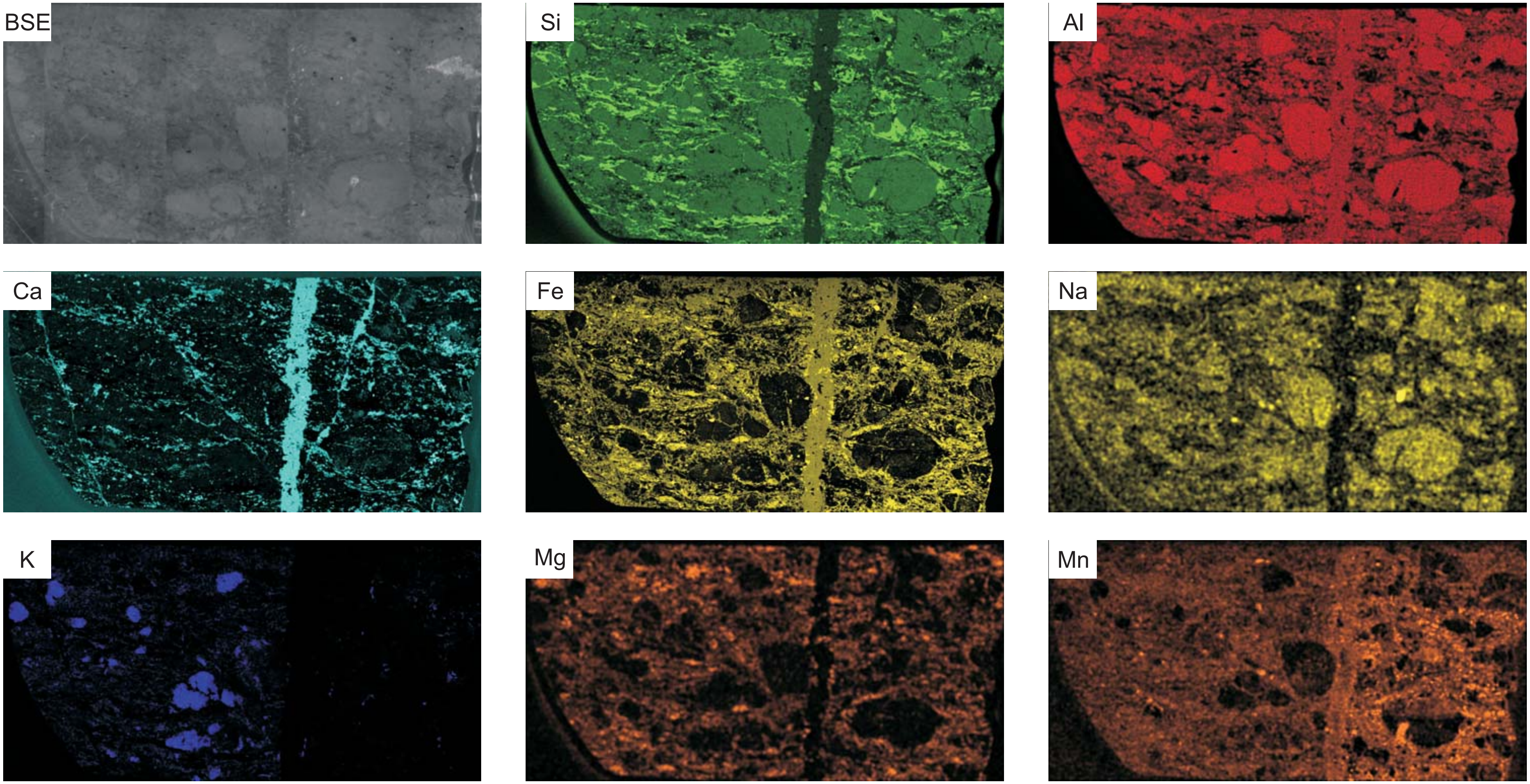



Figure 3-4.3: Sample 9954a XRF maps for individual elements.

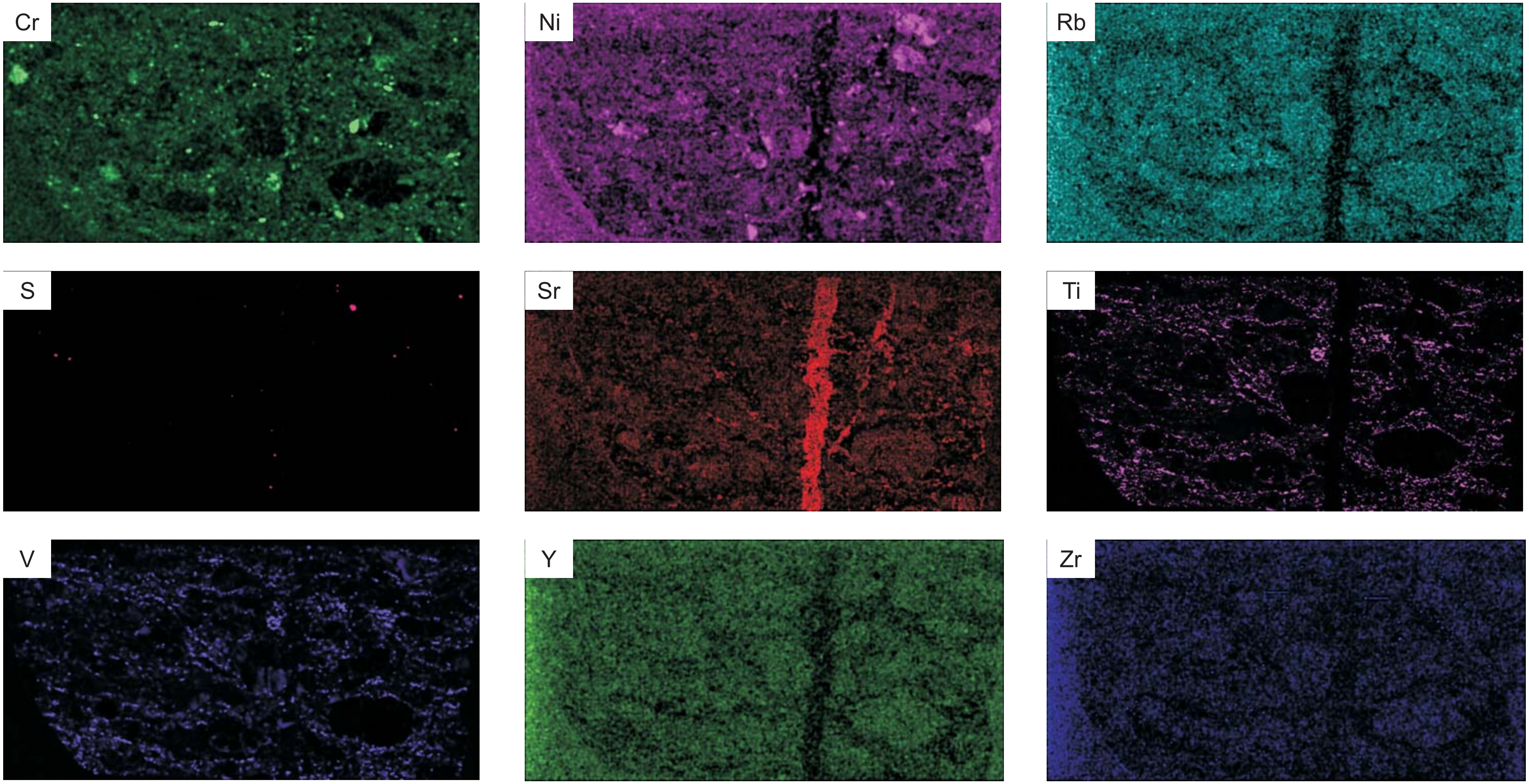


Figure 3-4.4: Sample 9954a XRF maps for individual elements.

# Appendix 3-5: XRF thin section maps of sample 9956a.

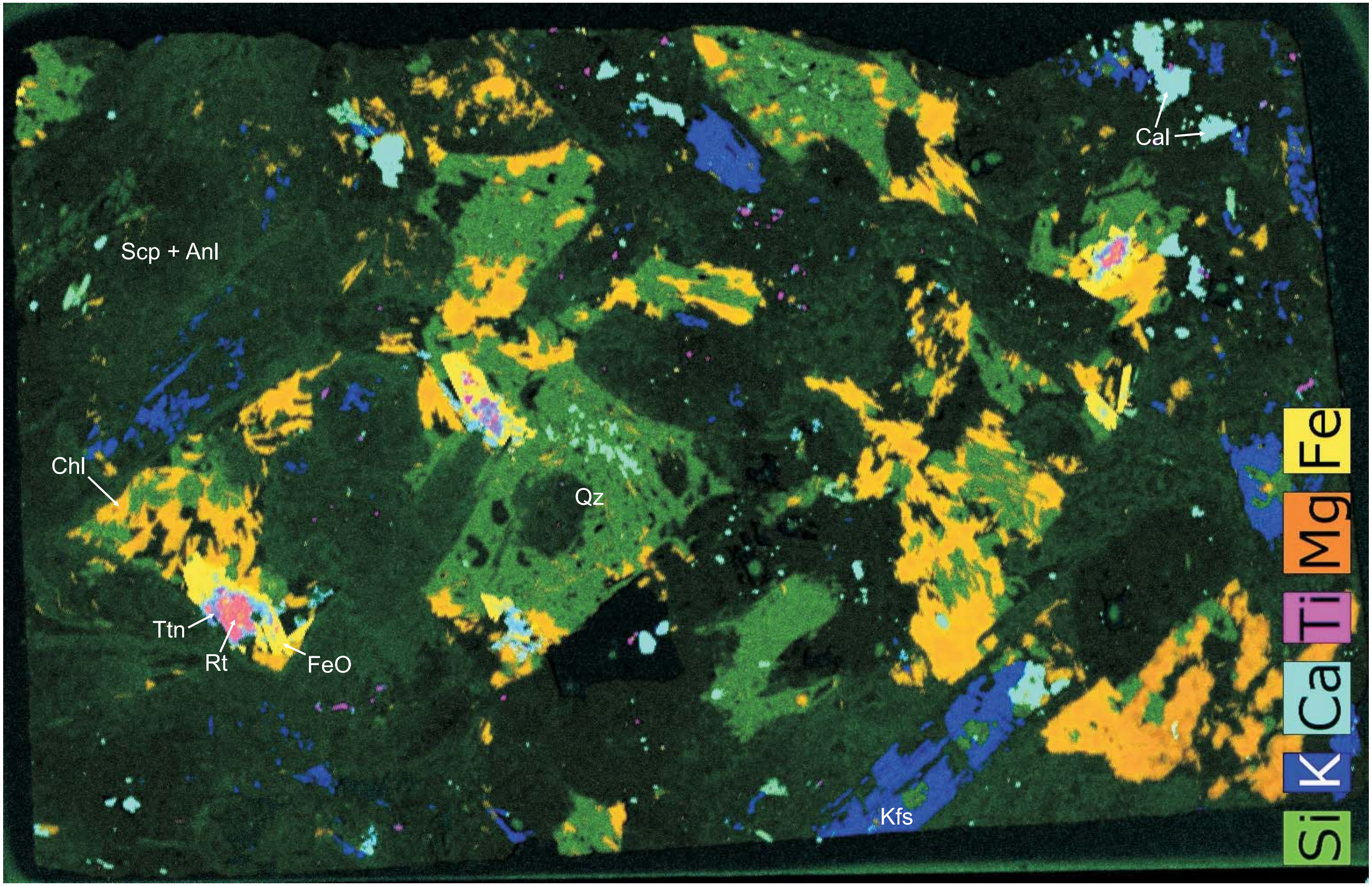



Figure 3-5.1: Sample 9956a XRF composite map of elements (Si, K, Ca, Ti, Mg, Fe).

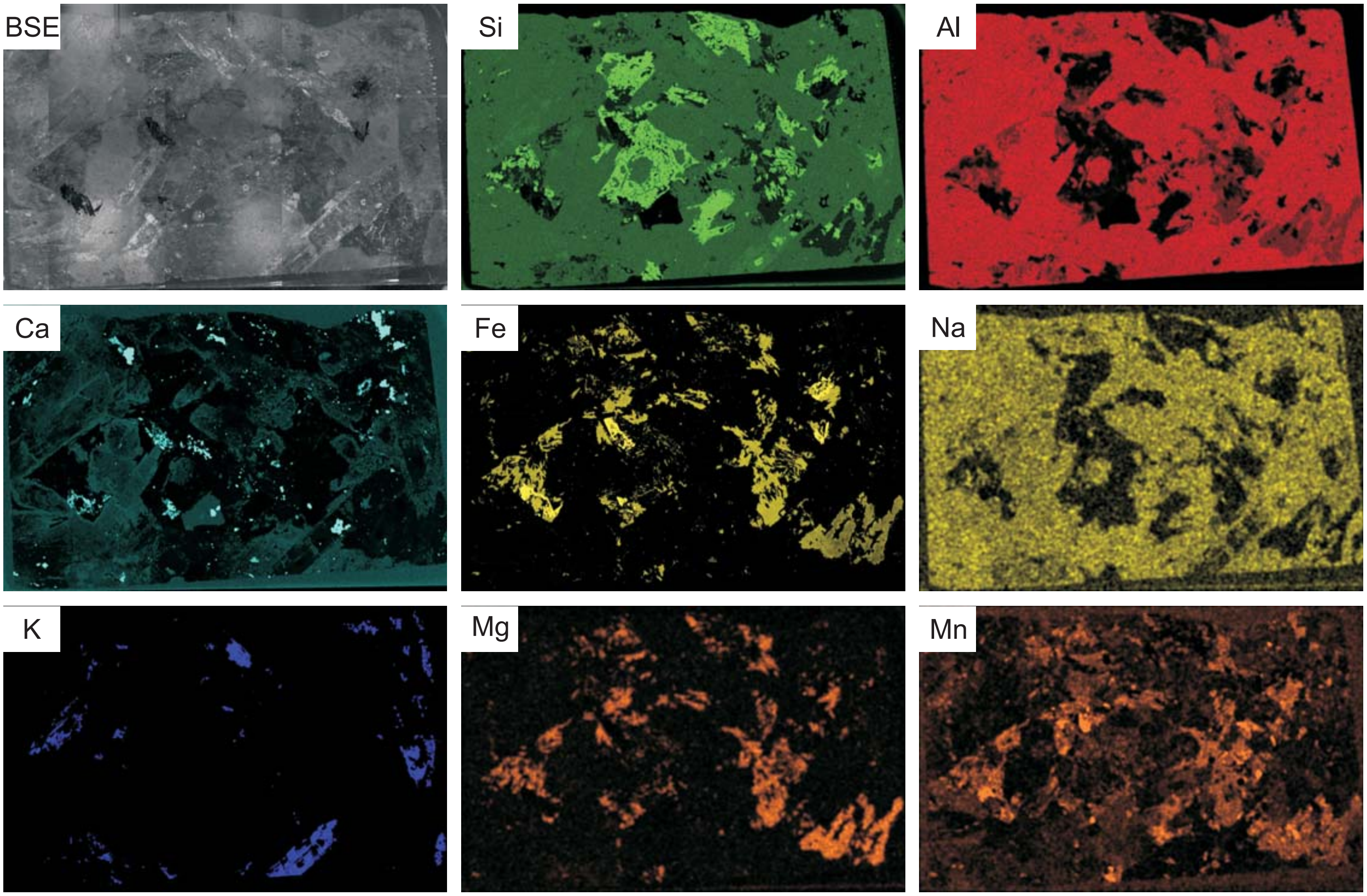


Figure 3-5.2: Sample 9956a XRF maps for individual elements.

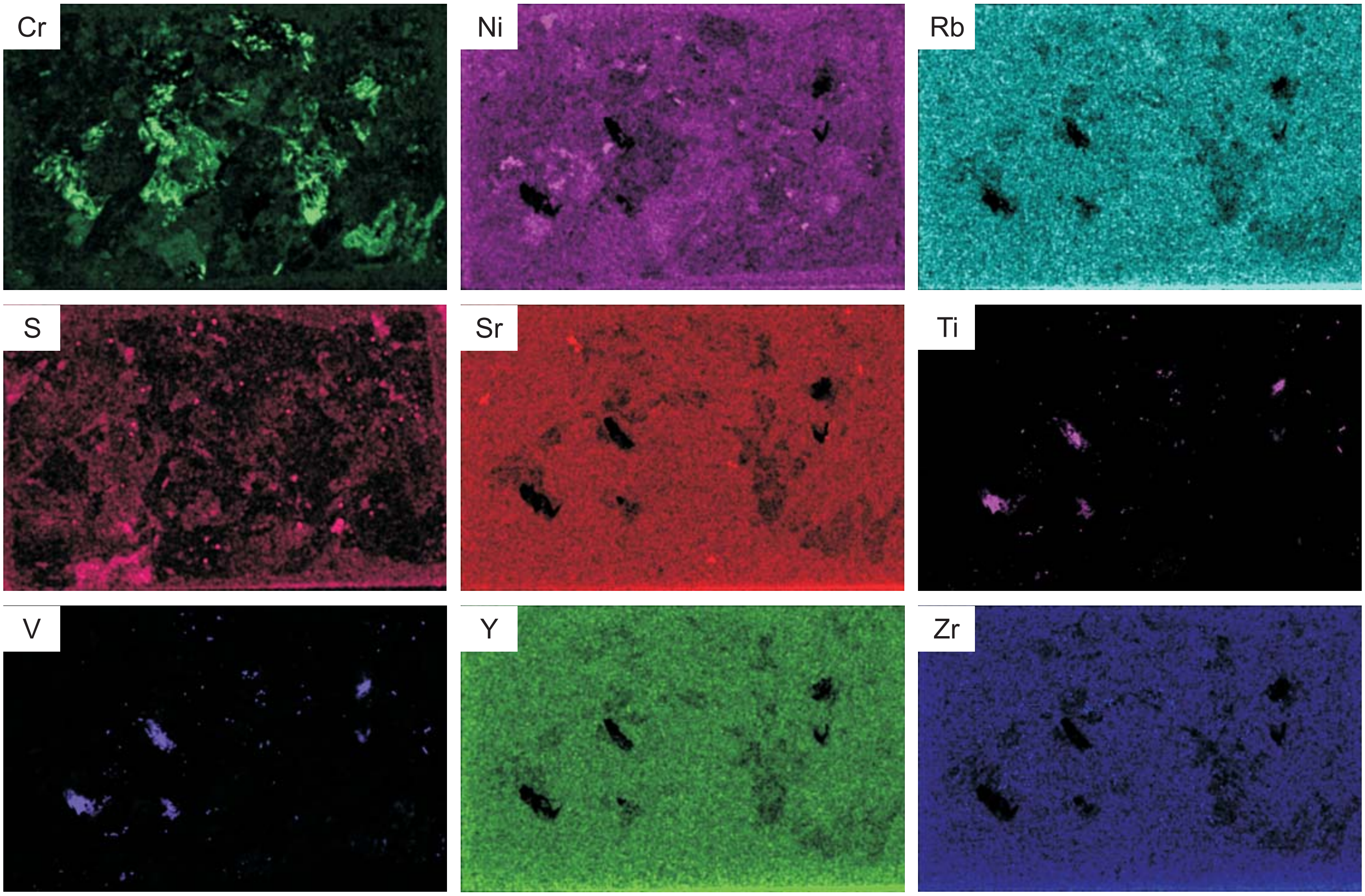



Figure 3-5.3: Sample 9956a XRF maps for individual elements.

# Appendix 3-6a: XRF thin section maps of sample 9956b.

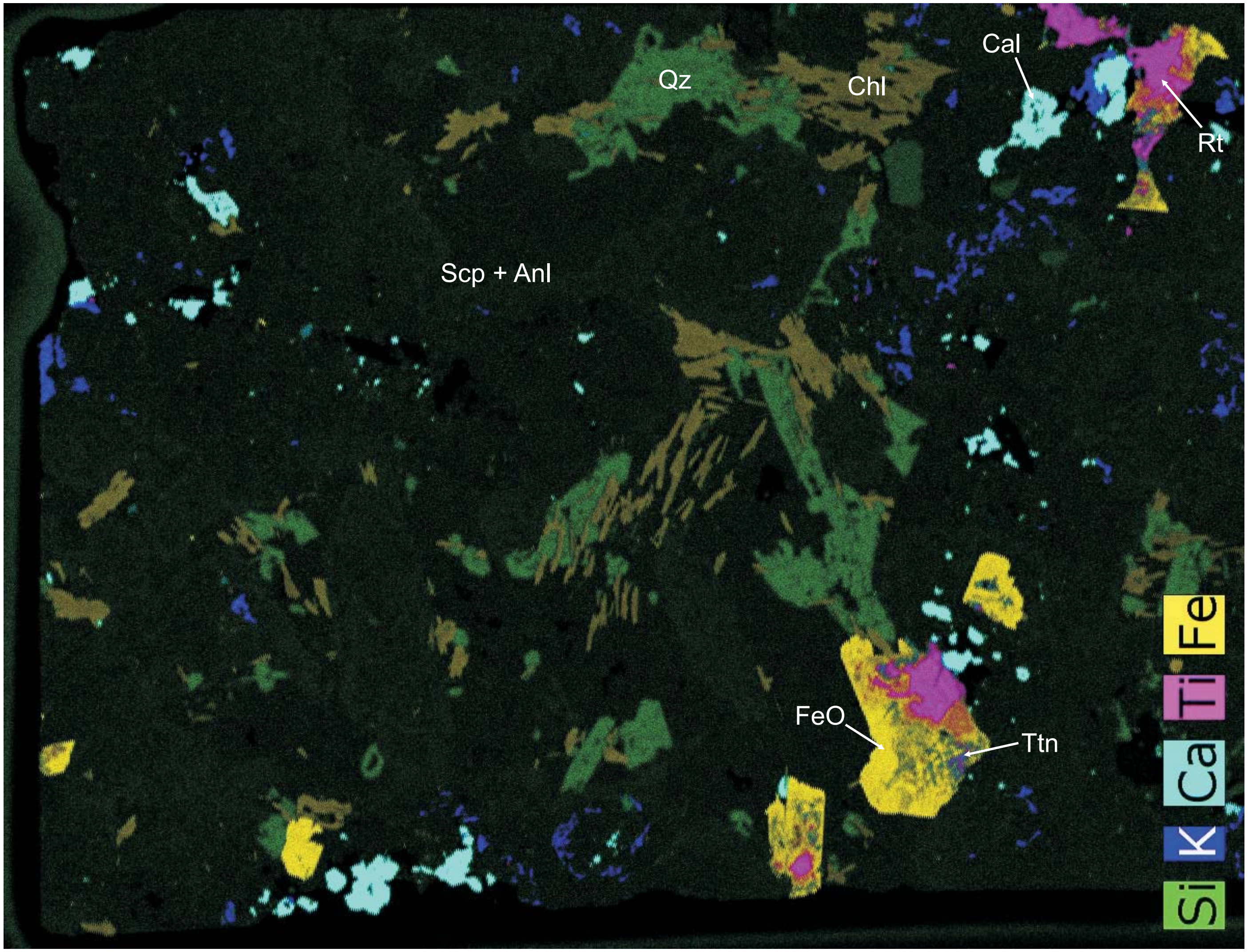


Figure 3-6a.1: Sample 9956b XRF composite map of elements (Si, K, Ca, Ti, Fe).

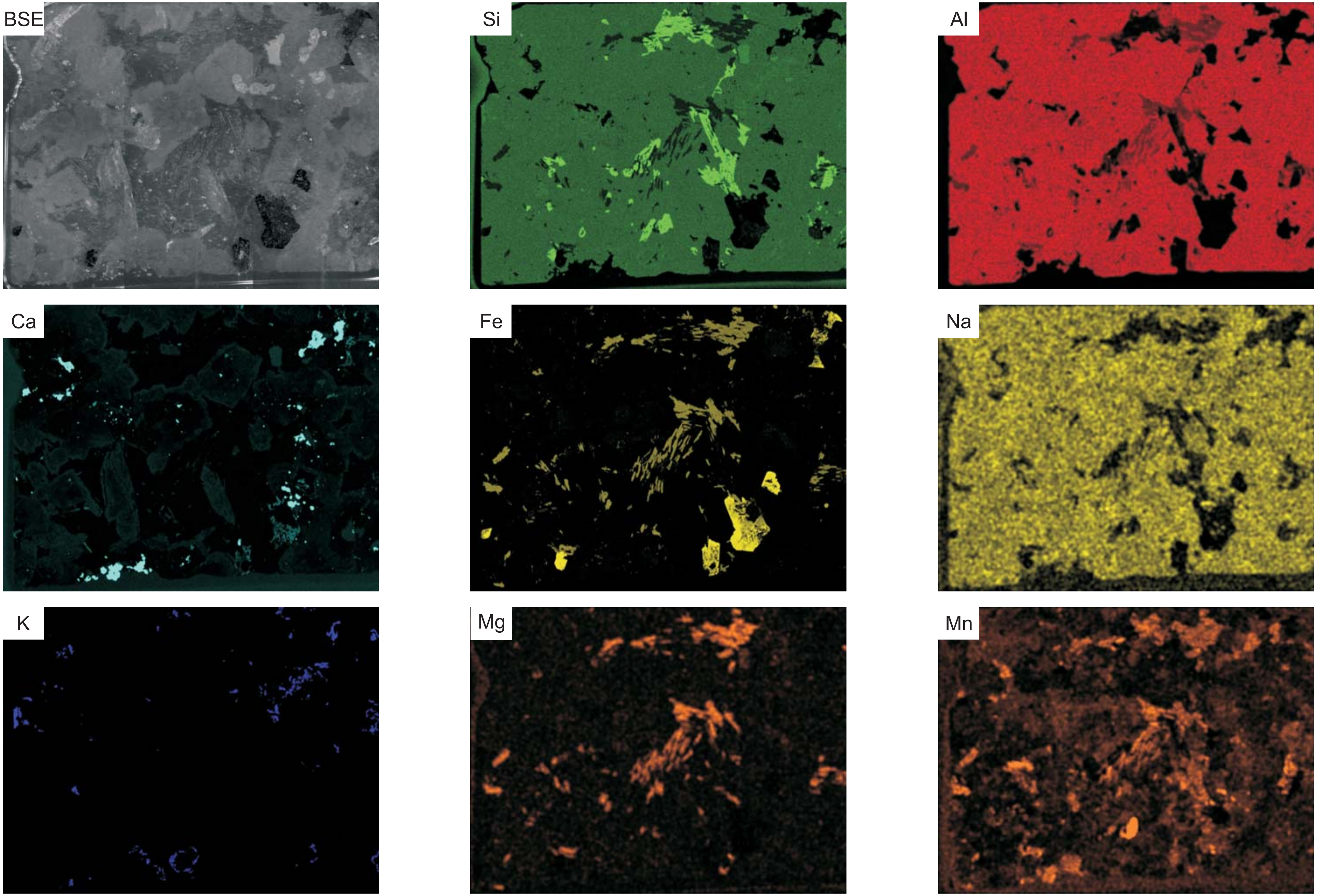



Figure 3-6a.2: Sample 9956b XRF maps for individual elements.

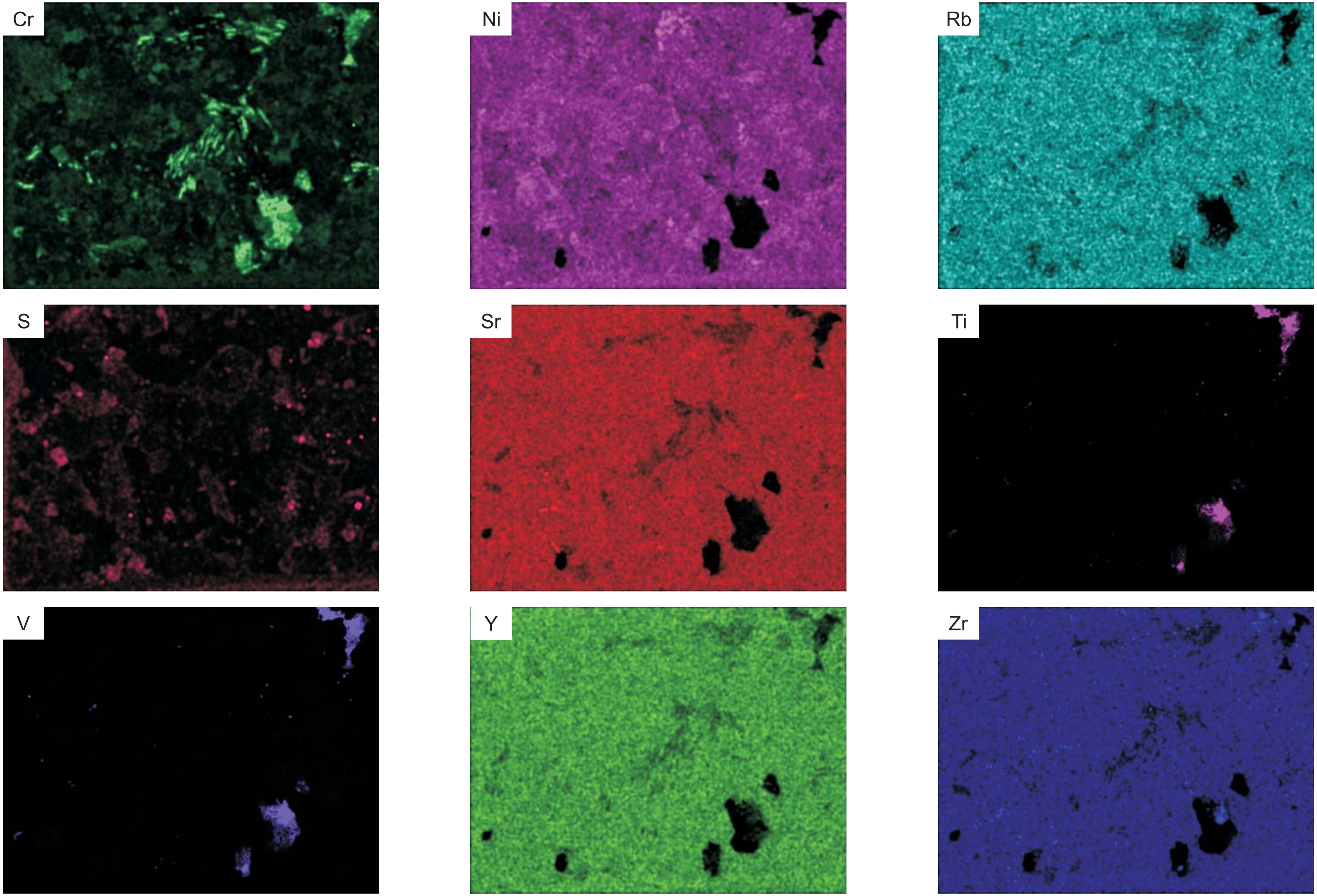



Figure 3-6a.3: Sample 9956b XRF maps for individual elements.

# Appendix 3-6b: XRF maps of a large grain from sample 9956b.

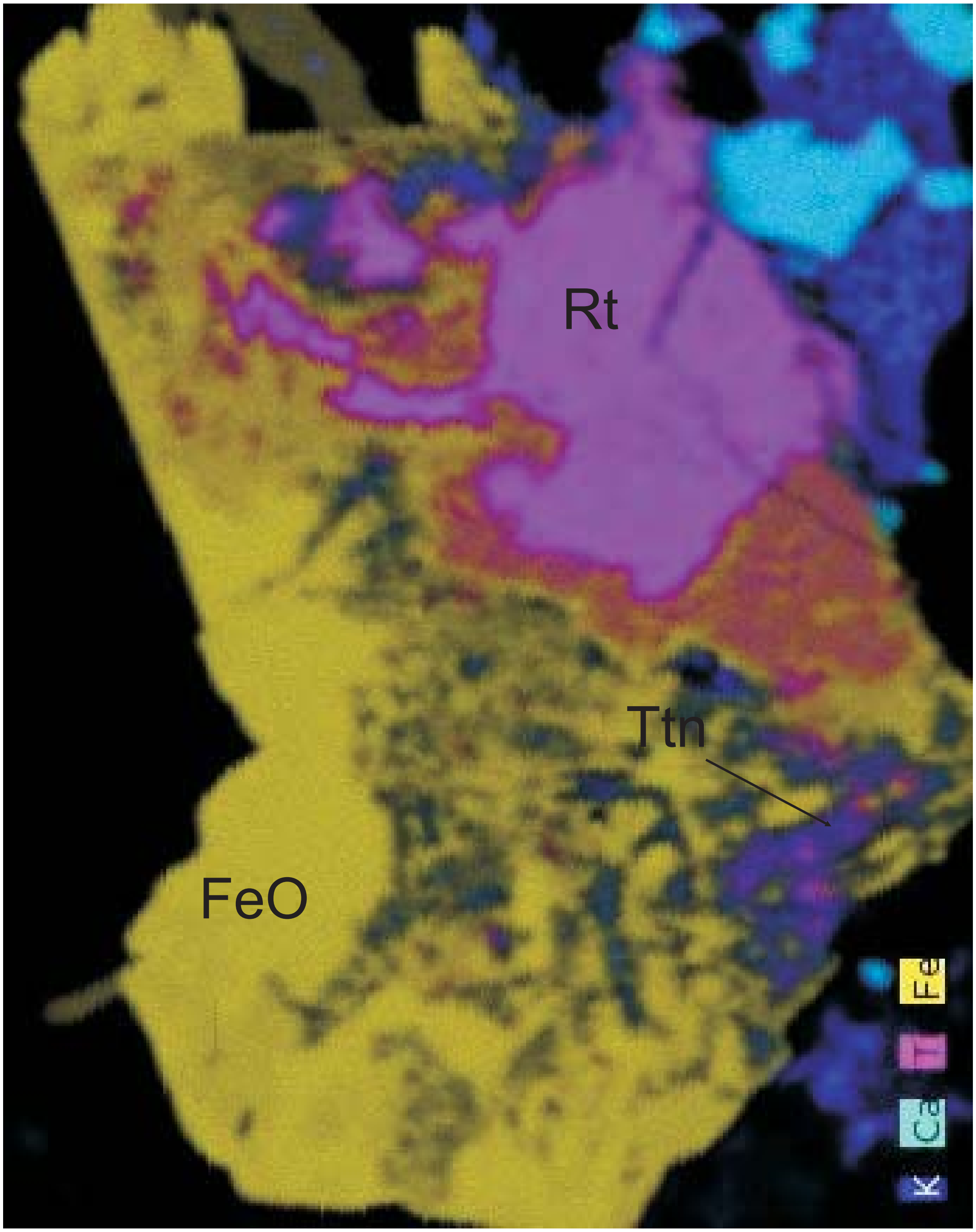



Figure 3-6b.1: Sample 9956b XRF composite map of elements (K, Ca, Ti, Fe).

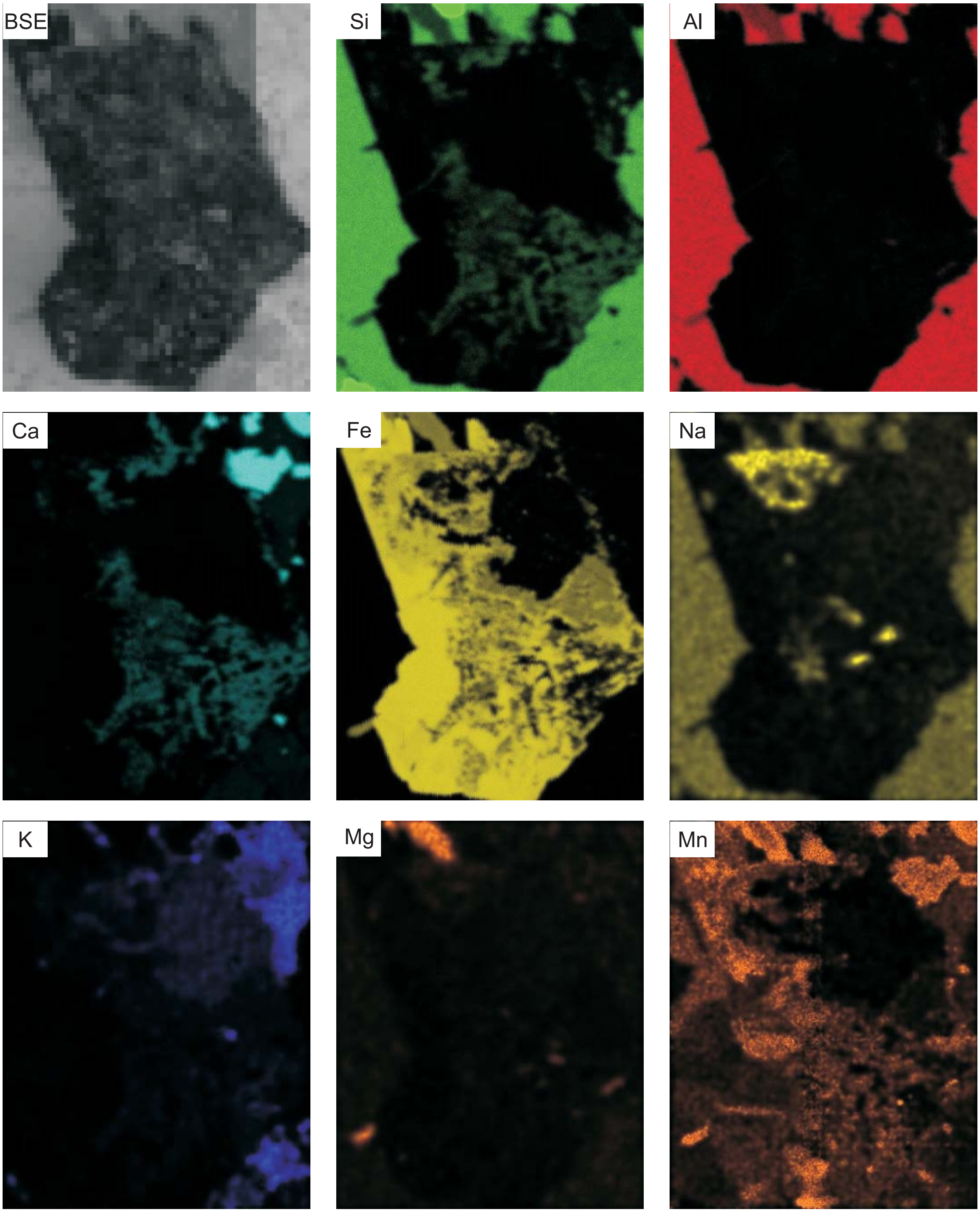


Figure 3-6b.2: Sample 9956b XRF maps for individual elements.

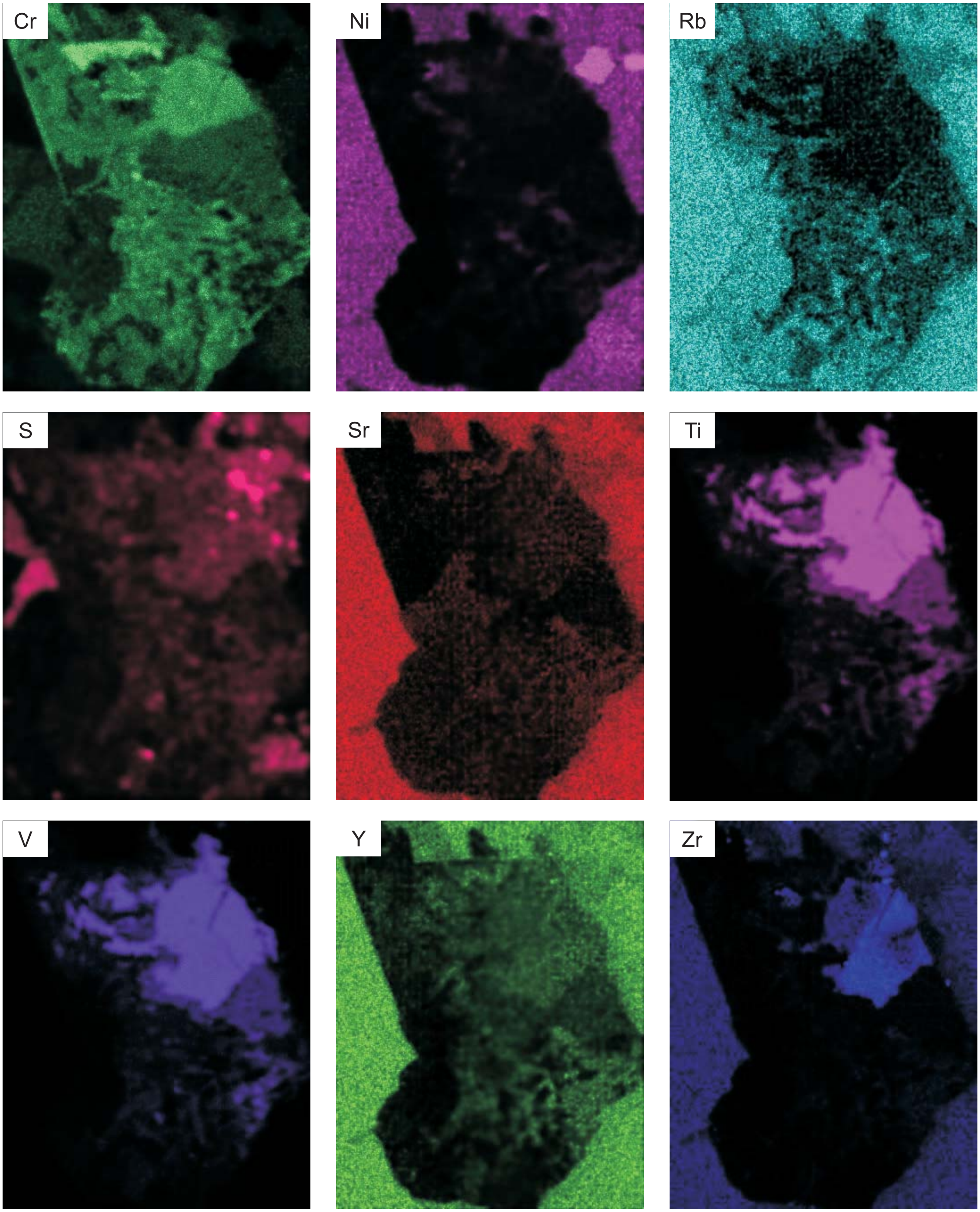



Figure 3-6b.3: Sample 9956b XRF maps for individual elements.

# Appendix 3-7a: XRF thin section maps of sample 9956c.

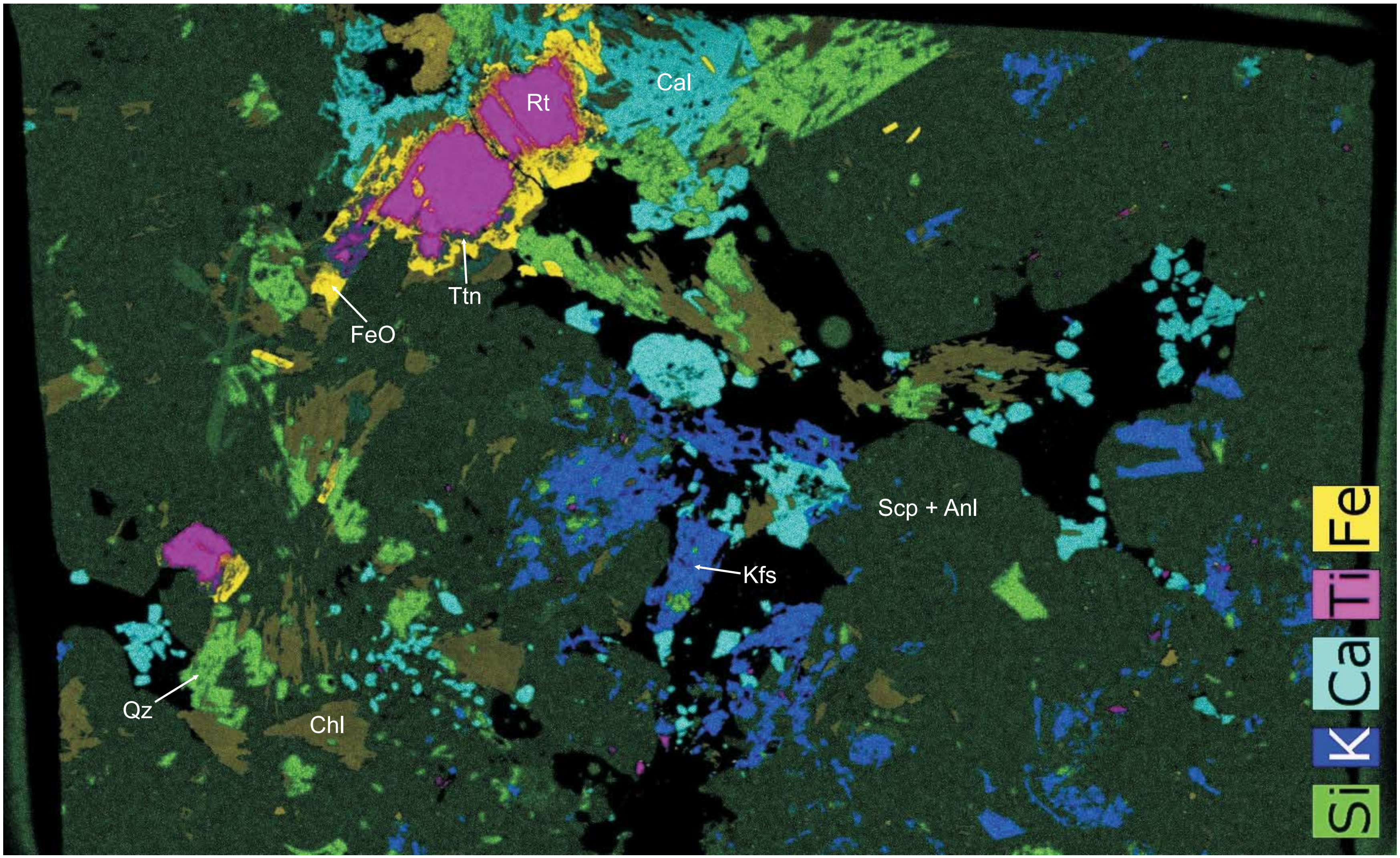



Figure 3-7a.1: Sample 9956c XRF composite map of elements (Si, K, Ca, Ti, Fe).

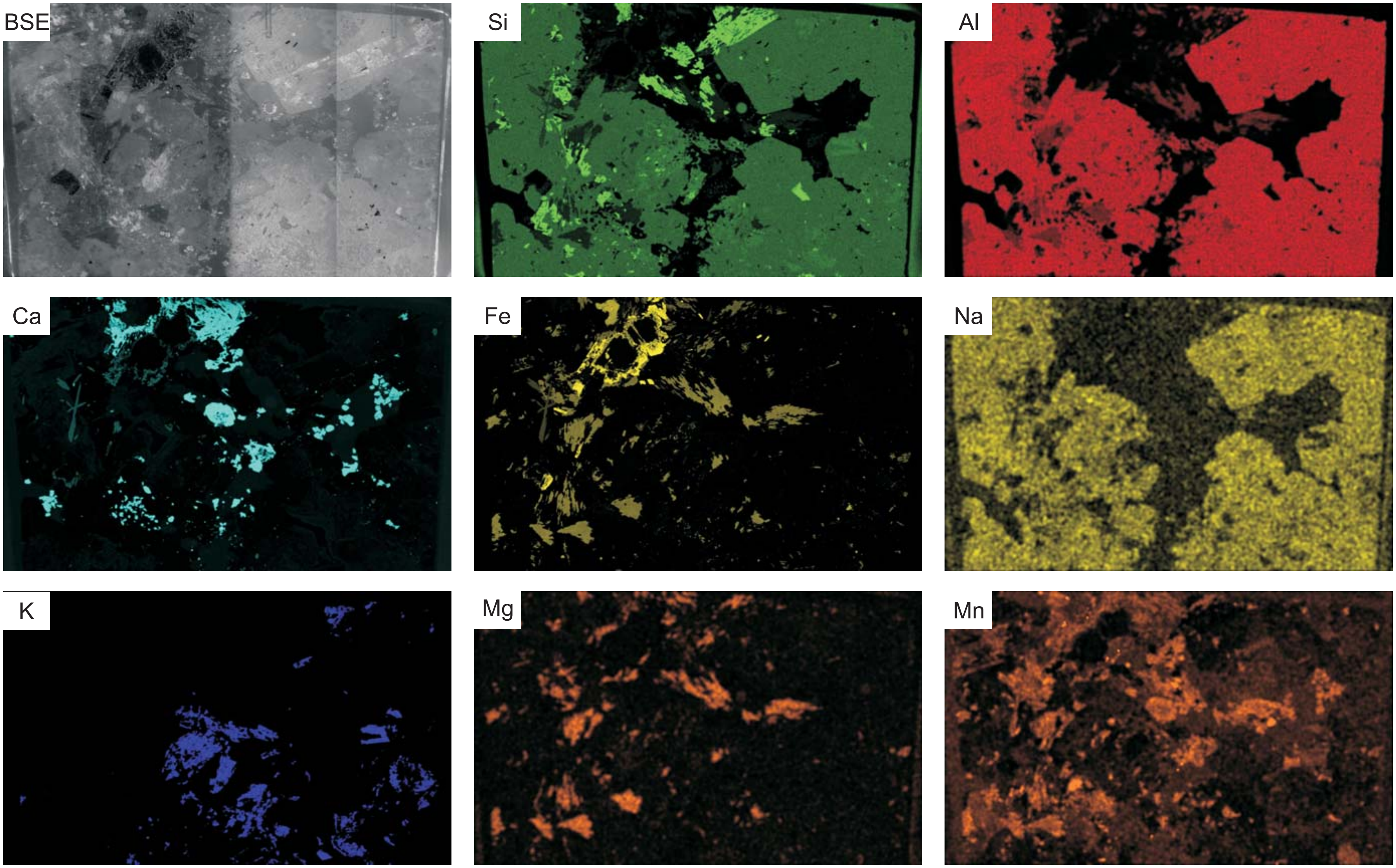



Figure 3-7a.2: Sample 9956c XRF maps for individual elements.

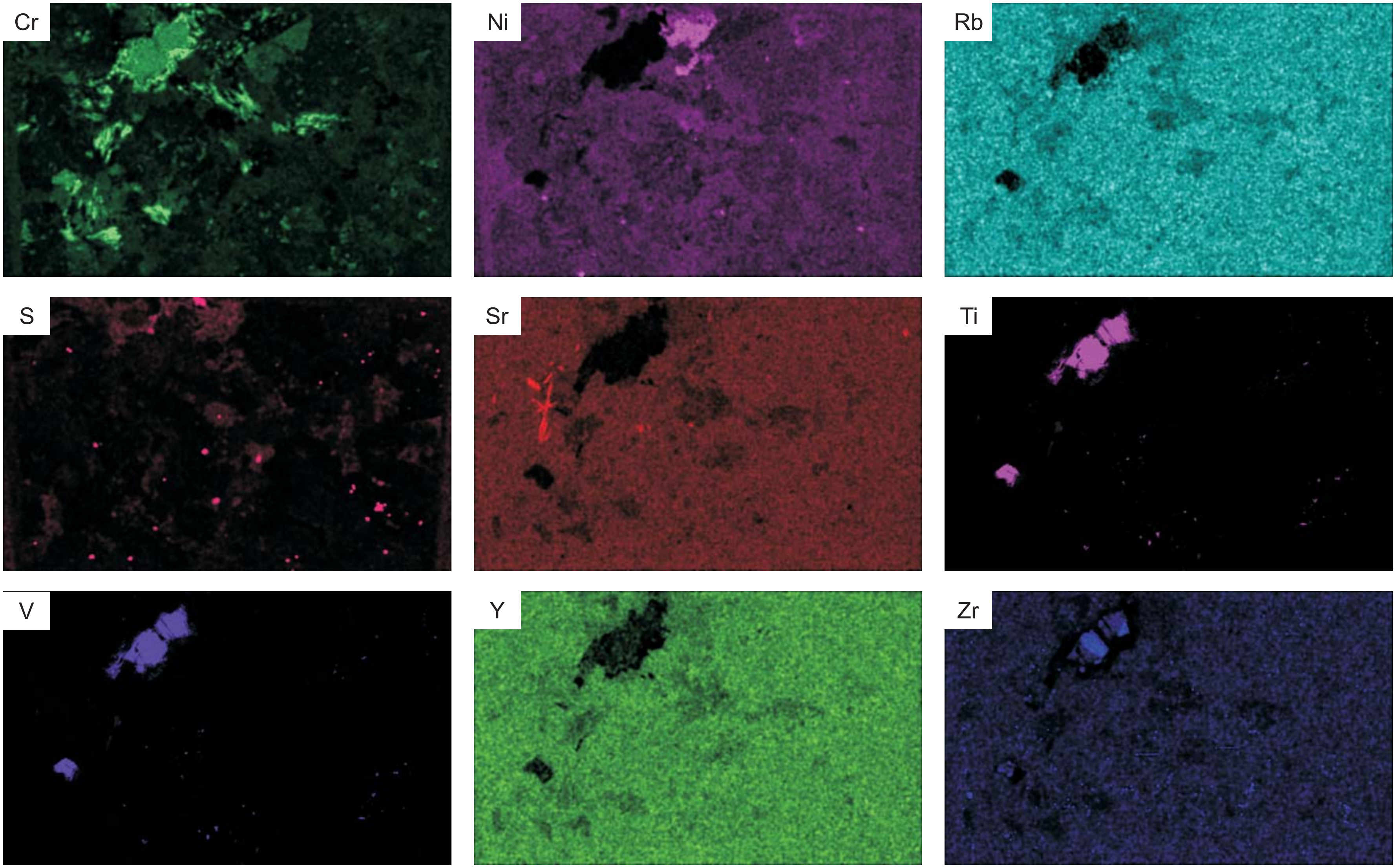



Figure 3-7a.3: Sample 9956c XRF maps for individual elements.

# Appendix 3-7b: XRF maps of a large grain from sample 9956c.

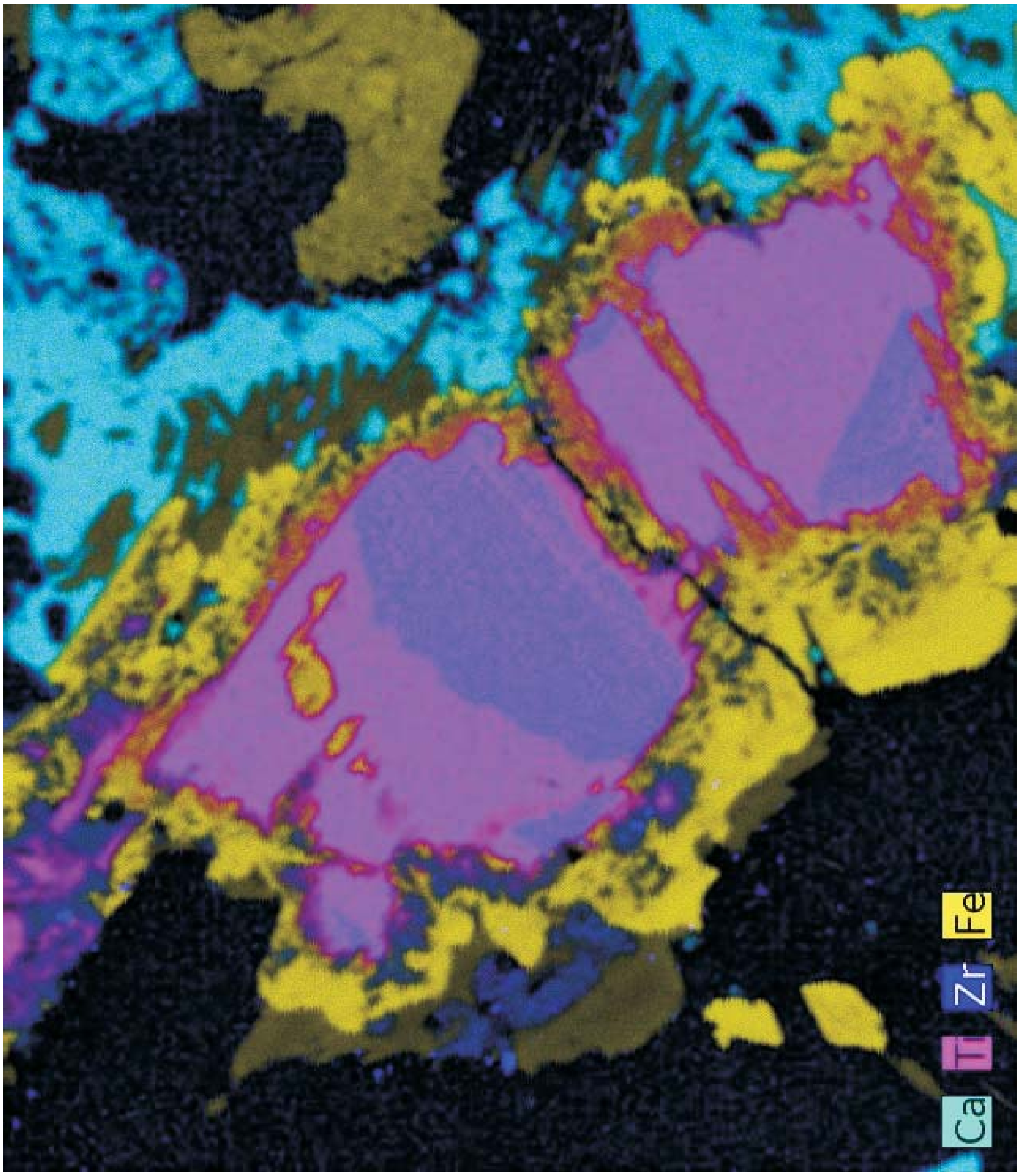



Figure 3-7b.1: Sample 9956c XRF composite map of elements (Ca, Ti, Zr, Fe).

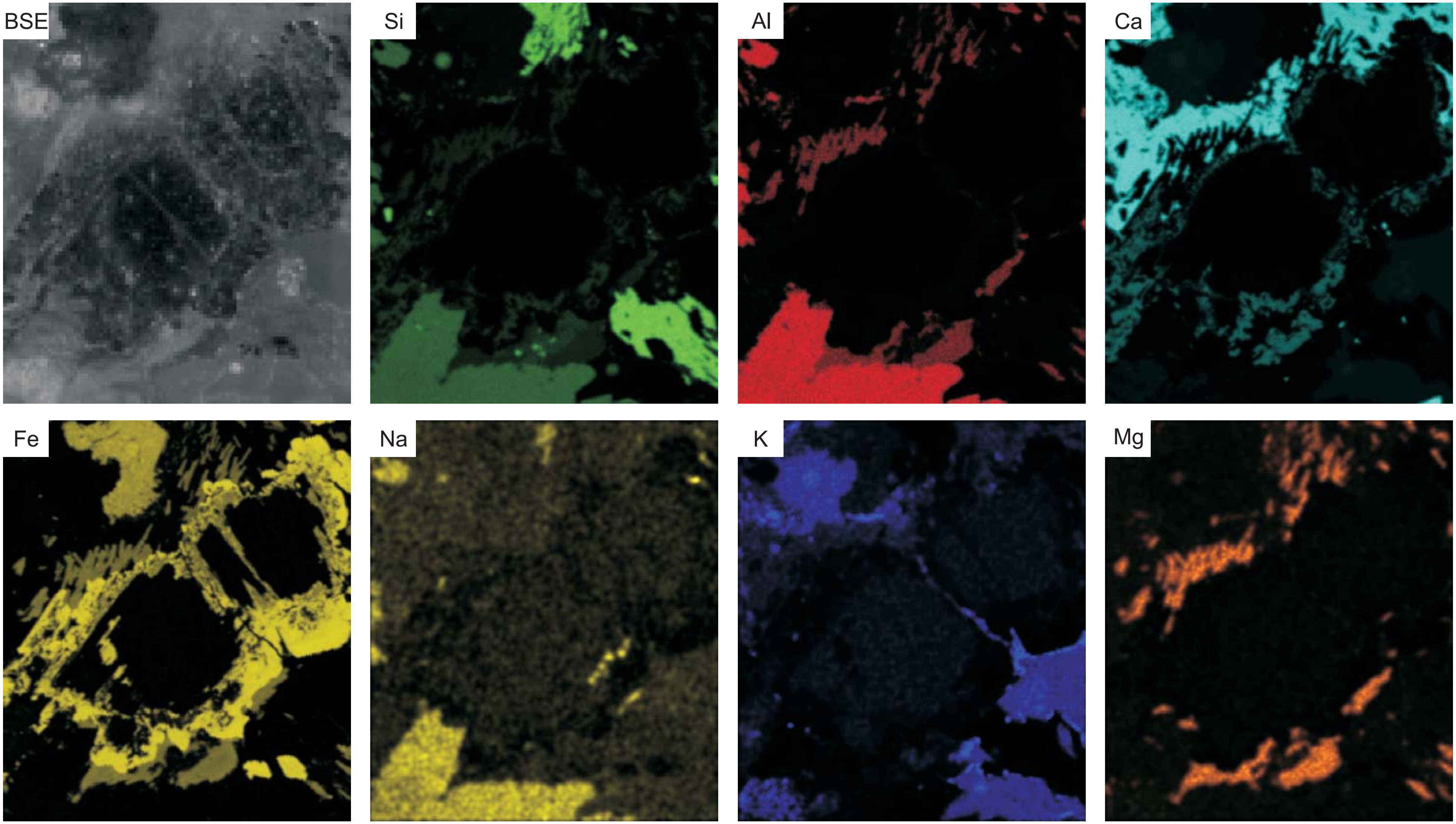



Figure 3-7b.2: Sample 9956c XRF maps for individual elements.

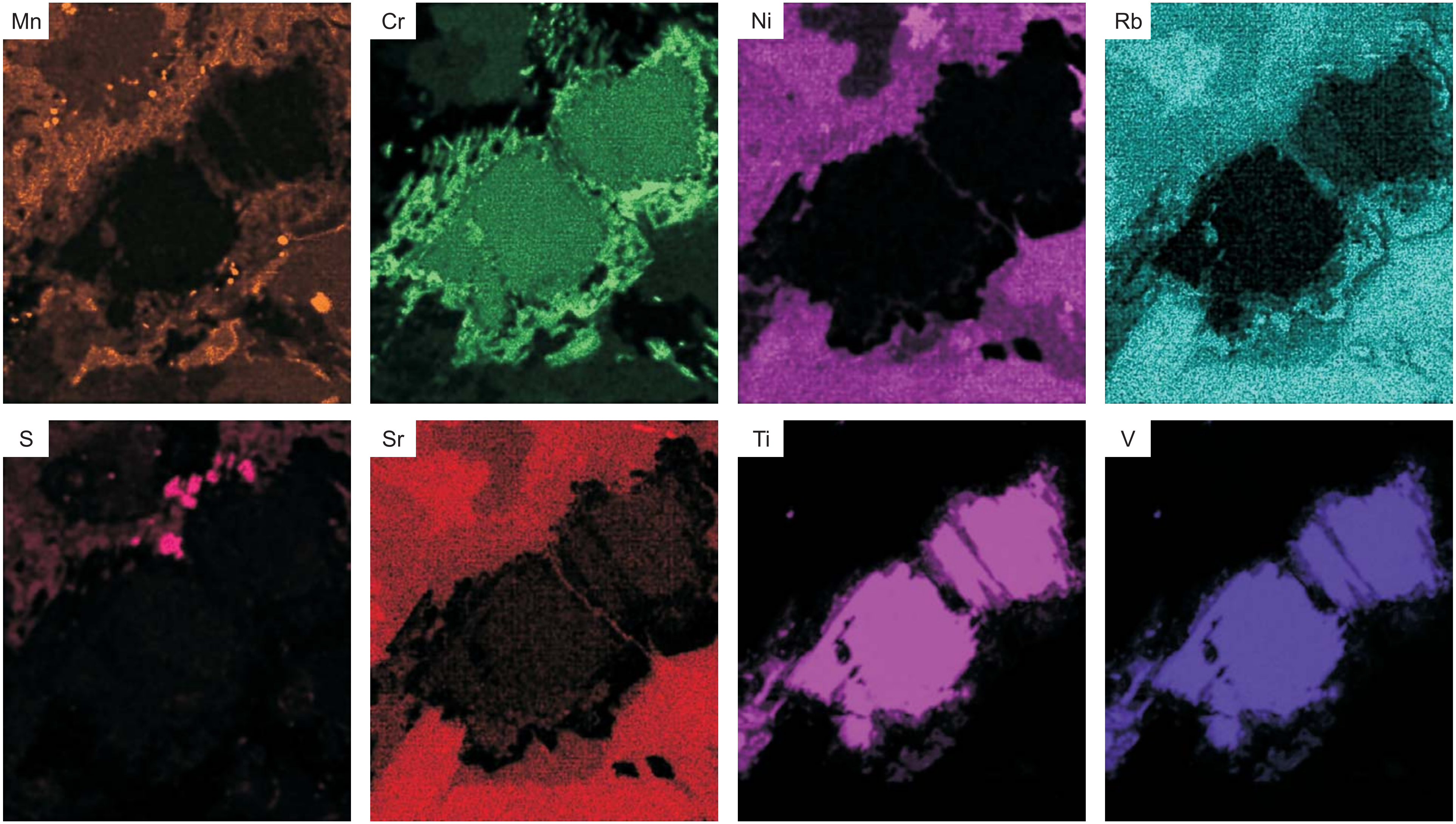



Figure 3-7b.3: Sample 9956c XRF maps for individual elements.

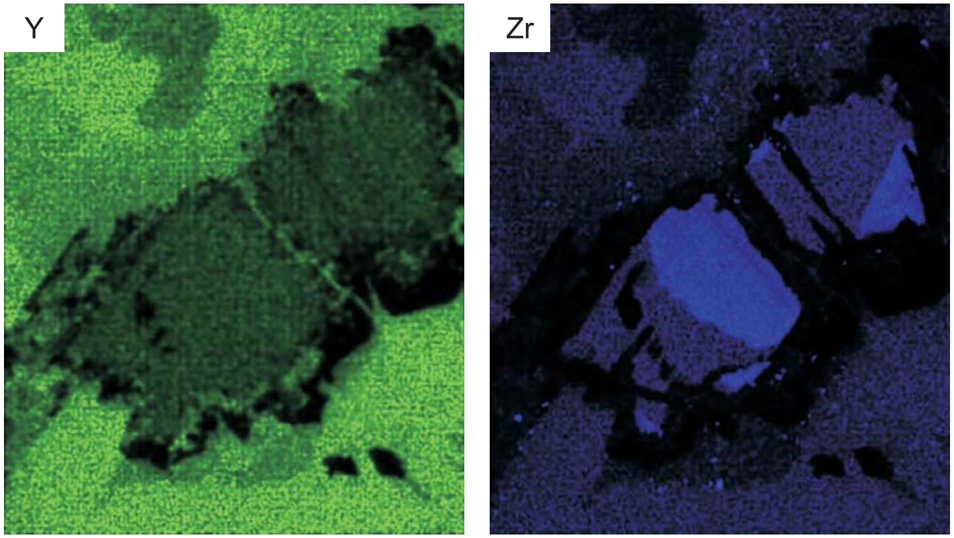



Figure 3-7b.4: Sample 9956c XRF maps for individual elements.

# Appendix 3-8a: XRF thin section maps of sample 9956d.

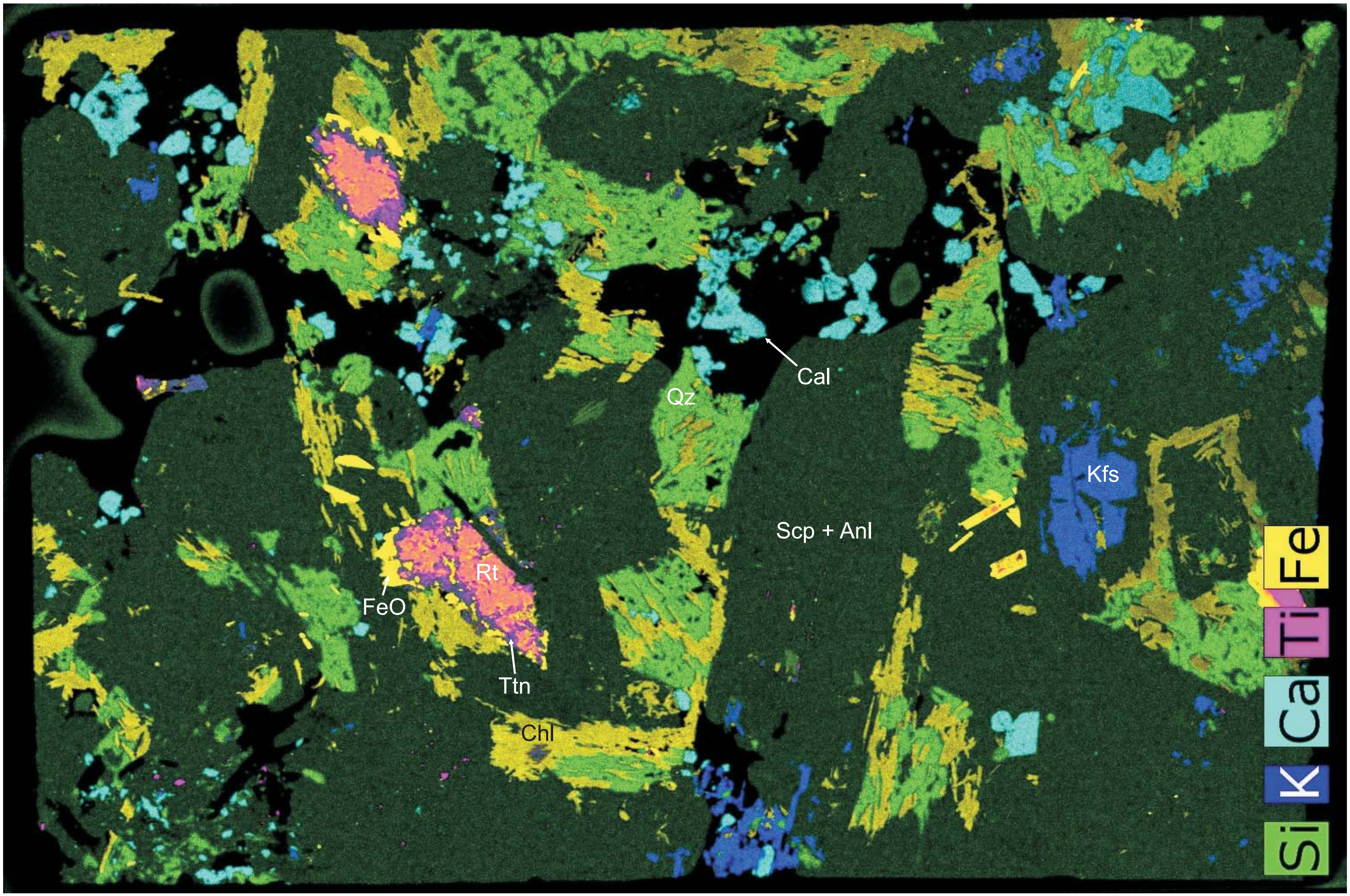



Figure 3-8a.1: Sample 9956d XRF composite map of elements (Si, K, Ca, Ti, Fe).

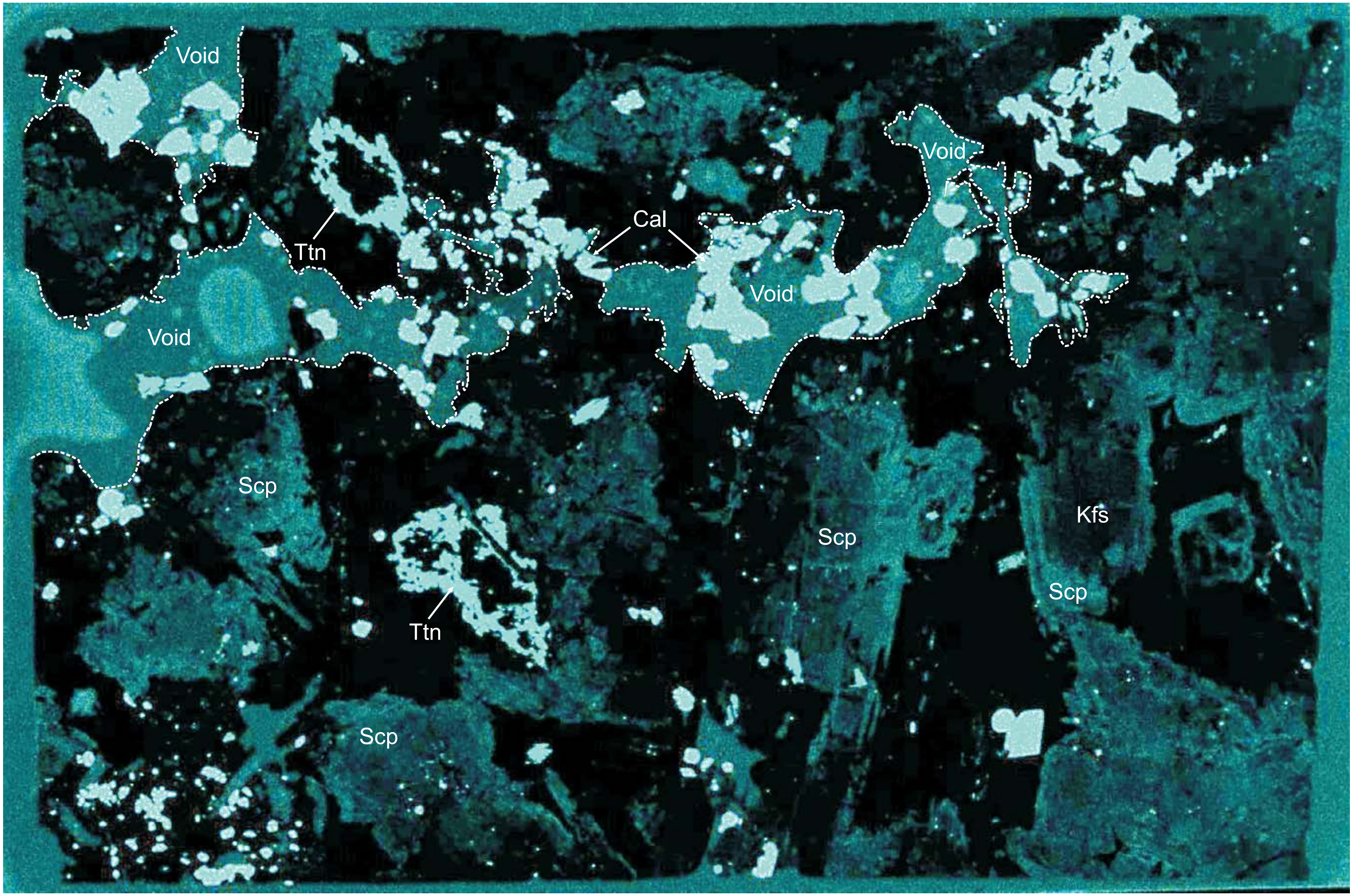



Figure 3-8a.2: Sample 9956d XRF map showing the concentration of calcium.

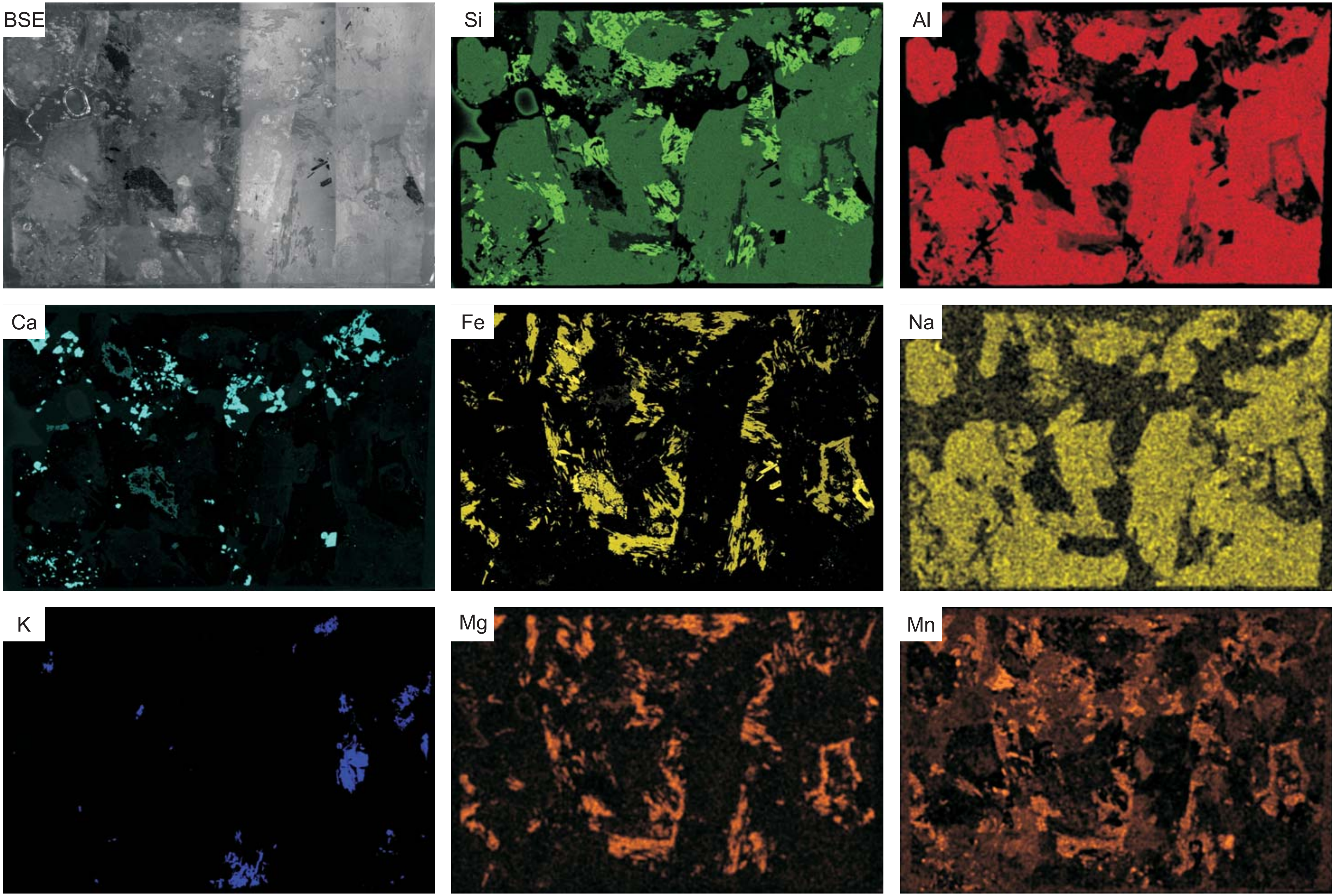


Figure 3-8a.3: Sample 9956d XRF maps for individual elements.

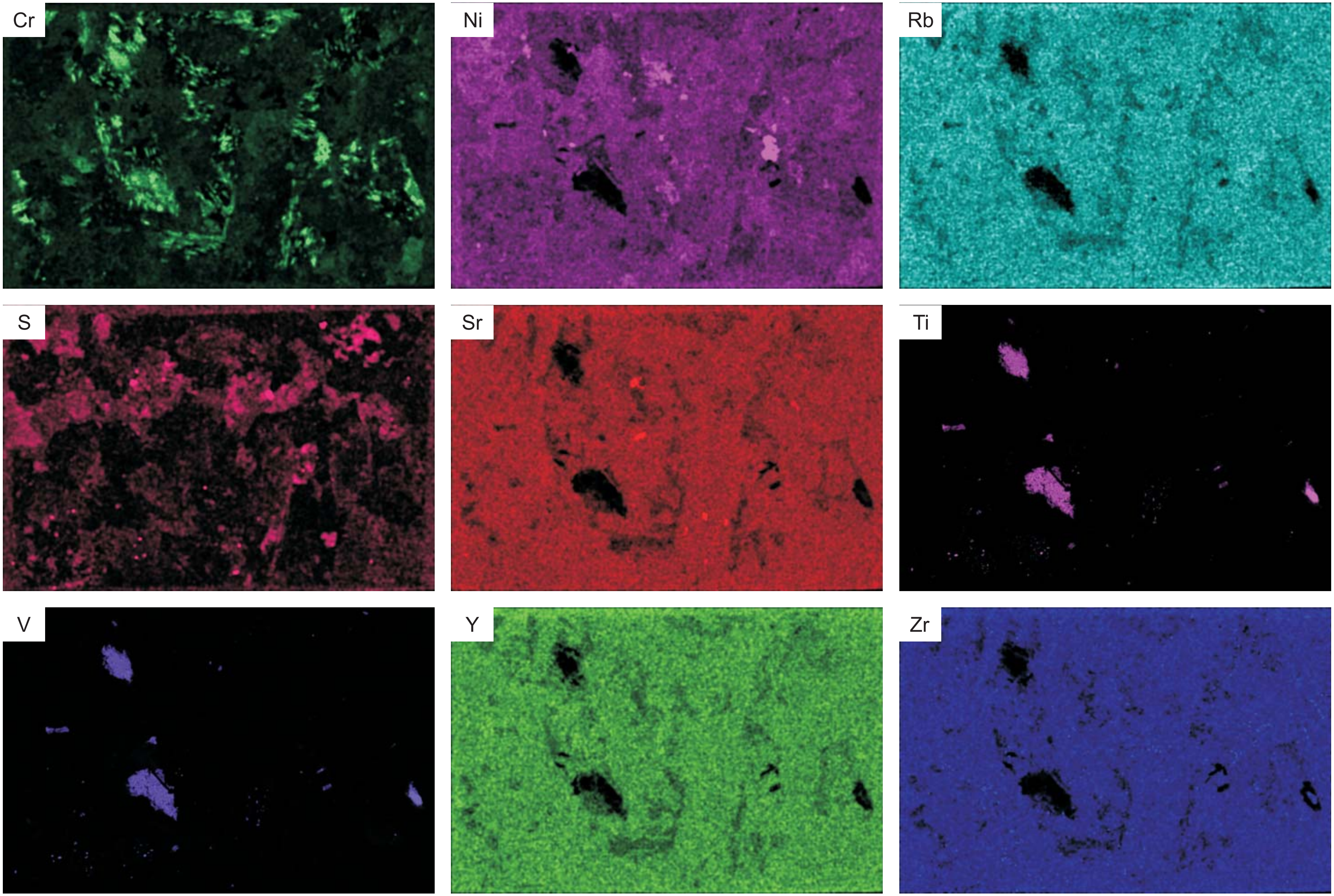



Figure 3-8a.4: Sample 9956d XRF maps for individual elements.

# Appendix 3-8b: XRF maps of a large grain from sample 9956d.

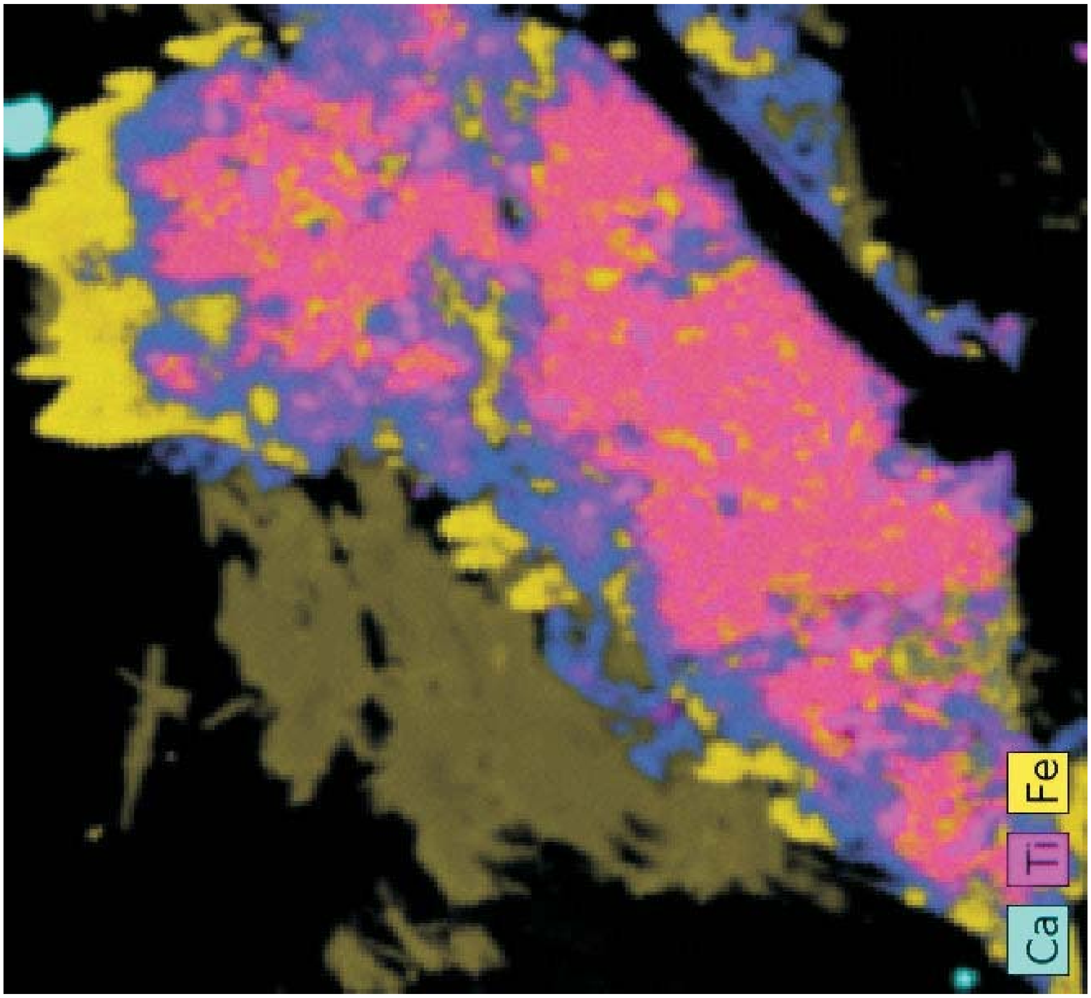



Figure 3-8b.1: Sample 9956d XRF composite map of elements (Ca, Ti, Fe).

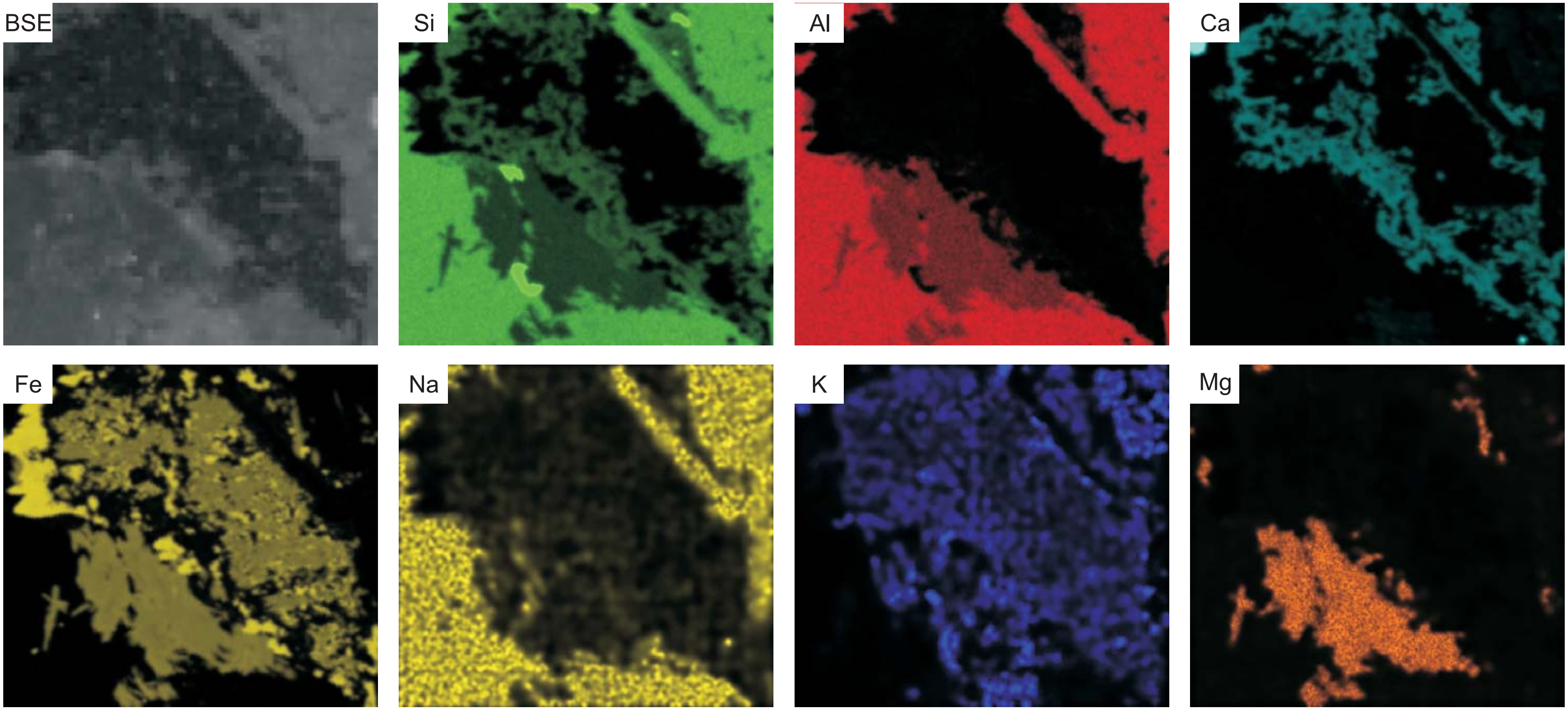



Figure 3-8b.2: Sample 9956d XRF maps for individual elements.

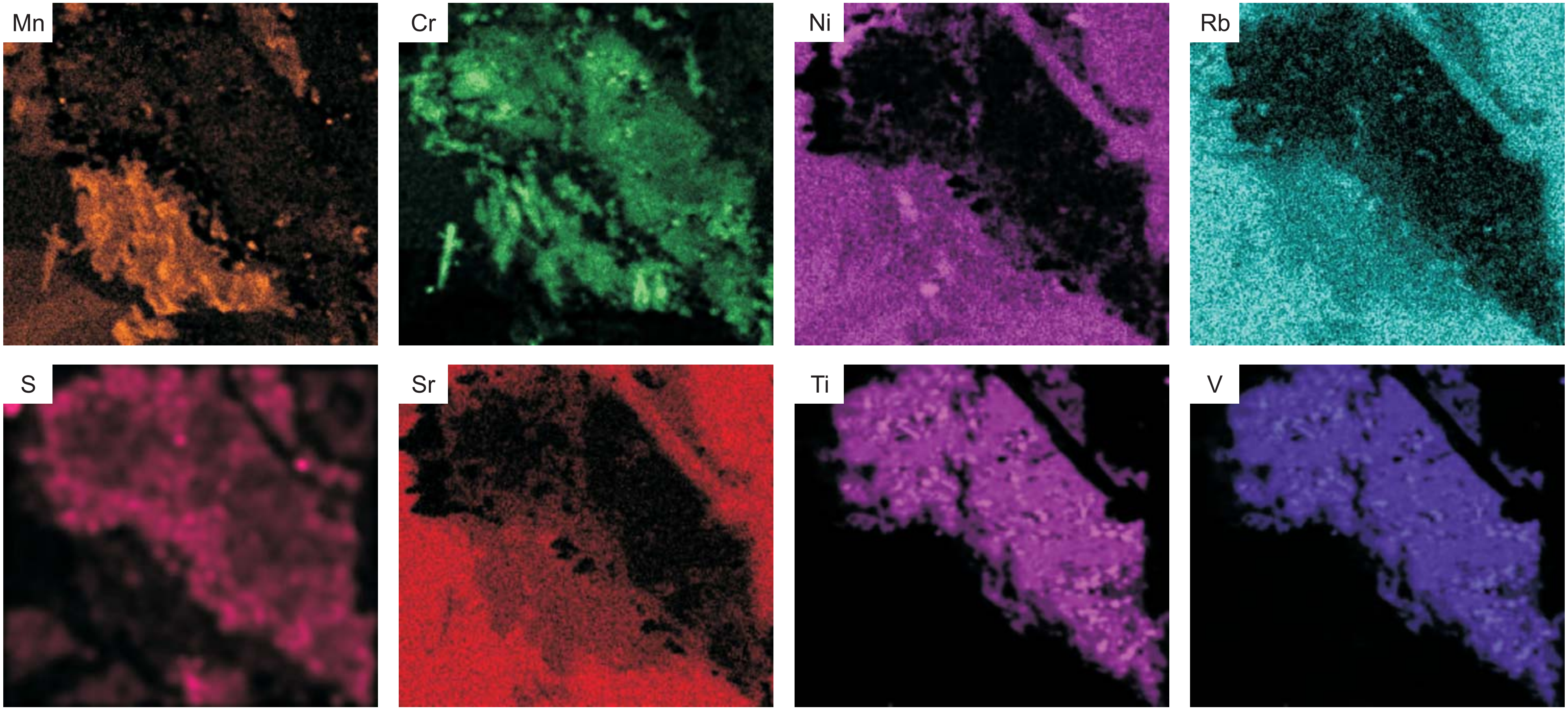



Figure 3-8b.3: Sample 9956dt XRF maps for individual elements.

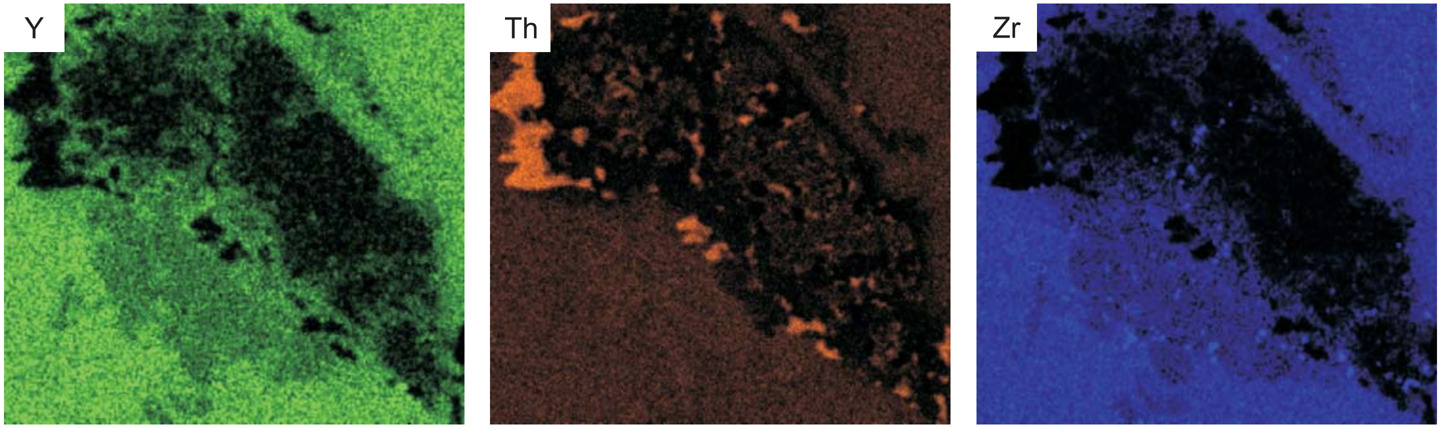



Figure 3-8b.4: Sample 9956d XRF maps for individual elements.

# Appendix 3-9: XRF thin section maps of sample 9957.

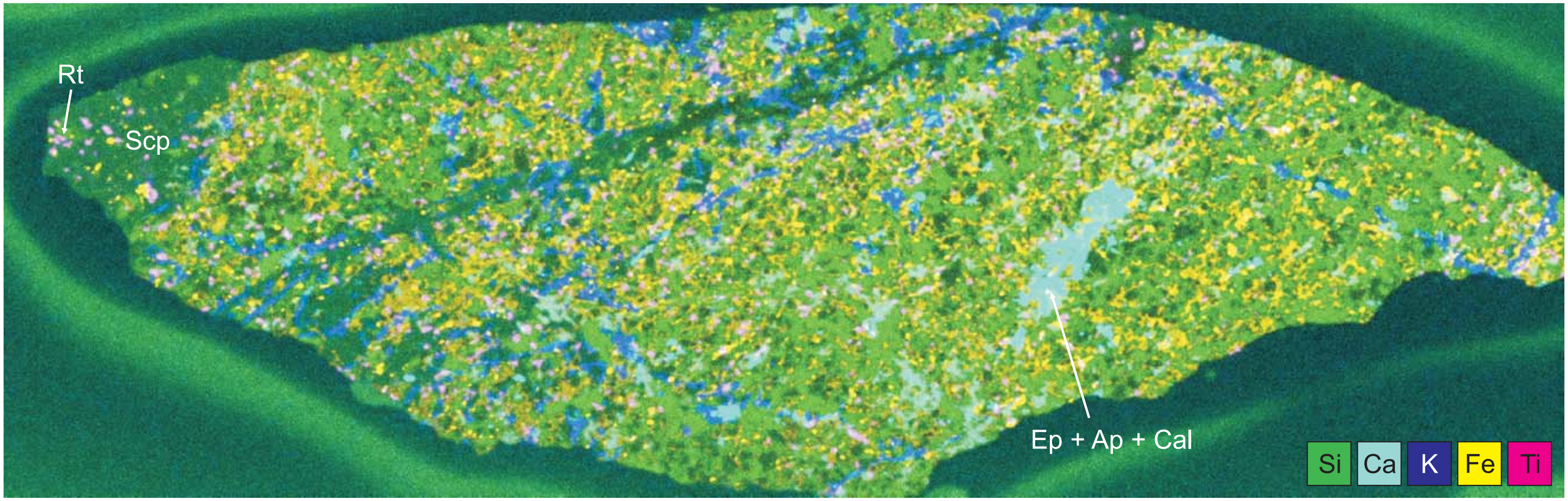



Figure 3-9.1: Sample 9957 XRF composite map of elements (SI, Ca, K, Fe, Ti).

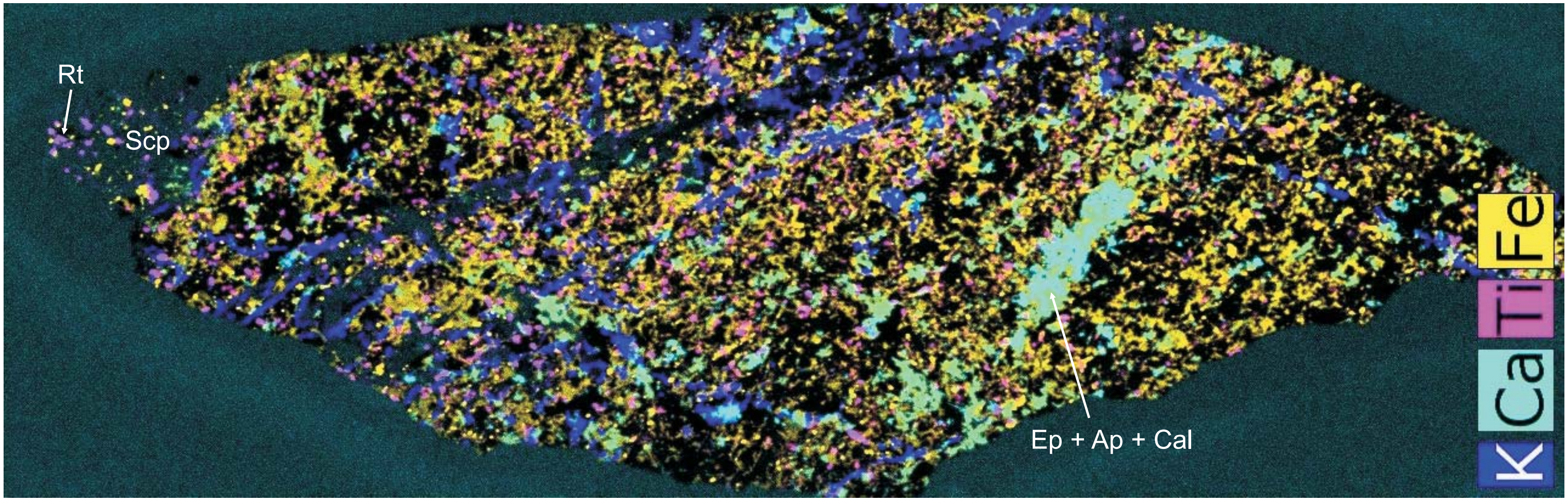



Figure 3-9.2: Sample 9957 XRF composite map of elements (K, Ca, Ti, Fe).

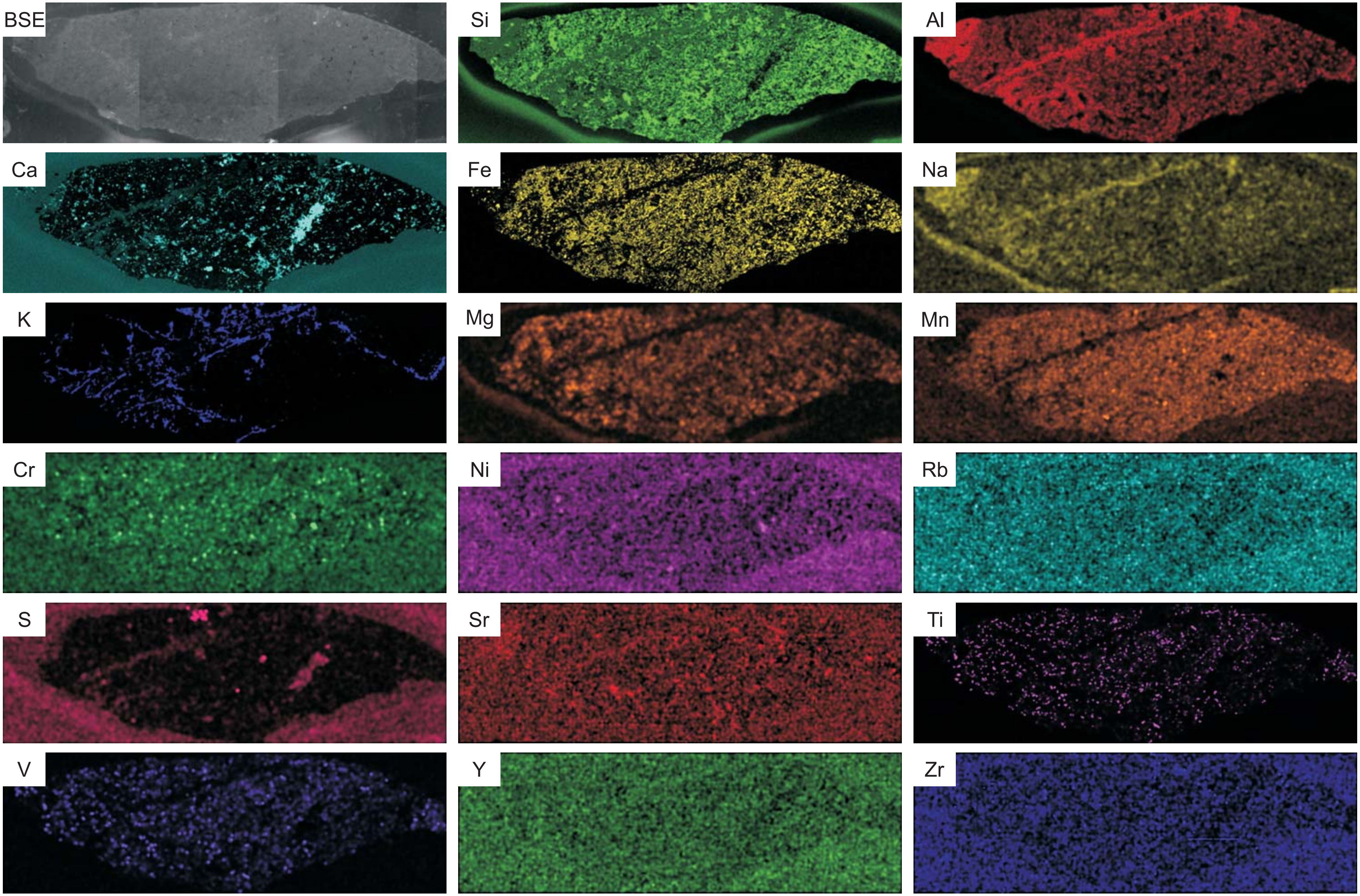



Figure 3-9.3: Sample 9957 XRF maps for individual elements.

# Appendix 3-10: XRF thin section maps of sample 9958a.

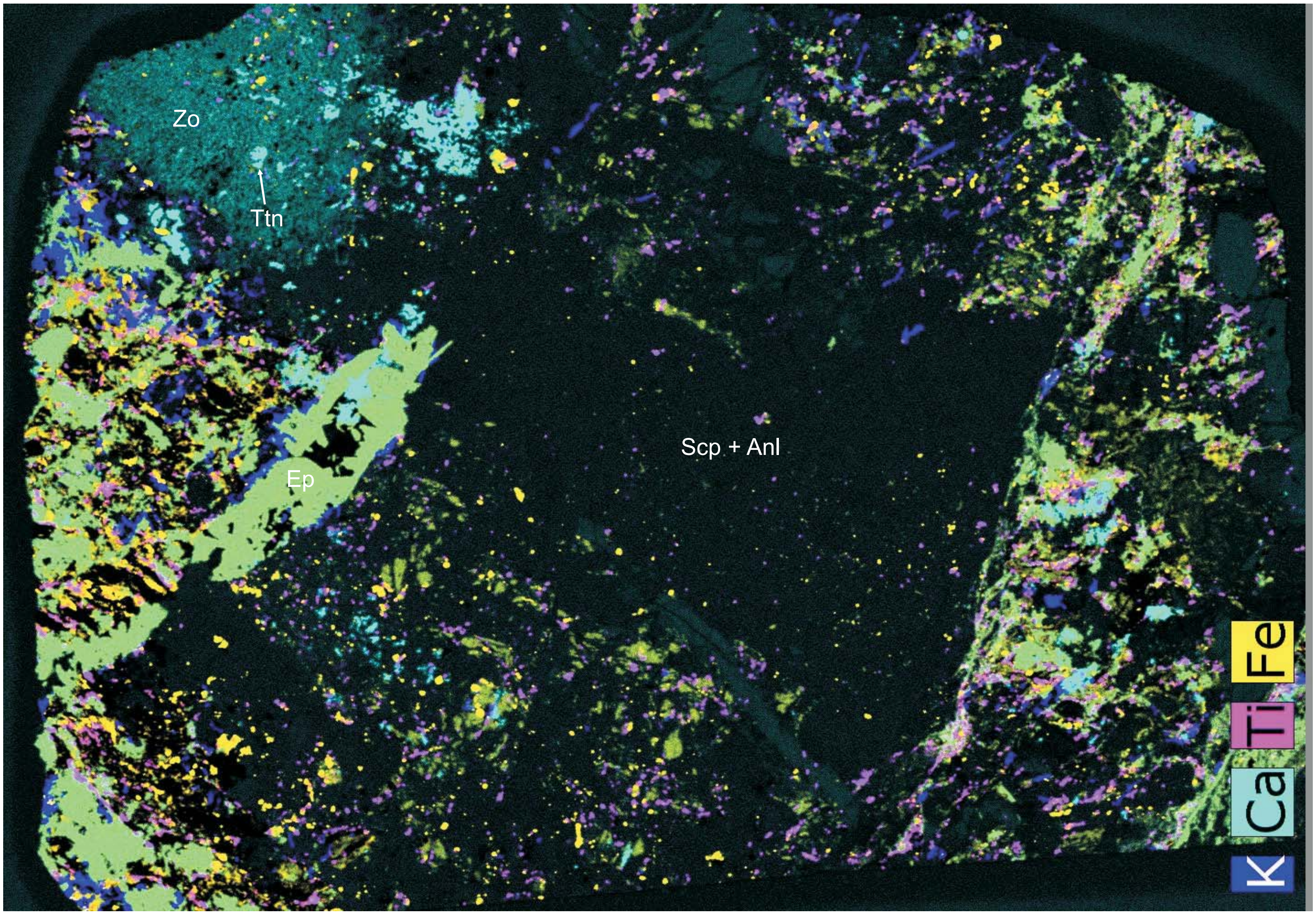


Figure 3-10.1: Sample 9958a XRF composite map of elements (K, Ca, Ti, Fe).

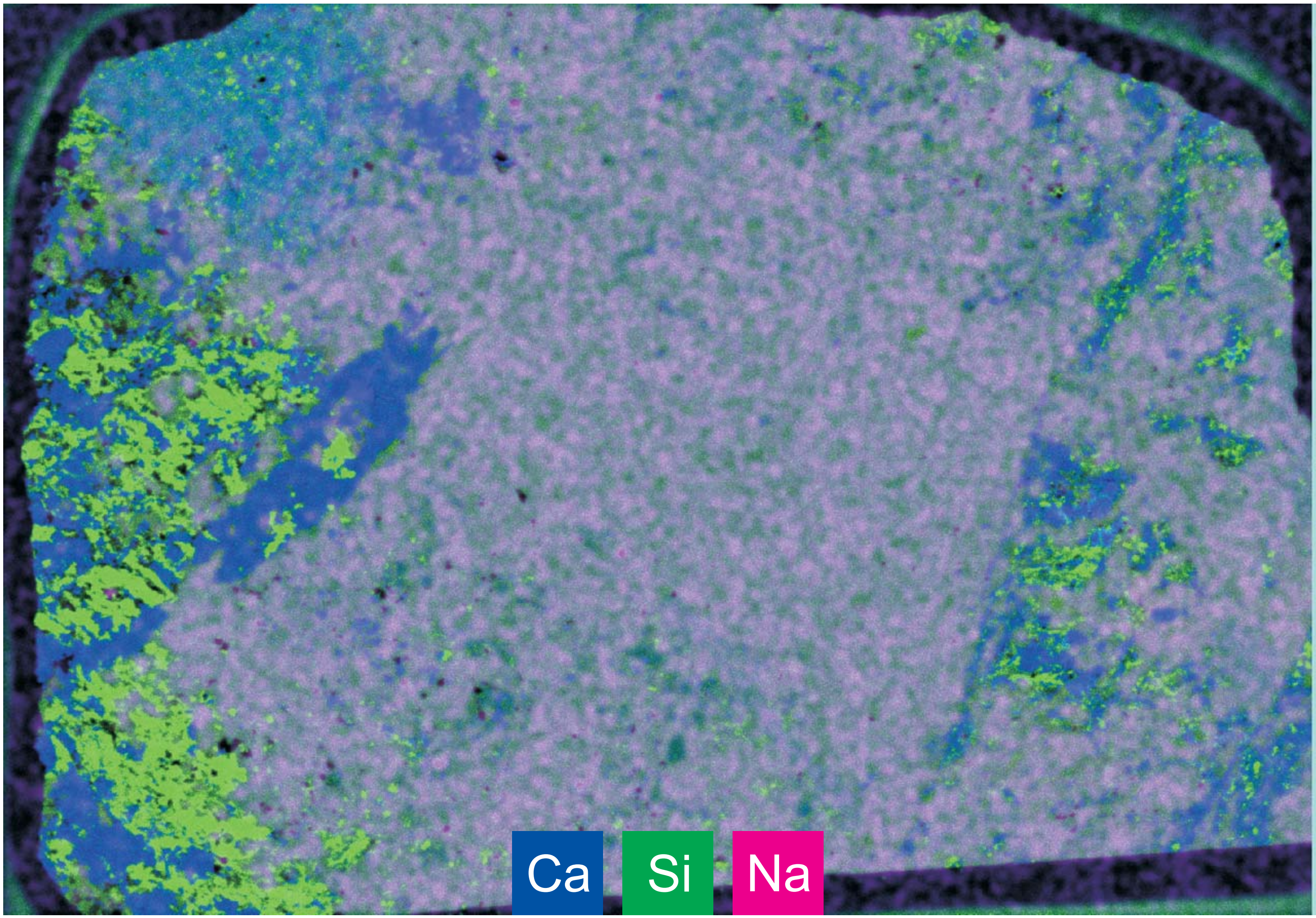


Figure 3-10.2: Sample 9958a XRF composite map of elements (Ca, Si, Na).

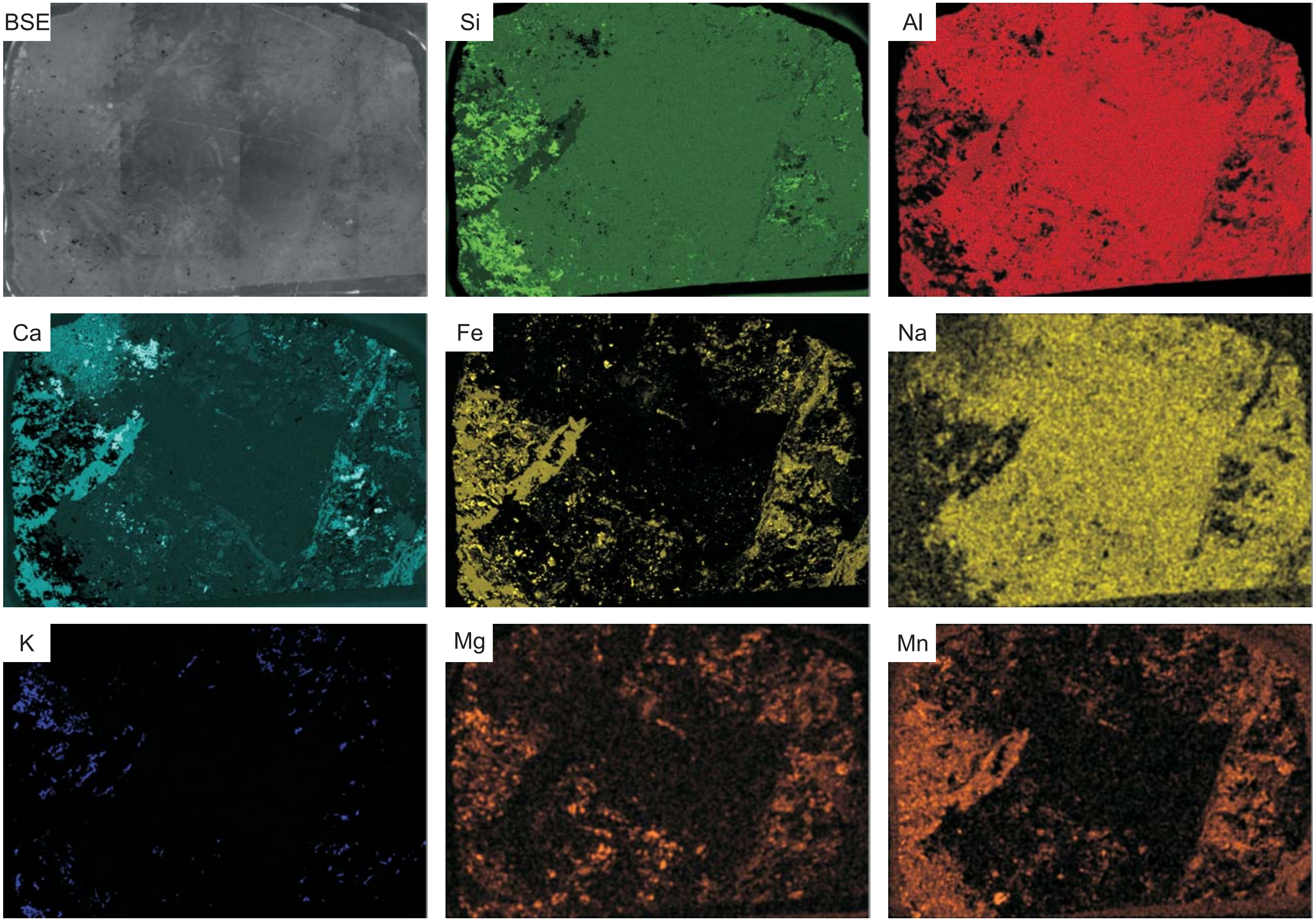



Figure 3-10.3: Sample 9958a XRF maps for individual elements.

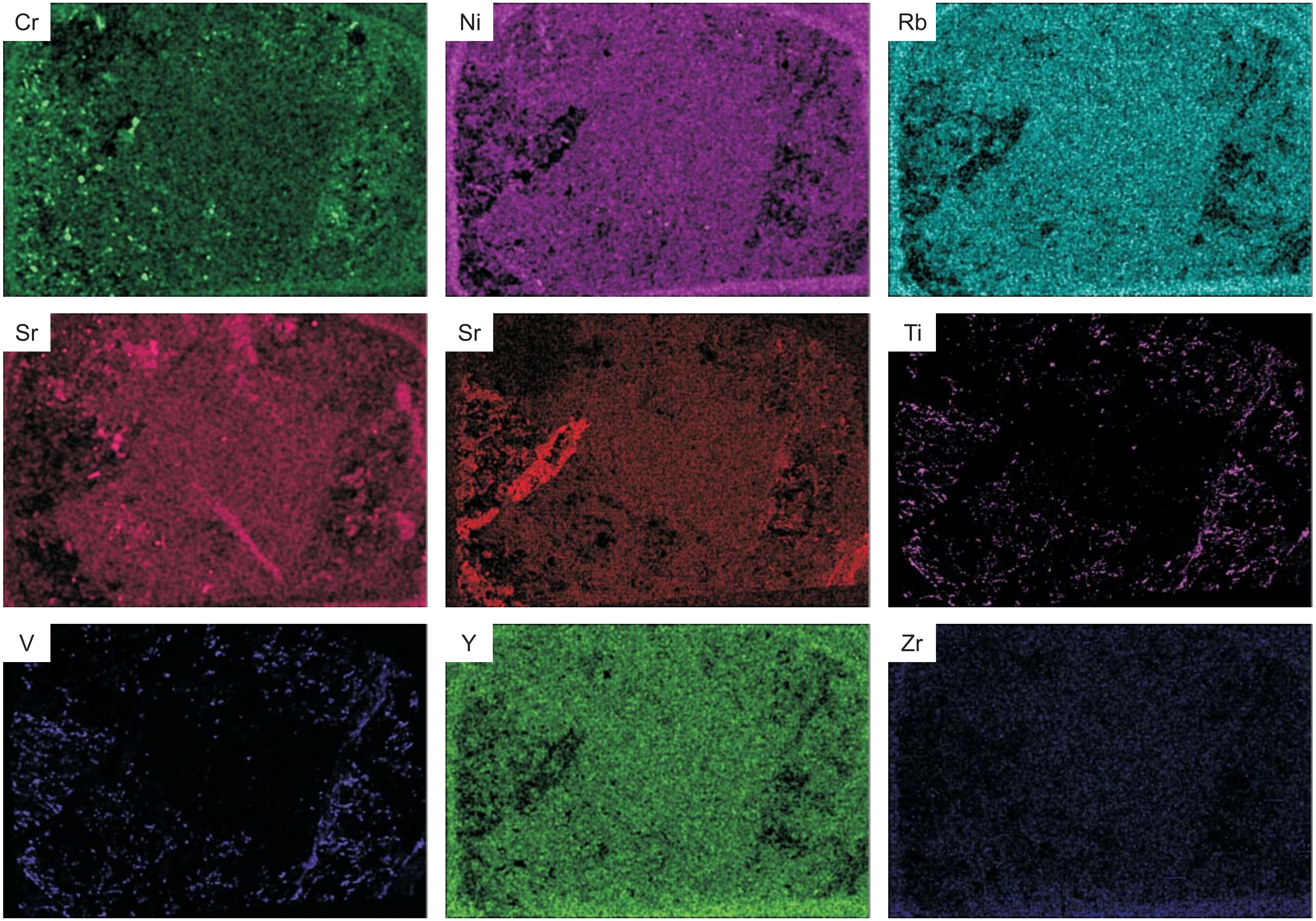



Figure 3-10.4: Sample 9958a XRF maps for individual elements.

# Appendix 4: SEM-BSE images for the titanite and rutile spots analyzed by laser ablation for trace elements of gabbro (9927(1)), diorite (9954a, 9957, 9958a), and syenite (9928a, b, 9956a, b, c, d).

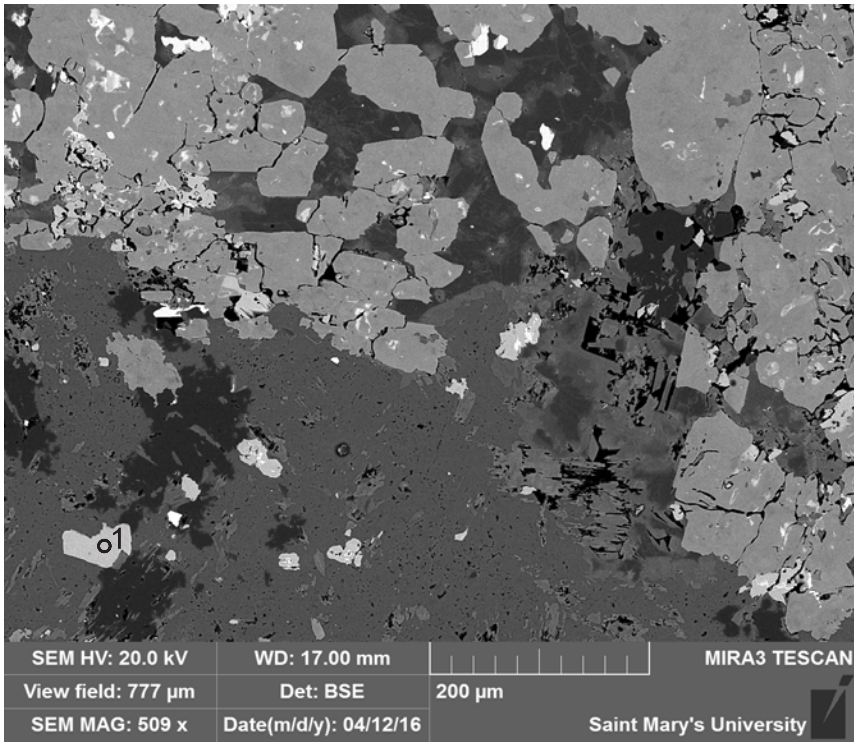



Figure 4.1: Sample 9927(1). Location of laser ablation analysis 1 (titanite (Table 4-1.1)).

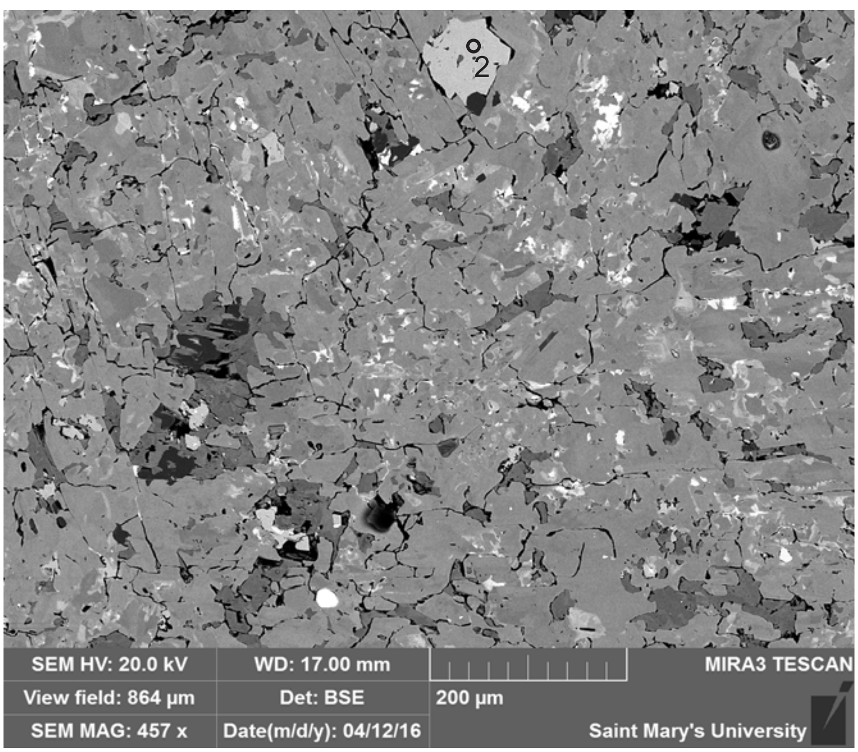



Figure 4.2: Sample 9927(1). Location of laser ablation analysis 2 (titanite (Table 4-1.1)).

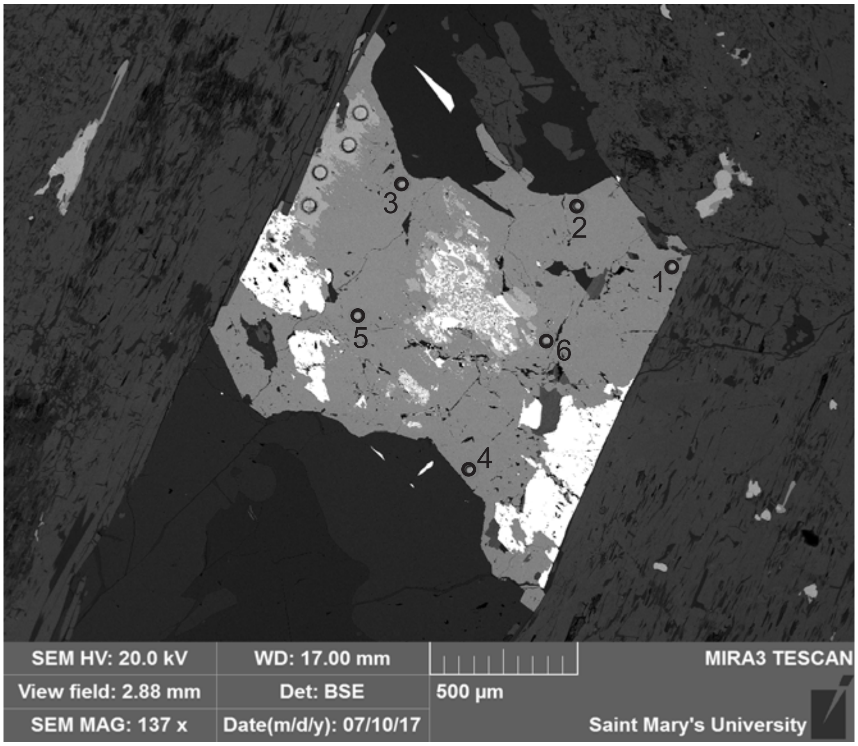



Figure 4.3: Sample 9928a. Location of laser ablation analyses 1-6 (titanite (Table 4-1.1)).

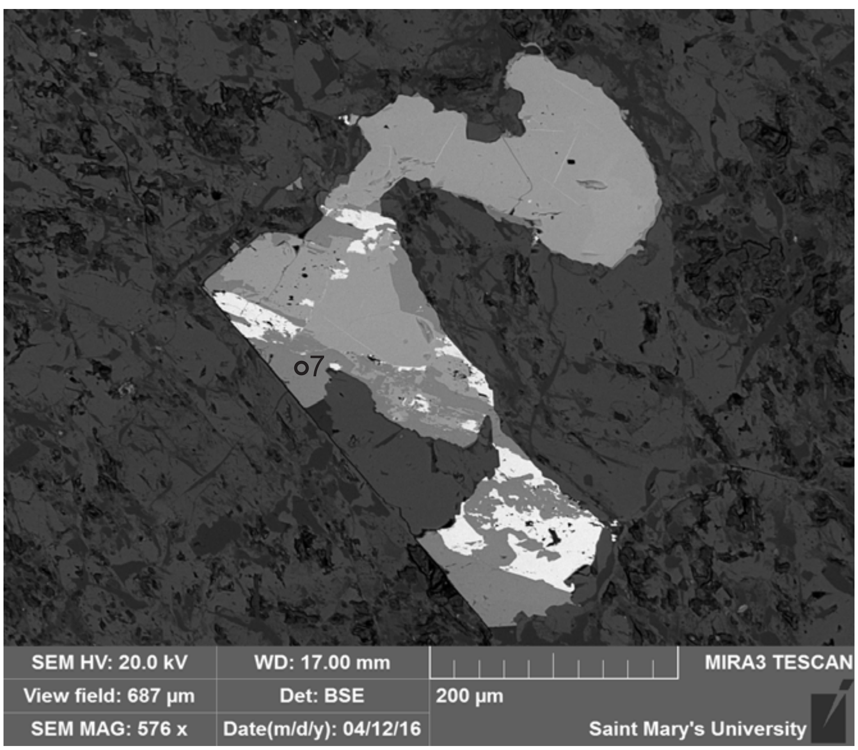



Figure 4.4: Sample 9928a. Location of laser ablation analysis 7 (titanite (Table 4-1.1)).

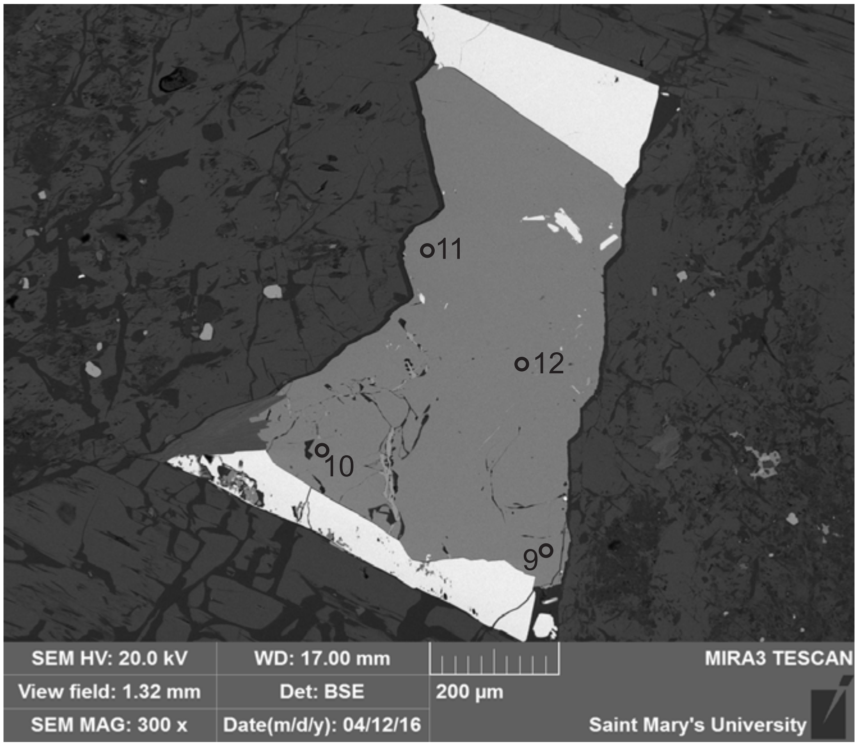



Figure 4.5: Sample 9928a. Location of laser ablation analyses 9-12 (titanite (Table 4-1.1)).

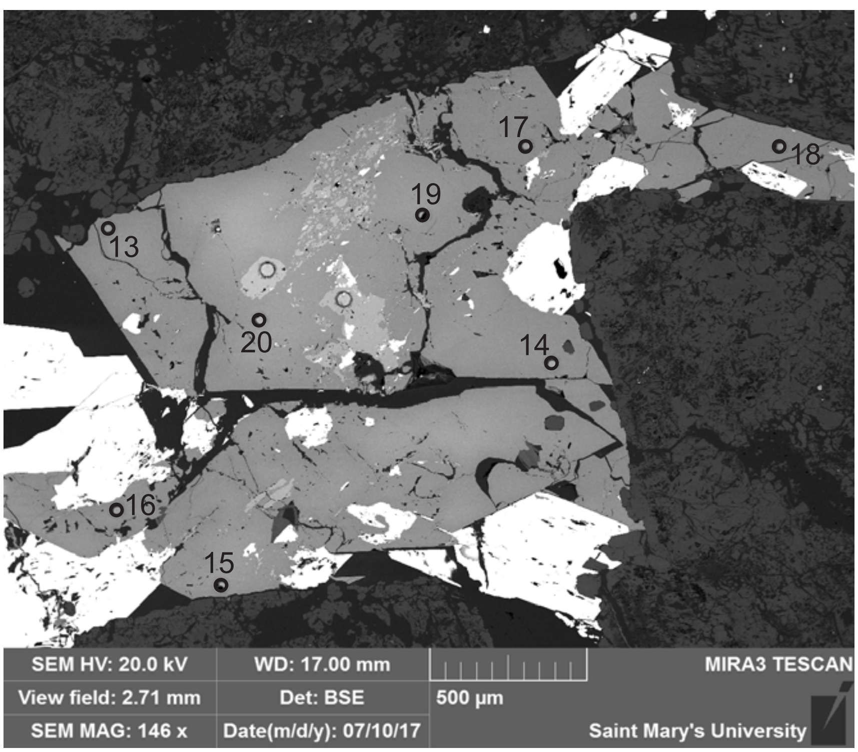



Figure 4.6: Sample 9928a. Location of laser ablation analyses 13-20 (titanite (Table 4-1.1)).

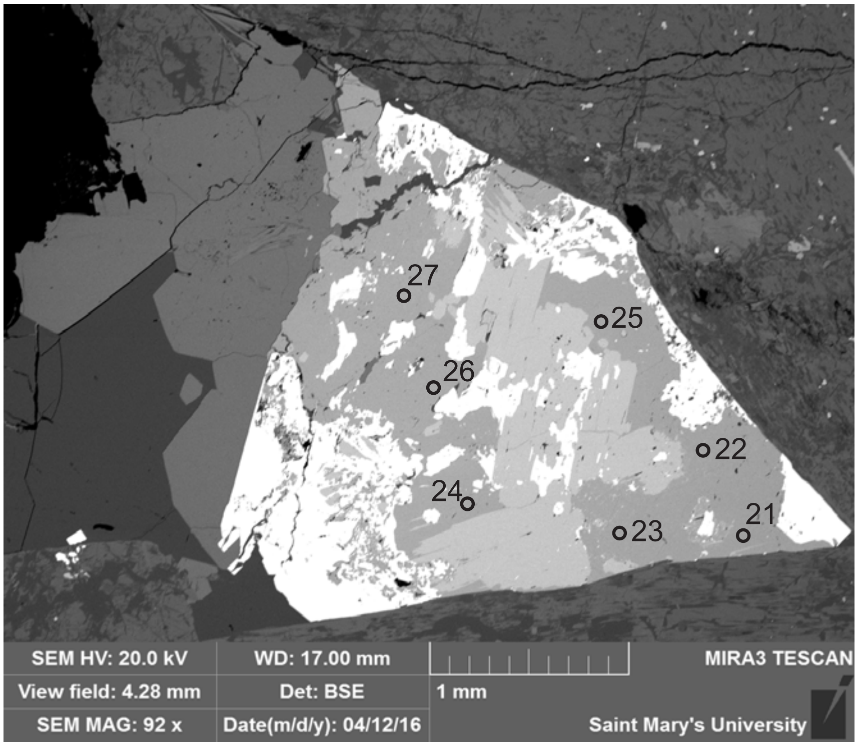



Figure 4.7: Sample 9928a. Location of laser ablation analyses 21-27 (titanite (Table 4-1.1)).

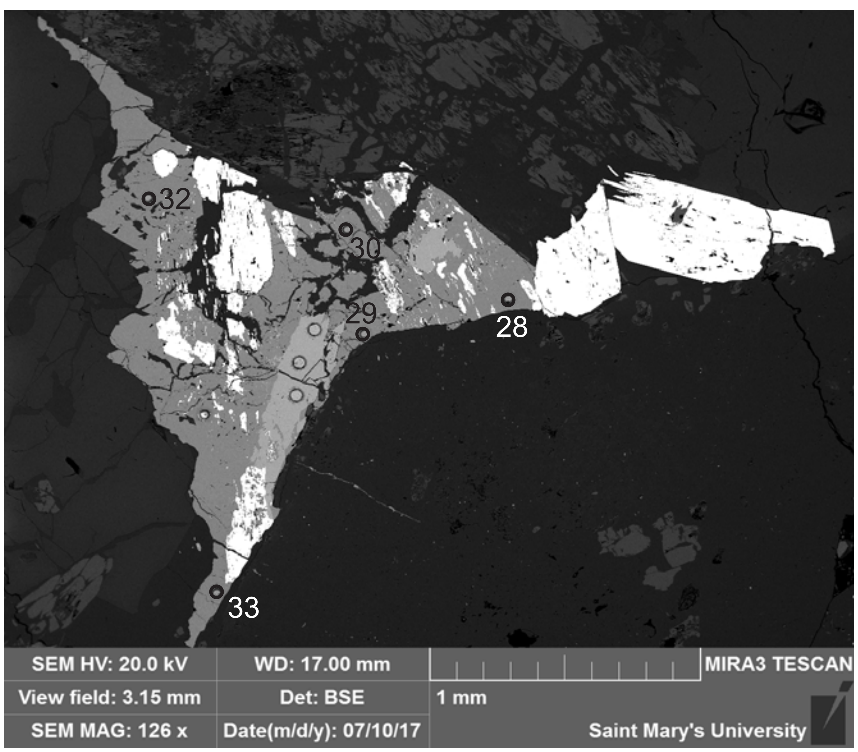



Figure 4.8: Sample 9928a. Location of laser ablation analyses 28-33 (titanite (Table 4-1.1)).

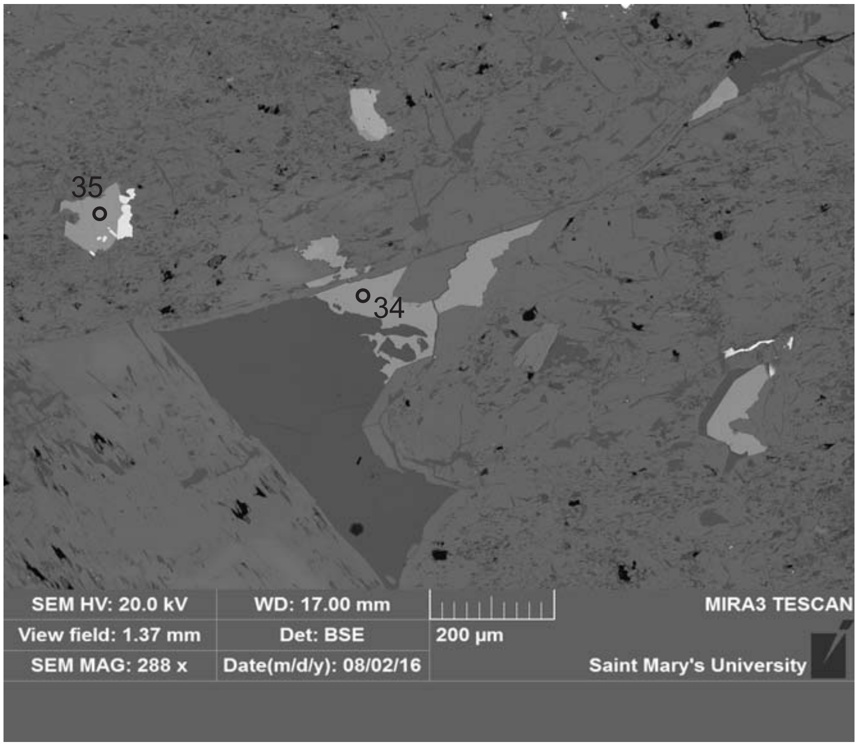



Figure 4.9: Sample 9928a. Location of laser ablation analyses 34-35 (titanite (Table 4-1.1)).

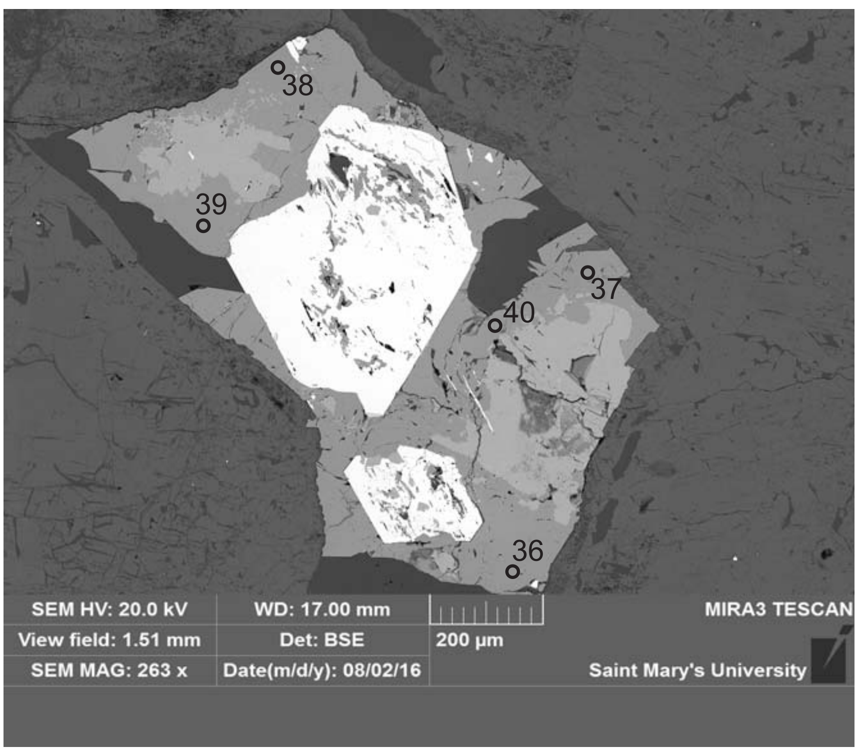



Figure 4.10: Sample 9928a. Location of laser ablation analyses 36-40 (titanite (Table 4-1.1)).

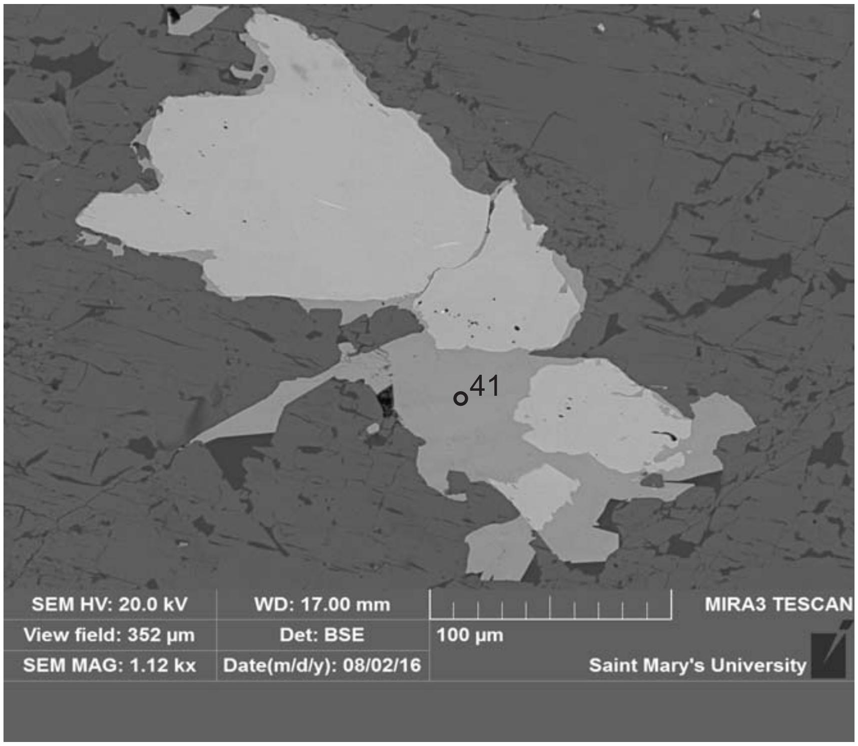



Figure 4.11: Sample 9928a. Location of laser ablation analysis 41 (titanite (Table 4-1.1)).

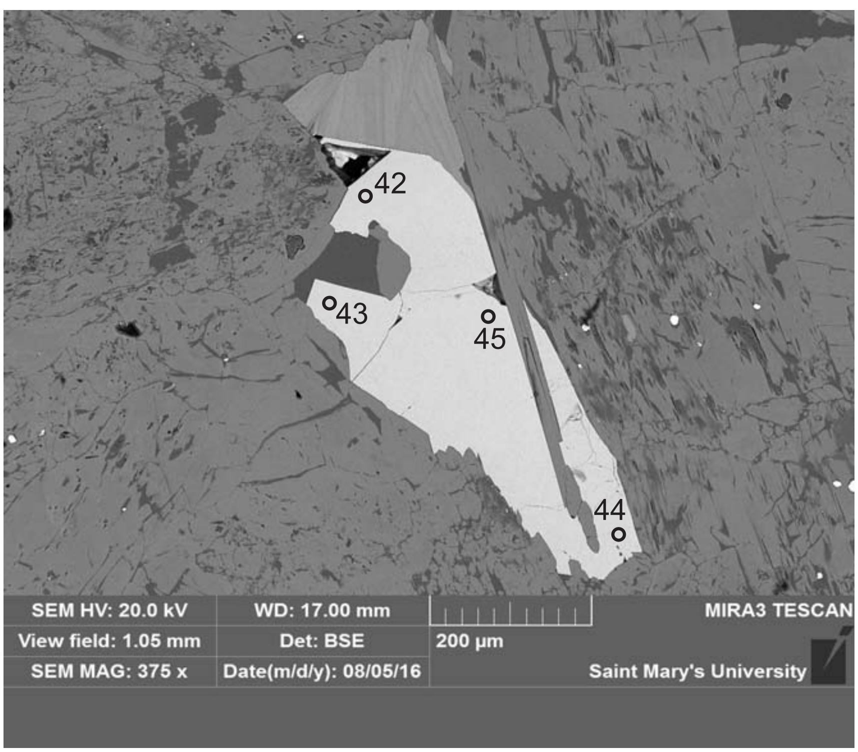



Figure 4.12: Sample 9928a. Location of laser ablation analyses 42-45 (titanite (Table 4-1.1)).

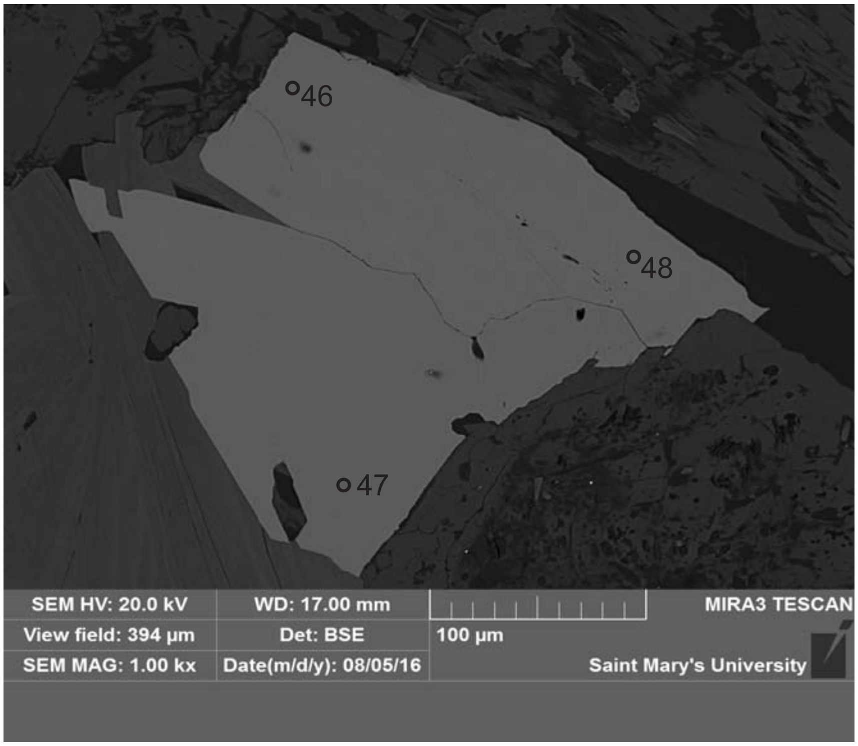



Figure 4.13: Sample 9928a. Location of laser ablation analyses 46-48 (titanite (Table 4-1.1)).

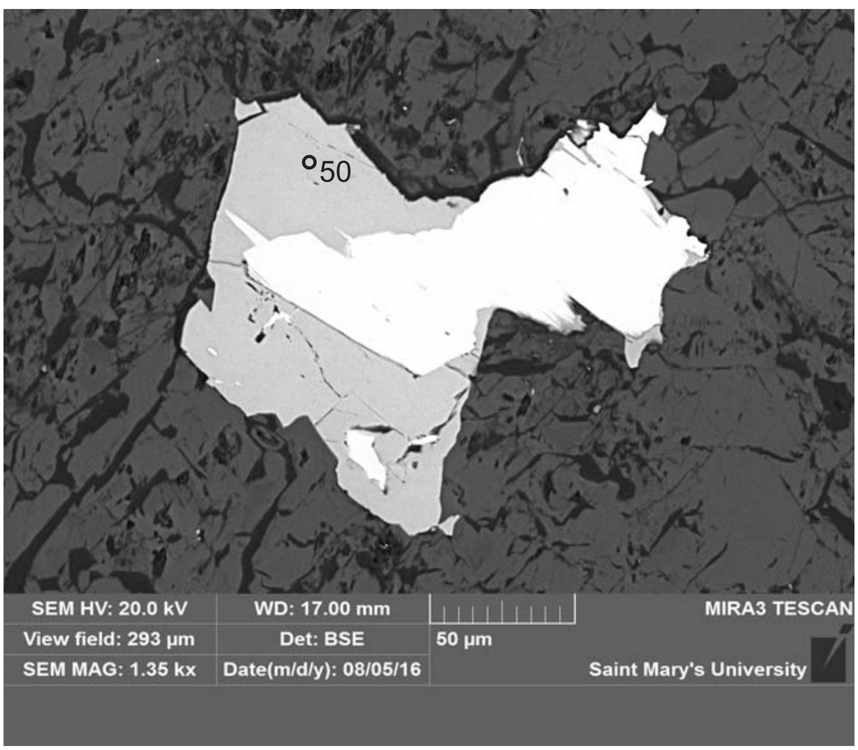



Figure 4.14: Sample 9928a. Location of laser ablation analysis 50 (titanite (Table 4-1.1)).

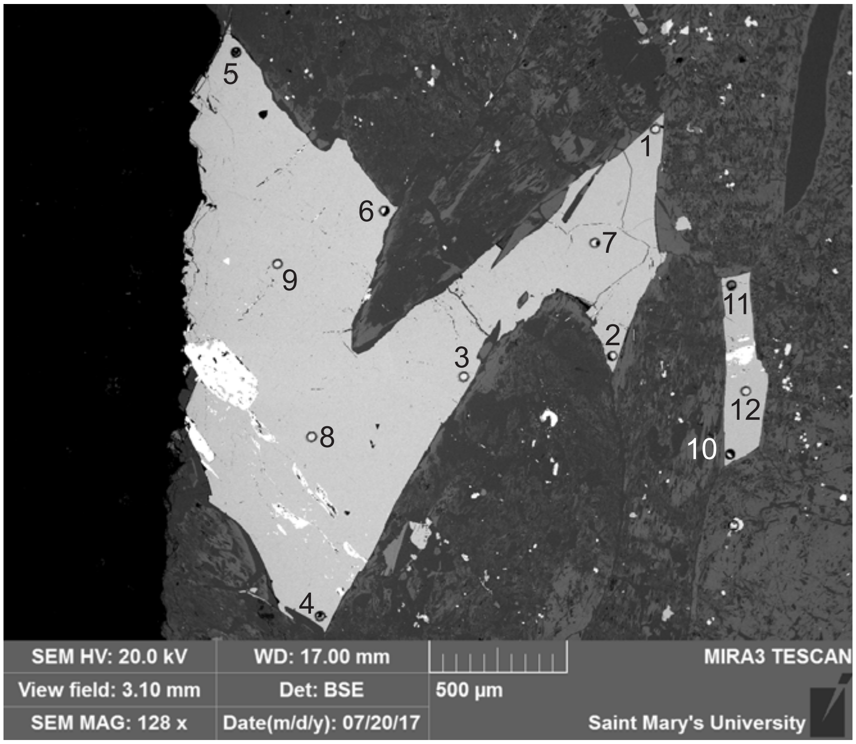



Figure 4.15: Sample 9928b. Location of laser ablation analyses 1-12 (titanite (Table 4-1.1)).

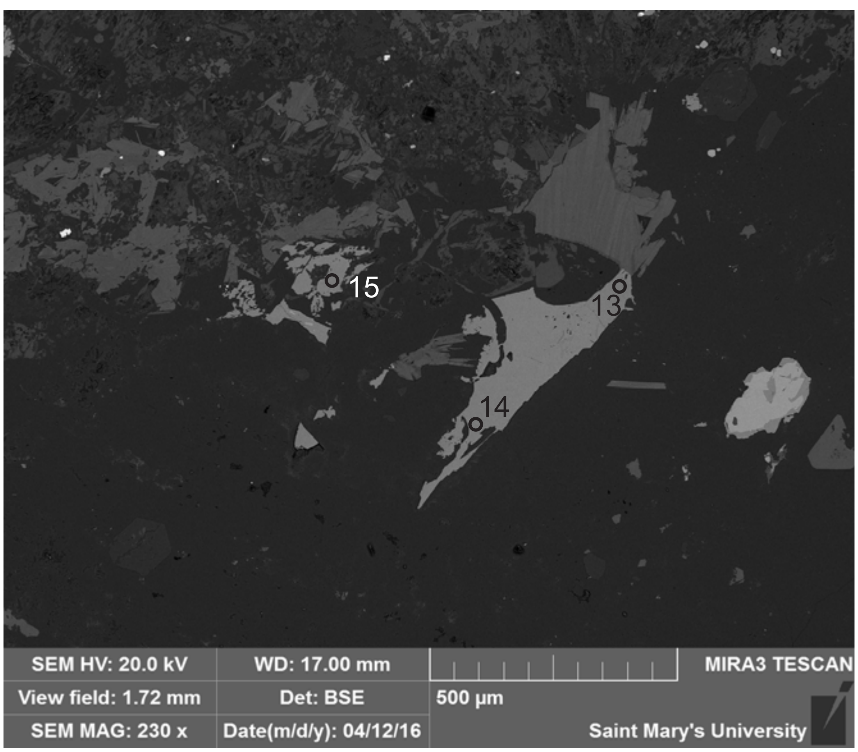



Figure 4.16: Sample 9928b. Location of laser ablation analyses 13-15 (titanite (Table 4-1.1)).

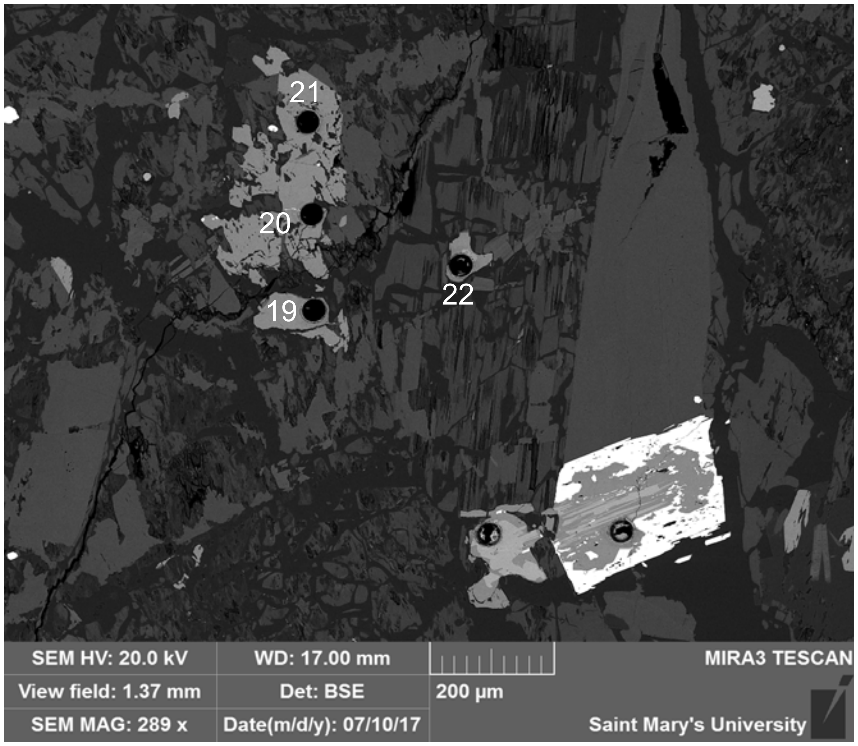



Figure 4.17: Sample 9928b. Location of laser ablation analyses 19-22 (titanite (Table 4-1.1)).

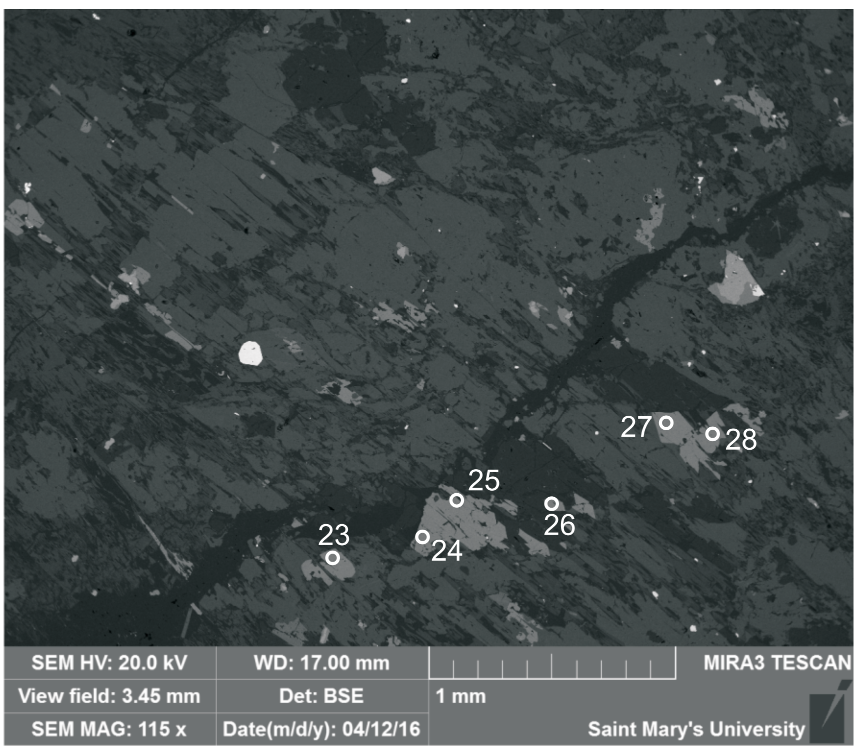



Figure 4.18: Sample 9928b. Location of laser ablation analyses 23-28 (titanite (Table 4-1.1)).

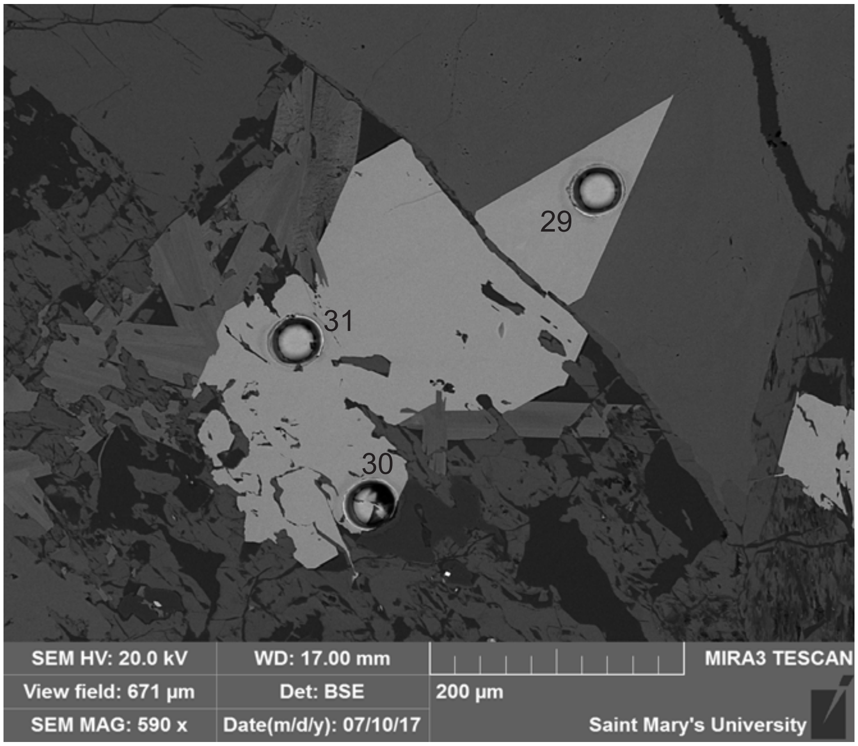



Figure 4.19: Sample 9928b. Location of laser ablation analyses 29-31 (titanite (Table 4-1.1)).

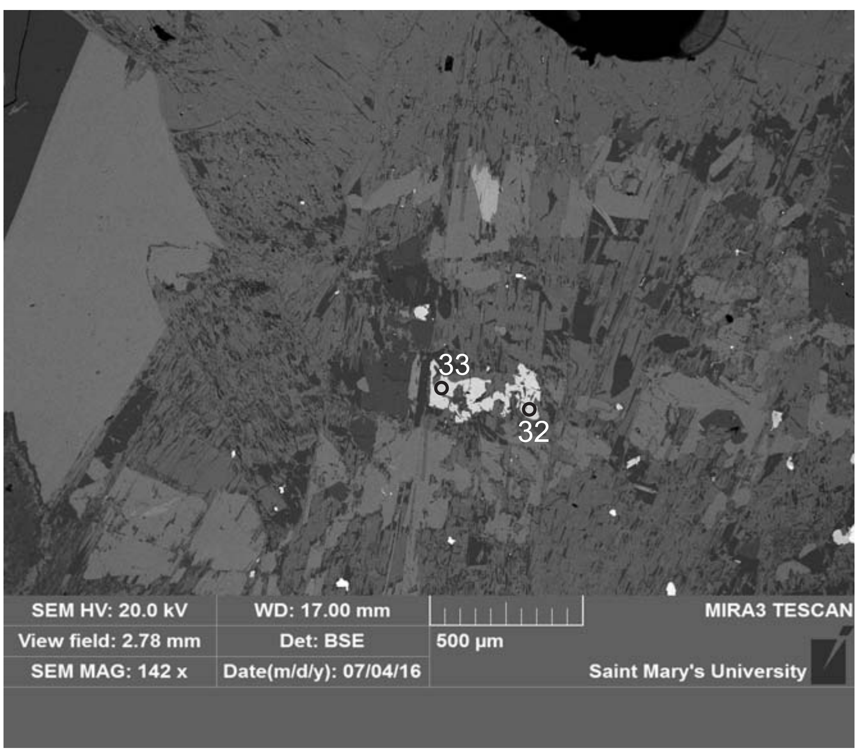



Figure 4.20: Sample 9928b. Location of laser ablation analyses 32-33 (titanite (Table 4-1.1)).

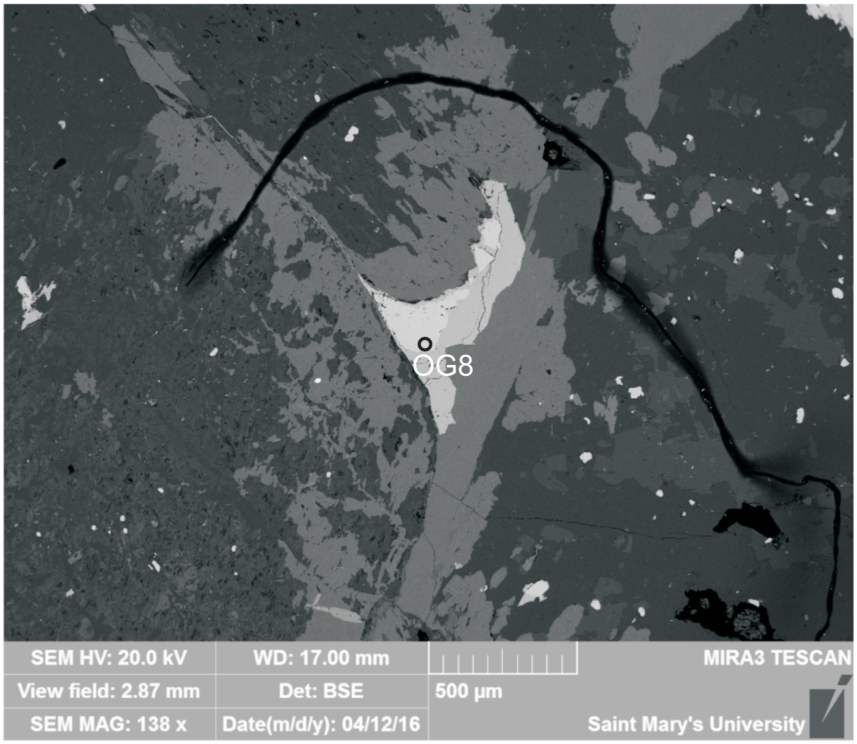



Figure 4.21: Sample 9928b. Location of laser ablation analysis OG8 (rutile (Table 4-2.1)).

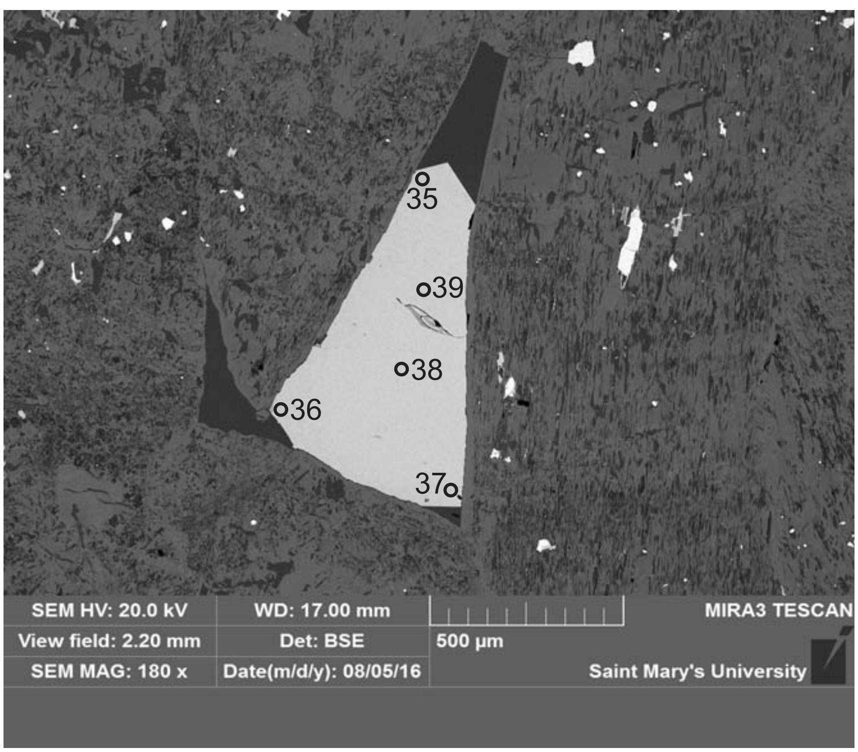



Figure 4.22: Sample 9928b. Location of laser ablation analyses 35-39 (titanite (Table 4-1.1)).

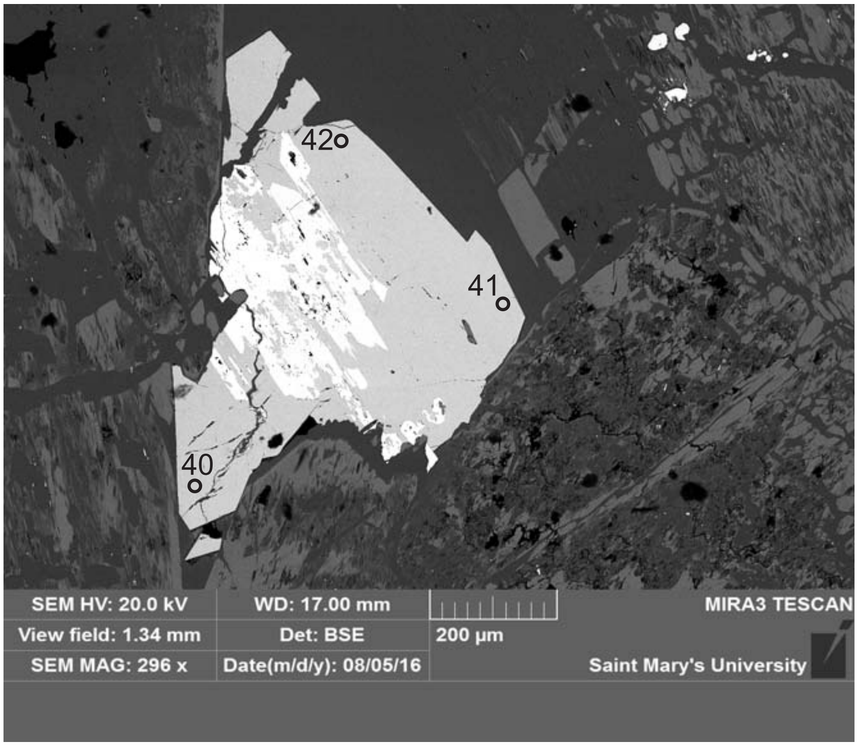



Figure 4.23: Sample 9928b. Location of laser ablation analyses 40-42 (titanite (Table 4-1.1)).

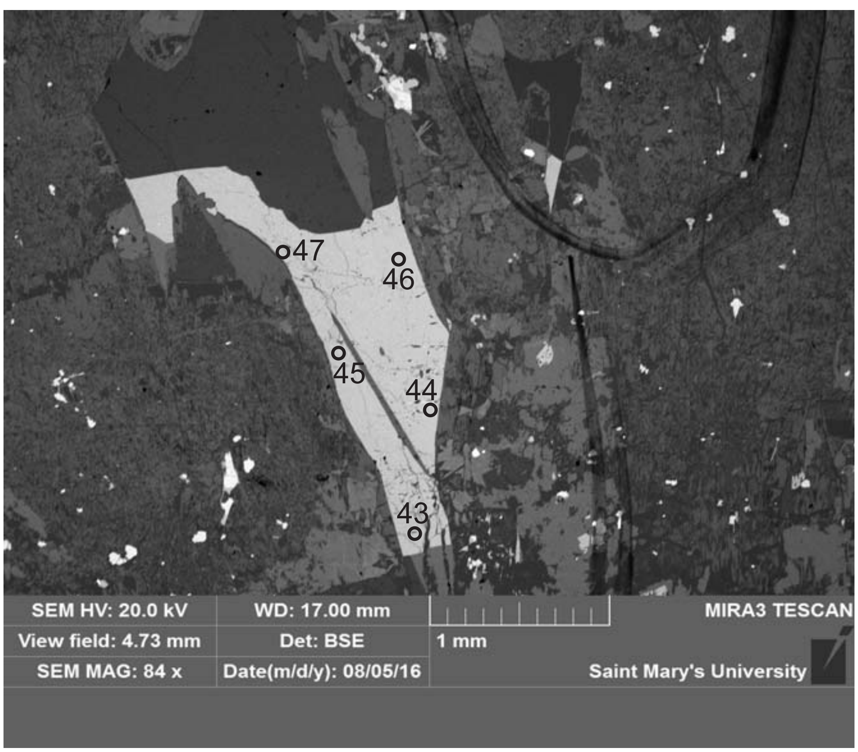



Figure 4.24: Sample 9928b. Location of laser ablation analyses 43-47 (titanite (Table 4-1.1)).

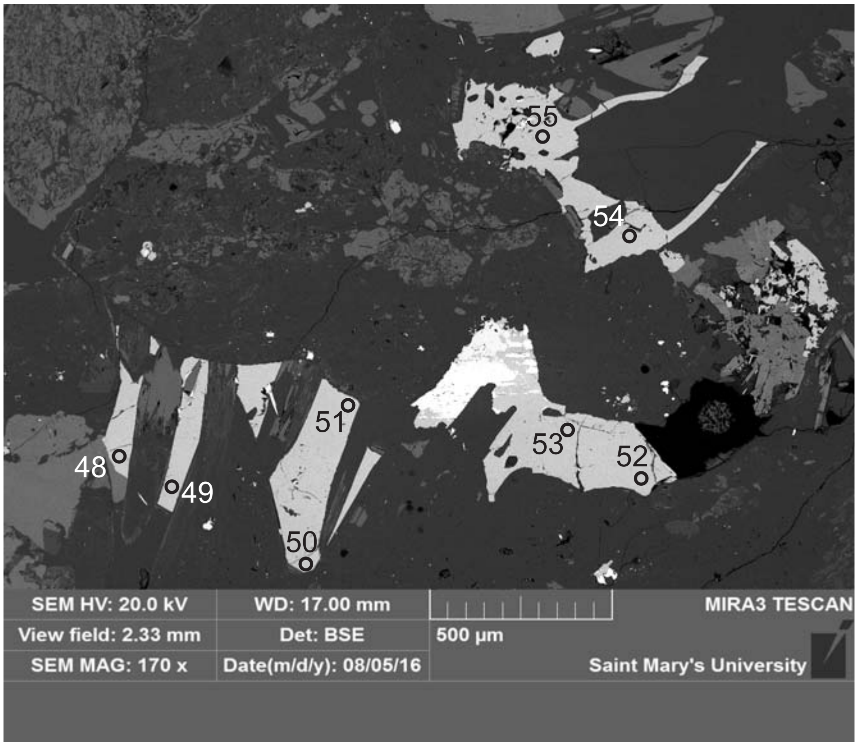



Figure 4.25: Sample 9928b. Location of laser ablation analyses 48-55 (titanite (Table 4-1.1)).

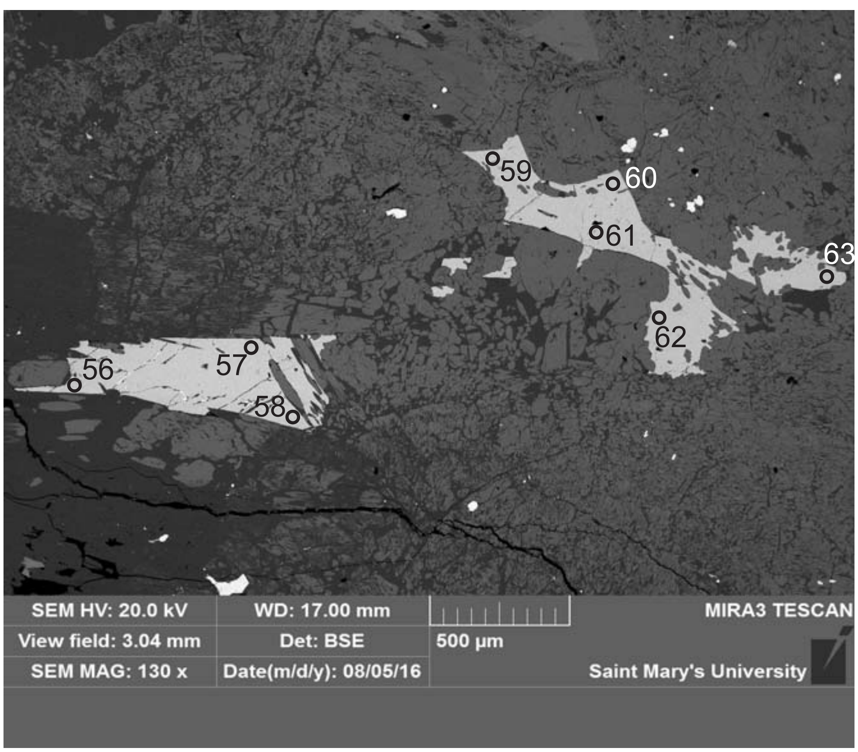



Figure 4.26: Sample 9928b. Location of laser ablation analyses 56-63 (titanite (Table 4-1.1)).

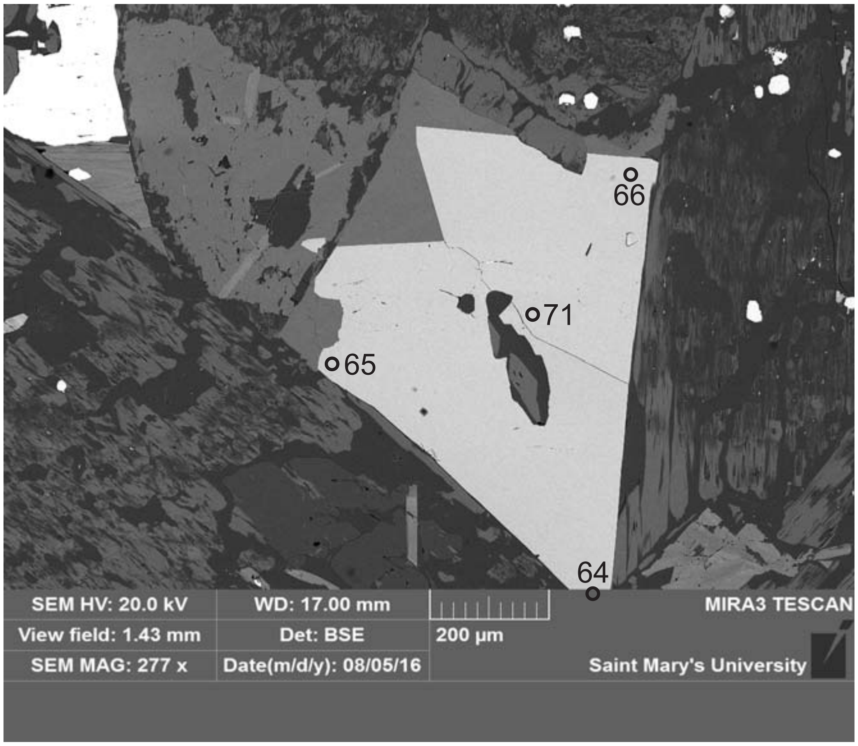



Figure 4.27: Sample 9928b. Location of laser ablation analyses 64-66, 71 (titanite (Table 4-1.1)).

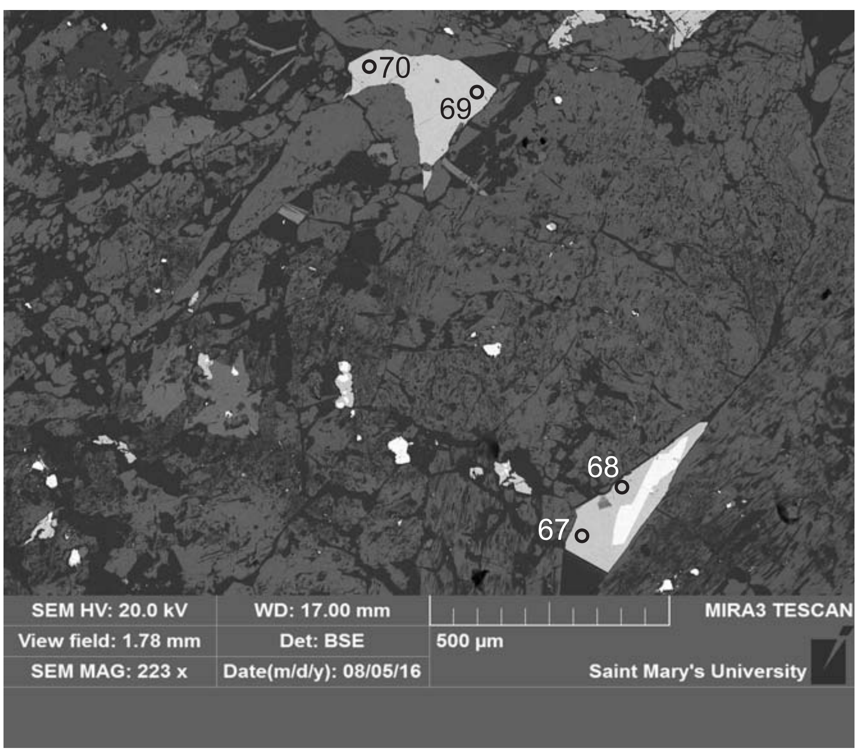



Figure 4.28: Sample 9928b. Location of laser ablation analyses 67-70 (titanite (Table 4-1.1)).

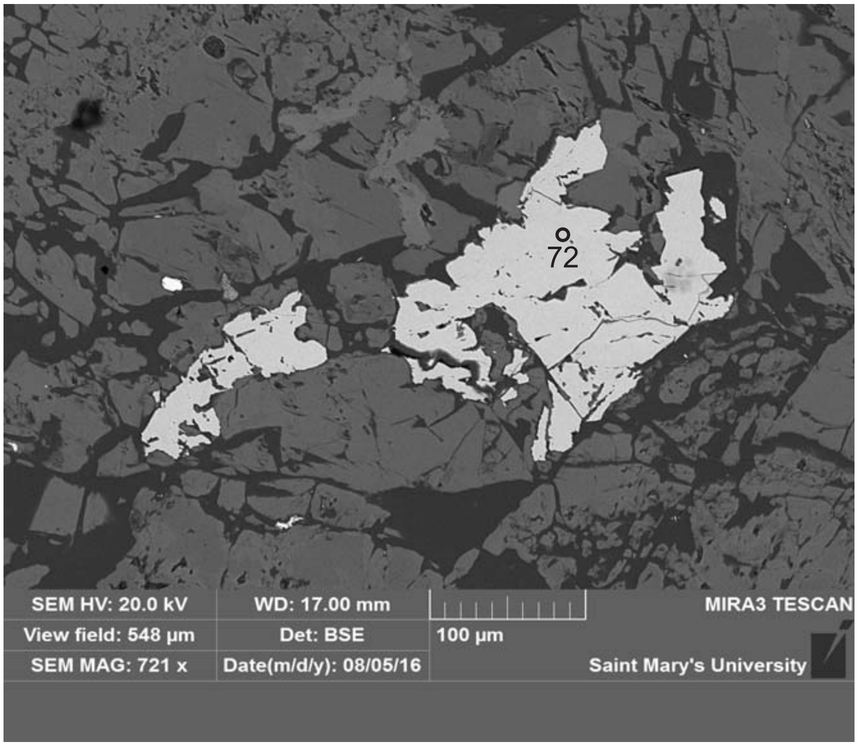



Figure 4.29: Sample 9928b. Location of laser ablation analysis 72 (titanite (Table 4-1.1)).

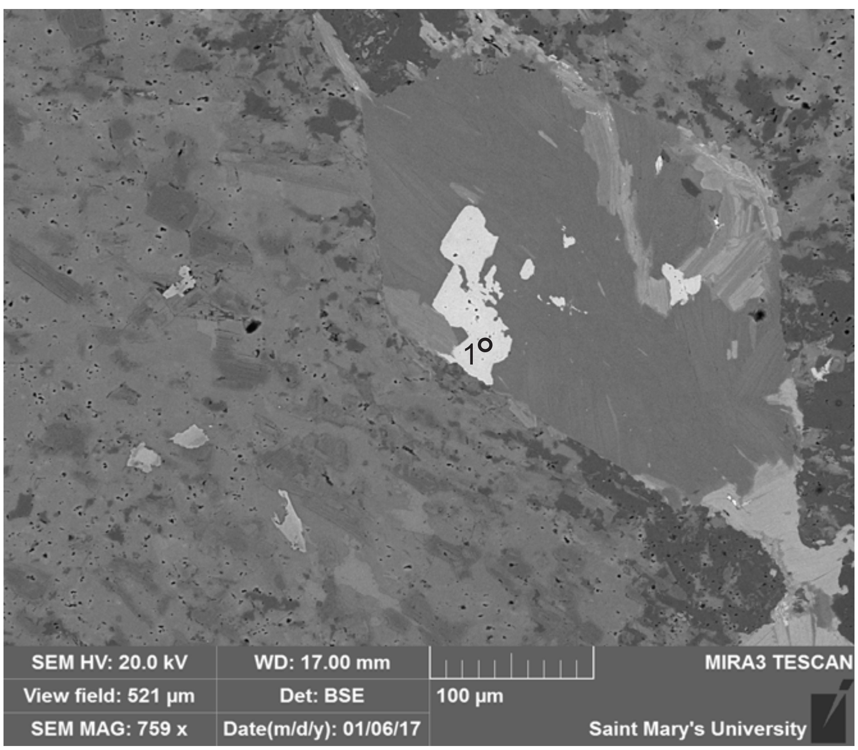



Figure 4.30: Sample 9954a. Location of laser ablation analysis 1 (titanite (Table 4-1.1)).

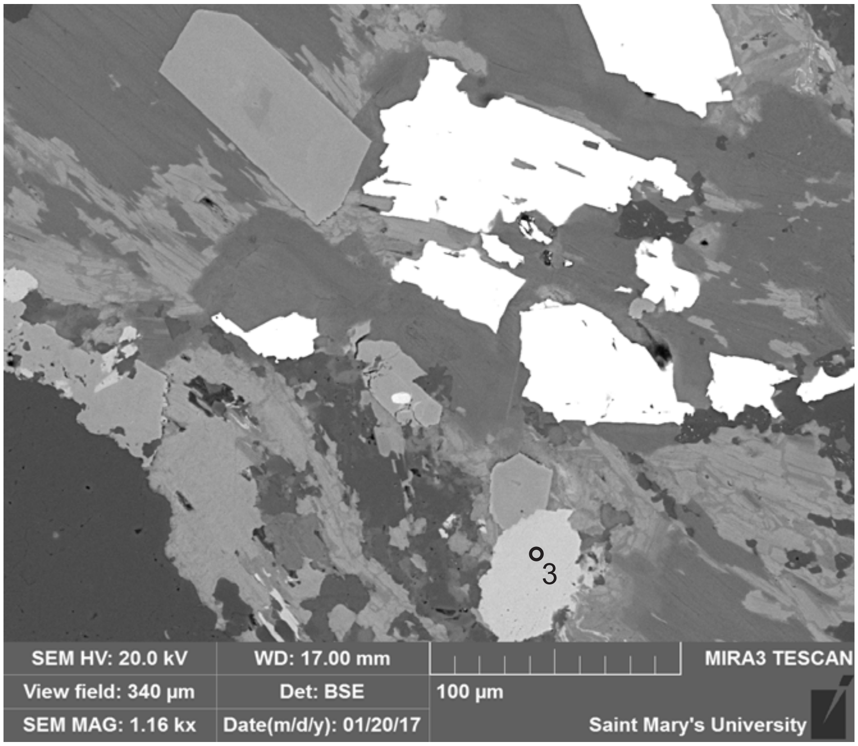



Figure 4.31: Sample 9954a. Location of laser ablation analysis 3 (titanite (Table 4-1.1)).

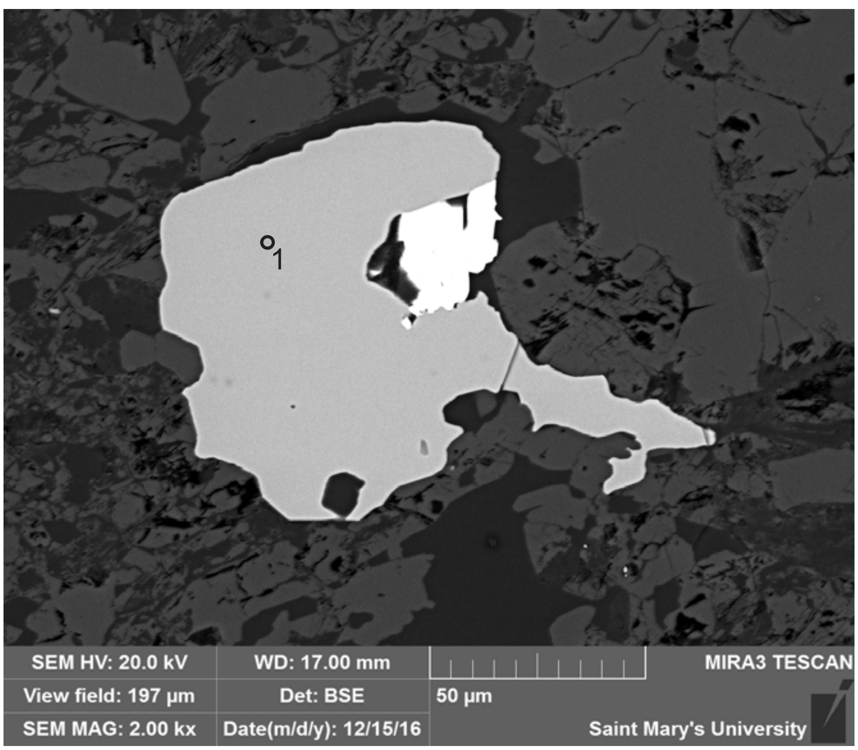



Figure 4.32: Sample 9956a. Location of laser ablation analysis 1 (rutile (Table 4-2.1)).

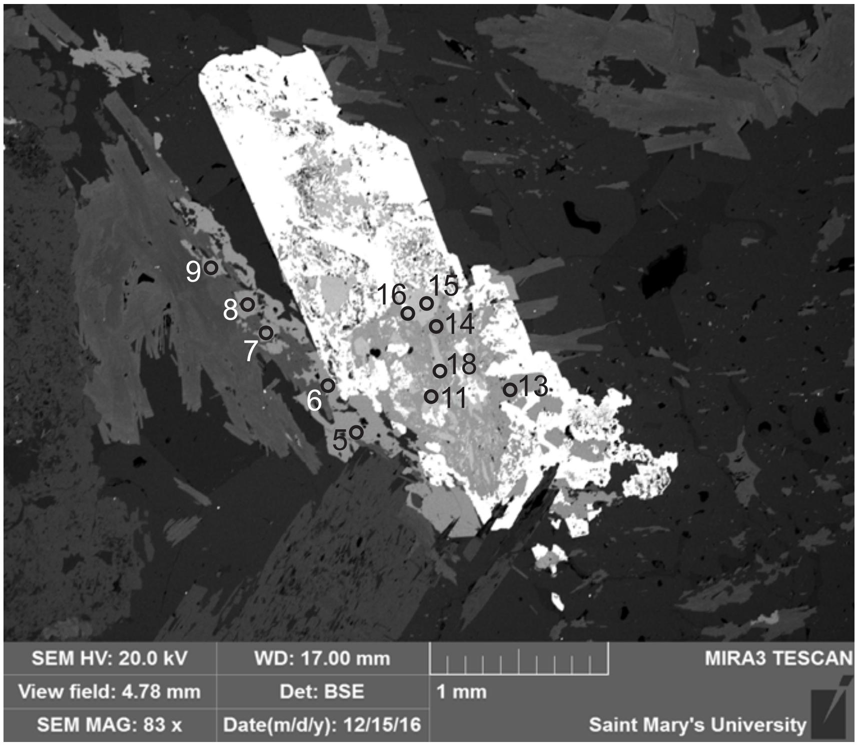



Figure 4.33: Sample 9956a. Location of laser ablation analyses (rutile 15,16,18 (Table 4-2.1)) (titanite 5-9,12,13,14 (Table 4-1.1)).

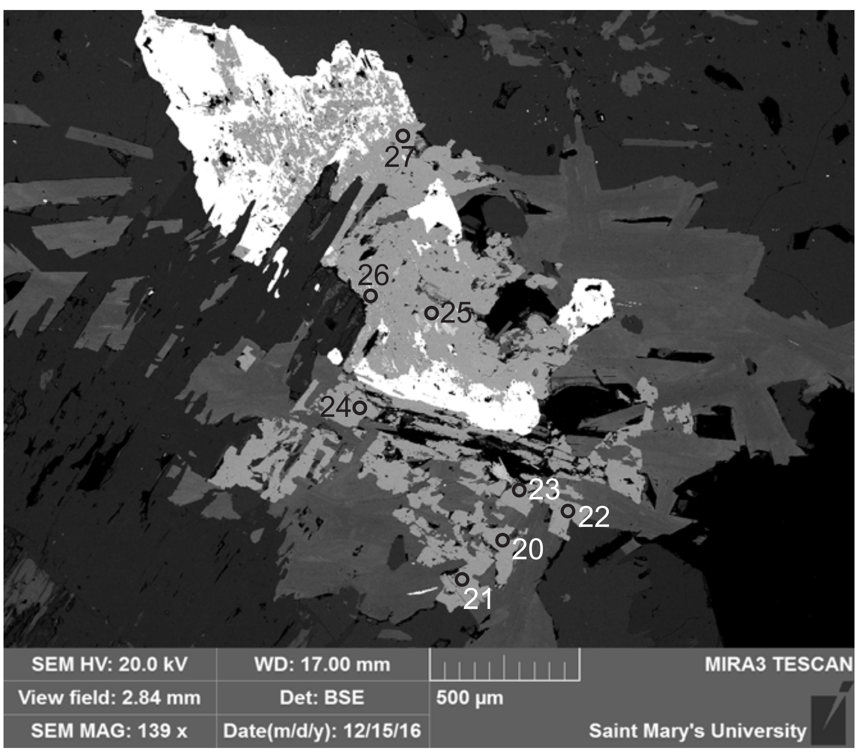



Figure 4.34: Sample 9956a. Location of laser ablation analyses 20-27 (titanite (Table 4-1.1)).

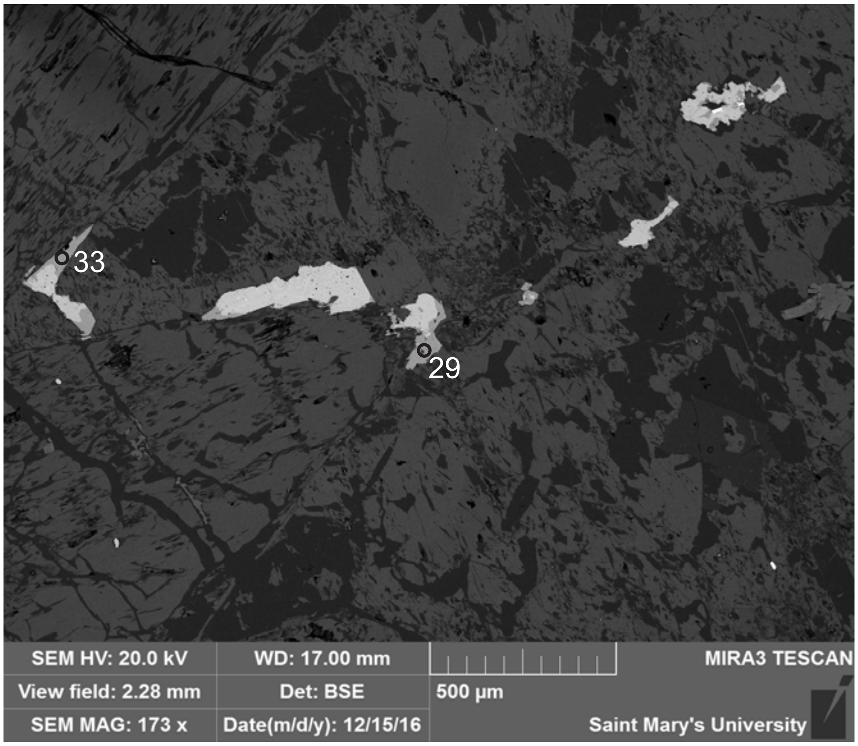



Figure 4.35: Sample 9956a. Location of laser ablation analyses 29, 33 (titanite (Table 4-1.1)).

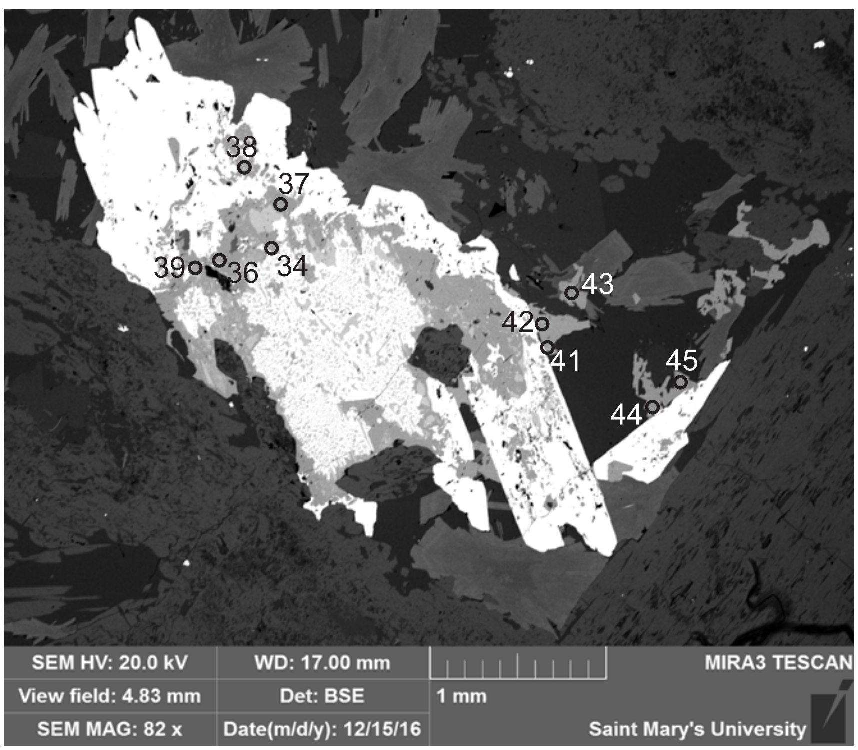



Figure 4.36: Sample 9956a. Location of laser ablation analyses 34, 36-39, 41-45 (titanite (Table 4-1.1)).

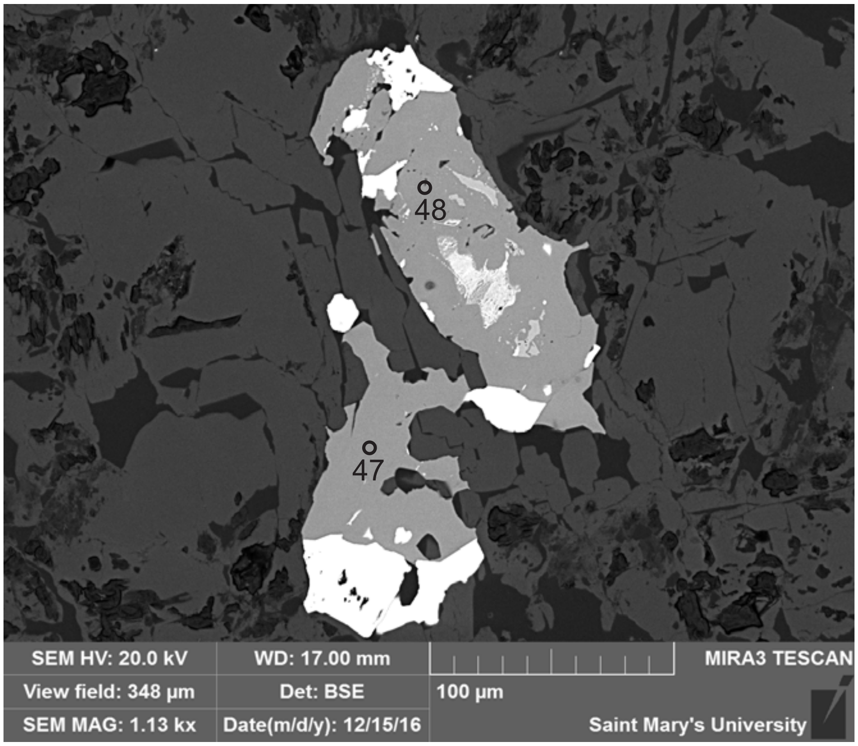



Figure 4.37: Sample 9956a. Location of laser ablation analyses 47-48 (titanite (Table 4-1.1)).

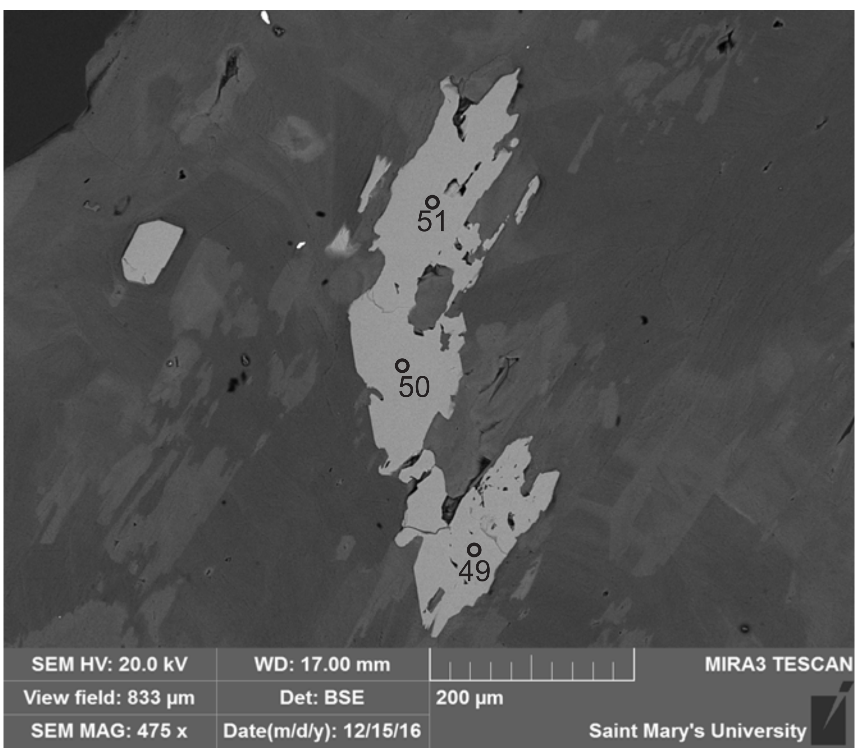



Figure 4.38: Sample 9956a. Location of laser ablation analyses 49-51 (titanite (Table 4-1.1)).

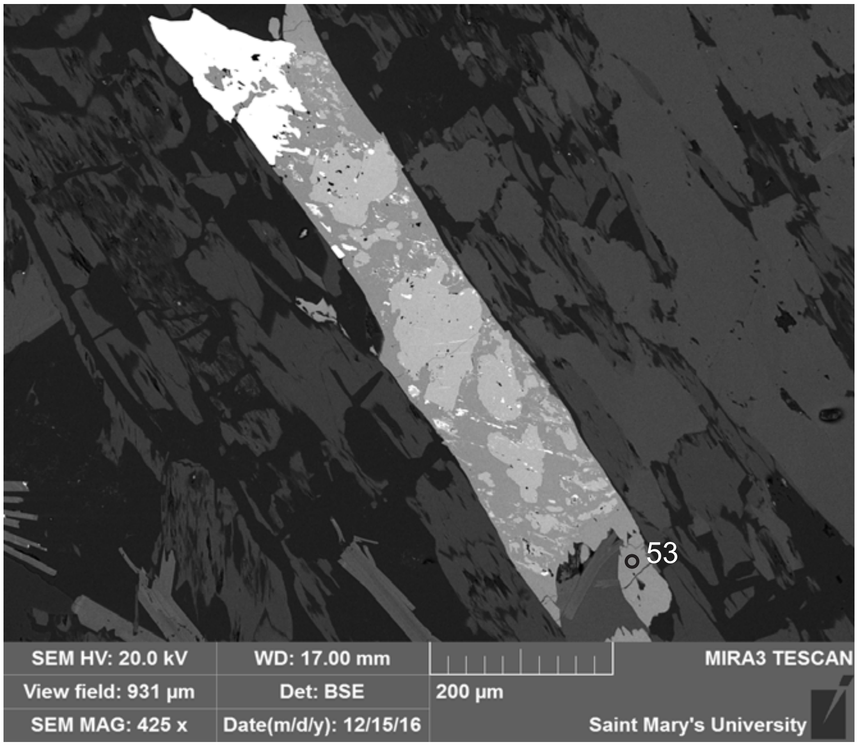



Figure 4.39: Sample 9956a. Location of laser ablation analysis 53 (titanite (Table 4-1.1)).

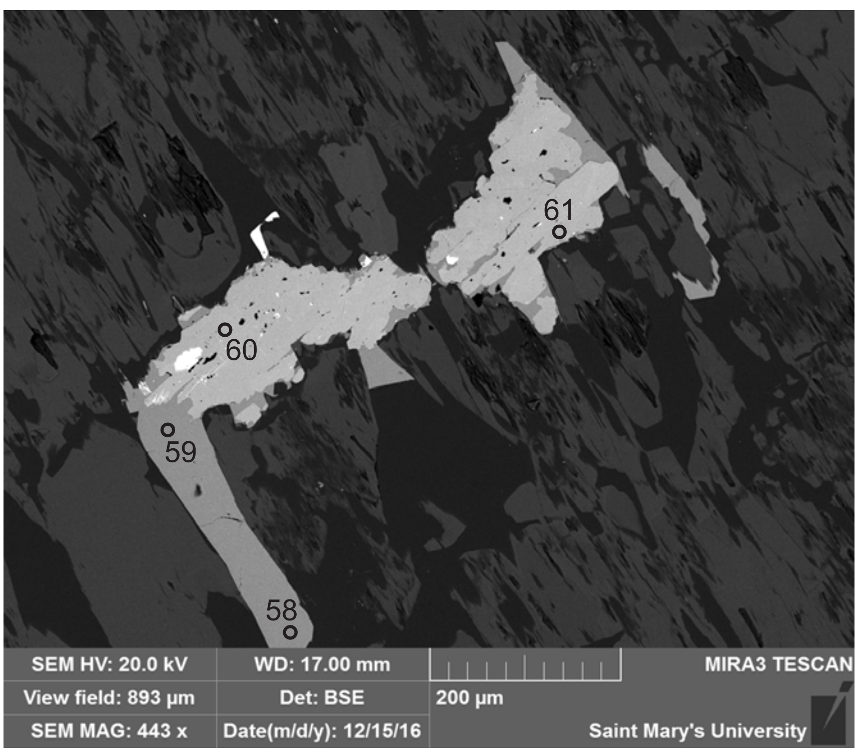



Figure 4.40: Sample 9956a. Location of laser ablation analyses (rutile 60-61 (Table 4-2.1)) (titanite 58-59 (Table 4-1.1)).

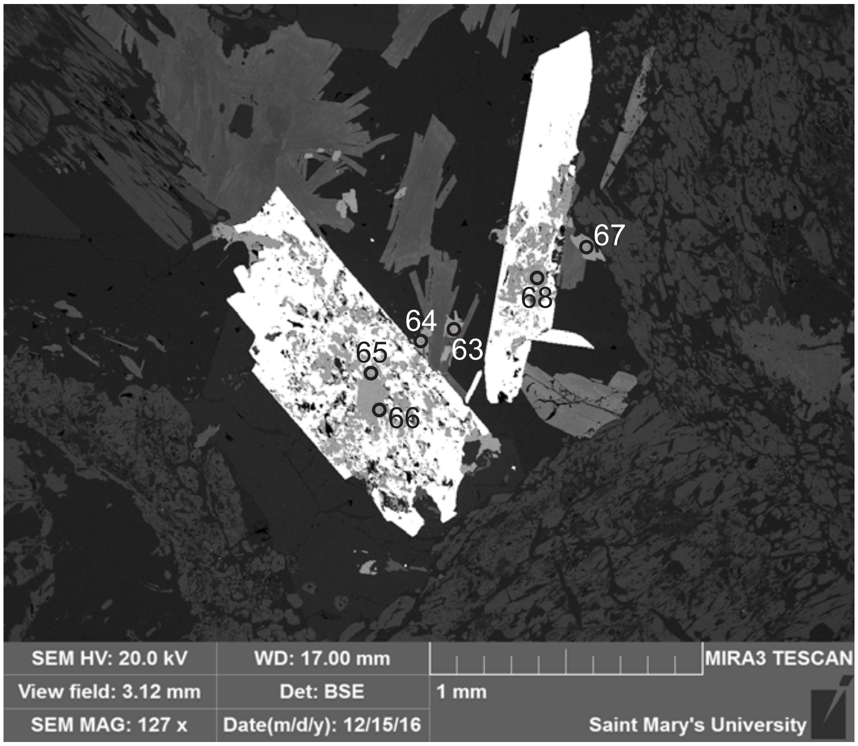



Figure 4.41: Sample 9956a. Location of laser ablation analyses 63-68 (titanite (Table 4-1.1)).

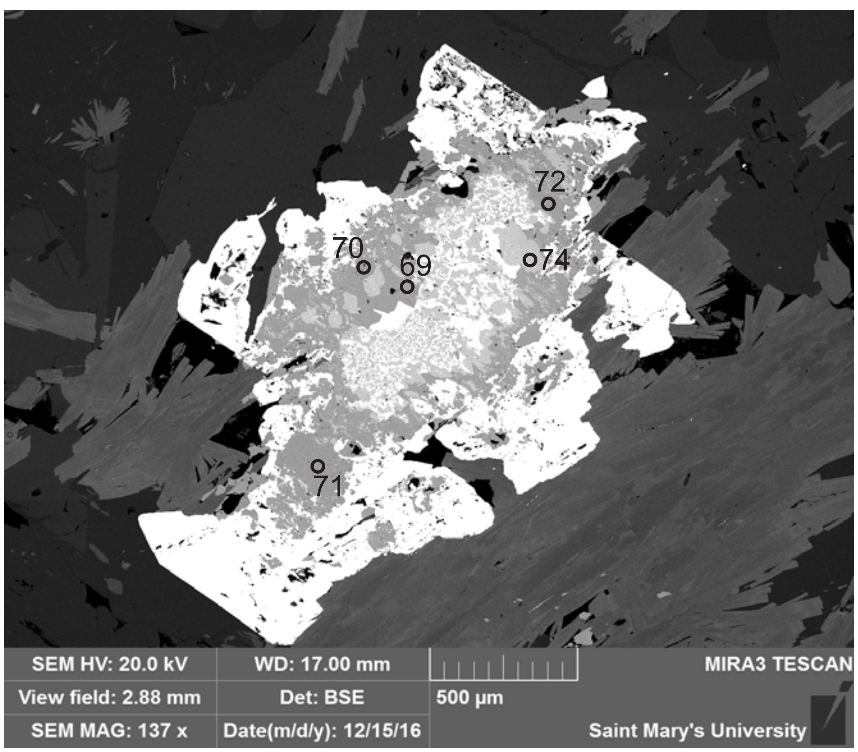



Figure 4.42: Sample 9956a. Location of laser ablation analyses (rutile 74 (Table 4-2.1)) (titanite 69-72 (Table 4-1.1)).

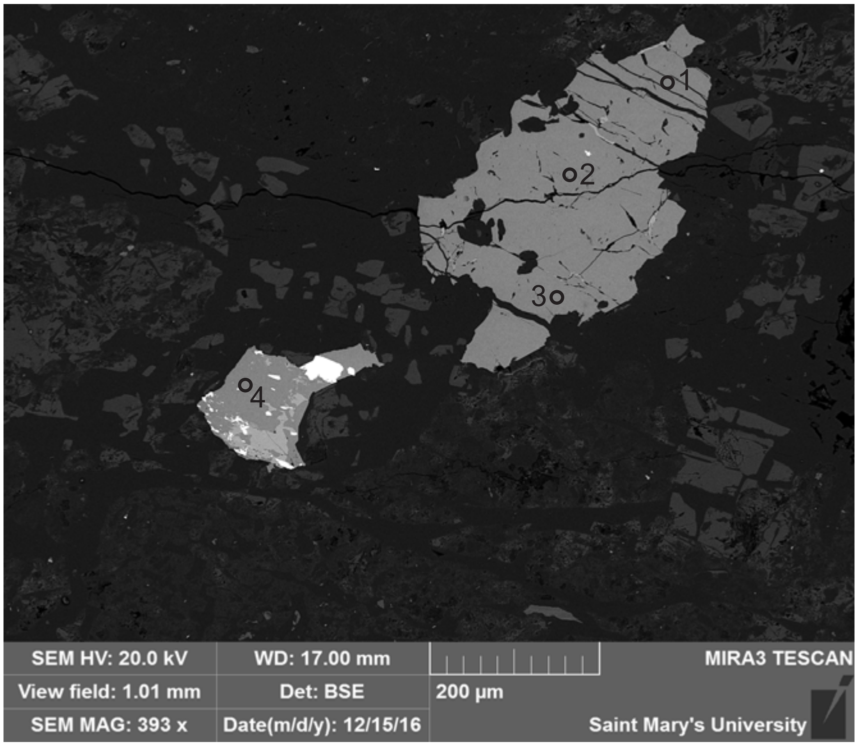



Figure 4.43: Sample 9956b. Location of laser ablation analyses 1-4 (titanite (Table 4-1.1)).

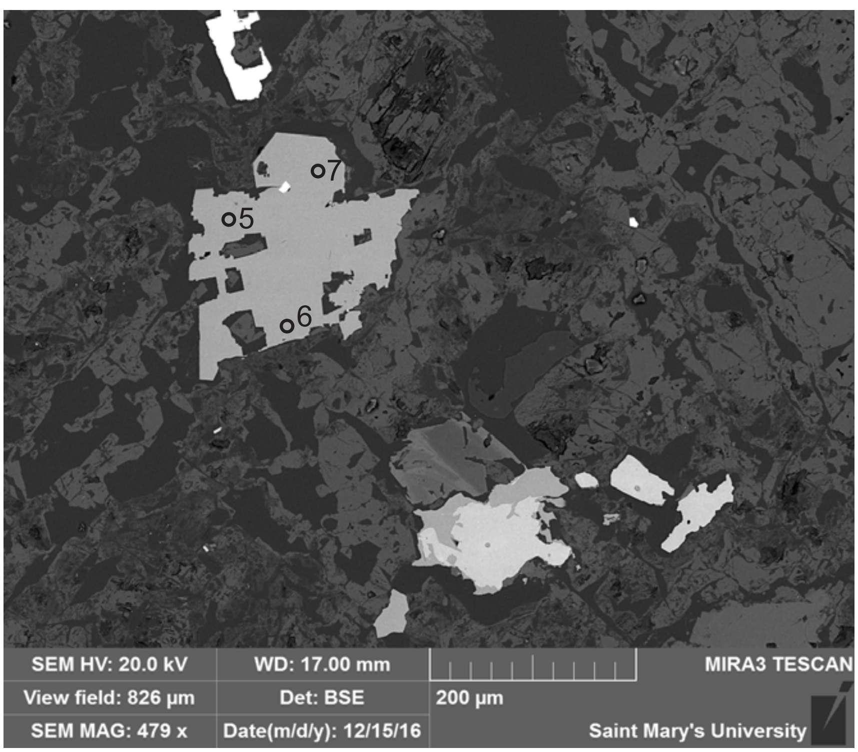



Figure 4.44: Sample 9956b. Location of laser ablation analyses 5-7 (titanite (Table 4-1.1)).

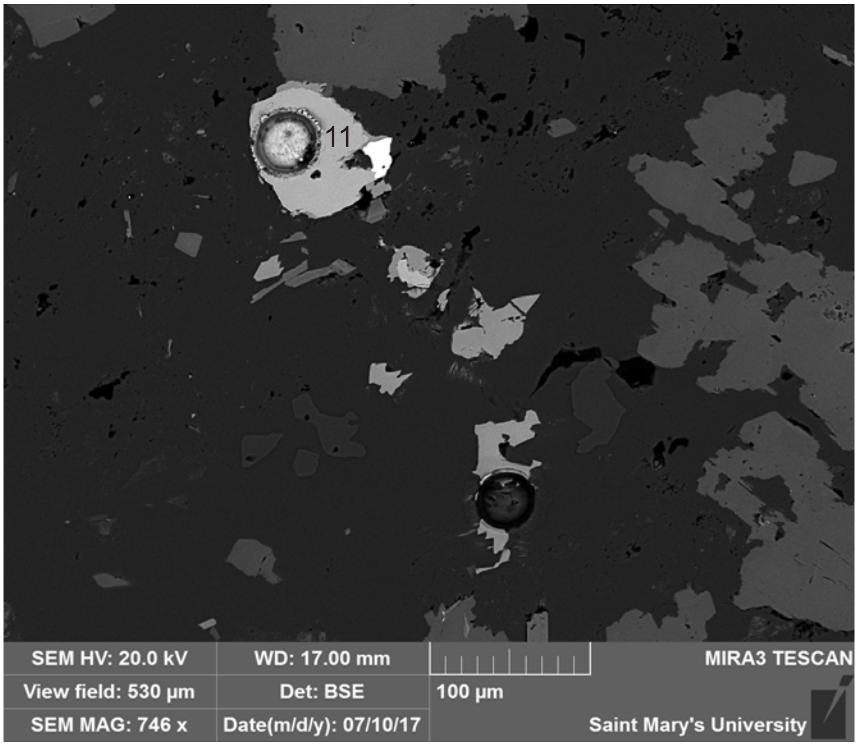



Figure 4.45: Sample 9956b. Location of laser ablation analysis 11 (rutile (Table 4-2.1)).

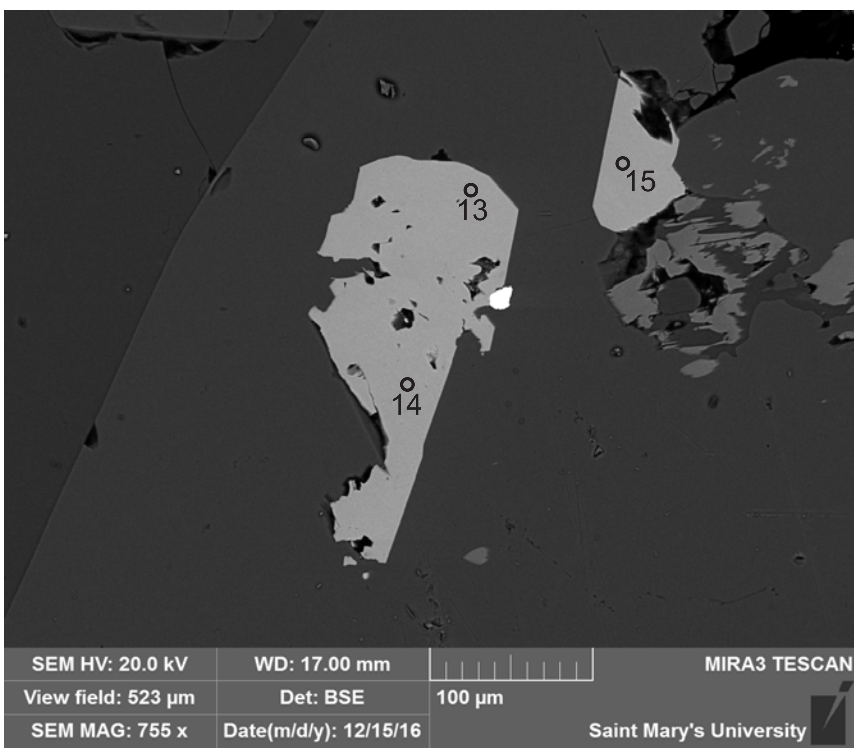



Figure 4.46: Sample 9956b. Location of laser ablation analyses 13-15 (titanite (Table 4-1.1)).

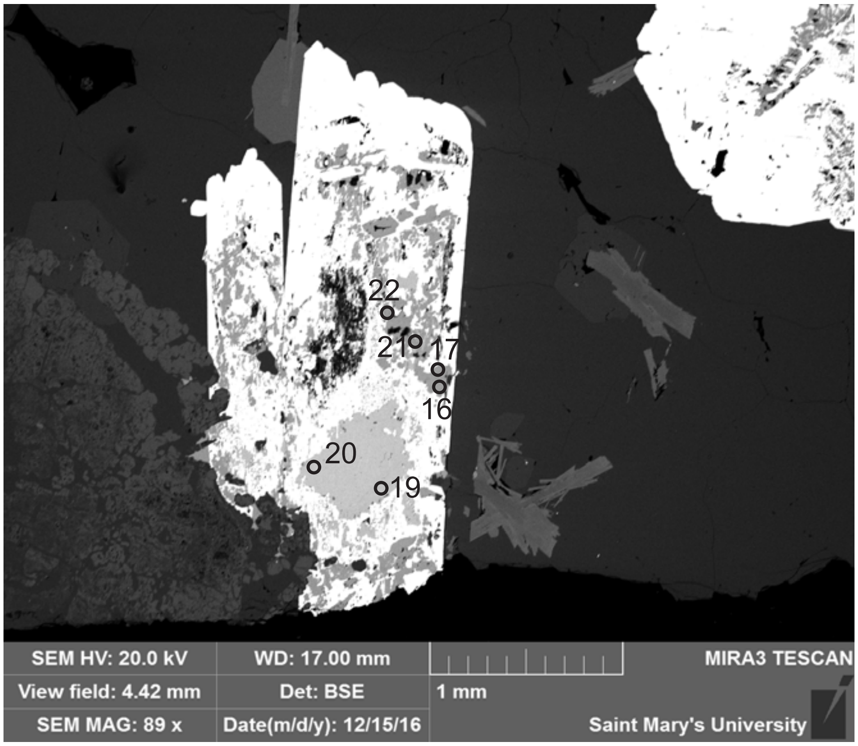



Figure 4.47: Sample 9956b. Location of laser ablation analyses (rutile 19-20 (Table 4-2.1)) (titanite 16-17, 21-22 (Table 4-1.1)).

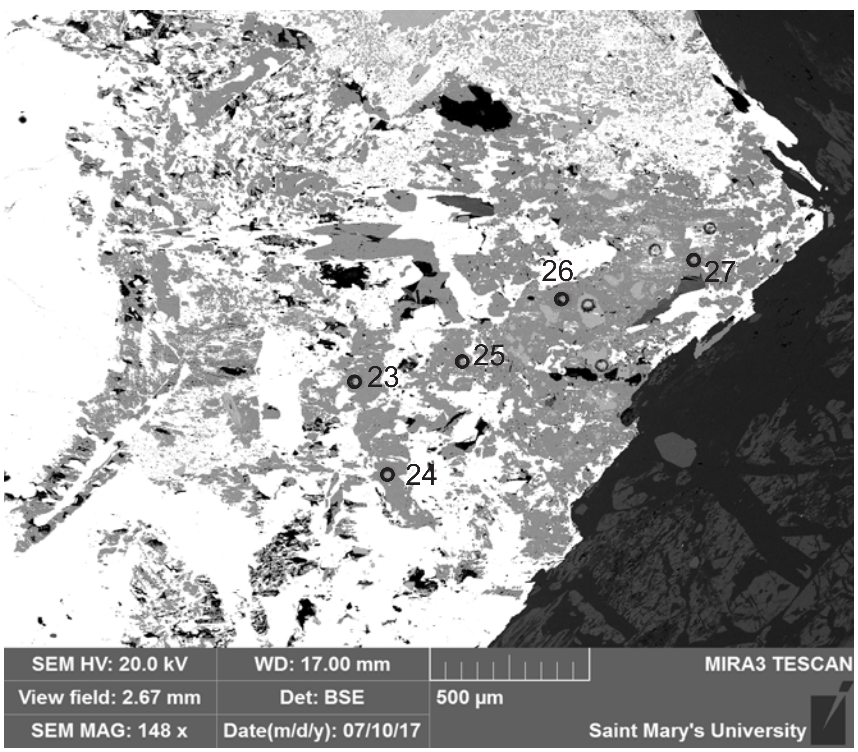



Figure 4.48: Sample 9956b. Location of laser ablation analyses 23-27 (titanite (Table 4-1.1)).

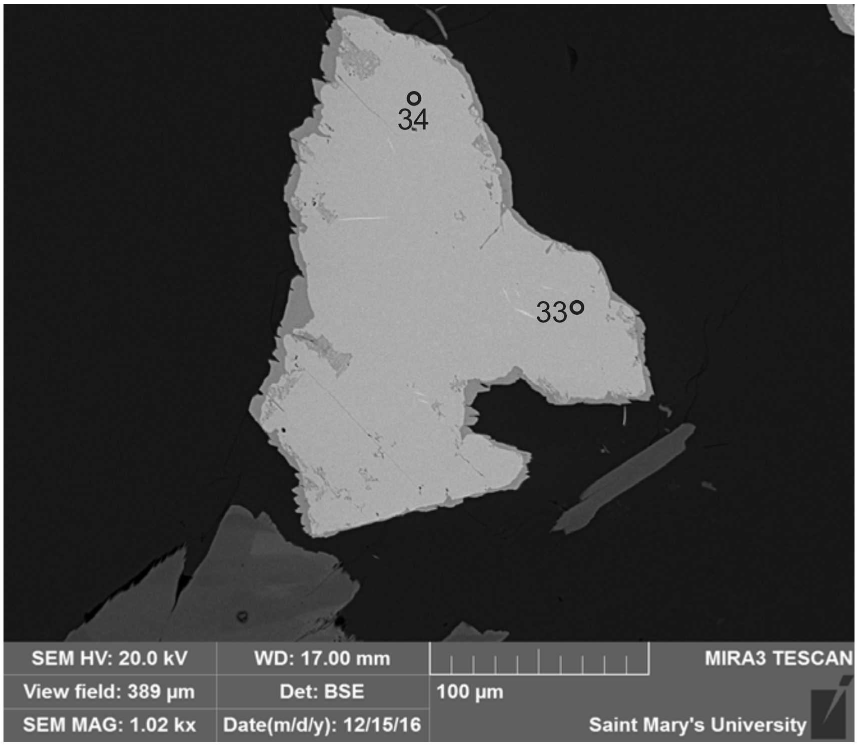



Figure 4.49: Sample 9956b. Location of laser ablation analyses 33-34 (rutile (Table 4-2.1)).

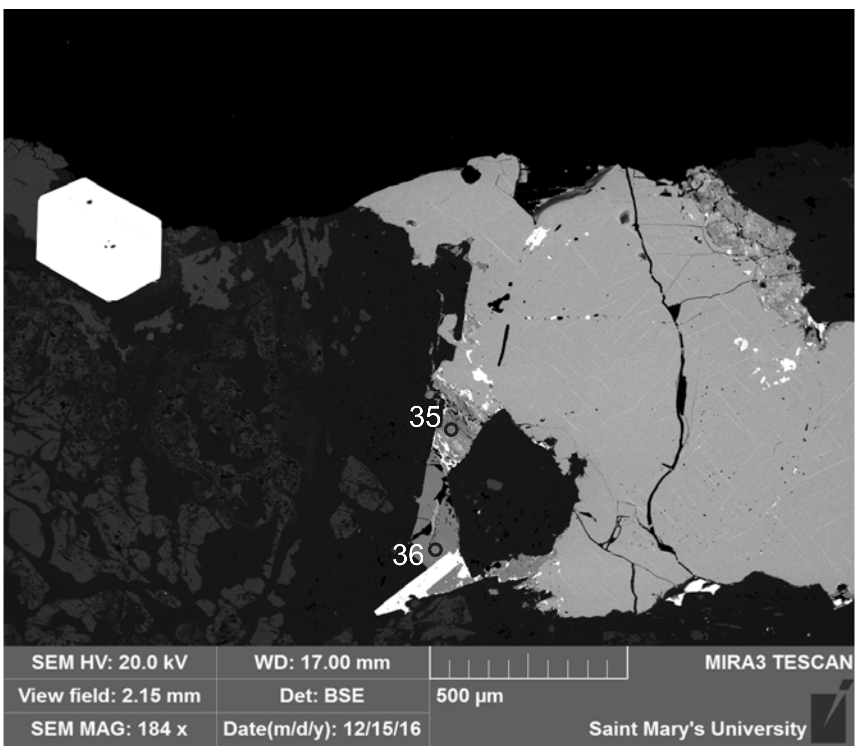



Figure 4.50: Sample 9956b. Location of laser ablation analyses 35-36 (titanite (Table 4-1.1)).

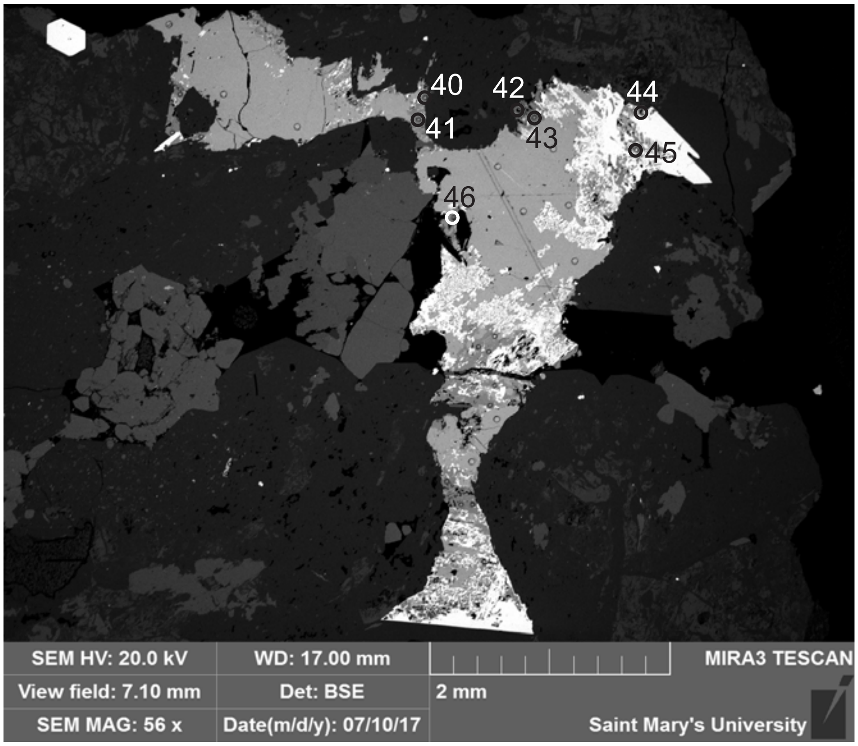



Figure 4.51: Sample 9956b. Location of laser ablation analyses 40-46 (titanite (Table 4-1.1)).

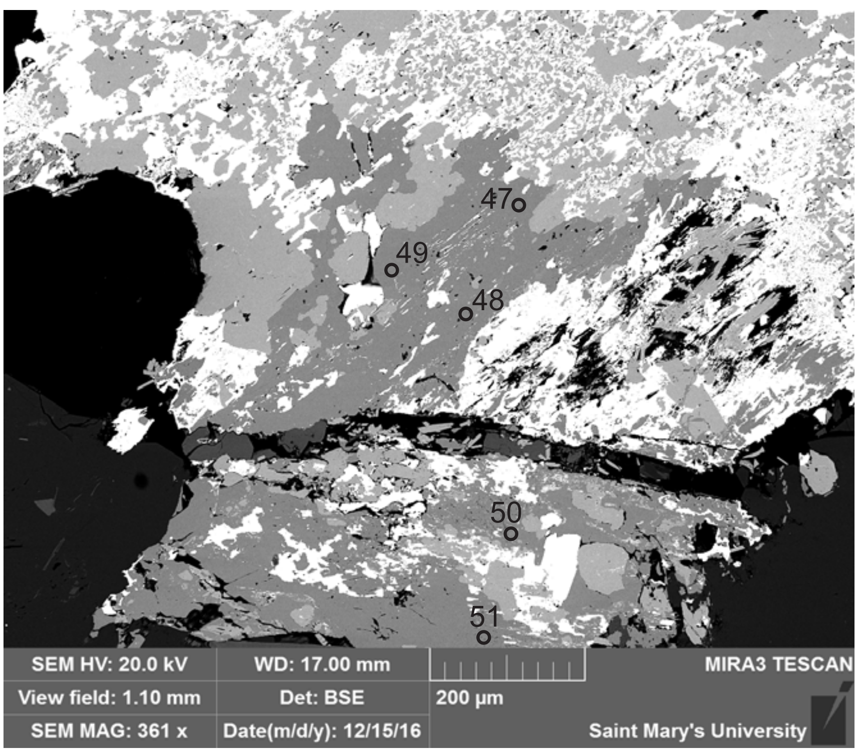



Figure 4.52: Sample 9956b. Location of laser ablation analyses 47-51 (titanite (Table 4-1.1)).

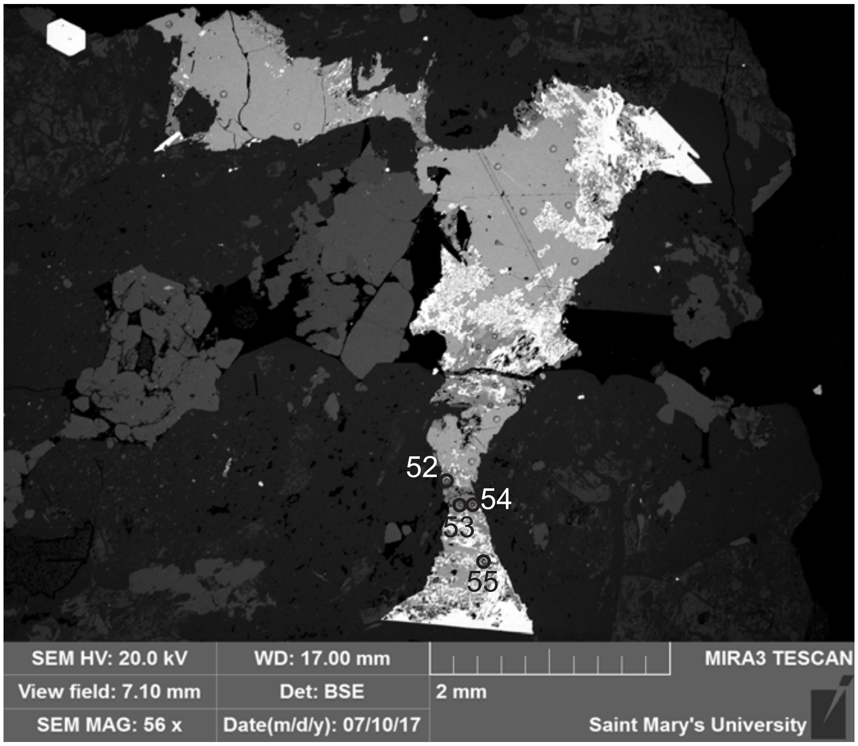



Figure 4.53: Sample 9956b. Location of laser ablation analyses 52-55 (titanite (Table 4-1.1)).

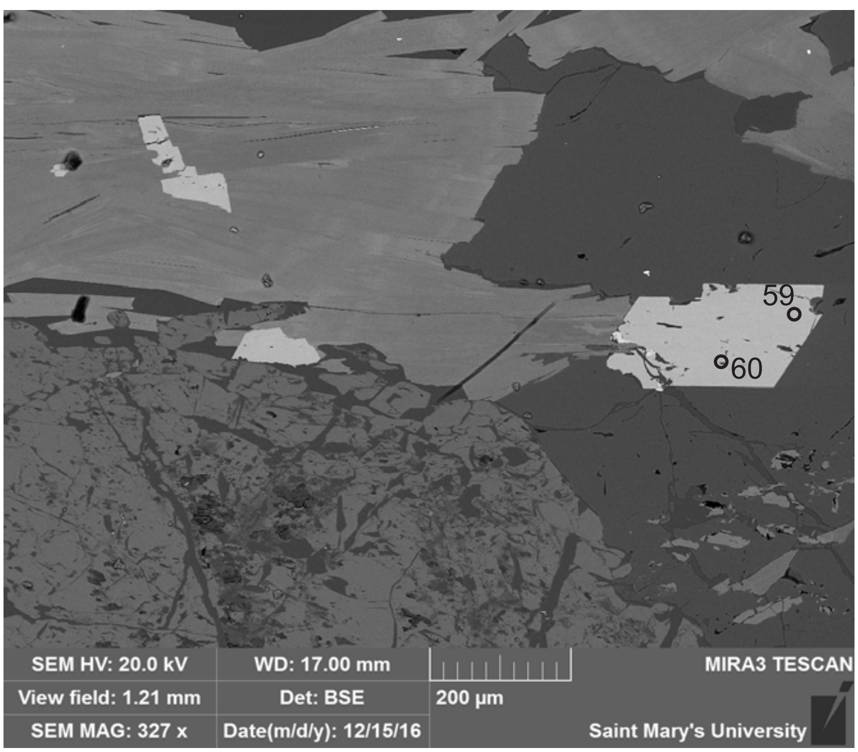



Figure 4.54: Sample 9956b. Location of laser ablation analyses 59-60 (titanite (Table 4-1.1)).

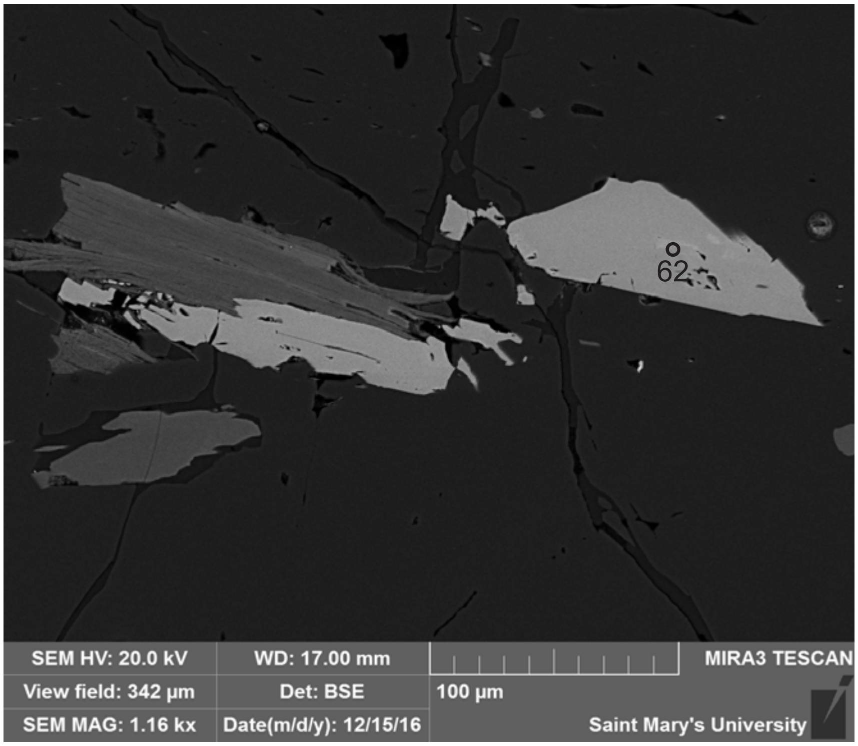



Figure 4.55: Sample 9956b. Location of laser ablation analysis 62 (titanite (Table 4-1.1)).

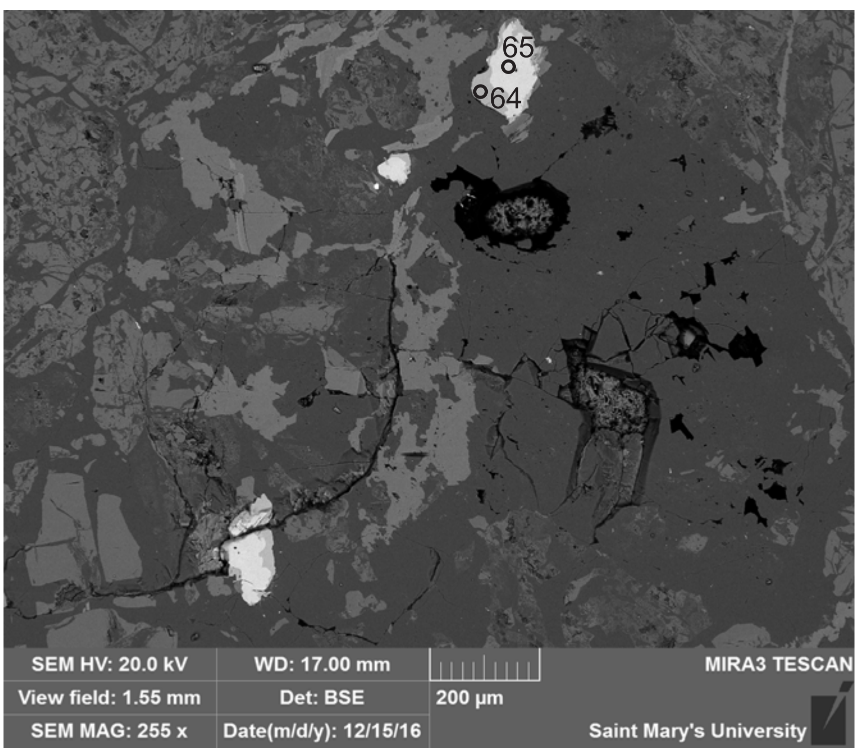



Figure 4.56: Sample 9956b. Location of laser ablation analyses (rutile 65 (Table 4-2.1)) (titanite 64 (Table 4-1.1)).

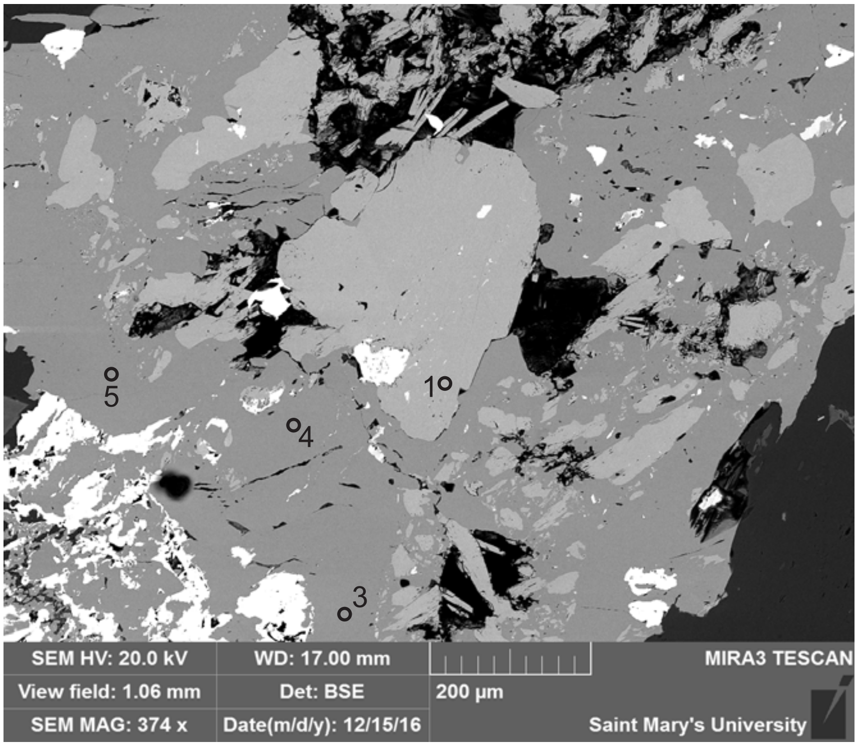



Figure 4.57: Sample 9956c. Location of laser ablation analyses (rutile 1 (Table 4-2.1)) (titanite 3-5 (Table 4-1.1)).

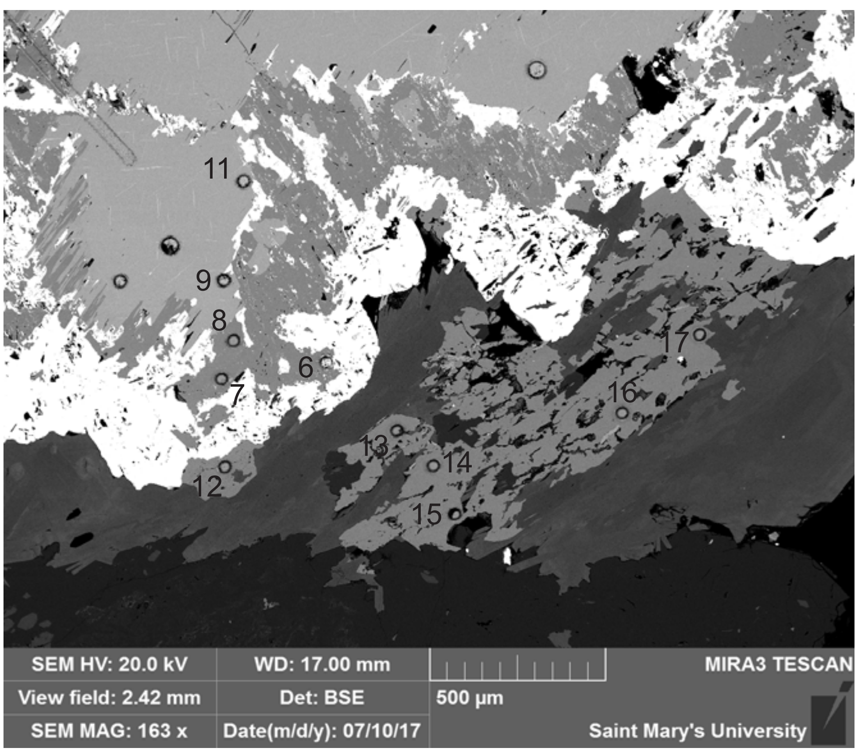



Figure 4.58: Sample 9956c. Location of laser ablation analyses (rutile 9,11 (Table 4-2.1)) (titanite 6-8,12-17 (Table 4-1.1)).

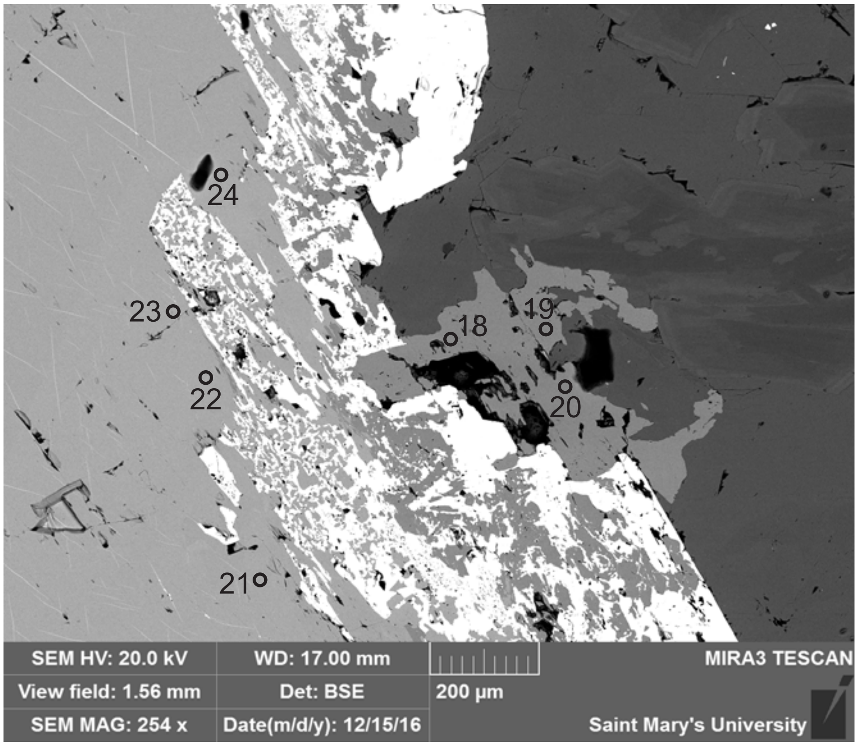



Figure 4.59: Sample 9956c. Location of laser ablation analyses (rutile 21-24 (Table 4-2.1)) (titanite 18-20 (Table 4-1.1)).

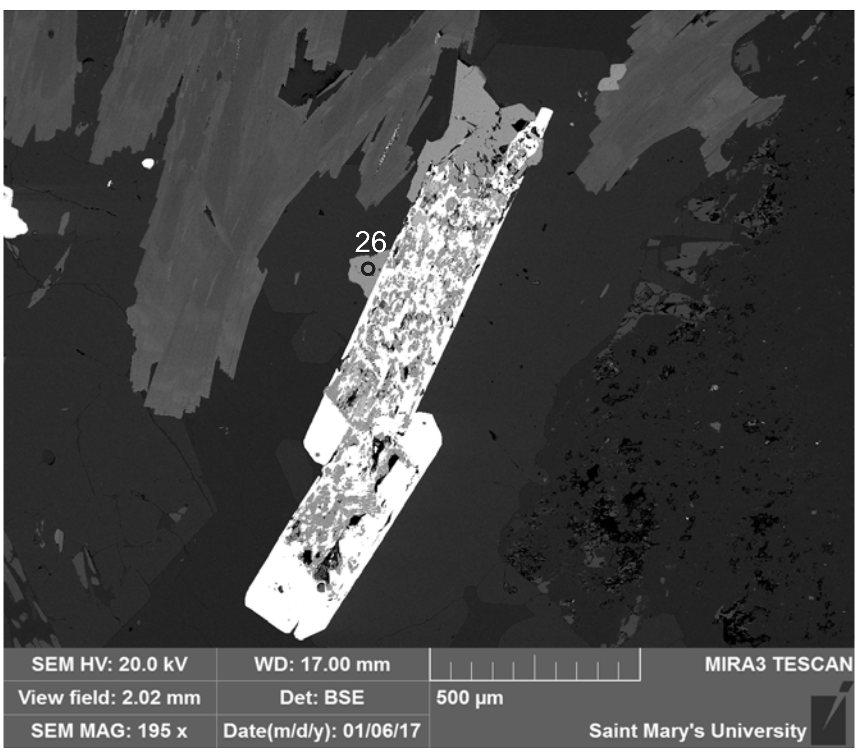



Figure 4.60: Sample 9956c. Location of laser ablation analysis 26 (titanite (Table 4-1.1)).

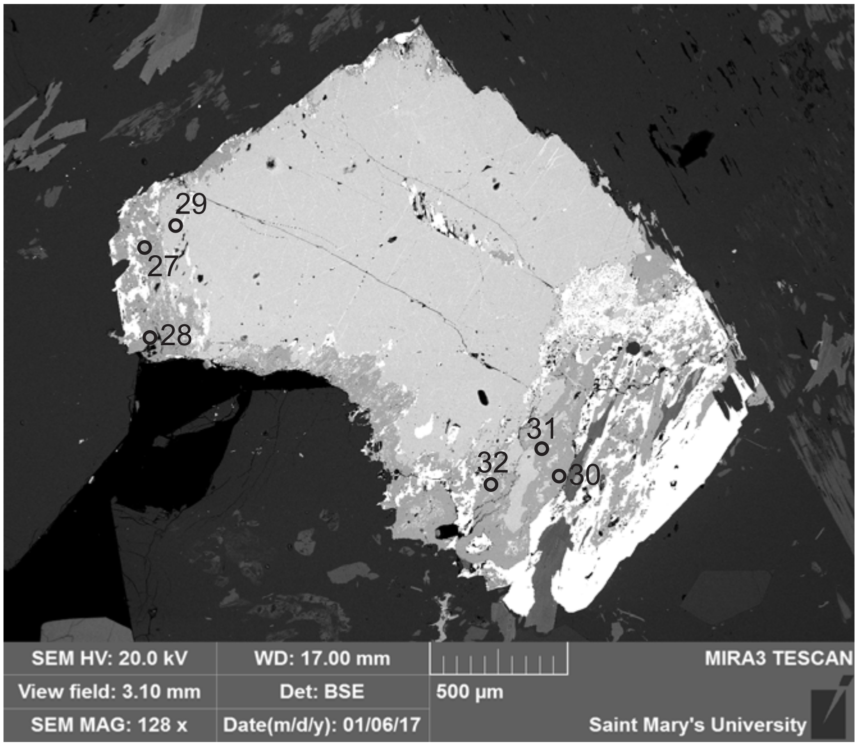



Figure 4.61: Sample 9956c. Location of laser ablation analyses (rutile 29 (Table 4-2.1)) (titanite 27-28, 30-32 (Table 4-1.1)).

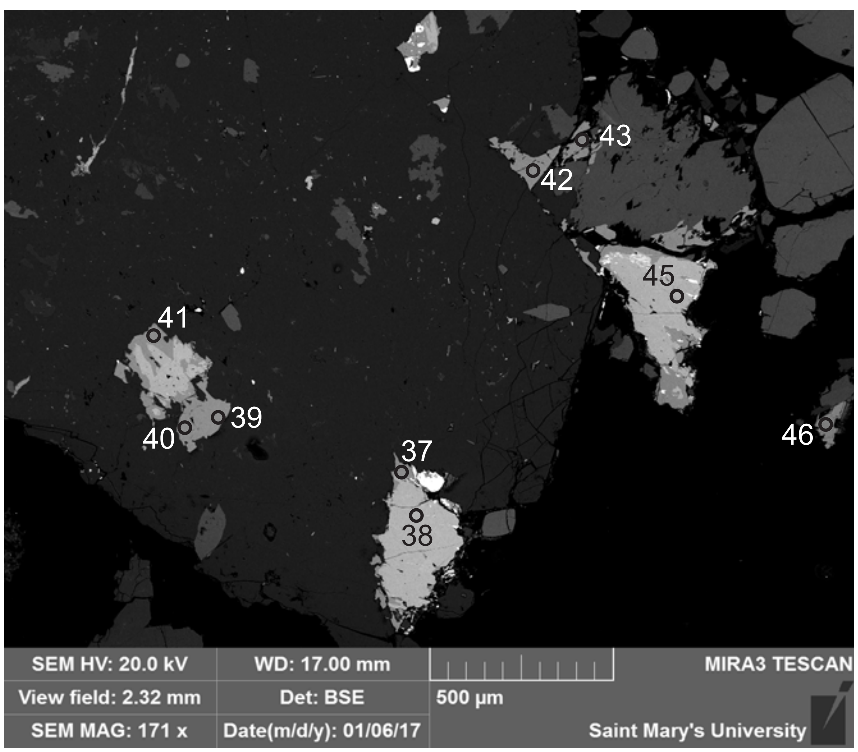



Figure 4.62: Sample 9956c. Location of laser ablation analyses (rutile 38, 45 (Table 4-2.1)) (titanite 37, 39-43, 46 (Table 4-1.1)).

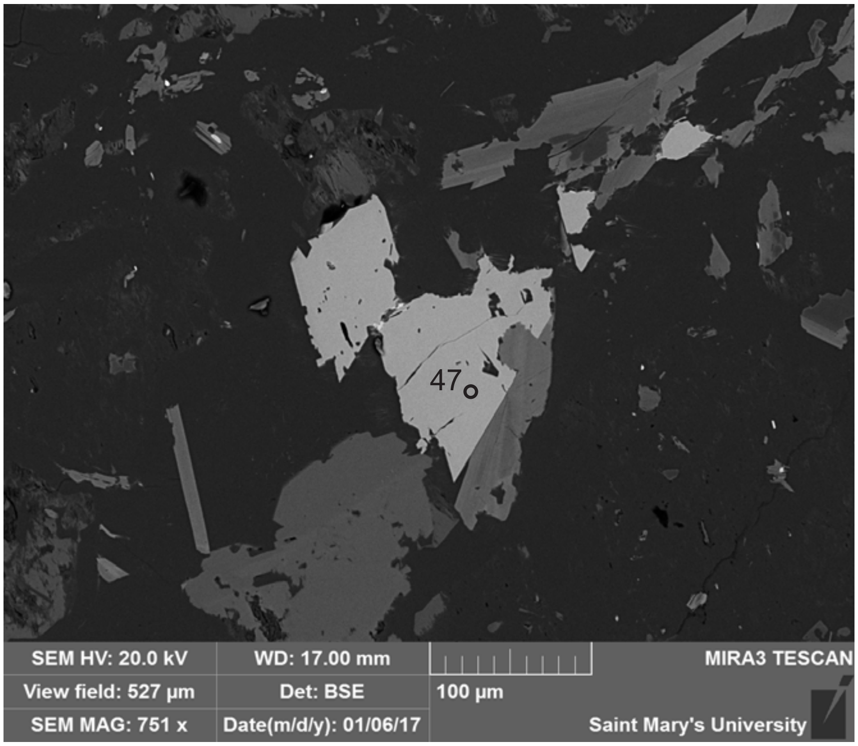



Figure 4.63: Sample 9956c. Location of laser ablation analysis 47 (titanite (Table 4-1.1)).

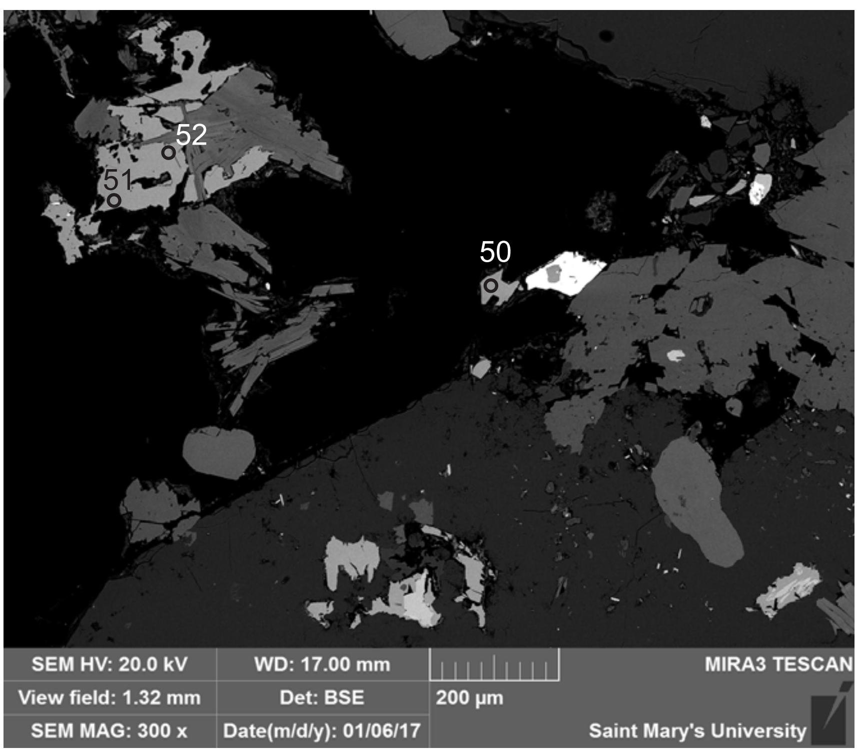



Figure 4.64: Sample 9956c. Location of laser ablation analyses 50-52 (titanite (Table 4-1.1)).

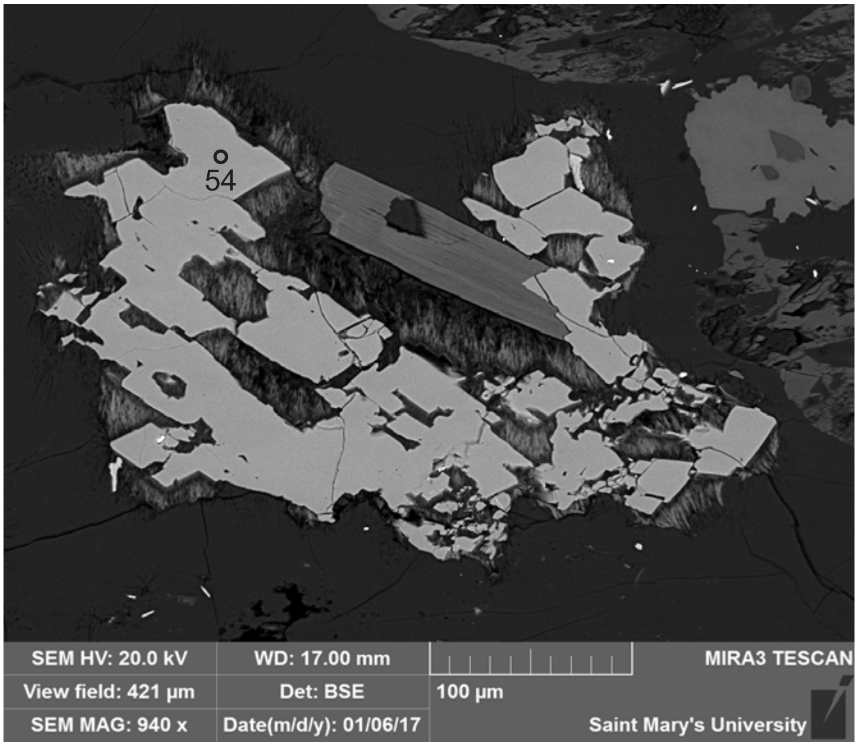



Figure 4.65: Sample 9956c. Location of laser ablation analysis 54 (titanite (Table 4-1.1)).

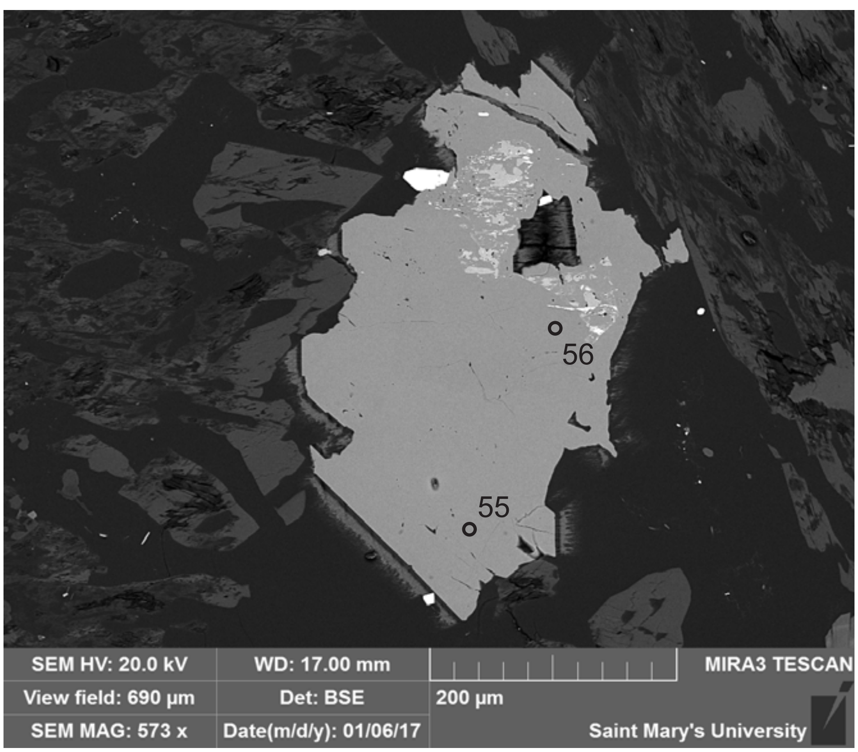



Figure 4.66: Sample 9956c. Location of laser ablation analyses 55-56 (titanite (Table 4-1.1)).

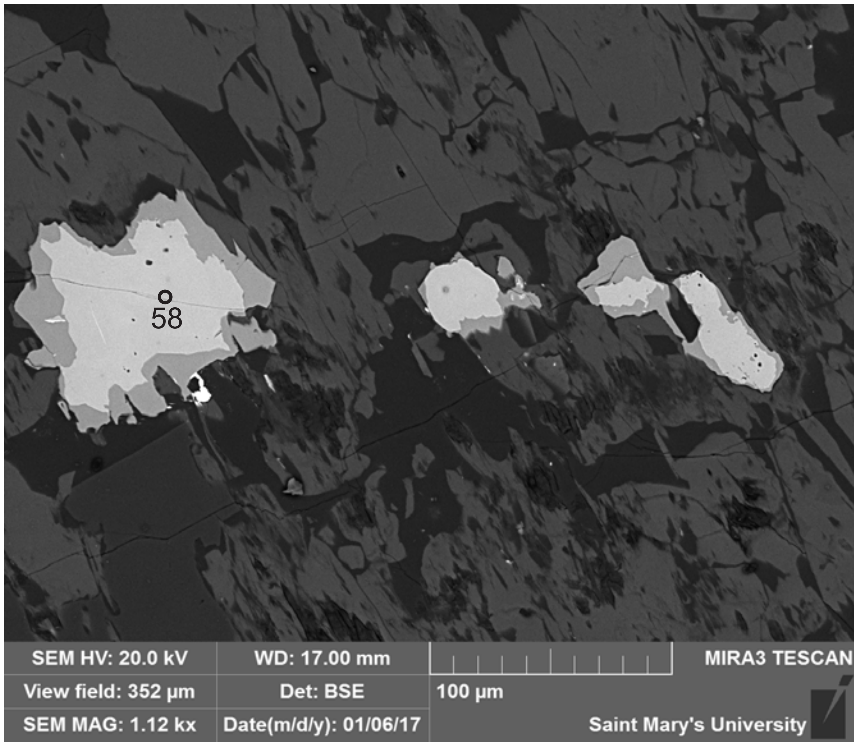



Figure 4.67: Sample 9956c. Location of laser ablation analysis 58 (rutile (Table 4-2.1)).

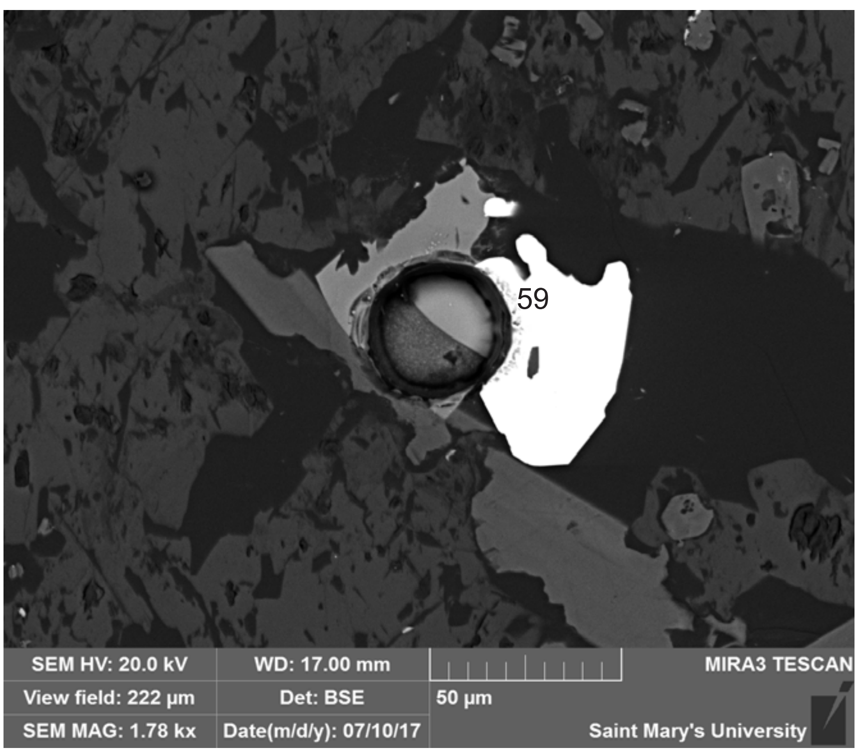



Figure 4.68: Sample 9956c. Location of laser ablation analysis 59 (titanite (Table 4-1.1)).

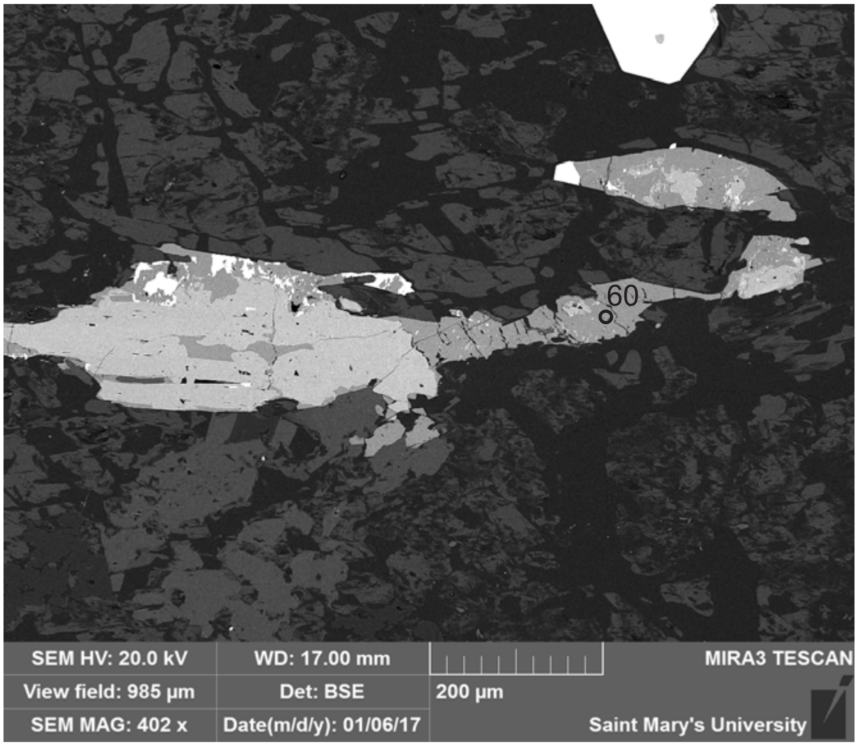



Figure 4.69: Sample 9956c. Location of laser ablation analysis 60 (titanite (Table 4-1.1)).

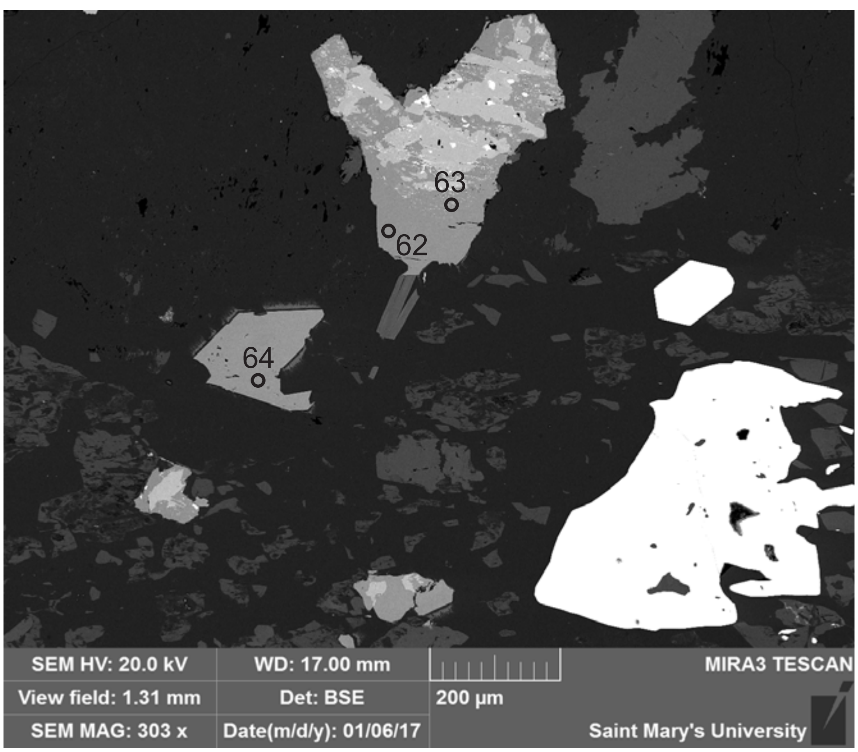



Figure 4.70: Sample 9956c. Location of laser ablation analyses 62-64 (titanite (Table 4-1.1)).

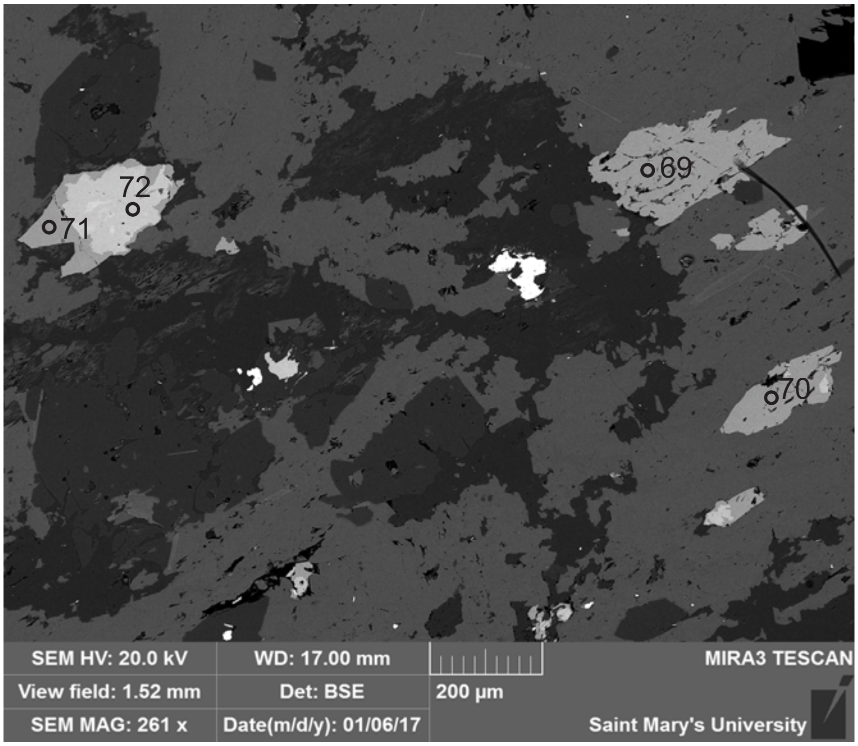



Figure 4.71: Sample 9956c. Location of laser ablation analyses (rutile 72 (Table 4-2.1)) (titanite 69-71 (Table 4-1.1)).

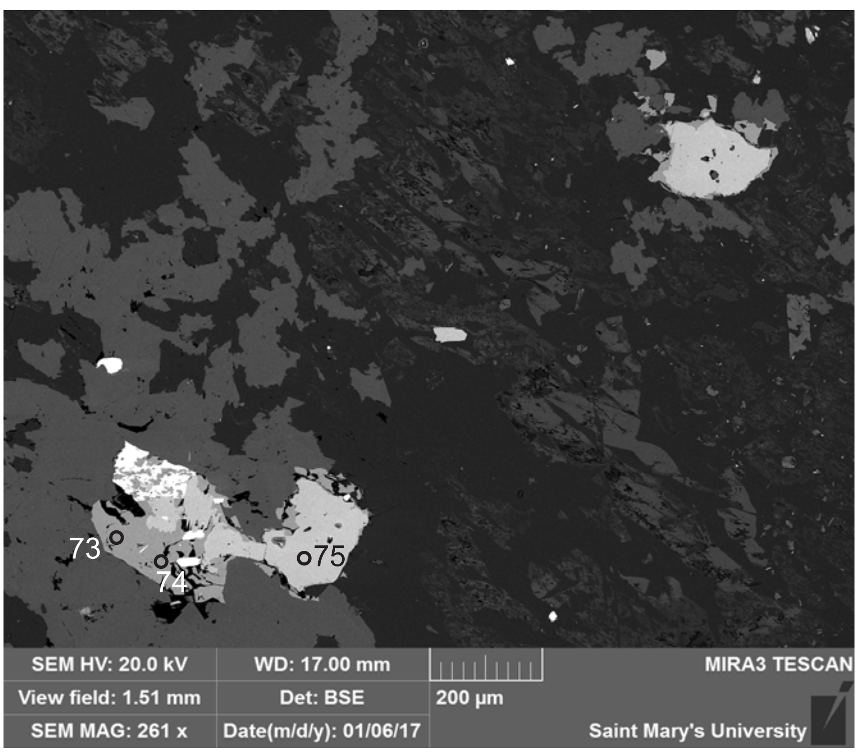



Figure 4.72: Sample 9956c. Location of laser ablation analyses (rutile 75 (Table 4-2.1)) (titanite 73-74 (Table 4-1.1)).

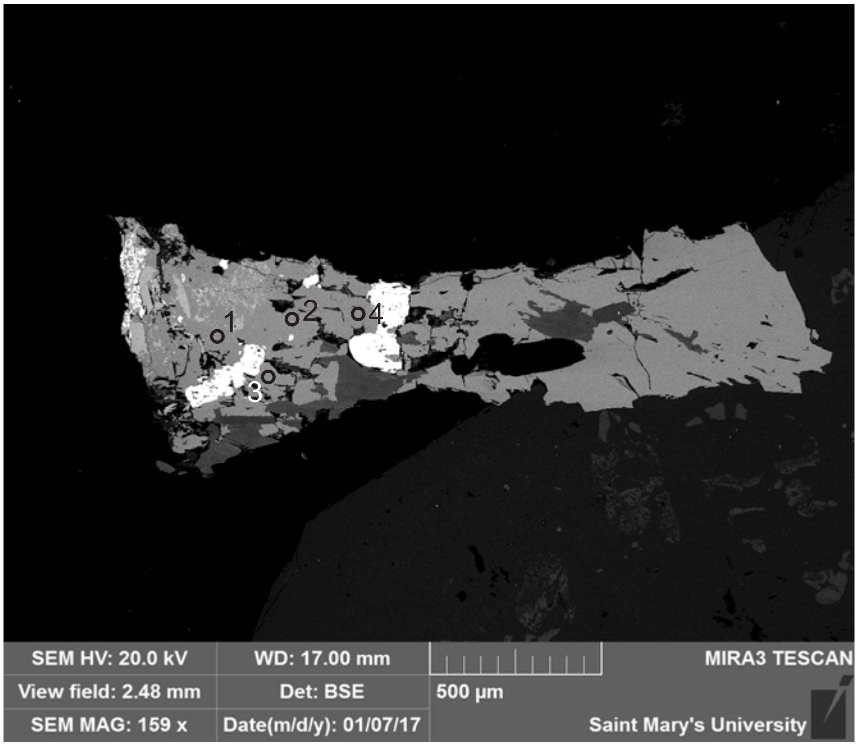



Figure 4.73: Sample 9956d. Location of laser ablation analyses 1-4 (titanite (Table 4-1.1)).

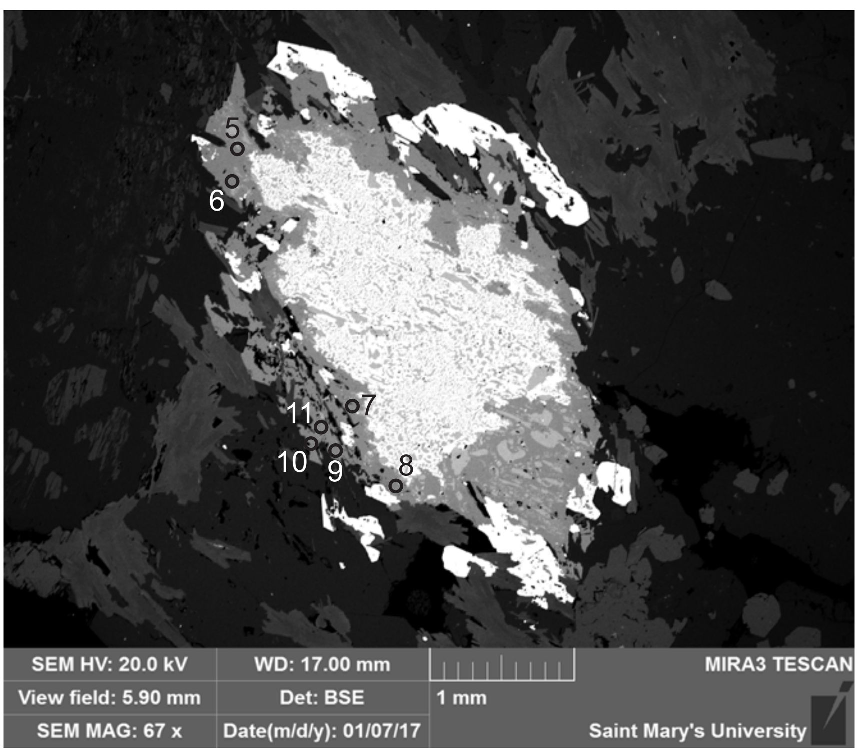



Figure 4.74: Sample 9956d. Location of laser ablation analyses 5-11 (titanite (Table 4-1.1)).

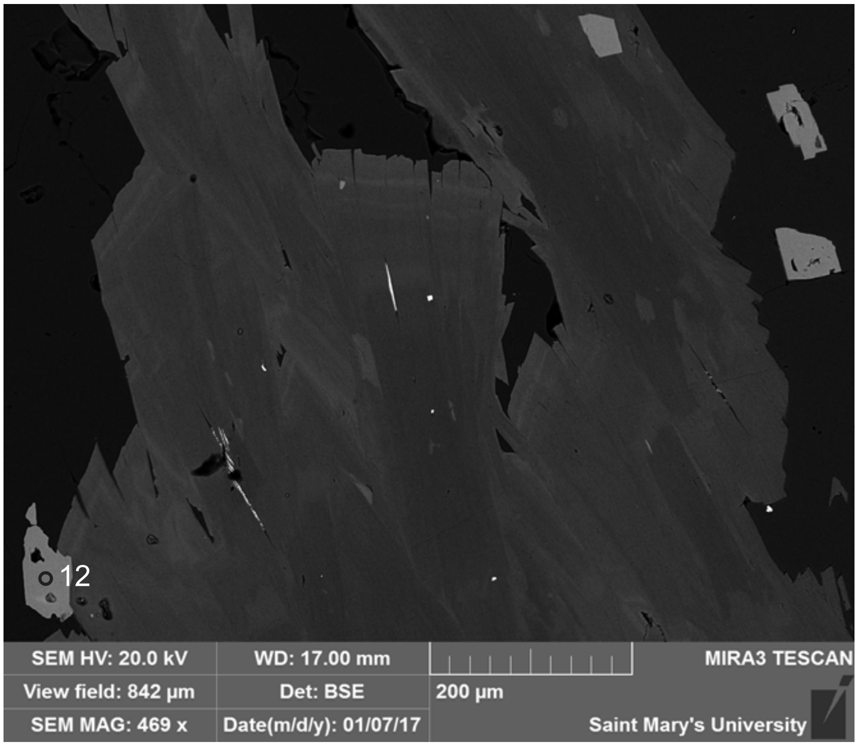



Figure 4.75: Sample 9956d. Location of laser ablation analysis 12 (titanite (Table 4-1.1)).

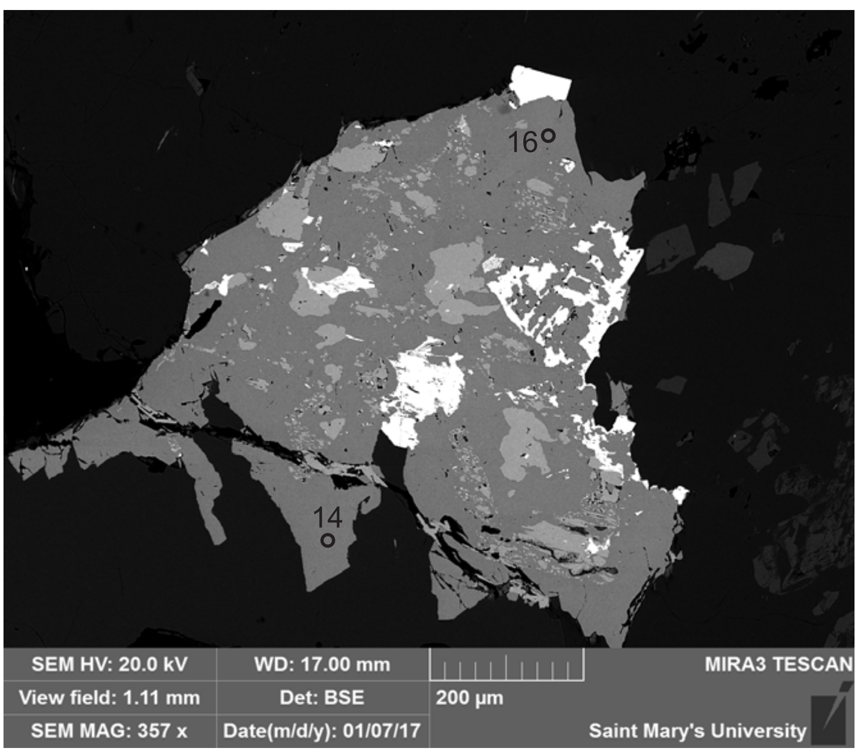



Figure 4.76: Sample 9956d. Location of laser ablation analyses 14, 16 (titanite (Table 4-1.1)).

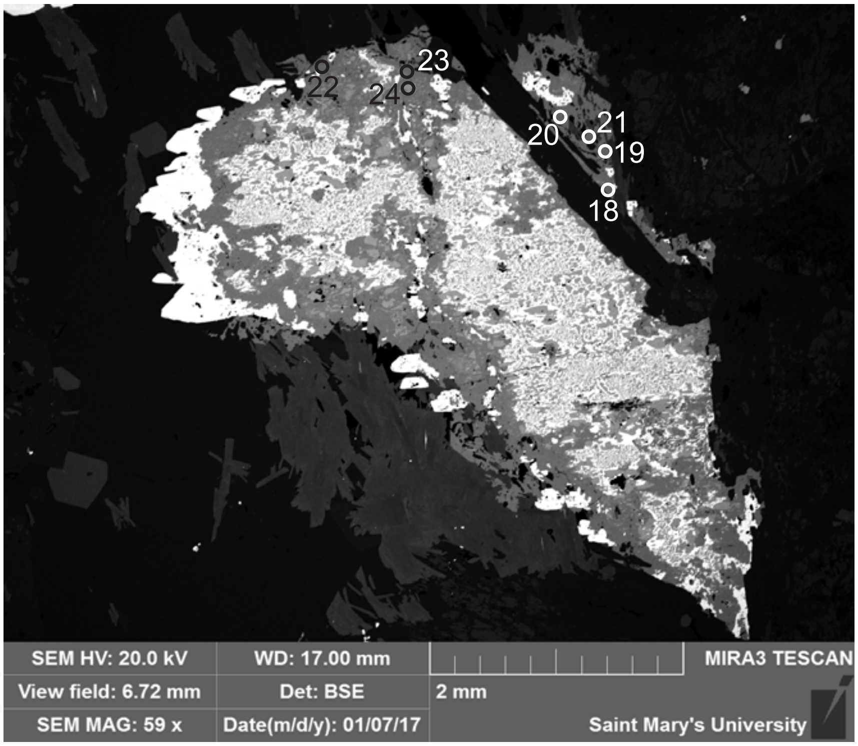



Figure 4.77: Sample 9956d. Location of laser ablation analyses 18-24 (titanite (Table 4-1.1)).

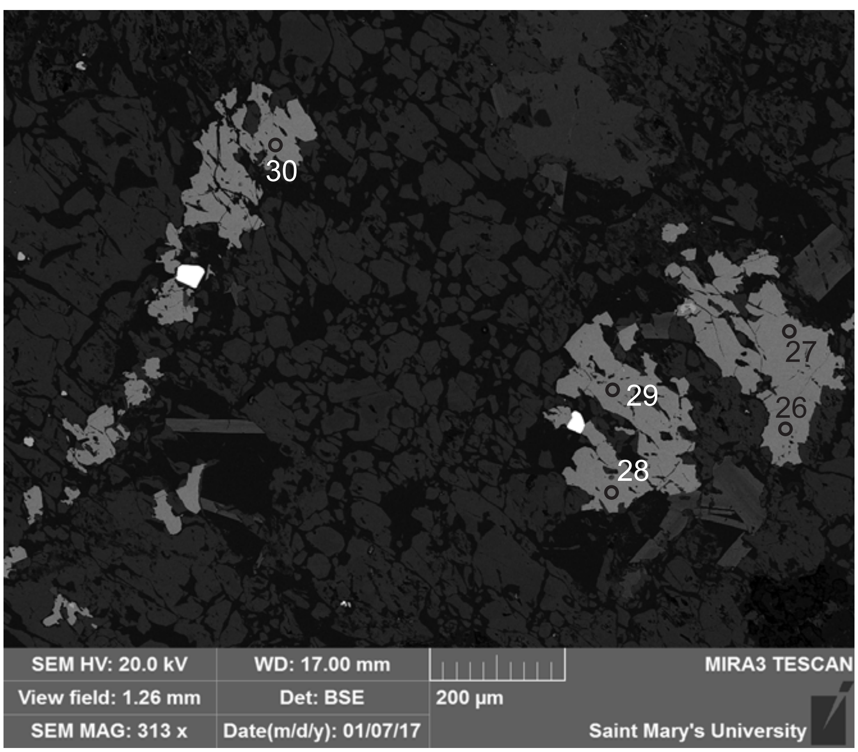



Figure 4.78: Sample 9956d. Location of laser ablation analyses 26-30 (titanite (Table 4-1.1)).

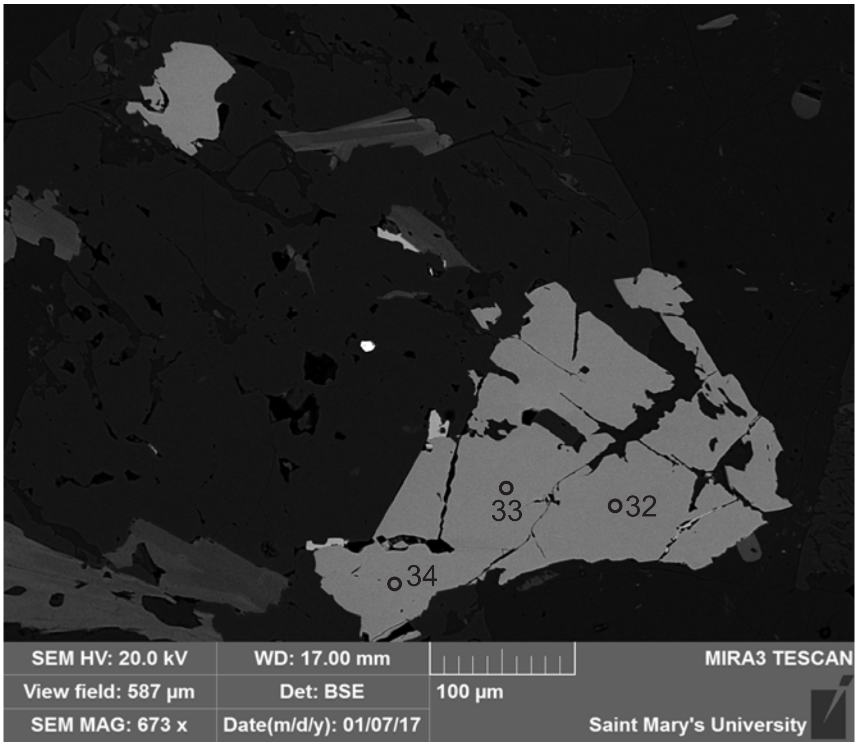



Figure 4.79: Sample 9956d. Location of laser ablation analyses 32-34 (titanite (Table 4-1.1)).

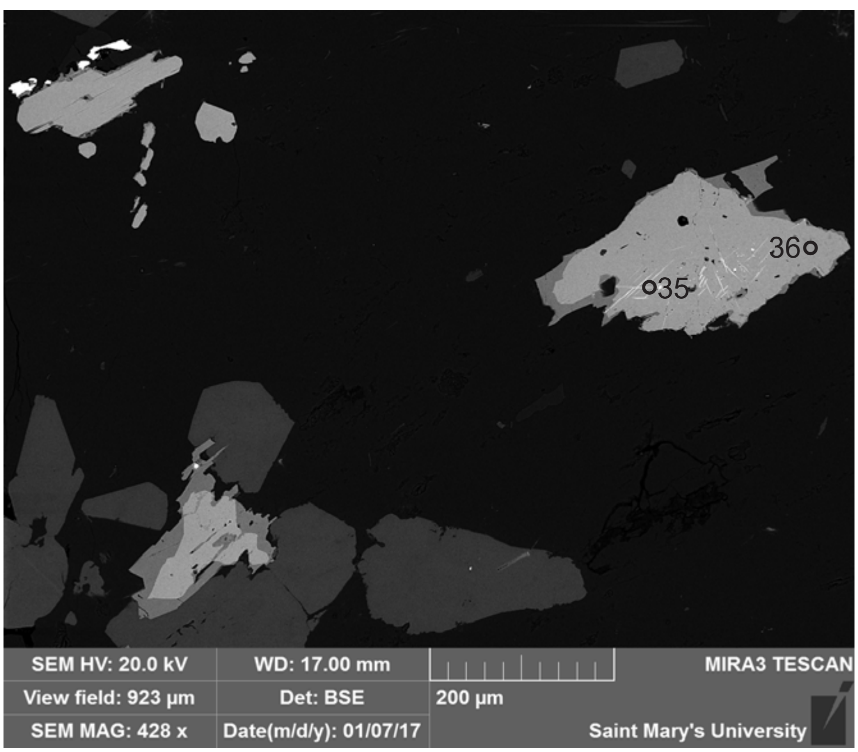



Figure 4.80: Sample 9956d. Location of laser ablation analyses 35-36 (rutile (Table 4-2.1)).

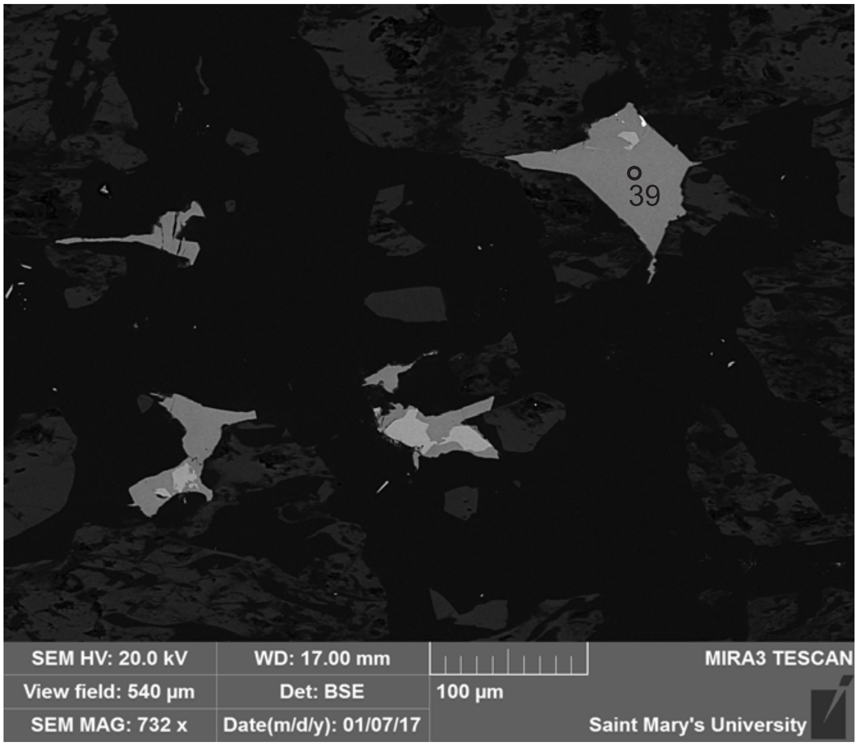



Figure 4.81: Sample 9956d. Location of laser ablation analysis 39 (titanite (Table 4-1.1)).

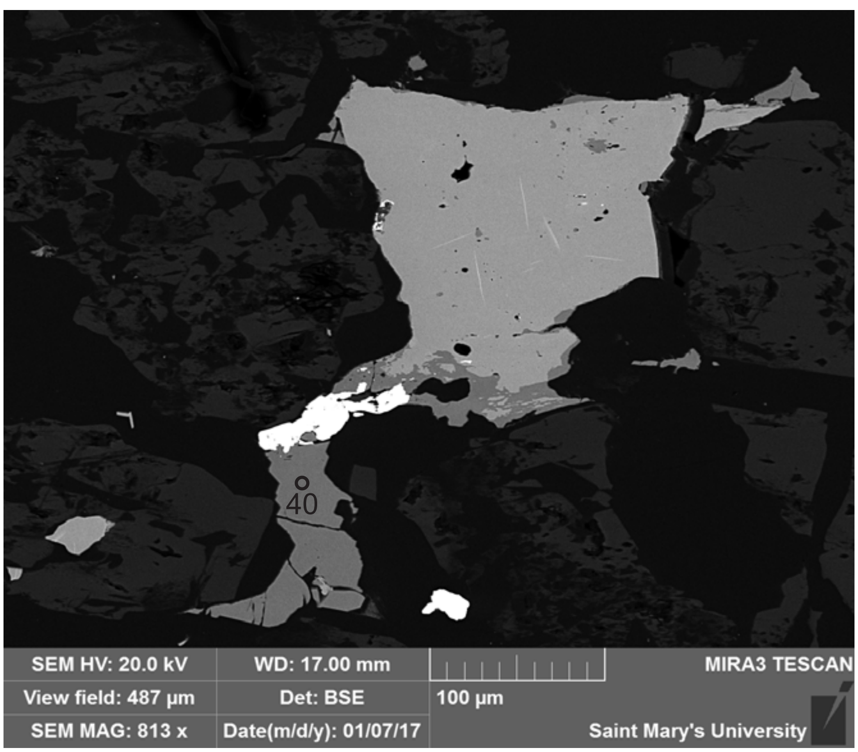



Figure 4.82: Sample 9956d. Location of laser ablation analysis 40 (titanite (Table 4-1.1)).

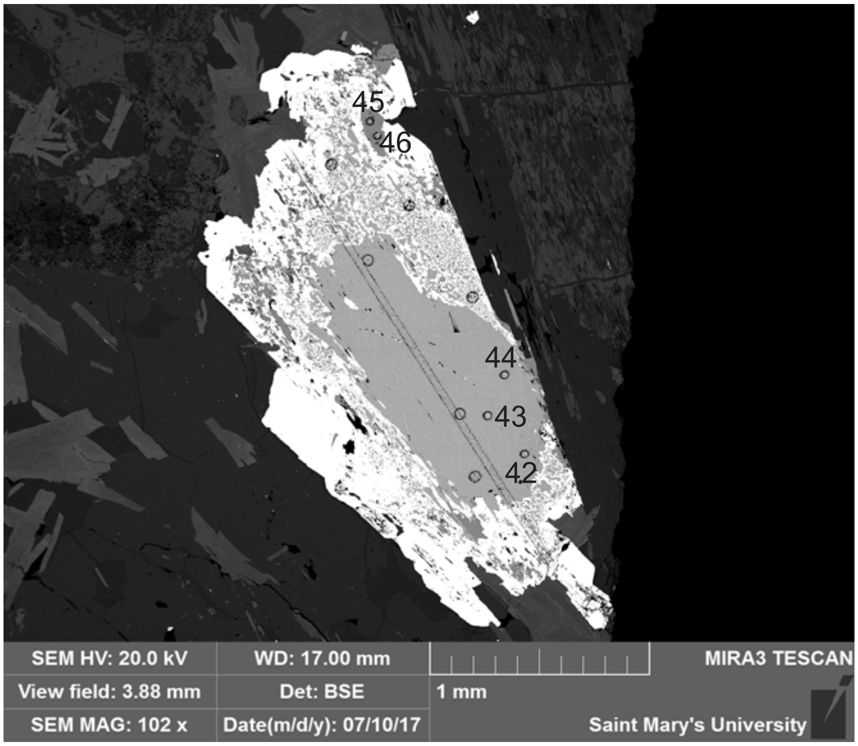



Figure 4.83: Sample 9956d. Location of laser ablation analyses (rutile 42-44 (Table 4-2.1)) (titanite 45-46 (Table 4-1.1)).

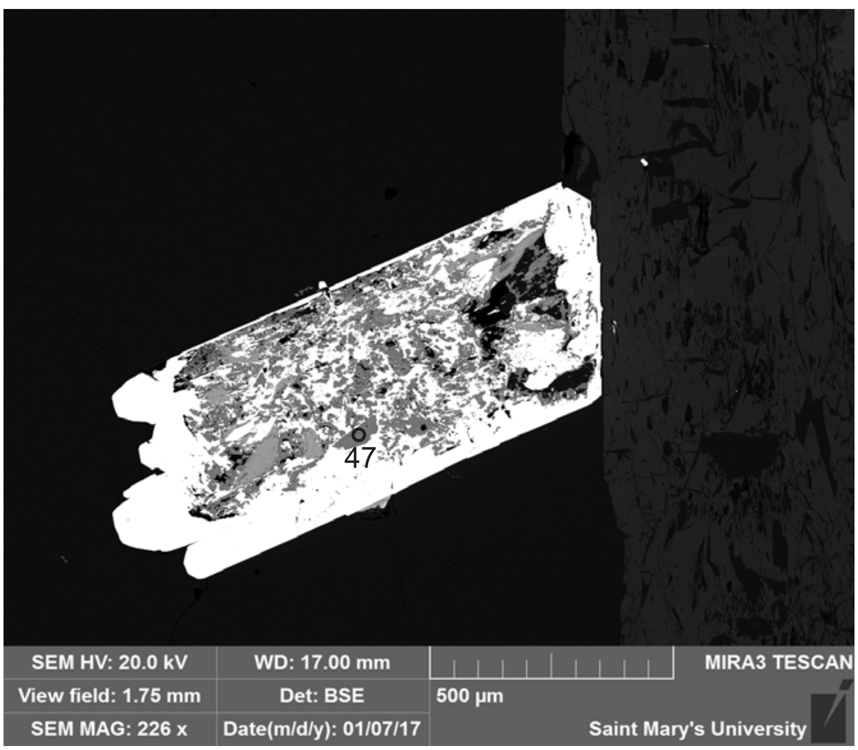



Figure 4.84: Sample 9956d. Location of laser ablation analysis 47 (titanite (Table 4-1.1)).

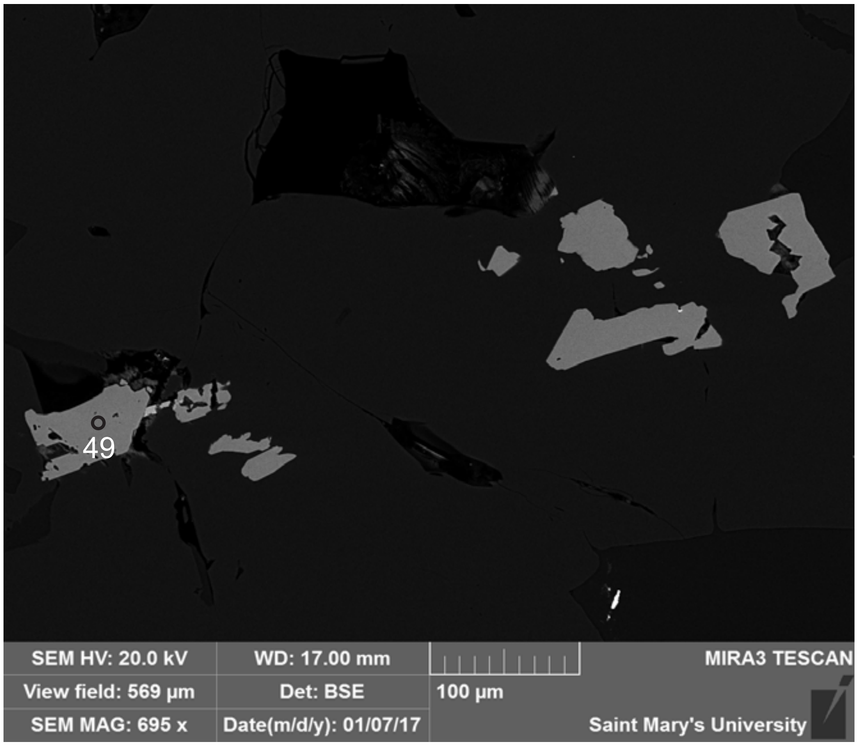



Figure 4.85: Sample 9956d. Location of laser ablation analysis 49 (titanite (Table 4-1.1)).

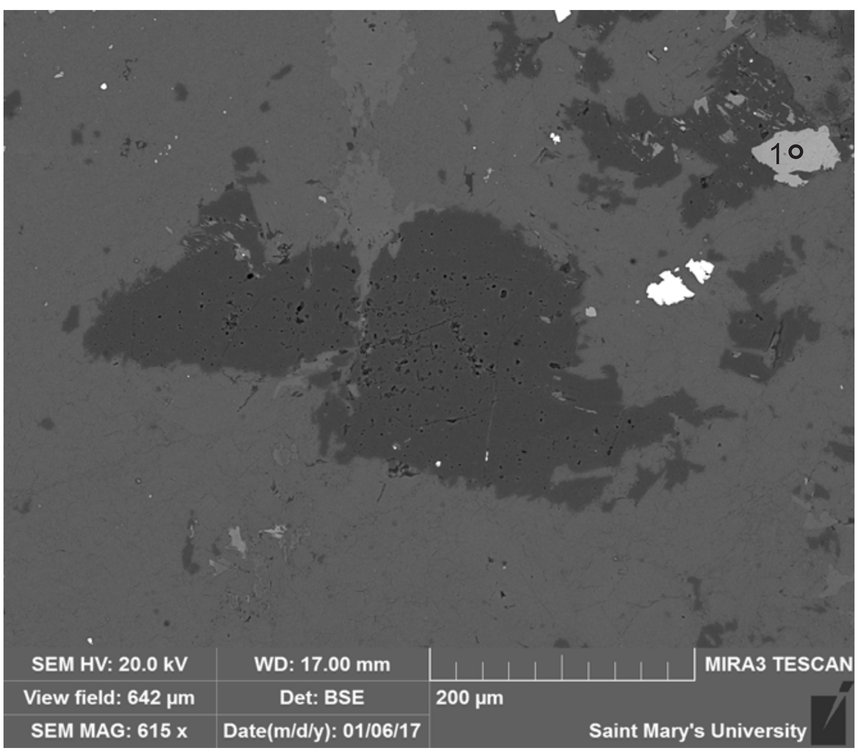



Figure 4.86: Sample 9957. Location of laser ablation analysis 1 (titanite (Table 4-1.1)).

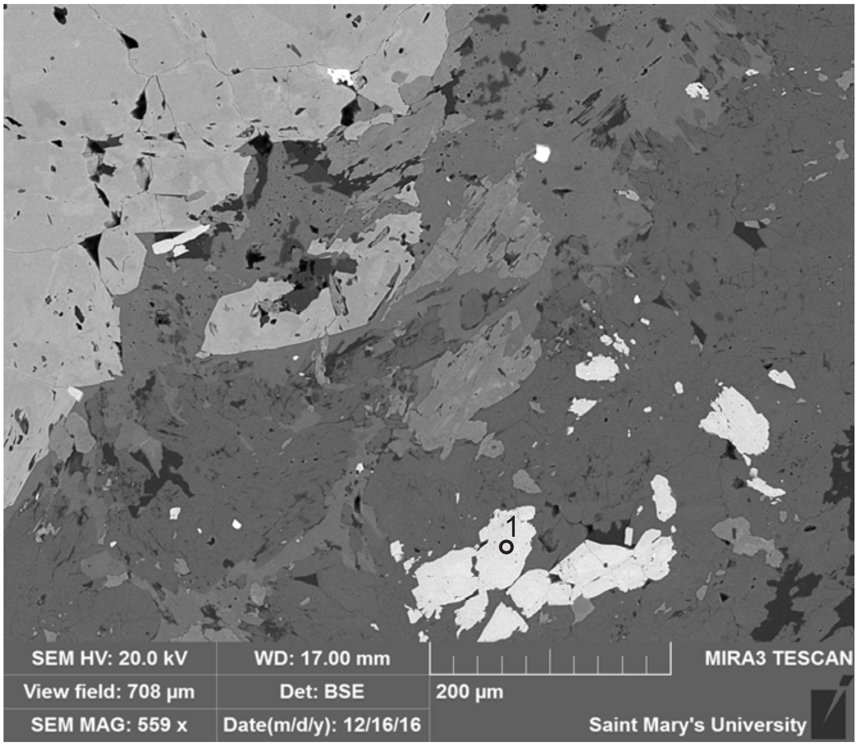



Figure 4.87: Sample 9958a. Location of laser ablation analysis 1 (titanite (Table 4-1.1)).

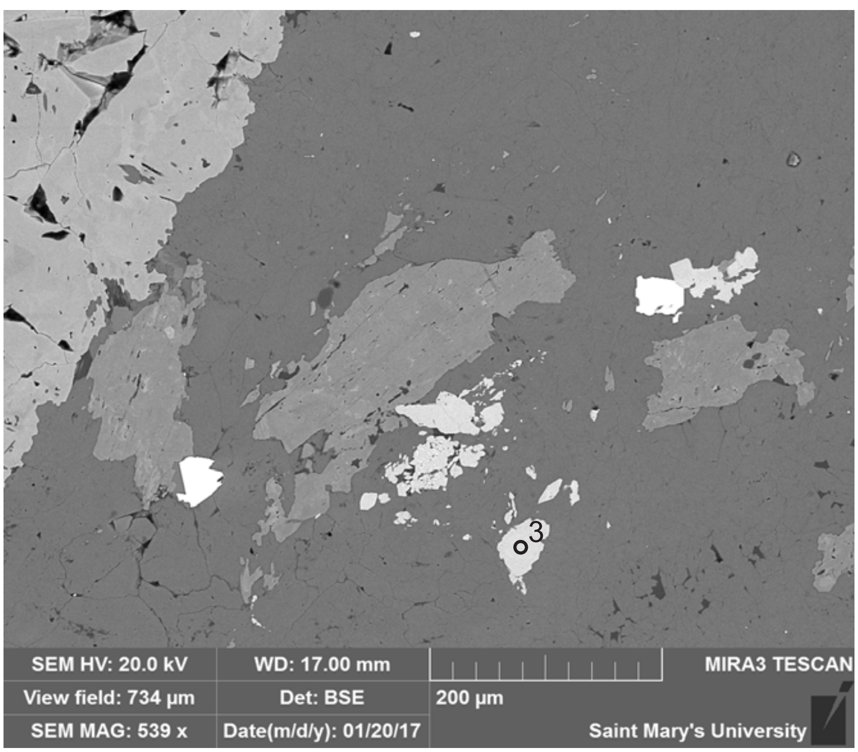



Figure 4.88: Sample 9958a. Location of laser ablation analysis 3 (titanite (Table 4-1.1)).

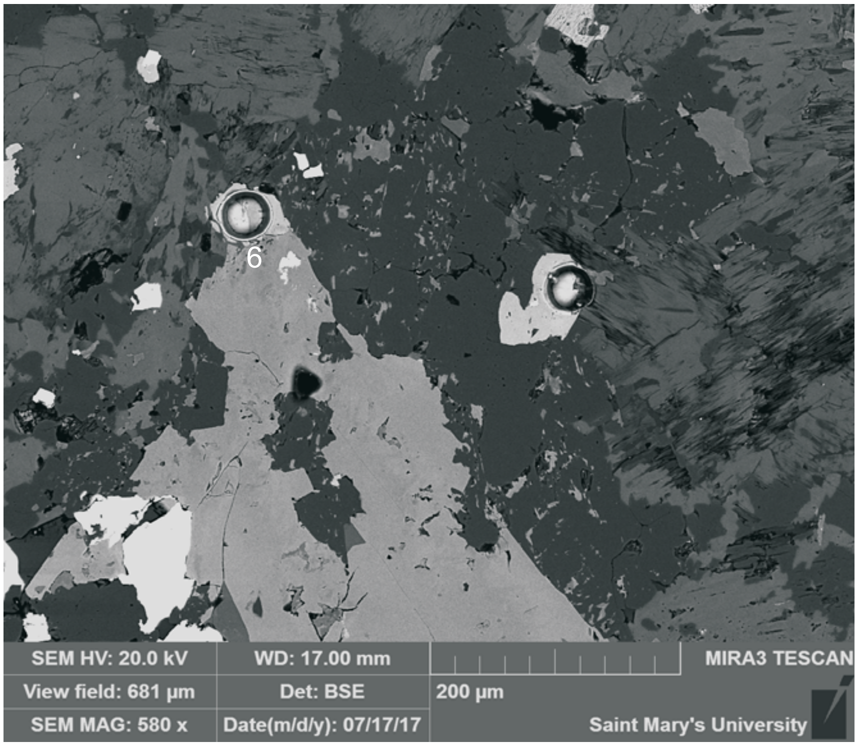



Figure 4.89: Sample 9958a. Location of laser ablation analysis 6 (titanite (Table 4-1.1)).

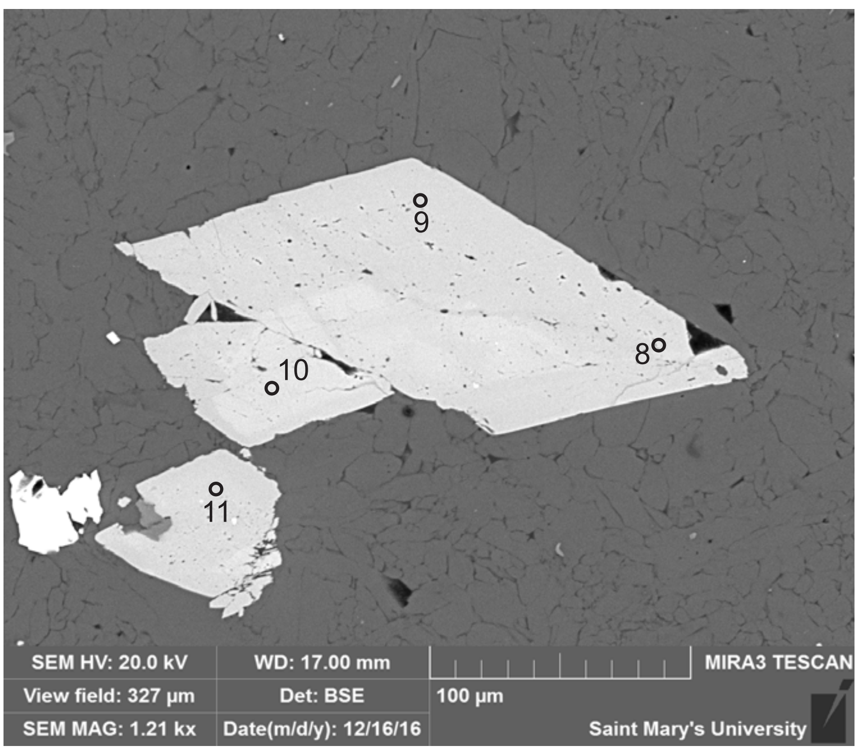



Figure 4.90: Sample 9958a. Location of laser ablation analyses 8-11 (titanite (Table 4-1.1)).

# Table 4-1.1: LA-ICP-MS trace element analyses for titanite.



| Sample | Position | Type | Ticps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9927(1) | 1 | 1 | 6370000 | 38.8 | 27.1 | 8.03 | 239.0 | 89.5 | 161.1 | 22.3 | 0.133 | 0.420 | 0.173 | 1.850 | 2.170 | 1.720 | 10.20 | 3.700 | 34.50 | 9.49 | 28.90 | 4.770 | 29.90 | 3.540 | 5.230 | 7.260 | 0.560 | 0.560 | 0.031 | 1.360 |
| 9927(1) | 2 | 1 | 6530000 | 35.2 | 29.4 | 99.00 | 402.0 | 74.1 | 196.0 | 20.7 | 2.440 | 5.400 | 0.640 | 3.700 | 4.300 | 3.330 | 19.20 | 6.380 | 60.50 | 15.30 | 48.10 | 7.230 | 48.10 | 6.750 | 3.620 | 7.880 | 1.100 | 0.386 | 0.137 | 3.370 |
| 9928a | 1 | 2 | 6910000 | 30.0 | 25.0 | 2.97 | 86.1 | 80.0 | 25.2 | 17.4 | 0.136 | 1.504 | 0.594 | 6.050 | 4.240 | 2.260 | 10.87 | 2.132 | 15.63 | 3.50 | 10.08 | 1.305 | 7.97 | 1.118 | 2.100 | 0.307 | | | 0.111 | 0.237 |
| 9928a | 2 | 2 | 7100000 | 29.6 | 24.8 | 8.28 | 108.7 | 16.0 | 81.8 | 13.5 | 0.082 | 1.085 | 0.489 | 5.090 | 5.440 | 2.200 | 12.81 | 2.820 | 19.86 | 4.41 | 11.48 | 1.490 | 8.66 | 1.051 | 1.200 | 15.900 | | 0.086 | 0.137 | 0.651 |
| 9928a | 3 | 2 | 7100000 | 29.1 | 24.5 | 3.73 | 91.4 | 23.8 | 27.0 | 12.0 | 0.229 | 2.360 | 0.920 | 8.680 | 5.850 | 2.730 | 11.80 | 2.558 | 17.69 | 3.82 | 10.02 | 1.280 | 7.62 | 0.970 | 0.469 | 0.318 | | 0.064 | 0.048 | 0.178 |
| 9928a | 4 | 2 | 7100000 | 29.2 | 24.6 | 3.78 | 137.8 | 8.3 | 66.3 | 14.9 | 0.137 | 2.022 | 0.906 | 8.910 | 7.720 | 3.380 | 17.42 | 3.890 | 26.90 | 5.69 | 14.30 | 1.965 | 11.43 | 1.347 | 0.690 | 1.900 | | 0.025 | 0.131 | 0.285 |
| 9928a | 5 | 2 | 6890000 | 29.6 | 24.9 | 3.07 | 68.3 | 46.4 | 28.6 | 18.0 | 0.094 | 1.250 | 0.554 | 4.610 | 3.690 | 1.610 | 8.70 | 1.775 | 12.11 | 2.79 | 7.83 | 1.040 | 6.24 | 0.853 | 0.793 | 0.229 | | | 0.040 | 0.085 |
| 9928a | 6 | 2 | 6620000 | 30.3 | 25.2 | 6.84 | 722.9 | 7.0 | 48.3 | 30.9 | 3.710 | 45.200 | 17.110 | 141.600 | 62.500 | 54.960 | 100.60 | 17.790 | 125.00 | 29.08 | 81.96 | 11.460 | 75.40 | 10.890 | 0.263 | 1.041 | 0.018 | 0.131 | 3.250 | 7.550 |
| 9928a | 7 | 1 | 5240000 | 34.3 | 26.7 | 28.24 | 525.1 | 27.6 | 961.0 | 27.3 | 0.208 | 0.536 | 0.168 | 1.930 | 4.720 | 0.904 | 20.25 | 7.620 | 74.80 | 20.25 | 64.90 | 10.220 | 70.10 | 8.590 | 2.710 | 54.500 | 6.310 | 0.512 | 1.943 | 2.760 |
| 9928a | 9 | 1 | 6700000 | 30.5 | 25.0 | 2.92 | 145.8 | 185.6 | 257.9 | 29.4 | 0.003 | 0.082 | 0.044 | 0.870 | 2.040 | 0.714 | 9.62 | 3.070 | 24.86 | 5.93 | 16.30 | 2.191 | 12.47 | 1.481 | 11.850 | 8.530 | | 0.120 | 0.047 | 0.051 |
| 9928a | 10 | 1 | 6360000 | 31.4 | 26.2 | 3.93 | 359.2 | 32.0 | 507.4 | 20.8 | 0.008 | 0.238 | 0.126 | 2.120 | 4.940 | 1.530 | 20.67 | 6.720 | 58.50 | 14.18 | 40.98 | 6.020 | 38.36 | 4.760 | 2.930 | 12.310 | 0.860 | 0.048 | 0.369 | 1.475 |
| 9928a | 11 | 1 | 5051000 | 32.2 | 27.0 | 5.52 | 438.8 | 63.1 | 119.1 | 44.9 | 0.016 | 0.648 | 0.328 | 4.320 | 8.680 | 3.520 | 32.58 | 9.160 | 72.60 | 17.39 | 49.70 | 6.990 | 46.40 | 6.430 | 1.990 | 1.781 | 3.580 | 0.051 | 1.814 | 8.230 |
| 9928a | 12 | 1 | 6590000 | 30.4 | 25.5 | 4.33 | 90.1 | 10.2 | 16.6 | 9.5 | 0.010 | 0.094 | 0.027 | 0.720 | 1.380 | 0.519 | 6.83 | 1.708 | 14.25 | 3.61 | 10.51 | 1.485 | 9.49 | 1.359 | 0.293 | 0.197 | 0.069 | 0.126 | 0.042 | 0.116 |
| 9928a | 13 | 3 | 6170000 | 31.3 | 26.4 | 4.25 | 354.7 | 55.8 | 69.1 | 37.0 | 1.631 | 16.800 | 6.090 | 50.400 | 25.510 | 17.920 | 45.35 | 8.940 | 64.90 | 14.66 | 40.37 | 5.680 | 36.49 | 5.180 | 2.460 | 3.138 | 0.059 | 0.029 | 1.251 | 5.690 |
| 9928a | 14 | 3 | 6430000 | 30.7 | 25.6 | 2.69 | 84.5 | 14.4 | 26.4 | 5.9 | 0.248 | 2.870 | 1.086 | 9.110 | 5.380 | 3.340 | 10.25 | 2.121 | 14.38 | 3.41 | 9.92 | 1.397 | 8.77 | 1.442 | 0.562 | 0.574 | 0.049 | | 0.087 | 0.926 |
| 9928a | 15 | 3 | 6690000 | 29.9 | 25.0 | 2.94 | 54.4 | 94.7 | 37.8 | 17.0 | 0.131 | 1.963 | 0.717 | 6.310 | 3.760 | 2.540 | 7.62 | 1.425 | 9.70 | 2.35 | 6.38 | 0.828 | 4.56 | 0.687 | 2.800 | 0.875 | | 0.076 | 0.008 | 0.028 |
| 9928a | 16 | 3 | 6810000 | 29.5 | 24.9 | 2.97 | 74.4 | 114.5 | 37.2 | 19.0 | 0.270 | 3.060 | 1.199 | 10.280 | 5.220 | 3.810 | 10.38 | 1.955 | 13.82 | 3.15 | 8.42 | 1.108 | 6.60 | 0.929 | 2.990 | 0.958 | | 0.009 | 0.050 | 0.096 |
| 9928a | 17 | 3 | 6230000 | 31.6 | 26.1 | 5.10 | 248.2 | 35.5 | 73.2 | 25.3 | 1.233 | 12.710 | 4.490 | 36.030 | 18.980 | 11.060 | 33.38 | 6.540 | 46.45 | 10.41 | 27.73 | 4.130 | 25.49 | 3.737 | 1.480 | 3.110 | 0.188 | 0.070 | 0.777 | 4.790 |
| 9928a | 18 | 3 | 6830000 | 29.7 | 24.8 | 3.01 | 56.2 | 90.5 | 29.8 | 16.8 | 0.124 | 1.763 | 0.722 | 6.770 | 4.430 | 2.750 | 8.28 | 1.481 | 10.34 | 2.46 | 6.43 | 0.841 | 5.01 | 0.690 | 2.980 | 1.065 | 0.003 | 0.012 | 0.032 | 0.065 |
| 9928a | 19 | 3 | 6100000 | 31.5 | 26.5 | 4.48 | 275.7 | 30.5 | 55.2 | 33.8 | 1.518 | 15.750 | 5.500 | 44.700 | 21.640 | 13.660 | 38.18 | 7.320 | 50.73 | 11.42 | 32.20 | 4.410 | 28.12 | 4.050 | 0.873 | 1.512 | 0.074 | 0.067 | 1.670 | 5.960 |
| 9928a | 20 | 3 | 6150000 | 31.4 | 26.5 | 4.07 | 306.6 | 31.2 | 45.6 | 21.6 | 1.356 | 15.310 | 5.580 | 45.500 | 22.330 | 15.240 | 39.00 | 7.610 | 54.40 | 12.70 | 36.92 | 5.010 | 34.39 | 4.930 | 1.180 | 1.421 | 0.076 | 0.114 | 1.288 | 3.560 |
| 9928a | 21 | 10 | 6710000 | 30.3 | 25.1 | 3.62 | 51.3 | 14.0 | 1.7 | 7.1 | 0.138 | 1.803 | 0.699 | 6.740 | 3.510 | 2.280 | 7.11 | 1.314 | 9.34 | 2.20 | 6.07 | 0.789 | 4.67 | 0.650 | 0.650 | 0.069 | 0.008 | 0.060 | 0.014 | 0.027 |
| 9928a | 22 | 10 | 6280000 | 30.9 | 26.0 | 3.15 | 134.6 | 13.5 | 23.1 | 6.2 | 0.406 | 4.370 | 1.695 | 13.750 | 7.260 | 4.980 | 15.35 | 3.010 | 22.03 | 5.54 | 16.61 | 2.284 | 16.15 | 2.657 | 0.487 | 0.564 | 0.097 | 0.034 | 0.158 | 1.766 |
| 9928a | 23 | 10 | 6710000 | 29.9 | 24.8 | 2.88 | 58.0 | 60.7 | 18.3 | 15.6 | 0.184 | 2.121 | 0.731 | 7.050 | 3.890 | 2.540 | 7.59 | 1.491 | 10.45 | 2.46 | 7.03 | 0.823 | 5.32 | 0.816 | 1.380 | 0.489 | | 0.600 | 0.032 | 0.037 |
| 9928a | 24 | 10 | 6120000 | 31.6 | 26.5 | 4.73 | 259.4 | 28.4 | 42.3 | 33.3 | 0.954 | 10.820 | 3.770 | 33.100 | 18.660 | 10.100 | 33.00 | 6.580 | 46.56 | 10.46 | 29.88 | 4.040 | 27.73 | 3.810 | 0.866 | 0.993 | 0.070 | 0.235 | 1.088 | 4.780 |
| 9928a | 25 | 10 | 6830000 | 30.2 | 25.2 | 3.15 | 57.5 | 63.1 | 12.5 | 13.8 | 0.144 | 1.890 | 0.710 | 7.030 | 3.790 | 2.520 | 7.97 | 1.553 | 10.52 | 2.44 | 6.55 | 0.882 | 5.50 | 0.755 | 1.860 | 0.189 | | 0.035 | 0.019 | 0.037 |
| 9928a | 26 | 10 | 6150000 | 31.8 | 26.6 | 4.33 | 238.1 | 28.6 | 48.0 | 31.7 | 0.894 | 9.280 | 3.252 | 27.950 | 15.280 | 7.840 | 29.50 | 6.110 | 42.91 | 9.64 | 26.85 | 3.860 | 25.08 | 3.500 | 0.906 | 1.414 | 0.136 | 0.042 | 0.969 | 4.770 |
| 9928a | 27 | 10 | 6660000 | 30.3 | 25.4 | 3.92 | 49.0 | 13.3 | 3.0 | 7.4 | 0.095 | 1.190 | 0.476 | 4.640 | 2.750 | 1.447 | 5.81 | 1.166 | 8.20 | 2.06 | 5.67 | 0.797 | 4.76 | 0.718 | 0.520 | 0.126 | 0.005 | 0.044 | 0.014 | 0.031 |
| 9928a | 28 | 3 | 6190000 | 31.5 | 26.4 | 4.13 | 295.8 | 45.4 | 153.7 | 31.7 | 0.180 | 2.240 | 0.982 | 10.110 | 11.480 | 5.270 | 28.33 | 6.770 | 50.90 | 11.67 | 32.73 | 4.740 | 30.53 | 3.900 | 2.500 | 5.640 | 0.550 | 0.042 | 0.922 | 5.230 |
| 9928a | 29 | 3 | 6060000 | 31.9 | 26.7 | 3.39 | 183.3 | 7.3 | 39.8 | 6.6 | 0.063 | 0.914 | 0.413 | 4.220 | 5.370 | 2.590 | 15.50 | 3.790 | 29.46 | 7.22 | 22.21 | 3.350 | 22.87 | 3.460 | 0.219 | 0.845 | 0.165 | 0.063 | 0.396 | 0.946 |
| 9928a | 30 | 3 | 6190000 | 31.6 | 26.5 | 5.83 | 219.7 | 28.3 | 115.5 | 14.7 | 0.195 | 1.990 | 0.754 | 8.180 | 7.690 | 3.860 | 20.07 | 4.850 | 37.42 | 8.96 | 24.99 | 3.586 | 23.73 | 3.230 | 1.064 | 1.820 | 0.854 | 0.080 | 0.818 | 5.870 |
| 9928a | 32 | 3 | 6110000 | 31.5 | 26.5 | 4.34 | 254.4 | 34.8 | 100.8 | 35.0 | 0.161 | 2.051 | 0.862 | 9.500 | 10.380 | 4.490 | 24.60 | 6.060 | 45.10 | 10.24 | 28.80 | 3.900 | 25.99 | 3.380 | 1.141 | 1.268 | 0.179 | 0.057 | 1.720 | 5.080 |
| 9928a | 33 | 3 | 6750000 | 29.7 | 25.0 | 3.23 | 92.6 | 113.5 | 79.0 | 20.1 | 0.033 | 0.474 | 0.274 | 2.640 | 3.440 | 1.580 | 9.63 | 2.245 | 17.02 | 3.77 | 10.23 | 1.337 | 7.65 | 0.976 | 3.530 | 2.857 | 0.007 | 0.015 | 0.124 | 0.183 |
| 9928a | 34 | 6 | 6910000 | 29.6 | 26.0 | 3.44 | 358.9 | 42.6 | 661.4 | 17.2 | 0.029 | 0.466 | 0.239 | 3.040 | 6.600 | 2.570 | 23.94 | 7.030 | 59.90 | 14.26 | 40.70 | 5.690 | 37.50 | 4.800 | 4.360 | 11.060 | 1.720 | 0.020 | 0.597 | 2.920 |
| 9928a | 35 | 6 | 7440000 | 28.5 | 26.0 | 4.75 | 495.0 | 63.4 | 329.0 | 16.5 | 0.865 | 10.040 | 3.510 | 27.800 | 17.000 | 9.930 | 42.30 | 10.480 | 82.20 | 19.80 | 57.00 | 8.370 | 53.20 | 6.680 | 4.940 | 12.540 | 0.193 | 0.370 | 2.310 | 2.050 |
| 9928a | 36 | 3 | 6020000 | 31.6 | 26.3 | 5.93 | 442.2 | 24.1 | 186.1 | 30.4 | 0.188 | 2.820 | 1.219 | 10.200 | 11.120 | 5.180 | 34.40 | 9.340 | 75.10 | 17.66 | 49.52 | 7.000 | 44.48 | 5.550 | 1.490 | 5.840 | 0.465 | 0.084 | 1.355 | 3.680 |
| 9928a | 37 | 3 | 6090000 | 30.6 | 25.2 | 5.47 | 235.3 | 22.6 | 125.3 | 14.6 | 0.101 | 0.830 | 0.259 | 2.750 | 4.270 | 1.800 | 15.09 | 4.410 | 37.30 | 8.83 | 27.30 | 4.040 | 27.10 | 3.760 | 1.030 | 4.190 | 1.210 | 2.500 | 0.500 | 2.910 |
| 9928a | 38 | 3 | 5880000 | 32.1 | 26.6 | 7.21 | 407.9 | 6.0 | 83.1 | 20.7 | 0.040 | 0.734 | 0.382 | 4.860 | 9.200 | 3.670 | 29.10 | 7.910 | 64.70 | 16.27 | 47.43 | 7.090 | 45.79 | 6.470 | 0.332 | 1.980 | 1.810 | 0.149 | 2.404 | 5.280 |
| 9928a | 39 | 3 | 6660000 | 29.6 | 24.9 | 3.84 | 156.4 | 8.2 | 121.8 | 13.2 | 0.025 | 0.297 | 0.160 | 2.320 | 4.810 | 1.810 | 15.02 | 3.970 | 29.33 | 6.25 | 16.98 | 2.201 | 12.70 | 1.354 | 0.695 | 3.470 | 0.011 | | 0.102 | 0.213 |
| 9928a | 40 | 3 | 5420000 | 35.9 | 25.7 | 4.02 | 225.5 | 7.1 | 119.1 | 14.8 | 0.034 | 0.359 | 0.120 | 1.760 | 3.760 | 1.700 | 14.92 | 4.390 | 36.28 | 8.76 | 26.28 | 3.860 | 24.24 | 3.380 | 0.379 | 2.220 | 0.366 | 0.396 | 0.380 | 0.990 |
| 9928a | 41 | 3 | 5527000 | 30.8 | 25.8 | 3.93 | 2.3 | 18.2 | 1978.0 | 12.8 | 0.525 | 1.651 | 0.174 | 0.710 | 0.168 | 0.110 | 0.25 | 0.047 | 0.36 | 0.08 | 0.31 | 0.049 | 0.27 | 0.043 | 1.590 | 96.300 | 5.370 | 0.202 | 0.652 | 2.800 |
| 9928a | 42 | 1 | 6090000 | 31.2 | 25.8 | 2.41 | 252.4 | 5.4 | 31.5 | 4.9 | 0.087 | 1.280 | 0.550 | 5.220 | 4.810 | 3.370 | 16.22 | 4.460 | 37.92 | 9.94 | 30.70 | 4.690 | 30.62 | 4.270 | 0.294 | 8.160 | | | 0.189 | 0.203 |
| 9928a | 43 | 1 | 6620000 | 29.9 | 25.0 | 3.44 | 157.6 | 263.9 | 302.6 | 28.5 | 0.025 | 0.298 | 0.167 | 2.130 | 3.920 | 1.560 | 14.22 | 3.565 | 27.55 | 6.24 | 16.67 | 2.280 | 13.08 | 1.565 | 19.630 | 17.630 | 0.017 | | 0.168 | 0.202 |
| 9928a | 44 | 1 | 6000000 | 33.3 | 25.8 | 12.50 | 228.1 | 131.0 | 144.5 | 24.6 | 0.057 | 0.756 | 0.284 | 3.580 | 6.620 | 2.890 | 20.85 | 5.090 | 39.20 | 8.96 | 24.34 | 3.360 | 20.87 | 2.330 | 4.120 | 29.140 | 0.027 | 0.016 | 0.531 | 2.880 |
| 9928a | 45 | 1 | 6180000 | 31.2 | 25.8 | 3.13 | 257.7 | 23.6 | 209.1 | 11.0 | 0.040 | 0.483 | 0.263 | 3.160 | 5.680 | 2.640 | 18.72 | 4.910 | 41.84 | 10.21 | 30.50 | 4.420 | 28.93 | 3.873 | 1.260 | 16.830 | 0.930 | 0.012 | 0.448 | 3.870 |
| 9928a | 46 | 1 | 5850000 | 32.1 | 26.5 | 2.74 | 285.3 | 19.9 | 282.1 | 9.4 | 0.001 | 0.097 | 0.054 | 0.770 | 2.400 | 0.537 | 11.20 | 3.950 | 39.23 | 11.03 | 36.48 | 5.830 | 38.51 | 5.260 | 2.130 | 8.430 | 0.890 | | 0.162 | 0.493 |
| 9928a | 47 | 1 | 5910000 | 32.0 | 26.6 | 4.15 | 316.7 | 54.9 | 113.0 | 31.4 | 0.198 | 2.790 | 1.178 | 12.390 | 12.530 | 5.540 | 30.03 | 7.400 | 55.79 | 12.42 | 35.38 | 5.190 | 33.70 | 4.330 | 3.140 | 32.420 | 0.385 | 0.023 | 1.633 | 4.630 |
| 9928a | 48 | 1 | 6140000 | 31.4 | 26.0 | 9.49 | 453.0 | 87.4 | 272.0 | 33.9 | 0.221 | 2.710 | 1.186 | 11.900 | 12.030 | 5.480 | 35.30 | 9.290 | 76.80 | 17.60 | 50.80 | 7.220 | 47.30 | 5.640 | 6.330 | 33.100 | 0.271 | 0.212 | 1.027 | 2.540 |
| 9928a | 50 | 4 | 5770000 | 32.3 | 24.3 | 15.80 | 264.0 | 21.8 | 536.0 | 22.3 | 0.126 | 0.470 | 0.129 | 1.230 | 2.760 | 0.687 | 11.91 | 4.290 | 39.50 | 10.55 | 32.40 | 4.720 | 29.30 | 3.780 | 1.340 | 32.300 | 0.486 | 0.410 | 0.430 | 0.725 |
| 9928b | 1 | 6 | 6680000 | 33.6 | 27.2 | 4.05 | 311.1 | 33.6 | 93.8 | 19.2 | 0.023 | 0.436 | 0.186 | 3.170 | 6.200 | 2.350 | 20.39 | 5.740 | 47.90 | 11.98 | 37.08 | 5.550 | 37.00 | 5.680 | 1.360 | 7.660 | 2.920 | 0.128 | 0.804 | 3.280 |
| 9928b | 2 | 6 | 6960000 | 32.9 | 26.2 | 3.70 | 150.8 | 48.9 | 63.4 | 14.9 | 0.031 | 0.342 | 0.154 | 1.770 | 2.940 | 1.210 | 10.58 | 3.110 | 25.20 | 6.05 | 17.55 | 2.470 | 15.18 | 2.012 | 1.050 | 2.642 | 0.280 | 0.118 | 0.174 | 0.620 |
| 9928b | 3 | 6 | 6950000 | 32.4 | 26.5 | 3.74 | 137.1 | 18.1 | 45.7 | 12.9 | 0.004 | 0.132 | 0.062 | 0.950 | 2.320 | 0.990 | 8.97 | 2.675 | 22.53 | 5.55 | 15.62 | 2.265 | 13.88 | 1.814 | 0.798 | 2.980 | 0.087 | 0.021 | 0.206 | 0.593 |
| 9928b | 4 | 6 | 7210000 | 31.4 | 25.9 | 3.33 | 126.1 | 96.5 | 123.3 | 20.1 | 0.007 | 0.089 | 0.037 | 0.730 | 1.580 | 0.523 | 7.67 | 2.389 | 20.63 | 5.11 | 14.19 | 1.988 | 11.13 | 1.330 | 8.010 | 9.030 | 0.018 | 0.068 | 0.039 | 0.061 |
| 9928b | 5 | 6 | 7170000 | 31.7 | 25.8 | 3.60 | 71.9 | 16.1 | 26.6 | 9.0 | 0.002 | 0.078 | 0.040 | 0.670 | 1.470 | 0.503 | 5.77 | 1.563 | 11.99 | 2.80 | 8.30 | 1.078 | 7.07 | 0.897 | 0.685 | 2.863 | 0.006 | 0.105 | 0.010 | 0.026 |
| 9928b | 6 | 6 | 7100000 | 31.3 | 25.8 | 4.26 | 94.3 | 20.6 | 25.4 | 14.2 | 0.014 | 0.211 | 0.091 | 1.360 | 2.310 | 0.968 | 8.09 | 1.970 | 15.40 | 3.77 | 10.35 | 1.414 | 8.77 | 1.160 | 0.640 | 1.610 | 0.002 | 0.280 | 0.070 | 0.124 |
| 9928b | 7 | 6 | 6350000 | 33.6 | 27.6 | 3.86 | 460.7 | 45.4 | 94.3 | 44.1 | 0.044 | 0.515 | 0.296 | 4.020 | 7.910 | 3.350 | 31.80 | 9.280 | 76.30 | 17.96 | 52.70 | 7.800 | 50.76 | 6.510 | 1.290 | 6.970 | 1.050 | 0.046 | 1.376 | 5.970 |
| 9928b | 8 | 6 | 6860000 | 32.1 | 26.3 | 5.21 | 228.7 | 22.1 | 109.4 | 18.7 | 0.041 | 0.538 | 0.286 | 3.770 | 5.630 | 2.130 | 18.65 | 4.810 | 38.11 | 9.05 | 25.89 | 3.720 | 24.16 | 3.180 | 0.876 | 4.326 | 9.300 | 0.041 | 0.600 | 6.870 |
| 9928b | 9 | 6 | 6430000 | 33.2 | 27.4 | 6.31 | 354.7 | 9.7 | 45.1 | 14.0 | 0.048 | 0.529 | 0.266 | 3.580 | 6.750 | 2.590 | 23.75 | 6.390 | 54.00 | 13.80 | 42.45 | 6.430 | 43.95 | 6.780 | 0.457 | 3.780 | 3.190 | 0.154 | 1.269 | 2.960 |
| 9928b | 10 | 6 | 7180000 | 31.5 | 25.5 | 2.62 | 120.2 | 72.7 | 69.7 | 20.9 | 0.004 | 0.096 | 0.058 | 0.880 | 1.980 | 0.852 | 7.89 | 2.307 | 19.90 | 4.93 | 13.93 | 1.889 | 11.34 | 1.459 | 1.890 | 2.040 | | 0.007 | 0.040 | 0.098 |
| 9928b | 11 | 6 | 6390000 | 34.6 | 27.2 | 9.50 | 477.1 | 55.6 | 159.4 | 43.2 | 0.058 | 0.722 | 0.391 | 4.660 | 9.550 | 3.730 | 32.80 | 9.630 | 80.70 | 18.88 | 53.40 | 7.930 | 49.80 | 6.340 | 2.310 | 8.030 | 1.370 | 0.036 | 1.400 | 5.820 |
| 9928b | 12 | 6 | 6640000 | 32.4 | 26.8 | 4.08 | 510.3 | 42.7 | 136.3 | 27.7 | 0.058 | 0.826 | 0.403 | 5.260 | 10.490 | 5.190 | 37.00 | 10.400 | 84.90 | 20.29 | 58.90 | 8.630 | 56.10 | 7.220 | 2.300 | 7.520 | 0.539 | 0.069 | 1.218 | 4.510 |
| 9928b | 13 | 6 | 6060000 | 33.9 | 27.9 | 3.19 | 216.0 | 42.8 | 214.7 | 9.1 | 0.003 | 0.134 | 0.088 | 0.900 | 1.780 | 0.371 | 7.61 | 2.930 | 29.78 | 8.32 | 27.31 | 4.470 | 29.81 | 3.700 | 2.990 | 12.360 | 0.980 | 0.013 | 0.285 | 0.514 |
| 9928b | 14 | 6 | 6570000 | 32.1 | 26.6 | 5.17 | 410.7 | 388.5 | 464.6 | 37.2 | 0.040 | 0.531 | 0.279 | 4.380 | 8.460 | 3.000 | 29.41 | 8.140 | 67.00 | 15.86 | 45.50 | 6.770 | 44.00 | 5.590 | 23.140 | 40.090 | 4.270 | 0.080 | 1.182 | 5.890 |
| 9928b | 15 | 6 | 6380000 | 35.6 | 26.4 | 9.40 | 261.0 | 94.8 | 143.2 | 11.4 | 0.197 | 2.590 | 0.990 | 9.600 | 7.200 | 4.130 | 21.50 | 5.480 | 44.20 | 10.67 | 30.70 | 4.580 | 28.30 | 3.890 | 5.870 | 16.370 | 0.650 | 0.240 | 0.649 | 1.514 |
| 9928b | 19 | 1 | 6450000 | 32.5 | 26.4 | 6.55 | 457.0 | 680.5 | 324.0 | 38.0 | 0.054 | 0.811 | 0.444 | 5.470 | 9.760 | 3.450 | 33.70 | 9.030 | 74.50 | 17.79 | 50.60 | 7.570 | 47.70 | 6.160 | 31.950 | 21.770 | 2.450 | 0.205 | 1.943 | 6.470 |

# Table 4-1.1: LA-ICP-MS trace element analyses for titanite.



| Sample | Position | Type | Ticps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9928b | 20 | 1 | 6370000 | 33.0 | 26.6 | 6.65 | 400.8 | 367.0 | 360.8 | 24.1 | 0.059 | 0.748 | 0.419 | 4.970 | 8.900 | 3.420 | 29.50 | 7.520 | 62.30 | 15.32 | 46.10 | 7.100 | 45.80 | 6.390 | 18.640 | 16.120 | 5.870 | 0.347 | 1.640 | 7.620 |
| 9928b | 21 | 1 | 6950000 | 31.3 | 26.1 | 4.39 | 239.0 | 492.0 | 218.0 | 26.7 | 0.020 | 0.229 | 0.138 | 2.050 | 4.220 | 1.270 | 15.60 | 4.790 | 39.10 | 9.59 | 27.10 | 3.840 | 23.30 | 2.850 | 22.900 | 9.840 | 0.274 | 0.260 | 0.223 | 0.910 |
| 9928b | 22 | 1 | 6920000 | 31.8 | 25.8 | 4.67 | 167.0 | 209.9 | 107.8 | 12.4 | 0.114 | 1.590 | 0.600 | 5.100 | 4.300 | 2.330 | 12.50 | 3.490 | 27.40 | 6.53 | 18.60 | 2.600 | 15.80 | 2.080 | 8.840 | 5.930 | 0.057 | 0.220 | 0.330 | 0.400 |
| 9928b | 23 | 1 | 6510000 | 32.0 | 26.5 | 5.17 | 335.0 | 651.0 | 470.0 | 27.2 | 0.015 | 0.209 | 0.133 | 1.900 | 3.890 | 1.190 | 18.20 | 5.970 | 51.70 | 12.70 | 38.20 | 5.370 | 36.00 | 4.120 | 29.000 | 21.400 | 1.280 | 0.037 | 0.740 | 2.400 |
| 9928b | 24 | 1 | 6110000 | 33.4 | 27.3 | 6.09 | 715.0 | 163.0 | 484.0 | 37.7 | 0.014 | 0.335 | 0.186 | 2.510 | 6.770 | 1.950 | 31.20 | 11.330 | 108.50 | 27.87 | 84.60 | 12.870 | 84.10 | 10.360 | 11.280 | 21.940 | 1.260 | 0.077 | 1.181 | 3.130 |
| 9928b | 25 | 1 | 6070000 | 33.9 | 27.4 | 5.34 | 535.0 | 337.0 | 426.0 | 35.2 | 0.009 | 0.284 | 0.162 | 2.600 | 6.010 | 1.580 | 26.30 | 8.910 | 81.20 | 20.60 | 63.10 | 9.760 | 64.10 | 8.310 | 16.800 | 18.440 | 2.140 | 0.062 | 1.368 | 4.000 |
| 9928b | 26 | 1 | 6090000 | 34.4 | 27.0 | 19.10 | 379.4 | 260.0 | 376.0 | 39.6 | 0.076 | 0.281 | 0.116 | 1.210 | 3.130 | 0.710 | 13.38 | 5.360 | 54.60 | 14.09 | 45.39 | 7.440 | 49.80 | 5.220 | 15.460 | 12.760 | 0.467 | 0.166 | 0.207 | 1.607 |
| 9928b | 27 | 1 | 6870000 | 31.0 | 25.6 | 3.21 | 147.4 | 628.8 | 311.8 | 41.6 | 0.003 | 0.059 | 0.021 | 0.401 | 0.890 | 0.174 | 4.77 | 2.003 | 20.33 | 5.83 | 18.10 | 2.932 | 17.67 | 1.780 | 36.310 | 10.920 | 0.015 | 0.140 | 0.035 | 0.022 |
| 9928b | 28 | 1 | 6280000 | 33.5 | 26.6 | 5.87 | 206.0 | 429.0 | 246.7 | 16.2 | 0.028 | 0.119 | 0.062 | 1.060 | 2.250 | 0.610 | 10.24 | 3.330 | 30.80 | 8.14 | 25.53 | 3.800 | 25.00 | 3.340 | 18.080 | 8.960 | 0.710 | 0.130 | 0.266 | 0.690 |
| 9928b | 29 | 6 | 6460000 | 31.9 | 26.5 | 3.54 | 228.5 | 111.5 | 281.0 | 13.8 | 0.014 | 0.225 | 0.132 | 1.790 | 3.980 | 1.180 | 13.88 | 4.200 | 35.00 | 8.91 | 27.80 | 4.160 | 27.27 | 3.850 | 5.620 | 9.640 | 1.830 | 0.024 | 0.253 | 1.660 |
| 9928b | 30 | 6 | 6070000 | 34.3 | 26.8 | 7.59 | 458.7 | 119.5 | 372.1 | 25.4 | 0.195 | 2.490 | 1.091 | 10.230 | 10.210 | 5.380 | 32.07 | 9.370 | 74.40 | 18.28 | 53.00 | 7.860 | 50.40 | 6.290 | 8.400 | 20.940 | 0.684 | 0.071 | 1.419 | 3.200 |
| 9928b | 31 | 6 | 6260000 | 33.2 | 27.0 | 6.76 | 467.5 | 119.4 | 349.4 | 30.4 | 0.099 | 1.165 | 0.498 | 5.420 | 9.970 | 3.770 | 32.18 | 9.350 | 76.25 | 18.10 | 52.74 | 7.830 | 51.07 | 6.370 | 7.960 | 19.860 | 0.920 | 0.113 | 1.260 | 4.260 |
| 9928b | 32 | 7 | 6710000 | 31.6 | 25.5 | 5.46 | 152.0 | 624.0 | 256.0 | 25.0 | 0.011 | 0.108 | 0.045 | 0.520 | 1.540 | 0.447 | 7.37 | 2.614 | 23.80 | 5.96 | 17.77 | 2.612 | 15.15 | 1.829 | 26.370 | 9.610 | 0.008 | 0.003 | 0.029 | 0.047 |
| 9928b | 33 | 7 | 5900000 | 34.2 | 27.7 | 8.60 | 825.0 | 139.0 | 552.0 | 39.0 | 0.019 | 0.490 | 0.258 | 3.440 | 8.370 | 1.580 | 33.70 | 12.850 | 122.90 | 31.57 | 97.80 | 15.420 | 102.40 | 11.430 | 11.090 | 25.700 | 1.460 | 0.031 | 1.230 | 2.370 |
| 9928b | 35 | 6 | 6320000 | 31.9 | 26.4 | 4.26 | 370.5 | 8.6 | 207.9 | 32.1 | 0.014 | 0.255 | 0.177 | 2.320 | 5.840 | 2.240 | 22.82 | 7.340 | 61.55 | 14.47 | 41.19 | 6.080 | 39.18 | 4.280 | 0.719 | 12.770 | 0.111 | 0.023 | 0.214 | 0.563 |
| 9928b | 36 | 6 | 6720000 | 30.7 | 25.5 | 3.69 | 80.6 | 11.2 | 37.2 | 8.9 | 0.033 | 0.543 | 0.214 | 2.170 | 2.300 | 1.210 | 6.80 | 1.840 | 13.50 | 3.30 | 8.64 | 1.220 | 7.68 | 0.950 | 0.519 | 2.400 | 0.018 | | 0.083 | 0.296 |
| 9928b | 37 | 6 | 6440000 | 31.4 | 26.2 | 3.39 | 166.9 | 17.8 | 63.4 | 7.8 | 0.099 | 1.230 | 0.527 | 5.510 | 5.440 | 2.580 | 14.68 | 3.720 | 27.60 | 6.62 | 19.76 | 2.900 | 19.00 | 2.793 | 0.553 | 2.431 | 0.373 | 0.018 | 0.372 | 2.330 |
| 9928b | 38 | 6 | 6910000 | 30.5 | 25.3 | 2.86 | 52.5 | 53.0 | 19.6 | 12.2 | 0.015 | 0.298 | 0.116 | 1.310 | 1.940 | 0.909 | 5.00 | 1.122 | 9.07 | 2.24 | 6.11 | 0.811 | 4.69 | 0.676 | 1.570 | 0.826 | | 0.002 | 0.010 | 0.017 |
| 9928b | 39 | 6 | 7100000 | 29.7 | 24.9 | 3.53 | 82.9 | 159.8 | 79.4 | 18.4 | 0.046 | 0.630 | 0.265 | 3.100 | 3.730 | 1.568 | 9.57 | 2.151 | 15.81 | 3.40 | 8.90 | 1.138 | 7.04 | 0.837 | 7.620 | 10.180 | | 0.004 | 0.139 | 0.656 |
| 9928b | 40 | 6 | 7020000 | 29.8 | 26.2 | 7.92 | 202.2 | 4.9 | 72.2 | 29.3 | 0.002 | 0.048 | 0.028 | 0.540 | 1.020 | 0.244 | 5.88 | 2.560 | 27.32 | 7.67 | 25.21 | 4.070 | 26.10 | 2.800 | 0.136 | 13.290 | 0.298 | 0.151 | 0.076 | 0.604 |
| 9928b | 41 | 6 | 6840000 | 30.3 | 26.5 | 3.67 | 50.1 | 3.5 | 24.6 | 6.5 | 0.002 | 0.003 | 0.007 | 0.080 | 0.240 | 0.052 | 1.23 | 0.642 | 6.54 | 1.88 | 6.86 | 1.016 | 6.76 | 0.816 | 0.230 | 6.430 | 0.004 | 0.002 | | |
| 9928b | 42 | 6 | 6680000 | 30.8 | 26.2 | 2.96 | 66.9 | 22.5 | 67.3 | 12.7 | | 0.010 | 0.002 | 0.062 | 0.310 | 0.058 | 1.59 | 0.757 | 8.48 | 2.61 | 8.97 | 1.472 | 9.65 | 1.113 | 1.050 | 13.090 | 0.020 | 0.013 | 0.001 | 0.004 |
| 9928b | 43 | 6 | 5920000 | 33.1 | 26.9 | 4.00 | 826.1 | 213.9 | 555.7 | 62.1 | 0.031 | 0.699 | 0.360 | 5.540 | 11.630 | 3.870 | 47.30 | 15.220 | 133.30 | 31.88 | 93.70 | 13.860 | 91.80 | 10.890 | 15.140 | 19.090 | 0.990 | 0.012 | 1.309 | 5.450 |
| 9928b | 44 | 6 | 6080000 | 32.2 | 26.7 | 4.12 | 348.3 | 129.4 | 305.9 | 23.3 | 0.023 | 0.350 | 0.189 | 2.600 | 5.360 | 2.490 | 21.89 | 6.570 | 54.40 | 13.62 | 40.73 | 6.120 | 40.66 | 5.560 | 5.410 | 10.530 | 4.410 | 0.038 | 0.683 | 6.780 |
| 9928b | 45 | 6 | 6130000 | 32.6 | 26.7 | 5.65 | 411.0 | 204.1 | 493.5 | 24.5 | 0.075 | 0.629 | 0.270 | 3.950 | 7.530 | 3.030 | 27.00 | 8.060 | 67.20 | 15.99 | 46.20 | 6.890 | 44.80 | 5.500 | 9.160 | 16.030 | 7.540 | 0.155 | 1.134 | 12.110 |
| 9928b | 46 | 6 | 5980000 | 32.4 | 27.4 | 5.46 | 531.0 | 160.4 | 377.8 | 41.9 | 0.052 | 0.612 | 0.269 | 3.870 | 9.060 | 3.810 | 32.86 | 9.980 | 86.40 | 20.58 | 60.87 | 9.070 | 60.70 | 7.730 | 8.540 | 32.770 | 0.702 | 0.090 | 0.861 | 4.170 |
| 9928b | 47 | 6 | 5750000 | 35.1 | 26.8 | 6.87 | 422.6 | 246.6 | 503.8 | 36.1 | 0.015 | 0.432 | 0.271 | 2.950 | 6.890 | 2.640 | 25.68 | 8.150 | 69.00 | 16.37 | 47.58 | 7.070 | 45.70 | 5.600 | 15.950 | 18.300 | 0.950 | 0.177 | 0.788 | 5.400 |
| 9928b | 48 | 6 | 6030000 | 32.5 | 27.0 | 4.74 | 627.4 | 49.0 | 222.3 | 50.0 | 0.054 | 0.772 | 0.412 | 5.460 | 11.190 | 3.860 | 40.20 | 12.230 | 99.80 | 24.03 | 70.99 | 10.510 | 68.60 | 8.510 | 1.840 | 12.710 | 3.060 | 0.086 | 2.720 | 7.370 |
| 9928b | 49 | 6 | 5860000 | 33.4 | 26.9 | 4.79 | 337.5 | 27.0 | 140.6 | 20.5 | 0.059 | 0.445 | 0.198 | 2.670 | 5.400 | 1.810 | 20.50 | 5.920 | 50.30 | 12.83 | 40.00 | 6.120 | 40.90 | 6.140 | 1.070 | 6.550 | 2.740 | 3.120 | 0.694 | 3.350 |
| 9928b | 50 | 6 | 6760000 | 31.0 | 25.8 | 4.56 | 182.0 | 65.2 | 113.6 | 20.0 | 0.012 | 0.200 | 0.092 | 1.400 | 3.060 | 1.180 | 13.14 | 3.580 | 29.80 | 7.06 | 20.48 | 2.880 | 17.11 | 2.230 | 1.900 | 4.830 | 0.148 | 1.150 | 0.159 | 0.725 |
| 9928b | 51 | 6 | 6780000 | 30.2 | 25.4 | 3.46 | 138.8 | 128.2 | 173.4 | 26.7 | 0.006 | 0.204 | 0.112 | 1.560 | 3.350 | 1.148 | 11.08 | 3.000 | 23.21 | 5.52 | 15.27 | 2.038 | 11.84 | 1.673 | 3.460 | 5.140 | 0.060 | 0.029 | 0.141 | 0.267 |
| 9928b | 52 | 6 | 6660000 | 30.9 | 25.7 | 4.99 | 741.0 | 68.4 | 225.6 | 30.3 | 1.158 | 13.640 | 5.220 | 44.200 | 29.400 | 15.860 | 67.60 | 16.150 | 124.70 | 29.73 | 85.30 | 12.290 | 77.10 | 9.530 | 2.910 | 8.580 | 0.220 | 0.318 | 6.860 | 4.390 |
| 9928b | 53 | 6 | 6140000 | 32.3 | 26.9 | 5.18 | 445.7 | 61.3 | 379.7 | 29.5 | 0.035 | 0.540 | 0.279 | 3.290 | 7.660 | 3.320 | 27.93 | 8.730 | 72.50 | 17.09 | 50.05 | 7.370 | 48.50 | 6.240 | 2.790 | 38.030 | 3.690 | 0.105 | 1.481 | 11.430 |
| 9928b | 54 | 6 | 6820000 | 30.1 | 24.9 | 4.18 | 219.2 | 23.2 | 159.7 | 21.7 | 0.028 | 0.475 | 0.257 | 3.470 | 6.490 | 2.410 | 19.28 | 5.440 | 41.42 | 8.79 | 23.17 | 3.030 | 18.32 | 2.099 | 1.320 | 5.190 | 0.318 | 0.046 | 0.307 | 1.130 |
| 9928b | 55 | 6 | 6810000 | 30.2 | 25.2 | 5.41 | 290.5 | 47.1 | 255.7 | 32.4 | 0.038 | 0.656 | 0.352 | 4.660 | 8.630 | 3.090 | 25.72 | 6.740 | 50.83 | 11.59 | 31.47 | 4.360 | 27.16 | 3.050 | 2.420 | 4.770 | 0.349 | 0.030 | 0.353 | 3.040 |
| 9928b | 56 | 6 | 6850000 | 29.1 | 24.3 | 3.36 | 63.6 | 11.0 | 34.0 | 7.3 | 0.015 | 0.125 | 0.040 | 0.489 | 0.970 | 0.472 | 4.11 | 1.272 | 9.85 | 2.54 | 7.40 | 0.966 | 6.04 | 0.817 | 0.354 | 1.877 | 0.191 | 0.630 | 0.043 | 0.075 |
| 9928b | 57 | 6 | 6080000 | 32.5 | 26.7 | 3.15 | 353.4 | 12.0 | 95.2 | 13.8 | 0.009 | 0.292 | 0.130 | 2.120 | 5.060 | 2.360 | 20.89 | 6.500 | 56.17 | 14.06 | 42.41 | 6.330 | 41.44 | 5.680 | 0.604 | 3.730 | 0.770 | 0.020 | 0.675 | 1.627 |
| 9928b | 58 | 6 | 6150000 | 32.0 | 26.6 | 3.79 | 537.5 | 46.7 | 263.0 | 32.6 | 0.041 | 0.525 | 0.312 | 4.230 | 9.570 | 3.820 | 34.79 | 10.380 | 87.80 | 20.94 | 61.45 | 8.980 | 58.60 | 7.350 | 2.630 | 11.560 | 2.170 | 0.033 | 1.221 | 5.750 |
| 9928b | 59 | 6 | 6350000 | 31.4 | 26.9 | 5.89 | 326.8 | 24.5 | 112.9 | 21.8 | 0.094 | 1.039 | 0.483 | 6.150 | 8.580 | 3.970 | 26.43 | 6.630 | 54.70 | 12.89 | 38.11 | 5.490 | 35.43 | 4.830 | 1.020 | 5.030 | 0.299 | 0.203 | 0.960 | 3.160 |
| 9928b | 60 | 6 | 6550000 | 31.0 | 25.8 | 3.36 | 151.1 | 36.0 | 91.6 | 10.9 | 0.041 | 0.549 | 0.207 | 2.810 | 3.650 | 1.870 | 11.90 | 3.180 | 24.54 | 6.05 | 17.94 | 2.597 | 16.15 | 2.310 | 1.430 | 2.271 | 0.308 | 0.001 | 0.292 | 1.587 |
| 9928b | 61 | 6 | 6300000 | 31.8 | 26.9 | 4.48 | 376.5 | 65.4 | 155.3 | 39.6 | 0.136 | 1.761 | 0.802 | 9.110 | 11.920 | 5.880 | 32.78 | 8.400 | 64.51 | 14.76 | 41.80 | 6.040 | 39.51 | 4.930 | 3.190 | 5.800 | 0.305 | 0.200 | 1.339 | 5.330 |
| 9928b | 62 | 6 | 6270000 | 31.4 | 26.2 | 4.21 | 246.8 | 9.6 | 51.6 | 9.2 | 0.043 | 0.588 | 0.289 | 3.330 | 5.220 | 2.570 | 17.80 | 4.770 | 39.40 | 9.49 | 29.45 | 4.300 | 28.90 | 3.890 | 0.450 | 1.916 | 0.102 | 0.093 | 0.541 | 0.928 |
| 9928b | 63 | 6 | 6200000 | 31.9 | 26.3 | 3.76 | 442.7 | 88.2 | 221.2 | 39.6 | 0.010 | 0.390 | 0.219 | 3.500 | 7.150 | 3.140 | 28.90 | 8.670 | 72.80 | 17.01 | 49.70 | 7.330 | 47.50 | 5.790 | 4.380 | 12.440 | 0.533 | | 0.912 | 4.130 |
| 9928b | 64 | 1 | 5940000 | 32.8 | 27.0 | 4.55 | 653.2 | 72.2 | 278.0 | 60.2 | 0.010 | 0.461 | 0.266 | 3.350 | 8.410 | 2.270 | 34.10 | 11.750 | 102.40 | 24.95 | 74.78 | 11.250 | 75.00 | 9.100 | 3.050 | 18.250 | 2.140 | 0.015 | 1.413 | 6.140 |
| 9928b | 65 | 1 | 6670000 | 30.4 | 25.6 | 3.54 | 102.3 | 11.8 | 12.4 | 9.2 | 0.016 | 0.098 | 0.032 | 0.446 | 1.170 | 0.341 | 5.29 | 1.882 | 16.59 | 4.01 | 11.54 | 1.624 | 9.07 | 0.900 | 1.370 | 2.290 | | 0.090 | 0.006 | 0.008 |
| 9928b | 66 | 1 | 5790000 | 33.0 | 27.8 | 5.20 | 478.9 | 21.9 | 120.2 | 23.3 | 0.026 | 0.317 | 0.159 | 2.240 | 5.970 | 1.558 | 24.58 | 8.300 | 73.09 | 18.61 | 57.19 | 8.800 | 59.68 | 7.990 | 0.866 | 11.670 | 2.730 | 0.080 | 1.186 | 3.080 |
| 9928b | 67 | 6 | 6120000 | 32.0 | 26.8 | 9.87 | 348.0 | 29.5 | 541.4 | 24.4 | 0.009 | 0.212 | 0.114 | 1.650 | 4.660 | 1.257 | 18.86 | 6.210 | 54.74 | 13.59 | 41.93 | 6.110 | 41.52 | 5.550 | 2.890 | 38.490 | 3.010 | 0.240 | 0.234 | 3.800 |
| 9928b | 68 | 6 | 5960000 | 32.4 | 27.3 | 7.69 | 590.9 | 53.6 | 275.8 | 42.1 | 0.012 | 0.360 | 0.152 | 2.670 | 6.680 | 1.990 | 28.14 | 10.020 | 92.00 | 23.08 | 69.23 | 10.560 | 71.00 | 9.410 | 5.820 | 32.150 | 3.130 | 0.278 | 0.773 | 6.050 |
| 9928b | 69 | 6 | 5640000 | 34.0 | 27.9 | 4.52 | 445.0 | 141.7 | 658.0 | 54.4 | 0.029 | 0.380 | 0.178 | 2.210 | 4.900 | 0.967 | 18.92 | 6.840 | 67.10 | 16.88 | 52.40 | 8.420 | 57.60 | 6.520 | 10.160 | 29.450 | 3.290 | 0.131 | 1.203 | 6.030 |
| 9928b | 70 | 6 | 6210000 | 31.9 | 26.5 | 2.02 | 338.7 | 8.5 | 37.2 | 6.3 | | 0.063 | 0.044 | 0.840 | 2.290 | 0.364 | 10.38 | 4.290 | 44.63 | 12.71 | 42.75 | 6.920 | 47.32 | 6.050 | 0.684 | 2.869 | 0.128 | | 0.030 | 0.034 |
| 9928b | 71 | 1 | 6460000 | 31.3 | 26.1 | 3.69 | 121.5 | 11.7 | 27.3 | 9.4 | | 0.053 | 0.036 | 0.590 | 1.390 | 0.334 | 6.21 | 2.024 | 18.31 | 4.85 | 14.96 | 2.030 | 13.10 | 1.756 | 0.438 | 3.090 | 0.035 | 0.060 | 0.039 | 0.099 |
| 9928b | 72 | 6 | 6320000 | 32.6 | 25.9 | 4.59 | 235.9 | 50.0 | 134.0 | 18.0 | 0.027 | 0.209 | 0.107 | 1.180 | 2.860 | 0.846 | 12.89 | 4.190 | 37.00 | 9.17 | 27.00 | 4.180 | 26.30 | 3.420 | 1.960 | 2.121 | 0.519 | 0.122 | 0.250 | 0.970 |
| 9954a | 1 | 9 | 5490000 | 38.6 | 26.6 | 19.80 | 64.8 | 559.0 | 132.3 | 12.3 | 0.013 | 0.085 | 0.050 | 0.860 | 1.520 | 0.136 | 3.81 | 1.092 | 9.46 | 2.29 | 7.58 | 1.295 | 9.75 | 1.208 | 75.300 | 8.270 | 4.790 | 7.630 | | 0.006 |
| 9954a | 3 | 1 | 7030000 | 33.4 | 25.7 | 52.50 | 724.0 | 98.8 | 413.9 | 25.3 | 66.300 | 427.000 | 103.800 | 647.000 | 194.100 | 68.300 | 164.40 | 24.090 | 137.50 | 26.50 | 69.20 | 10.680 | 74.80 | 10.920 | 8.810 | 18.450 | 2.760 | 2.170 | 0.786 | 13.370 |
| 9956a | 5 | 6 | 7540000 | 30.1 | 24.2 | 3.97 | 262.5 | 5.6 | 17.6 | 11.4 | 0.913 | 9.940 | 3.850 | 33.210 | 20.090 | 11.210 | 35.50 | 7.390 | 53.81 | 10.83 | 27.07 | 3.600 | 20.74 | 2.304 | 0.547 | 0.263 | | 0.072 | 0.311 | 0.301 |
| 9956a | 6 | 6 | 7140000 | 31.5 | 24.9 | 4.24 | 549.0 | 48.0 | 32.9 | 32.1 | 1.355 | 14.870 | 5.930 | 52.000 | 33.200 | 21.010 | 62.00 | 13.400 | 99.70 | 21.83 | 59.90 | 8.450 | 53.50 | 6.480 | 3.100 | 0.675 | 0.029 | 0.080 | 2.340 | 4.820 |
| 9956a | 7 | 6 | 7260000 | 30.7 | 24.7 | 3.79 | 329.6 | 14.7 | 15.7 | 12.4 | 0.781 | 8.400 | 3.180 | 28.700 | 18.290 | 9.800 | 36.80 | 8.110 | 59.00 | 13.10 | 35.51 | 5.040 | 32.27 | 4.110 | 0.749 | 0.274 | 0.034 | 0.830 | 1.546 | 1.500 |
| 9956a | 8 | 6 | 7710000 | 30.1 | 24.3 | 3.33 | 229.4 | 10.6 | 15.1 | 11.5 | 0.606 | 6.640 | 2.540 | 23.550 | 14.480 | 7.890 | 27.65 | 6.320 | 44.30 | 9.37 | 23.84 | 3.270 | 18.80 | 2.064 | 0.511 | 0.138 | 0.002 | 0.023 | 0.259 | 0.450 |
| 9956a | 9 | 6 | 6730000 | 32.4 | 25.4 | 5.11 | 506.0 | 28.4 | 36.6 | 21.8 | 1.020 | 11.440 | 4.190 | 36.700 | 23.630 | 12.740 | 48.30 | 11.490 | 87.90 | 19.52 | 55.70 | 7.920 | 50.40 | 6.340 | 1.760 | 0.816 | 0.068 | 1.460 | 2.100 | 2.850 |
| 9956a | 11 | 3 | 7650000 | 28.0 | 22.2 | 5.40 | 21.4 | 2.6 | 6.0 | 0.9 | | 0.033 | 0.010 | 0.255 | 0.340 | 0.090 | 1.18 | 0.352 | 2.83 | 0.84 | 2.79 | 0.440 | 3.06 | 0.436 | 0.201 | 0.323 | 0.015 | 9.590 | 0.034 | 0.008 |
| 9956a | 13 | 3 | 7390000 | 30.2 | 24.7 | 3.77 | 181.6 | 52.4 | 28.1 | 15.6 | 0.267 | 3.320 | 1.251 | 13.180 | 10.110 | 3.760 | 20.53 | 4.670 | 33.60 | 7.09 | 18.96 | 2.520 | 15.27 | 1.864 | 1.610 | 0.354 | 0.002 | 0.280 | 0.543 | 0.700 |
| 9956a | 14 | 3 | 7410000 | 30.2 | 24.6 | 6.99 | 31.8 | 1.6 | 3.0 | 1.0 | 0.025 | 0.161 | 0.061 | 0.690 | 0.990 | 0.222 | 1.79 | 0.543 | 5.07 | 1.22 | 4.12 | 0.587 | 4.32 | 0.587 | 0.045 | 0.059 | 0.144 | 0.910 | 0.055 | 0.019 |
| 9956a | 20 | 6 | 7170000 | 30.7 | 24.9 | 3.72 | 247.8 | 16.8 | 33.0 | 12.8 | 0.324 | 3.550 | 1.510 | 13.800 | 10.990 | 4.150 | 23.30 | 5.840 | 45.80 | 9.80 | 26.60 | 3.540 | 21.95 | 2.510 | 0.846 | 0.454 | 0.055 | 0.105 | 0.437 | 1.180 |
| 9956a | 21 | 6 | 7430000 | 30.4 | 24.6 | 5.19 | 260.4 | 67.9 | 22.0 | 16.5 | 0.384 | 4.410 | 1.754 | 17.840 | 14.520 | 6.660 | 28.93 | 6.600 | 48.99 | 10.45 | 27.52 | 3.770 | 22.26 | 2.458 | 2.170 | 0.352 | | 0.800 | 1.139 | 1.142 |
| 9956a | 22 | 6 | 7690000 | 29.6 | 24.1 | 3.11 | 171.1 | 2.2 | 25.3 | 6.2 | 0.165 | 2.192 | 0.919 | 9.110 | 8.980 | 3.200 | 19.91 | 4.740 | 33.67 | 6.70 | 17.23 | 2.233 | 12.92 | 1.350 | 0.180 | 0.289 | | | 0.243 | 0.123 |
| 9956a | 23 | 6 | 7680000 | 29.9 | 24.4 | 2.99 | 161.6 | 33.7 | 18.8 | 11.4 | 0.236 | 2.790 | 1.074 | 10.340 | 8.890 | 3.270 | 18.68 | 4.370 | 30.80 | 6.33 | 16.92 | 2.230 | 12.96 | 1.418 | 1.100 | 0.288 | | 0.320 | 0.175 | 0.241 |
| 9956a | 24 | 6 | 6850000 | 31.4 | 25.3 | 4.19 | 663.0 | 59.1 | 42.5 | 33.7 | 1.657 | 18.290 | 6.920 | 61.700 | 38.500 | 24.750 | 71.60 | 16.000 | 117.80 | 26.01 | 72.60 | 10.110 | 64.60 | 8.230 | 4.100 | 1.037 | 0.080 | 0.112 | 3.130 | 5.920 |

# Table 4-1.1: LA-ICP-MS trace element analyses for titanite.

| Sample | Position | Type | Ticps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956a | 25 | 9 | 6840000 | 30.6 | 24.5 | 5.20 | 216.4 | 6.4 | 19.0 | 7.7 | 0.216 | 3.030 | 1.182 | 12.610 | 10.120 | 3.790 | 22.36 | 5.130 | 37.50 | 8.58 | 23.58 | 3.339 | 20.88 | 2.531 | 0.314 | 0.348 | 0.033 | 0.700 | 0.445 | 0.401 |
| 9956a | 26 | 9 | 7240000 | 27.7 | 22.1 | 5.58 | 284.0 | 15.2 | 39.2 | 11.0 | 0.233 | 2.160 | 0.890 | 9.100 | 8.550 | 3.130 | 21.60 | 5.620 | 45.30 | 11.04 | 32.90 | 4.960 | 31.10 | 4.220 | 0.700 | 0.660 | 0.670 | 3.000 | 1.262 | 1.480 |
| 9956a | 27 | 9 | 6560000 | 31.8 | 25.6 | 4.38 | 720.0 | 21.3 | 46.5 | 25.6 | 0.740 | 7.700 | 3.010 | 30.600 | 29.000 | 10.600 | 62.50 | 16.100 | 122.00 | 27.90 | 78.00 | 10.500 | 69.60 | 7.800 | 0.663 | 1.190 | 0.242 | 0.060 | 2.700 | 3.230 |
| 9956a | 29 | 2 | 5970000 | 34.9 | 26.0 | 9.00 | 688.0 | 26.5 | 316.2 | 42.0 | 0.040 | 0.389 | 0.130 | 1.720 | 4.180 | 1.190 | 19.55 | 8.460 | 91.80 | 25.91 | 86.00 | 13.910 | 89.90 | 9.990 | 1.910 | 8.630 | 1.840 | 0.990 | 5.780 | 2.060 |
| 9956a | 33 | 3 | 6580000 | 31.6 | 25.4 | 5.30 | 628.0 | 52.2 | 272.2 | 34.4 | 0.050 | 0.512 | 0.275 | 2.840 | 5.970 | 2.050 | 25.00 | 9.190 | 88.20 | 23.31 | 74.10 | 11.010 | 70.60 | 8.530 | 3.070 | 9.690 | 1.150 | 0.401 | 10.800 | 2.530 |
| 9956a | 34 | 2 | 7220000 | 29.2 | 24.0 | 2.63 | 10.4 | 0.1 | 0.6 | 0.7 | 0.014 | 0.037 | 0.020 | 0.139 | 0.171 | 0.059 | 0.64 | 0.176 | 1.51 | 0.43 | 1.33 | 0.219 | 1.55 | 0.240 | 0.009 | 0.025 | 0.010 | 0.340 | 0.035 | 0.012 |
| 9956a | 36 | 2 | 6410000 | 31.9 | 25.9 | 2.96 | 460.0 | 2.4 | 12.0 | 10.5 | 0.009 | 0.167 | 0.073 | 1.200 | 2.940 | 1.740 | 15.79 | 5.820 | 61.00 | 17.61 | 57.30 | 8.970 | 62.90 | 9.060 | 0.081 | 0.139 | 0.740 | 0.103 | 0.519 | 1.188 |
| 9956a | 37 | 2 | 6870000 | 30.6 | 24.6 | 3.96 | 208.0 | 3.8 | 21.3 | 22.6 | 0.212 | 2.250 | 0.850 | 8.900 | 8.570 | 3.010 | 19.80 | 4.750 | 36.80 | 8.33 | 22.90 | 3.080 | 20.20 | 2.540 | 0.089 | 0.355 | 0.084 | 0.139 | 0.720 | 1.640 |
| 9956a | 38 | 2 | 6400000 | 31.9 | 25.6 | 8.90 | 172.1 | 1.4 | 4.9 | 16.6 |  | 0.070 | 0.039 | 0.424 | 0.940 | 0.243 | 4.48 | 1.902 | 22.39 | 6.71 | 23.49 | 3.660 | 24.65 | 3.100 | 0.070 | 0.063 | 0.410 | 0.760 | 0.229 | 0.206 |
| 9956a | 39 | 2 | 6360000 | 32.1 | 26.1 | 4.06 | 658.6 | 30.5 | 129.4 | 38.3 | 0.075 | 1.079 | 0.456 | 5.880 | 10.650 | 5.080 | 40.09 | 12.180 | 104.10 | 24.97 | 73.42 | 10.960 | 71.90 | 8.400 | 3.550 | 3.040 | 0.542 | 0.140 | 5.580 | 4.930 |
| 9956a | 41 | 6 | 6840000 | 30.5 | 24.5 | 3.01 | 174.5 | 13.1 | 76.3 | 8.4 | 0.132 | 1.468 | 0.616 | 6.370 | 6.580 | 2.500 | 16.30 | 4.000 | 29.91 | 6.83 | 19.06 | 2.539 | 16.07 | 1.971 | 1.050 | 0.676 | 0.169 | 0.010 | 0.474 | 1.006 |
| 9956a | 42 | 6 | 6980000 | 30.4 | 24.7 | 4.78 | 374.3 | 25.0 | 47.9 | 25.4 | 0.556 | 6.300 | 2.540 | 22.660 | 19.480 | 6.860 | 39.50 | 8.930 | 68.00 | 14.75 | 40.10 | 5.600 | 35.29 | 4.240 | 1.160 | 0.716 | 0.007 | 0.086 | 1.383 | 1.530 |
| 9956a | 43 | 6 | 6990000 | 30.1 | 24.6 | 3.72 | 208.8 | 17.5 | 50.4 | 10.8 | 0.171 | 2.190 | 0.911 | 8.960 | 8.820 | 3.080 | 20.58 | 5.120 | 37.49 | 8.22 | 22.33 | 3.050 | 19.52 | 2.225 | 0.876 | 0.525 | 0.131 | 0.030 | 0.488 | 1.022 |
| 9956a | 44 | 6 | 6340000 | 32.7 | 24.8 | 3.36 | 248.7 | 16.0 | 67.4 | 11.6 | 0.161 | 1.760 | 0.755 | 8.240 | 9.110 | 3.340 | 22.42 | 5.760 | 43.91 | 9.69 | 26.25 | 3.720 | 22.60 | 2.730 | 1.380 | 0.817 | 0.047 | 0.340 | 0.773 | 0.649 |
| 9956a | 45 | 6 | 6920000 | 30.2 | 24.6 | 3.92 | 271.9 | 13.5 | 71.9 | 16.6 | 0.150 | 1.890 | 0.859 | 8.720 | 10.350 | 3.930 | 24.16 | 6.420 | 48.60 | 10.62 | 28.93 | 4.110 | 24.27 | 2.866 | 1.173 | 1.141 |  | 0.049 | 0.805 | 0.597 |
| 9956a | 47 | 6 | 4630000 | 38.1 | 22.4 | 82.10 | 203.5 | 23.2 | 149.6 | 13.1 | 0.015 | 0.134 | 0.059 | 0.830 | 1.370 | 0.634 | 7.45 | 2.800 | 28.70 | 7.39 | 24.54 | 3.780 | 25.40 | 3.270 | 1.620 | 4.460 | 1.290 | 0.361 | 2.570 | 0.944 |
| 9956a | 48 | 6 | 6790000 | 27.8 | 22.0 | 9.88 | 212.0 | 10.3 | 388.0 | 19.0 | 0.017 | 0.168 | 0.079 | 0.800 | 1.820 | 0.763 | 7.83 | 2.930 | 30.60 | 8.09 | 24.60 | 3.920 | 26.70 | 3.090 | 0.990 | 22.600 | 2.360 | 19.600 | 2.410 | 1.160 |
| 9956a | 49 | 1 | 7550000 | 29.1 | 24.8 | 3.72 | 323.0 | 35.7 | 150.0 | 18.3 | 0.230 | 2.470 | 1.000 | 9.500 | 10.600 | 3.780 | 26.70 | 7.000 | 53.60 | 12.00 | 34.50 | 5.030 | 32.60 | 3.550 | 3.600 | 6.610 | 0.251 | 0.340 | 1.310 | 2.240 |
| 9956a | 50 | 1 | 6570000 | 31.7 | 25.6 | 15.70 | 465.0 | 44.6 | 75.4 | 30.5 | 0.929 | 9.990 | 3.660 | 32.290 | 24.020 | 10.660 | 47.40 | 11.070 | 81.20 | 18.22 | 51.31 | 7.250 | 47.16 | 5.850 | 2.810 | 6.570 | 0.070 | 0.920 | 2.330 | 4.050 |
| 9956a | 51 | 1 | 6600000 | 32.0 | 24.4 | 3.83 | 126.2 | 50.2 | 21.8 | 13.9 | 0.177 | 1.834 | 0.693 | 6.730 | 4.920 | 2.550 | 11.05 | 2.660 | 22.21 | 5.00 | 14.45 | 2.023 | 11.31 | 1.343 | 2.580 | 1.086 |  | 35.000 | 0.090 | 0.074 |
| 9956a | 53 | 2 | 6580000 | 30.7 | 25.0 | 4.25 | 383.0 | 60.3 | 181.9 | 26.3 | 0.013 | 0.247 | 0.112 | 1.480 | 3.140 | 1.160 | 13.28 | 5.280 | 55.60 | 14.58 | 46.80 | 7.330 | 46.60 | 5.080 | 6.180 | 7.580 | 1.140 | 0.274 | 5.570 | 1.460 |
| 9956a | 58 | 3 | 5710000 | 33.0 | 26.8 | 5.80 | 785.0 | 34.3 | 209.2 | 30.6 | 0.023 | 0.363 | 0.162 | 2.420 | 5.130 | 2.130 | 25.63 | 10.320 | 105.30 | 29.50 | 96.70 | 15.450 | 105.30 | 12.990 | 3.050 | 10.030 | 2.200 | 0.358 | 9.830 | 2.211 |
| 9956a | 59 | 3 | 6380000 | 30.8 | 25.3 | 4.19 | 213.2 | 80.6 | 236.8 | 17.5 | 0.005 | 0.069 | 0.032 | 0.540 | 1.290 | 0.569 | 7.03 | 2.738 | 29.54 | 8.31 | 27.09 | 4.030 | 24.74 | 3.300 | 2.950 | 10.500 | 0.091 | 0.084 | 0.512 | 0.103 |
| 9956a | 63 | 6 | 6150000 | 32.8 | 24.4 | 3.74 | 186.8 | 15.7 | 133.3 | 15.9 | 0.019 | 0.140 | 0.067 | 0.730 | 1.450 | 0.498 | 6.32 | 2.560 | 27.20 | 7.27 | 22.61 | 3.480 | 21.15 | 2.013 | 2.440 | 4.080 | 0.007 | 0.169 | 0.263 | 0.177 |
| 9956a | 64 | 6 | 5100000 | 35.9 | 25.3 | 4.55 | 309.5 | 21.8 | 84.7 | 23.6 | 0.008 | 0.128 | 0.052 | 0.810 | 1.900 | 0.513 | 9.26 | 3.950 | 42.12 | 11.64 | 38.15 | 6.040 | 39.11 | 4.310 | 2.350 | 1.130 | 0.329 | 2.580 | 0.757 | 0.442 |
| 9956a | 65 | 2 | 5750000 | 30.4 | 25.8 | 17.10 | 229.4 | 1.0 | 11.7 | 23.8 | 0.043 | 0.146 | 0.046 | 0.620 | 1.580 | 0.389 | 7.02 | 2.720 | 30.79 | 8.73 | 29.82 | 4.870 | 31.44 | 3.920 | 0.029 | 0.191 | 0.650 | 2.520 | 0.519 | 0.598 |
| 9956a | 66 | 2 | 5560000 | 30.8 | 25.1 | 43.00 | 206.5 | 3.0 | 14.0 | 20.6 | 0.315 | 0.490 | 0.073 | 0.650 | 1.440 | 0.347 | 5.89 | 2.553 | 27.01 | 7.97 | 26.44 | 4.300 | 28.61 | 3.400 | 0.089 | 0.250 | 0.750 | 2.280 | 0.623 | 0.680 |
| 9956a | 67 | 6 | 6560000 | 30.4 | 25.1 | 7.36 | 474.0 | 44.5 | 214.5 | 26.1 | 0.087 | 1.060 | 0.452 | 5.220 | 7.390 | 2.390 | 23.20 | 7.950 | 73.30 | 17.74 | 53.20 | 7.940 | 50.30 | 5.340 | 6.340 | 12.030 | 0.287 | 0.364 | 2.820 | 1.461 |
| 9956a | 68 | 2 | 6680000 | 29.6 | 24.3 | 11.60 | 65.7 | 0.3 | 1.1 | 6.8 | 0.025 | 0.105 | 0.037 | 0.359 | 0.540 | 0.145 | 1.95 | 0.799 | 8.31 | 2.53 | 8.99 | 1.381 | 9.94 | 1.269 | 0.006 | 0.029 | 0.251 | 1.620 | 0.176 | 0.164 |
| 9956a | 69 | 2 | 6540000 | 30.5 | 25.0 | 5.92 | 7.7 | 0.5 | 8.2 | 2.1 | 0.015 | 0.246 | 0.064 | 0.490 | 0.323 | 0.249 | 0.63 | 0.147 | 1.27 | 0.33 | 1.05 | 0.144 | 1.15 | 0.200 | 0.012 | 0.276 | 2.490 | 0.026 | 0.027 | 0.180 |
| 9956a | 70 | 2 | 6720000 | 29.4 | 24.6 | 3.81 | 75.3 | 0.3 | 2.2 | 3.0 |  | 0.142 | 0.043 | 0.590 | 0.840 | 0.414 | 3.46 | 1.143 | 10.56 | 3.04 | 9.54 | 1.414 | 9.55 | 1.299 | 0.012 | 0.080 | 0.630 | 0.174 | 0.419 | 0.371 |
| 9956a | 71 | 2 | 6040000 | 31.5 | 26.1 | 3.02 | 221.6 | 8.8 | 5.6 | 14.4 |  | 0.076 | 0.031 | 0.420 | 1.230 | 0.338 | 6.23 | 2.609 | 27.71 | 8.30 | 29.31 | 4.620 | 30.85 | 4.360 | 0.241 | 0.116 | 0.128 | 0.038 | 0.088 | 0.078 |
| 9956a | 72 | 2 | 6190000 | 30.9 | 25.5 | 9.90 | 201.9 | 3.7 | 21.8 | 15.5 |  | 0.065 | 0.022 | 0.500 | 1.130 | 0.524 | 5.93 | 2.515 | 27.20 | 7.83 | 25.90 | 3.920 | 25.83 | 3.400 | 0.131 | 0.738 | 0.256 | 0.600 | 0.850 | 0.243 |
| 9956b | 1 | 1 | 5490000 | 36.9 | 24.4 | 4.01 | 230.2 | 21.9 | 286.0 | 17.1 | 0.017 | 0.204 | 0.105 | 1.250 | 2.770 | 1.165 | 10.78 | 3.960 | 35.89 | 8.87 | 25.92 | 3.770 | 22.41 | 2.440 | 3.110 | 20.220 |  | 0.085 | 1.156 | 0.116 |
| 9956b | 2 | 1 | 6590000 | 31.1 | 24.7 | 9.60 | 353.0 | 40.1 | 295.3 | 19.6 | 0.050 | 0.717 | 0.343 | 3.640 | 6.000 | 2.510 | 20.00 | 6.360 | 56.60 | 13.76 | 39.40 | 5.700 | 36.00 | 3.950 | 3.750 | 26.140 | 0.184 | 0.427 | 2.330 | 1.180 |
| 9956b | 3 | 1 | 6730000 | 30.9 | 24.4 | 3.61 | 325.5 | 22.4 | 262.2 | 24.7 | 0.002 | 0.142 | 0.078 | 1.150 | 2.310 | 0.935 | 11.40 | 4.730 | 48.49 | 12.86 | 38.73 | 5.810 | 36.00 | 3.720 | 3.370 | 11.890 | 0.005 | 0.284 | 0.928 | 0.233 |
| 9956b | 4 | 2 | 5870000 | 29.4 | 23.1 | 3.92 | 230.2 | 44.7 | 273.0 | 13.7 | 0.268 | 0.960 | 0.250 | 1.850 | 2.140 | 1.210 | 9.92 | 3.560 | 32.50 | 8.80 | 27.98 | 4.290 | 28.02 | 3.900 | 2.090 | 25.170 | 0.930 | 0.252 | 1.870 | 2.510 |
| 9956b | 5 | 1 | 5160000 | 36.8 | 26.6 | 13.60 | 360.8 | 48.2 | 211.9 | 23.5 | 0.009 | 0.174 | 0.074 | 1.280 | 2.650 | 1.012 | 11.91 | 4.790 | 49.70 | 13.67 | 45.59 | 7.310 | 48.75 | 6.260 | 3.230 | 9.810 | 1.060 | 0.331 | 6.620 | 1.438 |
| 9956b | 6 | 1 | 6430000 | 32.2 | 24.8 | 5.18 | 167.0 | 222.1 | 163.3 | 24.6 | 0.008 | 0.114 | 0.038 | 0.640 | 1.480 | 0.564 | 7.33 | 2.460 | 23.60 | 6.41 | 20.28 | 2.890 | 18.30 | 2.280 | 5.840 | 5.310 | 0.124 | 0.086 | 1.230 | 0.326 |
| 9956b | 7 | 1 | 5990000 | 33.0 | 26.7 | 6.34 | 414.0 | 293.0 | 361.4 | 31.5 | 0.017 | 0.215 | 0.108 | 1.540 | 2.810 | 1.320 | 14.31 | 5.540 | 56.50 | 15.64 | 50.60 | 8.080 | 55.70 | 7.090 | 10.420 | 18.120 | 2.010 | 0.314 | 7.990 | 2.500 |
| 9956b | 13 | 6 | 6680000 | 30.2 | 24.5 | 9.00 | 296.9 | 31.3 | 129.4 | 16.9 | 0.002 | 0.296 | 0.146 | 1.970 | 3.910 | 1.700 | 14.98 | 5.250 | 47.33 | 11.29 | 32.43 | 4.650 | 27.92 | 2.960 | 5.110 | 8.480 | 0.062 | 0.260 | 1.448 | 0.651 |
| 9956b | 14 | 6 | 7380000 | 30.0 | 25.0 | 3.12 | 297.0 | 38.4 | 122.4 | 16.4 | 0.010 | 0.263 | 0.137 | 1.960 | 4.640 | 1.860 | 16.80 | 5.310 | 47.30 | 11.40 | 32.20 | 4.590 | 27.40 | 2.930 | 5.510 | 6.150 | 0.161 | 0.590 | 1.210 | 0.920 |
| 9956b | 15 | 6 | 6480000 | 32.5 | 24.6 | 3.67 | 308.0 | 35.0 | 147.0 | 18.5 | 0.026 | 0.356 | 0.167 | 2.360 | 4.470 | 2.309 | 18.37 | 5.710 | 49.80 | 11.78 | 34.00 | 4.890 | 30.40 | 3.460 | 4.450 | 4.440 | 0.050 | 0.074 | 1.541 | 0.853 |
| 9956b | 16 | 2 | 6420000 | 30.4 | 24.8 | 5.37 | 323.9 | 10.0 | 68.6 | 25.2 | 0.029 | 0.178 | 0.081 | 0.830 | 1.980 | 0.885 | 10.76 | 4.360 | 46.40 | 12.58 | 40.00 | 6.030 | 39.91 | 4.510 | 0.527 | 2.054 | 0.415 | 2.120 | 1.008 | 0.668 |
| 9956b | 17 | 2 | 6620000 | 30.4 | 24.5 | 4.61 | 309.0 | 9.8 | 71.0 | 18.1 | 0.006 | 0.120 | 0.078 | 0.990 | 2.520 | 0.943 | 11.41 | 4.470 | 45.80 | 11.93 | 37.40 | 5.470 | 34.40 | 3.720 | 0.796 | 1.660 | 0.219 | 0.072 | 0.843 | 0.488 |
| 9956b | 21 | 2 | 6460000 | 30.2 | 24.6 | 11.30 | 297.7 | 1.4 | 43.1 | 24.8 | 0.011 | 0.150 | 0.073 | 1.070 | 1.860 | 0.851 | 10.15 | 4.010 | 42.40 | 11.63 | 36.41 | 5.510 | 36.47 | 4.490 | 0.039 | 1.638 | 0.740 | 1.950 | 1.300 | 1.113 |
| 9956b | 22 | 2 | 6280000 | 31.5 | 25.6 | 8.40 | 448.0 | 4.0 | 36.5 | 30.3 | 0.017 | 0.235 | 0.133 | 1.550 | 3.340 | 1.101 | 14.70 | 5.850 | 61.70 | 17.17 | 56.70 | 8.690 | 59.60 | 7.370 | 0.246 | 1.522 | 1.470 | 0.453 | 2.100 | 1.352 |
| 9956b | 23 | 2 | 5870000 | 32.0 | 25.9 | 8.30 | 180.2 | 5.2 | 56.7 | 12.4 | 0.006 | 0.154 | 0.050 | 0.720 | 1.180 | 0.658 | 6.45 | 2.364 | 25.25 | 7.04 | 23.68 | 3.540 | 24.67 | 3.590 | 0.228 | 2.790 | 2.030 | 1.250 | 0.649 | 0.715 |
| 9956b | 24 | 2 | 6070000 | 31.7 | 25.5 | 5.10 | 284.5 | 11.0 | 17.0 | 26.5 |  | 0.145 | 0.086 | 0.840 | 2.050 | 0.938 | 10.84 | 3.810 | 40.44 | 11.03 | 35.08 | 5.540 | 36.55 | 4.600 | 0.420 | 0.463 | 0.784 | 0.199 | 3.480 | 1.543 |
| 9956b | 25 | 2 | 5630000 | 30.9 | 25.6 | 9.20 | 669.0 | 3.4 | 22.1 | 35.6 | 0.144 | 0.582 | 0.229 | 2.650 | 6.060 | 2.540 | 25.80 | 9.570 | 94.70 | 25.13 | 79.20 | 12.170 | 81.60 | 9.950 | 0.140 | 0.810 | 1.640 | 1.020 | 7.720 | 4.210 |
| 9956b | 26 | 2 | 7270000 | 27.6 | 22.8 | 5.72 | 6.9 | 1.8 | 25.4 | 3.0 | 0.260 | 0.514 | 0.071 | 0.334 | 0.195 | 0.101 | 0.50 | 0.098 | 1.10 | 0.29 | 0.92 | 0.122 | 0.92 | 0.162 | 0.065 | 1.219 | 0.840 | 1.980 | 0.062 | 0.133 |
| 9956b | 27 | 2 | 6040000 | 30.3 | 24.7 | 14.23 | 147.4 | 0.8 | 37.4 | 13.2 | 0.010 | 0.096 | 0.049 | 0.428 | 1.010 | 0.482 | 5.25 | 1.926 | 19.91 | 5.86 | 18.47 | 2.793 | 18.43 | 2.370 | 0.029 | 2.262 | 0.674 | 5.850 | 0.456 | 0.393 |
| 9956b | 35 | 3 | 5770000 | 29.0 | 23.4 | 13.03 | 105.6 | 1.9 | 28.4 | 11.3 | 0.056 | 0.134 | 0.041 | 0.282 | 0.550 | 0.142 | 2.31 | 1.087 | 12.94 | 4.01 | 15.13 | 2.530 | 18.11 | 2.388 | 0.092 | 0.575 | 3.140 | 12.940 | 0.568 | 0.471 |
| 9956b | 36 | 3 | 6430000 | 30.7 | 25.0 | 6.80 | 46.4 | 51.2 | 88.6 | 14.2 |  | 0.024 | 0.009 | 0.216 | 0.302 | 0.074 | 1.24 | 0.543 | 5.83 | 1.75 | 5.77 | 1.015 | 6.20 | 0.720 | 4.600 | 9.390 |  | 0.249 | 0.069 | 0.024 |
| 9956b | 40 | 3 | 5120000 | 32.1 | 26.1 | 18.00 | 161.3 | 4.1 | 67.0 | 16.2 |  | 0.046 | 0.024 | 0.307 | 0.430 | 0.222 | 3.44 | 1.392 | 18.05 | 6.20 | 24.19 | 4.060 | 27.57 | 3.550 | 0.272 | 4.530 | 0.534 | 2.250 | 0.403 | 0.102 |
| 9956b | 41 | 3 | 5780000 | 32.2 | 26.2 | 30.30 | 116.8 | 5.2 | 263.6 | 12.3 | 0.016 | 0.110 | 0.028 | 0.189 | 0.400 | 0.168 | 2.52 | 1.100 | 13.19 | 4.49 | 16.99 | 2.888 | 19.35 | 2.550 | 0.272 | 31.730 | 0.469 | 2.160 | 0.299 | 0.204 |
| 9956b | 42 | 3 | 3810000 | 37.4 | 29.8 | 5.77 | 89.7 | 6.4 | 121.9 | 10.3 | 0.047 | 0.544 | 0.215 | 1.900 | 2.310 | 0.506 | 5.34 | 1.520 | 12.80 | 3.43 | 10.47 | 1.521 | 11.40 | 1.743 | 0.338 | 10.270 | 4.080 | 0.385 | 5.370 | 3.040 |
| 9956b | 43 | 3 | 5160000 | 34.8 | 27.9 | 13.70 | 45.8 | 24.9 | 146.8 | 6.3 | 0.067 | 0.346 | 0.091 | 0.850 | 0.860 | 0.242 | 2.47 | 0.662 | 6.19 | 1.64 | 5.34 | 0.813 | 5.52 | 0.835 | 0.780 | 10.310 | 1.770 | 1.800 | 1.391 | 0.545 |
| 9956b | 44 | 3 | 4580000 | 29.6 | 24.4 | 6.66 | 23.3 | 1.4 | 14.4 | 9.8 | 0.009 | 0.061 | 0.034 | 0.320 | 0.107 | 0.134 | 0.70 | 0.229 | 3.03 | 0.86 | 2.98 | 0.384 | 3.20 | 0.417 | 0.057 | 0.225 | 0.610 | 0.700 | 0.058 | 0.249 |
| 9956b | 45 | 3 | 5260000 | 28.5 | 23.7 | 4.18 | 24.1 | 0.5 | 6.2 | 5.2 | 0.014 | 0.076 | 0.017 | 0.107 | 0.149 | 0.080 | 0.68 | 0.271 | 2.83 | 0.91 | 3.89 | 0.503 | 4.27 | 0.668 | 0.007 | 0.158 | 0.680 | 0.880 | 0.111 | 0.110 |
| 9956b | 46 | 3 | 4430000 | 35.7 | 27.7 | 38.50 | 6.3 | 10.8 | 19.9 | 1.9 | 0.341 | 0.776 | 0.126 | 0.690 | 0.223 | 0.150 | 0.49 | 0.098 | 0.98 | 0.26 | 0.86 | 0.121 | 0.82 | 0.101 | 0.560 | 0.470 | 4.820 | 3.880 | 1.760 | 0.256 |
| 9956b | 47 | 3 | 6660000 | 28.8 | 24.2 | 5.15 | 294.8 | 5.7 | 17.6 | 16.7 | 0.045 | 0.339 | 0.185 | 1.970 | 3.950 | 1.540 | 14.13 | 4.490 | 41.50 | 10.58 | 33.60 | 5.110 | 34.30 | 4.360 | 0.170 | 0.511 | 1.190 | 0.316 | 6.290 | 2.780 |
| 9956b | 48 | 3 | 6780000 | 28.4 | 22.9 | 11.70 | 775.0 | 18.0 | 45.5 | 14.3 | 0.398 | 4.830 | 1.930 | 18.600 | 21.500 | 7.740 | 57.70 | 16.100 | 137.00 | 31.10 | 87.50 | 12.300 | 74.30 | 7.270 | 0.737 | 0.768 | 0.253 | 1.120 | 2.420 | 1.550 |
| 9956b | 49 | 3 | 6380000 | 29.7 | 24.4 | 4.75 | 188.1 | 5.4 | 4.6 | 9.8 | 0.006 | 0.158 | 0.080 | 0.950 | 2.170 | 0.952 | 8.31 | 2.800 | 25.61 | 6.82 | 22.35 | 3.380 | 22.59 | 3.230 | 0.179 | 0.121 | 0.833 | 0.830 | 1.611 | 0.604 |
| 9956b | 50 | 3 | 6000000 | 27.4 | 22.5 | 18.70 | 31.3 | 4.7 | 20.7 | 5.5 | 0.136 | 0.243 | 0.036 | 0.301 | 0.339 | 0.124 | 1.03 | 0.414 | 4.34 | 1.15 | 4.46 | 0.700 | 5.46 | 0.729 | 0.302 | 0.852 | 2.060 | 3.590 | 0.758 | 0.349 |
| 9956b | 51 | 3 | 5820000 | 32.3 | 26.4 | 6.36 | 210.5 | 6.5 | 11.0 | 15.9 | 0.002 | 0.078 | 0.029 | 0.492 | 0.820 | 0.260 | 4.71 | 2.139 | 25.52 | 8.05 | 30.74 | 4.920 | 33.62 | 4.430 | 0.189 | 0.236 | 0.850 | 0.820 | 0.468 | 0.355 |
| 9956b | 52 | 3 | 5310000 | 32.9 | 26.6 | 8.96 | 176.3 | 3.6 | 16.1 | 10.8 | 0.011 | 0.072 | 0.038 | 0.356 | 0.720 | 0.296 | 4.17 | 1.782 | 21.40 | 6.56 | 24.68 | 4.040 | 28.47 | 4.030 | 0.157 | 0.331 | 0.373 | 0.413 | 0.161 | 0.103 |

# Table 4-1.1: LA-ICP-MS trace element analyses for titanite.

| Sample | Position | Type | Ticps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956b | 53 | 3 | 5580000 | 32.8 | 26.4 | 4.00 | 152.4 | 3.0 | 28.0 | 8.8 | | 0.025 | 0.011 | 0.140 | 0.530 | 0.160 | 3.13 | 1.471 | 17.37 | 5.76 | 21.82 | 3.650 | 26.53 | 3.954 | 0.123 | 0.933 | 0.074 | 0.121 | 0.030 | 0.007 |
| 9956b | 54 | 3 | 5520000 | 33.1 | 26.3 | 13.20 | 227.1 | 26.8 | 69.3 | 19.7 | 0.017 | 0.131 | 0.062 | 0.610 | 1.530 | 0.352 | 6.58 | 2.550 | 28.46 | 8.49 | 30.61 | 4.900 | 33.06 | 3.990 | 0.920 | 1.884 | 1.100 | 1.180 | 0.806 | 0.384 |
| 9956b | 55 | 3 | 3160000 | 30.4 | 25.4 | 15.96 | 44.1 | 3.1 | 3.0 | 12.2 | 0.430 | 0.680 | 0.073 | 0.460 | 0.260 | 0.229 | 1.19 | 0.453 | 5.29 | 1.73 | 6.72 | 1.031 | 7.43 | 0.982 | 0.009 | 0.025 | 2.180 | 7.200 | 0.542 | 0.613 |
| 9956b | 59 | 6 | 6360000 | 30.8 | 24.7 | 3.09 | 104.5 | 29.8 | 23.1 | 8.2 | 0.111 | 1.437 | 0.558 | 5.630 | 4.290 | 1.810 | 10.39 | 2.400 | 17.53 | 4.23 | 11.59 | 1.561 | 10.07 | 1.271 | 2.320 | 1.690 | | 0.050 | 0.264 | 0.193 |
| 9956b | 60 | 6 | 5990000 | 34.8 | 24.9 | 11.70 | 151.5 | 50.6 | 48.1 | 11.5 | 0.037 | 0.420 | 0.197 | 2.000 | 3.020 | 1.300 | 10.48 | 2.860 | 23.60 | 5.86 | 16.67 | 2.400 | 14.97 | 1.880 | 4.720 | 1.960 | | 1.000 | 0.348 | 0.111 |
| 9956b | 62 | 6 | 6430000 | 31.0 | 24.6 | 5.38 | 445.0 | 42.2 | 64.6 | 18.5 | 0.635 | 8.210 | 3.320 | 31.800 | 23.000 | 14.870 | 48.00 | 10.000 | 79.20 | 17.51 | 50.40 | 6.930 | 45.40 | 5.850 | 3.980 | 7.410 | 0.021 | 0.204 | 1.291 | 2.080 |
| 9956b | 64 | 2 | 5790000 | 33.3 | 26.6 | 7.99 | 323.3 | 461.8 | 395.6 | 10.7 | 0.021 | 0.211 | 0.083 | 1.200 | 2.270 | 0.901 | 10.38 | 4.150 | 41.74 | 11.94 | 40.96 | 6.520 | 48.40 | 7.160 | 21.930 | 36.710 | 6.430 | 1.020 | 10.510 | 2.308 |
| 9956c | 3 | 2 | 6480000 | 30.5 | 24.9 | 3.96 | 367.4 | 37.3 | 62.2 | 26.0 | 0.670 | 7.160 | 2.740 | 24.170 | 18.800 | 6.970 | 38.04 | 8.660 | 65.40 | 14.11 | 39.76 | 5.660 | 35.98 | 4.420 | 1.800 | 1.089 | 0.092 | 0.065 | 2.009 | 2.681 |
| 9956c | 4 | 2 | 6250000 | 31.3 | 25.7 | 3.20 | 324.7 | 5.9 | 22.3 | 7.8 | 0.241 | 2.940 | 1.129 | 11.680 | 11.160 | 3.920 | 26.09 | 6.510 | 50.97 | 12.23 | 37.92 | 5.540 | 37.83 | 5.550 | 0.187 | 0.181 | 0.197 | 0.116 | 2.080 | 1.251 |
| 9956c | 5 | 2 | 6730000 | 29.9 | 24.4 | 4.14 | 288.0 | 24.6 | 65.3 | 18.8 | 0.555 | 6.570 | 2.310 | 21.120 | 15.990 | 6.470 | 30.90 | 7.100 | 51.50 | 11.22 | 30.23 | 4.260 | 26.37 | 3.090 | 1.330 | 1.853 | 0.048 | 0.030 | 0.869 | 1.187 |
| 9956c | 6 | 2 | 6740000 | 27.8 | 24.0 | 9.60 | 137.5 | 3.3 | 22.1 | 10.3 | 0.042 | 0.151 | 0.070 | 0.940 | 1.630 | 0.750 | 6.96 | 2.270 | 21.40 | 5.48 | 16.50 | 2.350 | 16.40 | 2.200 | 0.314 | 0.960 | 0.390 | 0.560 | 0.376 | 0.775 |
| 9956c | 7 | 2 | 6000000 | 31.7 | 25.8 | 4.88 | 664.1 | 55.1 | 157.4 | 34.2 | 0.078 | 0.991 | 0.519 | 5.920 | 11.560 | 5.110 | 39.41 | 12.130 | 106.90 | 25.22 | 73.31 | 11.130 | 69.96 | 8.580 | 3.470 | 4.030 | 0.720 | 0.364 | 5.110 | 5.660 |
| 9956c | 8 | 2 | 6150000 | 31.8 | 25.9 | 4.29 | 729.1 | 76.2 | 179.5 | 43.8 | 0.073 | 1.300 | 0.672 | 7.380 | 13.670 | 6.070 | 46.50 | 13.870 | 116.60 | 27.37 | 81.37 | 12.220 | 79.30 | 9.200 | 4.960 | 5.990 | 0.617 | 0.223 | 6.170 | 7.150 |
| 9956c | 12 | 2 | 6910000 | 29.5 | 24.0 | 13.80 | 359.9 | 33.8 | 146.8 | 22.6 | 0.024 | 0.417 | 0.159 | 2.420 | 4.770 | 1.760 | 17.33 | 6.420 | 58.60 | 14.17 | 40.10 | 5.840 | 34.30 | 3.670 | 3.990 | 6.830 | 0.086 | 0.523 | 1.164 | 1.020 |
| 9956c | 13 | 6 | 5990000 | 32.6 | 24.8 | 4.22 | 257.1 | 14.7 | 67.3 | 10.5 | 0.033 | 0.376 | 0.216 | 2.650 | 4.170 | 1.810 | 15.10 | 4.640 | 40.00 | 9.91 | 29.26 | 4.300 | 27.10 | 3.310 | 1.260 | 3.490 | 0.070 | 13.600 | 0.828 | 0.598 |
| 9956c | 14 | 6 | 6910000 | 29.5 | 24.0 | 4.29 | 295.1 | 8.5 | 81.2 | 12.3 | 0.036 | 0.526 | 0.234 | 3.140 | 5.760 | 2.960 | 22.54 | 6.450 | 52.50 | 11.48 | 30.99 | 4.030 | 24.95 | 2.464 | 1.150 | 1.729 | 0.002 | 0.043 | 0.372 | 0.271 |
| 9956c | 15 | 6 | 6770000 | 29.9 | 24.2 | 4.53 | 237.1 | 43.0 | 63.8 | 14.0 | 0.011 | 0.254 | 0.126 | 1.440 | 3.480 | 1.590 | 12.90 | 4.410 | 39.70 | 8.90 | 25.63 | 3.610 | 21.60 | 2.140 | 3.550 | 3.320 | 0.013 | 0.116 | 0.368 | 0.417 |
| 9956c | 16 | 6 | 6630000 | 29.9 | 24.4 | 5.52 | 311.0 | 17.1 | 106.6 | 17.0 | 0.048 | 0.763 | 0.349 | 4.580 | 7.380 | 3.100 | 23.40 | 6.830 | 55.40 | 12.30 | 33.80 | 4.760 | 29.00 | 3.110 | 1.800 | 3.260 | 0.032 | 0.199 | 0.970 | 1.020 |
| 9956c | 17 | 6 | 6120000 | 31.4 | 25.6 | 4.62 | 378.0 | 53.7 | 157.0 | 30.3 | 0.165 | 1.930 | 0.853 | 8.750 | 11.010 | 4.150 | 29.40 | 8.030 | 63.60 | 14.44 | 41.50 | 5.840 | 38.80 | 4.540 | 4.280 | 10.290 | 0.149 | 0.127 | 2.220 | 3.150 |
| 9956c | 18 | 6 | 6190000 | 31.4 | 24.8 | 7.11 | 282.0 | 26.7 | 92.1 | 14.5 | 0.096 | 0.874 | 0.356 | 4.600 | 5.840 | 2.310 | 18.45 | 5.220 | 44.60 | 10.64 | 31.50 | 4.530 | 29.80 | 3.350 | 2.250 | 4.270 | 0.080 | 1.240 | 0.939 | 0.970 |
| 9956c | 19 | 6 | 6290000 | 31.2 | 25.4 | 4.75 | 336.0 | 45.6 | 102.4 | 22.3 | 0.327 | 3.230 | 1.215 | 12.030 | 12.690 | 4.240 | 30.40 | 7.330 | 58.00 | 12.81 | 36.00 | 5.070 | 34.20 | 3.920 | 3.370 | 8.650 | 0.094 | 0.440 | 2.900 | 2.080 |
| 9956c | 20 | 6 | 6930000 | 29.4 | 24.1 | 3.22 | 160.9 | 146.1 | 49.1 | 18.9 | 0.298 | 3.660 | 1.519 | 13.420 | 9.080 | 4.030 | 18.66 | 4.000 | 28.27 | 6.35 | 17.33 | 2.207 | 13.79 | 1.666 | 6.330 | 4.210 | 0.009 | 0.005 | 0.325 | 0.337 |
| 9956c | 26 | 6 | 6400000 | 30.5 | 24.7 | 7.07 | 533.0 | 50.8 | 65.1 | 29.3 | 1.208 | 13.690 | 5.410 | 47.700 | 30.900 | 19.500 | 61.50 | 12.780 | 95.80 | 21.10 | 59.00 | 8.120 | 51.80 | 6.380 | 3.380 | 2.490 | 0.005 | 4.560 | 1.863 | 3.520 |
| 9956c | 27 | 2 | 5840000 | 31.0 | 24.9 | 32.80 | 162.4 | 2.9 | 22.9 | 13.7 | 0.180 | 0.413 | 0.076 | 0.750 | 1.380 | 0.311 | 4.80 | 2.038 | 21.67 | 6.10 | 21.38 | 3.440 | 22.67 | 2.850 | 0.089 | 0.424 | 1.620 | 4.330 | 0.877 | 0.474 |
| 9956c | 28 | 2 | 5990000 | 30.5 | 25.3 | 19.70 | 246.0 | 12.0 | 20.0 | 16.5 | 0.650 | 0.960 | 0.100 | 0.700 | 1.310 | 0.386 | 5.82 | 2.580 | 30.24 | 9.01 | 32.06 | 5.160 | 34.78 | 4.290 | 0.480 | 0.331 | 0.440 | 11.700 | 2.240 | 0.880 |
| 9956c | 30 | 2 | 7140000 | 29.0 | 24.5 | 4.81 | 353.5 | 13.2 | 116.0 | 19.9 | 0.182 | 0.700 | 0.309 | 2.760 | 4.910 | 1.890 | 17.64 | 6.040 | 56.30 | 13.65 | 39.90 | 5.920 | 36.30 | 3.820 | 1.440 | 3.760 | 0.101 | 4.500 | 1.091 | 0.578 |
| 9956c | 31 | 2 | 7150000 | 28.5 | 23.7 | 3.42 | 16.9 | 0.2 | 1.8 | 2.7 | 0.012 | 0.141 | 0.037 | 0.480 | 0.457 | 0.319 | 1.49 | 0.308 | 2.63 | 0.69 | 2.00 | 0.273 | 1.99 | 0.279 | 0.005 | 0.124 | 0.419 | 0.364 | 0.058 | 0.151 |
| 9956c | 32 | 2 | 6550000 | 28.3 | 23.2 | 6.28 | 543.0 | 74.0 | 93.2 | 29.0 | 0.660 | 1.550 | 0.293 | 2.380 | 4.980 | 2.540 | 22.60 | 8.330 | 79.20 | 20.30 | 62.30 | 9.340 | 61.60 | 7.150 | 2.220 | 0.514 | 1.040 | 7.200 | 7.610 | 3.320 |
| 9956c | 37 | 2 | 5830000 | 31.2 | 24.4 | 6.73 | 242.4 | 20.8 | 439.0 | 18.4 | 0.183 | 0.820 | 0.120 | 1.330 | 2.080 | 0.862 | 9.35 | 3.780 | 36.80 | 9.41 | 28.37 | 4.210 | 27.20 | 2.880 | 1.360 | 11.100 | 0.192 | 3.750 | 1.980 | 0.718 |
| 9956c | 39 | 2 | 5790000 | 33.4 | 25.9 | 4.41 | 677.9 | 92.1 | 388.4 | 44.4 | 0.020 | 0.425 | 0.232 | 2.630 | 5.780 | 2.180 | 26.20 | 9.760 | 96.40 | 25.84 | 81.10 | 12.260 | 79.30 | 9.050 | 4.820 | 13.320 | 0.884 | 0.335 | 11.380 | 3.600 |
| 9956c | 40 | 2 | 5560000 | 33.6 | 26.7 | 7.61 | 1352.0 | 132.8 | 777.8 | 58.8 | 0.059 | 0.812 | 0.431 | 5.230 | 10.880 | 4.220 | 48.00 | 18.440 | 186.90 | 50.17 | 158.50 | 24.660 | 165.60 | 19.210 | 6.690 | 24.590 | 4.110 | 1.760 | 27.540 | 9.410 |
| 9956c | 41 | 2 | 5460000 | 36.4 | 26.7 | 5.53 | 617.0 | 26.9 | 693.0 | 23.6 | 0.022 | 0.316 | 0.143 | 1.740 | 4.180 | 1.810 | 20.46 | 7.860 | 83.00 | 23.49 | 77.50 | 12.120 | 85.10 | 10.920 | 1.260 | 16.640 | 3.600 | 1.320 | 5.510 | 3.050 |
| 9956c | 42 | 6 | 5880000 | 33.1 | 25.2 | 4.17 | 369.1 | 9.3 | 118.0 | 19.3 | 0.020 | 0.188 | 0.075 | 1.350 | 2.560 | 0.920 | 13.20 | 4.960 | 50.00 | 13.89 | 44.83 | 6.620 | 44.27 | 5.570 | 0.394 | 1.630 | 0.294 | 1.090 | 2.000 | 0.509 |
| 9956c | 43 | 6 | 5245000 | 35.5 | 25.5 | 7.01 | 725.1 | 129.2 | 359.1 | 34.4 | 0.144 | 0.615 | 0.247 | 2.710 | 5.770 | 2.010 | 23.99 | 9.480 | 98.40 | 27.52 | 90.10 | 14.130 | 95.10 | 11.280 | 8.080 | 16.670 | 1.860 | 11.910 | 9.800 | 2.820 |
| 9956c | 46 | 6 | 5040000 | 38.2 | 26.4 | 13.00 | 466.2 | 147.0 | 366.5 | 42.3 | 0.780 | 2.580 | 0.457 | 2.700 | 4.200 | 1.480 | 17.19 | 6.590 | 66.70 | 17.77 | 56.26 | 8.890 | 57.60 | 7.040 | 11.120 | 25.800 | 1.300 | 7.050 | 8.540 | 3.480 |
| 9956c | 47 | 6 | 6000000 | 32.3 | 25.5 | 3.33 | 175.5 | 22.6 | 107.2 | 9.5 | 0.006 | 0.055 | 0.039 | 0.435 | 1.170 | 0.486 | 5.71 | 2.276 | 25.24 | 6.91 | 22.46 | 3.470 | 23.48 | 3.097 | 2.030 | 3.710 | 0.366 | 0.380 | 1.110 | 0.339 |
| 9956c | 50 | 6 | 4750000 | 33.3 | 25.9 | 8.95 | 683.0 | 108.2 | 455.6 | 33.2 | 0.540 | 1.970 | 0.425 | 4.400 | 5.770 | 2.540 | 25.90 | 9.610 | 96.00 | 25.13 | 79.70 | 12.100 | 79.30 | 9.740 | 8.990 | 17.240 | 3.150 | 6.800 | 8.020 | 4.140 |
| 9956c | 51 | 6 | 5650000 | 31.3 | 24.8 | 3.93 | 181.4 | 188.0 | 174.0 | 21.3 | 0.058 | 0.350 | 0.051 | 0.810 | 1.510 | 0.554 | 7.42 | 2.610 | 25.29 | 7.02 | 21.89 | 3.270 | 18.59 | 2.245 | 10.740 | 8.030 | 0.071 | 0.870 | 0.838 | 0.337 |
| 9956c | 52 | 6 | 5010000 | 37.6 | 26.4 | 4.85 | 513.3 | 108.6 | 472.3 | 34.2 | 0.020 | 0.317 | 0.134 | 1.530 | 4.460 | 1.486 | 17.54 | 6.810 | 70.20 | 18.98 | 61.65 | 9.720 | 66.80 | 8.170 | 8.570 | 16.430 | 4.120 | 0.950 | 5.620 | 3.250 |
| 9956c | 54 | 9 | 6970000 | 31.4 | 25.3 | 6.18 | 200.0 | 63.7 | 137.7 | 14.6 | 0.015 | 0.099 | 0.050 | 0.470 | 1.810 | 0.490 | 6.03 | 2.520 | 29.50 | 7.53 | 23.90 | 3.880 | 23.10 | 2.890 | 6.240 | 6.430 | 0.023 | 6.700 | 0.600 | 0.148 |
| 9956c | 55 | 8 | 6470000 | 30.5 | 24.8 | 5.81 | 62.6 | 14.7 | 12.8 | 5.7 | | 0.048 | 0.016 | 0.258 | 0.670 | 0.216 | 2.65 | 0.969 | 9.07 | 2.43 | 7.45 | 1.002 | 6.32 | 0.791 | 1.700 | 2.351 | | 0.540 | 0.062 | 0.011 |
| 9956c | 56 | 8 | 6070000 | 31.9 | 26.0 | 4.57 | 285.5 | 22.2 | 30.7 | 17.9 | 0.003 | 0.146 | 0.093 | 1.010 | 2.260 | 0.753 | 9.94 | 3.678 | 38.08 | 10.52 | 35.81 | 5.360 | 37.05 | 5.140 | 0.825 | 0.990 | 1.640 | 0.450 | 1.356 | 1.385 |
| 9956c | 59 | 1 | 4360000 | 38.7 | 25.7 | 4.02 | 295.0 | 107.0 | 358.4 | 26.7 | 0.063 | 0.223 | 0.072 | 0.810 | 1.700 | 0.518 | 7.62 | 3.280 | 37.80 | 11.11 | 38.70 | 6.260 | 45.00 | 5.000 | 9.000 | 10.610 | 3.000 | 0.970 | 2.040 | 0.795 |
| 9956c | 60 | 3 | 5200000 | 37.1 | 25.9 | 11.50 | 316.9 | 2.2 | 145.4 | 21.6 | 0.085 | 0.294 | 0.107 | 0.870 | 1.960 | 0.665 | 8.88 | 3.750 | 42.59 | 12.12 | 41.17 | 6.600 | 44.46 | 5.640 | 0.100 | 4.460 | 1.390 | 10.200 | 2.780 | 1.269 |
| 9956c | 62 | 2 | 6020000 | 31.6 | 25.8 | 5.39 | 683.3 | 9.3 | 86.5 | 50.7 | 0.040 | 0.749 | 0.342 | 4.050 | 6.890 | 2.670 | 28.43 | 10.170 | 98.20 | 26.09 | 80.28 | 12.490 | 80.50 | 10.140 | 0.307 | 9.950 | 2.520 | 0.362 | 11.350 | 5.340 |
| 9956c | 63 | 2 | 6100000 | 31.4 | 25.5 | 4.47 | 213.3 | 4.2 | 29.9 | 14.6 | | 0.058 | 0.038 | 0.464 | 1.430 | 0.556 | 7.27 | 2.751 | 28.85 | 8.08 | 27.59 | 4.060 | 25.97 | 3.610 | 0.084 | 5.850 | 0.236 | 1.230 | 0.343 | 0.142 |
| 9956c | 64 | 1 | 6080000 | 32.0 | 25.0 | 4.33 | 269.0 | 50.5 | 187.6 | 25.8 | 0.018 | 0.161 | 0.067 | 0.920 | 2.050 | 0.717 | 8.60 | 3.600 | 37.90 | 10.17 | 32.80 | 5.190 | 34.10 | 3.750 | 5.330 | 6.450 | 0.435 | 0.153 | 2.390 | 1.080 |
| 9956c | 69 | 1 | 6490000 | 30.6 | 24.8 | 5.97 | 403.4 | 56.1 | 240.8 | 23.2 | 0.010 | 0.264 | 0.150 | 1.810 | 3.780 | 1.511 | 16.05 | 6.290 | 62.40 | 15.69 | 46.80 | 6.950 | 42.80 | 4.510 | 4.310 | 6.320 | 0.482 | 0.870 | 2.340 | 0.982 |
| 9956c | 70 | 2 | 6170000 | 31.4 | 25.0 | 4.40 | 337.6 | 112.0 | 236.0 | 22.5 | 0.019 | 0.164 | 0.090 | 1.280 | 2.420 | 1.000 | 11.12 | 4.750 | 49.15 | 13.09 | 40.98 | 6.430 | 41.00 | 4.590 | 7.600 | 10.670 | 0.217 | 1.900 | 1.910 | 0.820 |
| 9956c | 71 | 2 | 6390000 | 30.7 | 24.8 | 4.35 | 454.9 | 52.9 | 281.0 | 23.0 | 0.415 | 4.190 | 1.280 | 11.000 | 10.200 | 3.030 | 25.10 | 7.700 | 70.30 | 17.35 | 53.20 | 8.240 | 52.90 | 6.240 | 3.940 | 7.800 | 0.165 | 1.190 | 3.410 | 1.528 |
| 9956c | 73 | 2 | 5770000 | 32.0 | 26.2 | 6.65 | 260.2 | 9.1 | 125.7 | 22.4 | | 0.065 | 0.029 | 0.570 | 1.250 | 0.420 | 7.28 | 2.880 | 33.75 | 10.33 | 35.47 | 5.570 | 35.99 | 4.310 | 0.417 | 4.210 | 0.162 | 0.120 | 0.291 | 0.162 |
| 9956c | 74 | 2 | 4210000 | 33.1 | 26.2 | 5.18 | 334.1 | 17.7 | 218.9 | 26.1 | 0.009 | 0.133 | 0.057 | 0.760 | 1.780 | 0.443 | 8.55 | 3.750 | 43.20 | 12.76 | 45.01 | 6.910 | 45.63 | 5.260 | 0.860 | 9.180 | 0.146 | 0.378 | 0.480 | 0.328 |
| 9956d | 1 | 2 | 5940000 | 31.5 | 25.5 | 4.25 | 709.0 | 65.8 | 80.0 | 37.9 | 1.499 | 17.180 | 6.410 | 55.100 | 35.590 | 19.660 | 71.20 | 16.310 | 123.00 | 27.66 | 77.90 | 11.380 | 76.40 | 9.570 | 3.350 | 1.950 | 0.095 | 0.164 | 5.260 | 5.830 |
| 9956d | 2 | 2 | 6140000 | 31.2 | 25.3 | 4.19 | 330.4 | 36.1 | 71.2 | 18.3 | 0.860 | 9.290 | 3.260 | 28.690 | 16.150 | 9.020 | 33.00 | 7.240 | 55.40 | 12.88 | 37.70 | 5.420 | 35.69 | 5.090 | 1.390 | 1.198 | 0.332 | 0.098 | 1.922 | 5.400 |
| 9956d | 3 | 2 | 6080000 | 31.7 | 25.8 | 6.91 | 583.4 | 57.4 | 70.9 | 39.2 | 1.693 | 18.750 | 6.730 | 54.580 | 32.300 | 17.780 | 61.80 | 13.520 | 102.80 | 23.23 | 63.26 | 9.410 | 58.11 | 7.550 | 2.650 | 1.647 | 0.103 | 0.201 | 4.110 | 6.360 |
| 9956d | 4 | 2 | 6060000 | 31.0 | 25.3 | 5.63 | 557.7 | 90.0 | 78.1 | 35.1 | 1.288 | 14.240 | 5.320 | 44.100 | 28.400 | 15.090 | 54.10 | 12.990 | 96.80 | 21.88 | 61.60 | 8.800 | 56.30 | 7.040 | 3.700 | 1.566 | 0.073 | 0.630 | 4.080 | 5.760 |
| 9956d | 5 | 2 | 5930000 | 31.4 | 25.6 | 2.88 | 236.2 | 4.5 | 21.8 | 6.4 | 0.116 | 1.666 | 0.697 | 6.770 | 6.930 | 2.720 | 17.26 | 4.440 | 35.46 | 9.16 | 28.39 | 4.300 | 29.78 | 4.670 | 0.121 | 0.281 | 0.138 | 0.111 | 0.476 | 0.901 |
| 9956d | 6 | 2 | 5960000 | 31.3 | 25.5 | 4.42 | 442.0 | 46.9 | 72.6 | 30.9 | 0.636 | 6.950 | 2.664 | 25.360 | 21.190 | 7.460 | 42.50 | 10.060 | 76.80 | 17.13 | 48.36 | 7.050 | 45.29 | 5.810 | 1.970 | 1.204 | 0.216 | 0.150 | 3.850 | 4.450 |
| 9956d | 7 | 2 | 6430000 | 29.7 | 24.4 | 3.62 | 227.3 | 71.2 | 34.9 | 14.8 | 0.499 | 5.690 | 2.120 | 19.580 | 13.360 | 5.990 | 26.03 | 5.750 | 42.38 | 9.09 | 24.16 | 3.357 | 19.77 | 2.349 | 2.350 | 0.932 | | 0.050 | 0.784 | 1.249 |
| 9956d | 8 | 2 | 6020000 | 30.6 | 25.2 | 4.88 | 329.0 | 23.9 | 70.8 | 10.4 | 0.436 | 4.660 | 1.672 | 16.760 | 13.710 | 7.190 | 30.81 | 6.960 | 53.55 | 13.06 | 37.71 | 5.600 | 37.24 | 5.330 | 1.067 | 1.143 | 0.243 | 0.296 | 1.617 | 4.270 |
| 9956d | 9 | 2 | 6840000 | 29.1 | 24.6 | 3.79 | 246.3 | 53.1 | 42.6 | 15.7 | 0.355 | 3.860 | 1.630 | 14.660 | 12.080 | 5.540 | 23.77 | 5.680 | 42.60 | 9.55 | 27.14 | 3.700 | 23.48 | 2.900 | 2.300 | 1.540 | 0.016 | 0.027 | 0.728 | 1.120 |
| 9956d | 10 | 2 | 6980000 | 28.7 | 23.6 | 3.68 | 175.3 | 3.9 | 31.7 | 9.4 | 0.443 | 5.550 | 2.228 | 17.740 | 13.110 | 5.120 | 23.58 | 5.040 | 35.42 | 7.11 | 17.95 | 2.248 | 13.26 | 1.442 | 0.314 | 0.511 | 0.009 | 0.033 | 0.248 | 0.178 |
| 9956d | 11 | 2 | 6880000 | 29.1 | 23.7 | 11.50 | 240.3 | 19.7 | 46.3 | 17.7 | 0.570 | 6.580 | 2.529 | 21.870 | 15.060 | 7.120 | 28.79 | 6.440 | 45.30 | 9.80 | 24.99 | 3.420 | 20.38 | 2.300 | 1.000 | 0.702 | | 0.159 | 0.403 | 0.941 |
| 9956d | 12 | 6 | 6550000 | 29.5 | 24.5 | 19.30 | 269.0 | 74.7 | 109.1 | 18.4 | 0.199 | 2.000 | 0.803 | 7.630 | 7.650 | 3.330 | 18.00 | 5.230 | 44.10 | 10.42 | 29.90 | 4.330 | 25.80 | 2.760 | 4.490 | 3.400 | 0.015 | 0.920 | 0.889 | 0.979 |
| 9956d | 14 | 2 | 6600000 | 29.0 | 23.7 | 3.74 | 206.4 | 4.1 | 36.2 | 13.4 | 0.117 | 1.746 | 0.666 | 7.500 | 8.420 | 3.020 | 19.99 | 4.840 | 37.73 | 8.34 | 21.99 | 3.023 | 18.45 | 2.191 | 0.255 | 0.327 | 0.078 | 0.137 | 0.971 | 1.209 |
| 9956d | 16 | 2 | 6130000 | 30.0 | 24.7 | 4.99 | 360.5 | 13.9 | 75.5 | 21.5 | 0.236 | 2.730 | 1.164 | 11.520 | 12.220 | 4.920 | 31.97 | 8.030 | 61.10 | 13.96 | 39.30 | 5.650 | 36.53 | 4.360 | 0.465 | 0.437 | 0.476 | 0.285 | 2.840 | 3.730 |
| 9956d | 18 | 2 | 5930000 | 31.0 | 25.5 | 4.43 | 467.0 | 46.4 | 55.6 | 26.6 | 0.966 | 10.250 | 3.810 | 33.100 | 22.960 | 10.490 | 45.20 | 10.350 | 79.70 | 18.27 | 51.40 | 7.290 | 48.60 | 6.190 | 1.530 | 0.500 | 0.239 | 0.312 | 2.210 | 6.120 |

# Table 4-1.1: LA-ICP-MS trace element analyses for titanite.



| Sample | Position | Type | Ticps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9956d | 19 | 2 | 6280000 | 29.0 | 23.9 | 4.53 | 273.0 | 12.6 | 36.5 | 15.4 | 0.707 | 8.230 | 3.126 | 27.680 | 17.020 | 8.890 | 33.20 | 7.190 | 52.65 | 10.93 | 28.60 | 3.880 | 22.76 | 2.540 | 0.680 | 0.394 | | 4.450 | 0.459 | 0.825 |
| 9956d | 20 | 2 | 6880000 | 28.4 | 23.4 | 3.14 | 202.7 | 2.8 | 48.8 | 8.8 | 0.091 | 1.281 | 0.565 | 6.040 | 7.330 | 3.050 | 20.14 | 5.040 | 38.70 | 8.08 | 20.64 | 2.692 | 15.36 | 1.600 | 0.393 | 1.009 | | 0.009 | 0.325 | 0.140 |
| 9956d | 21 | 2 | 6950000 | 28.7 | 23.6 | 6.30 | 203.1 | 5.4 | 28.7 | 8.7 | 0.451 | 5.470 | 2.123 | 19.320 | 12.860 | 6.260 | 25.20 | 5.670 | 39.90 | 8.07 | 20.45 | 2.661 | 15.95 | 1.701 | 0.430 | 0.573 | | 0.061 | 0.221 | 0.256 |
| 9956d | 22 | 2 | 6500000 | 29.2 | 24.0 | 3.70 | 257.2 | 12.8 | 55.6 | 13.0 | 0.362 | 4.430 | 1.770 | 16.390 | 13.340 | 4.790 | 28.10 | 6.370 | 46.60 | 10.27 | 26.96 | 3.680 | 22.82 | 2.640 | 0.665 | 1.320 | 0.026 | 0.103 | 0.960 | 1.001 |
| 9956d | 23 | 2 | 5900000 | 30.9 | 25.3 | 3.58 | 269.2 | 14.6 | 38.1 | 10.4 | 0.172 | 1.940 | 0.833 | 8.520 | 8.360 | 3.030 | 21.52 | 5.370 | 42.20 | 10.31 | 30.52 | 4.640 | 30.63 | 4.240 | 0.546 | 0.726 | 0.212 | 0.160 | 1.302 | 1.586 |
| 9956d | 24 | 2 | 6290000 | 29.1 | 24.2 | 4.65 | 49.6 | 1.0 | 20.8 | 8.2 | 0.008 | 0.336 | 0.152 | 1.610 | 1.320 | 1.401 | 4.28 | 0.988 | 8.39 | 1.92 | 6.00 | 0.840 | 5.09 | 0.683 | 0.147 | 0.523 | 2.820 | 0.980 | 0.230 | 0.899 |
| 9956d | 26 | 6 | 5610000 | 33.2 | 25.6 | 15.00 | 743.0 | 37.1 | 425.6 | 16.3 | 0.077 | 0.996 | 0.483 | 5.540 | 9.080 | 3.820 | 33.00 | 10.390 | 99.80 | 27.48 | 88.60 | 13.780 | 95.60 | 12.720 | 3.740 | 8.810 | 2.130 | 0.229 | 3.840 | 3.560 |
| 9956d | 27 | 6 | 5830000 | 31.9 | 25.8 | 3.98 | 667.8 | 70.5 | 310.2 | 37.7 | 0.020 | 0.303 | 0.198 | 2.880 | 5.800 | 3.130 | 26.92 | 10.070 | 98.30 | 25.10 | 78.01 | 12.070 | 77.80 | 9.820 | 7.190 | 15.890 | 1.420 | 0.151 | 5.840 | 4.430 |
| 9956d | 28 | 6 | 6120000 | 31.2 | 25.3 | 6.23 | 506.0 | 145.0 | 338.0 | 40.7 | 0.031 | 0.271 | 0.140 | 1.880 | 4.180 | 1.620 | 18.50 | 6.920 | 70.70 | 18.80 | 57.20 | 8.800 | 56.40 | 5.940 | 13.330 | 9.580 | 0.660 | 0.171 | 2.800 | 1.930 |
| 9956d | 29 | 6 | 5930000 | 32.1 | 26.1 | 3.87 | 532.0 | 24.5 | 265.3 | 18.8 | 0.026 | 0.313 | 0.134 | 1.870 | 3.990 | 1.700 | 18.56 | 7.090 | 73.00 | 20.05 | 64.80 | 10.020 | 66.90 | 8.420 | 3.010 | 6.520 | 0.790 | 0.124 | 3.050 | 1.187 |
| 9956d | 30 | 6 | 5070000 | 36.5 | 26.3 | 11.72 | 628.0 | 71.0 | 307.0 | 22.7 | 0.074 | 0.554 | 0.239 | 2.470 | 5.520 | 2.390 | 24.00 | 8.940 | 86.40 | 23.10 | 74.20 | 11.460 | 76.40 | 9.720 | 4.880 | 11.300 | 2.050 | 0.167 | 4.390 | 2.250 |
| 9956d | 32 | 6 | 5570000 | 32.0 | 26.0 | 3.22 | 365.2 | 23.0 | 180.8 | 9.8 | | 0.131 | 0.076 | 0.950 | 2.490 | 1.271 | 12.77 | 4.760 | 49.03 | 13.78 | 46.18 | 7.290 | 50.68 | 7.210 | 1.570 | 7.380 | 1.210 | 0.038 | 1.670 | 1.830 |
| 9956d | 33 | 6 | 5730000 | 31.8 | 26.1 | 4.05 | 790.5 | 104.5 | 424.8 | 38.0 | 0.021 | 0.434 | 0.213 | 2.620 | 7.250 | 3.260 | 32.41 | 11.600 | 114.60 | 29.02 | 91.70 | 14.110 | 92.70 | 11.260 | 6.800 | 18.670 | 1.240 | 0.280 | 8.980 | 5.990 |
| 9956d | 34 | 6 | 5700000 | 31.7 | 24.8 | 4.33 | 276.0 | 65.0 | 165.7 | 15.3 | | 0.092 | 0.065 | 0.680 | 2.000 | 0.990 | 10.18 | 3.600 | 38.00 | 10.15 | 31.80 | 4.890 | 33.00 | 4.230 | 2.930 | 6.030 | 0.293 | 0.303 | 0.770 | 0.820 |
| 9956d | 39 | 3 | 5680000 | 34.0 | 25.2 | 11.00 | 161.6 | 25.9 | 131.7 | 14.1 | 0.117 | 0.289 | 0.057 | 0.453 | 1.010 | 0.422 | 5.62 | 2.036 | 22.30 | 6.34 | 20.53 | 3.100 | 20.57 | 2.700 | 1.570 | 7.890 | 0.346 | 0.242 | 0.907 | 0.260 |
| 9956d | 40 | 4 | 5450000 | 35.1 | 25.5 | 4.74 | 317.6 | 54.1 | 183.8 | 26.6 | 0.038 | 0.338 | 0.111 | 1.280 | 2.480 | 1.038 | 11.21 | 4.500 | 44.41 | 12.09 | 38.16 | 6.010 | 39.30 | 4.930 | 3.580 | 5.080 | 1.090 | 0.382 | 6.900 | 2.020 |
| 9956d | 45 | 2 | 6450000 | 29.4 | 24.0 | 14.40 | 341.5 | 11.9 | 155.5 | 19.8 | 0.027 | 0.362 | 0.217 | 2.240 | 4.380 | 1.630 | 15.79 | 5.730 | 54.10 | 13.22 | 38.00 | 5.510 | 33.43 | 3.410 | 1.420 | 1.814 | 0.223 | 0.440 | 1.020 | 0.475 |
| 9956d | 46 | 2 | 6240000 | 30.2 | 24.6 | 5.42 | 939.0 | 31.0 | 229.6 | 29.5 | 0.483 | 4.980 | 2.120 | 20.500 | 21.900 | 7.930 | 59.90 | 17.150 | 148.20 | 35.92 | 105.00 | 15.610 | 99.40 | 11.150 | 5.230 | 5.040 | 0.545 | 0.365 | 7.580 | 2.550 |
| 9956d | 47 | 2 | 5930000 | 30.9 | 24.5 | 10.86 | 273.3 | 5.5 | 22.6 | 23.0 | 0.031 | 0.190 | 0.065 | 0.730 | 1.610 | 0.530 | 7.81 | 3.331 | 36.83 | 10.45 | 34.75 | 5.570 | 37.22 | 4.090 | 0.370 | 0.581 | 0.637 | 0.446 | 0.698 | 0.532 |
| 9956d | 49 | 6 | 6270000 | 31.4 | 24.0 | 3.73 | 240.0 | 54.9 | 90.6 | 17.8 | 0.022 | 0.187 | 0.086 | 1.460 | 2.770 | 1.470 | 12.35 | 4.230 | 38.10 | 9.05 | 26.30 | 3.670 | 21.40 | 2.360 | 13.400 | 2.900 | 0.017 | 2.900 | 0.487 | 0.239 |
| 9957 | 1 | 1 | 7750000 | 32.0 | 25.3 | 43.47 | 916.0 | 112.8 | 381.9 | 25.4 | 133.200 | 730.300 | 166.500 | 1001.000 | 281.400 | 88.400 | 241.00 | 33.700 | 190.70 | 36.00 | 89.60 | 12.740 | 82.60 | 11.150 | 9.120 | 9.220 | 1.510 | 2.230 | 8.160 | 15.790 |
| 9958a | 1 | 6 | 7650000 | 32.4 | 25.6 | 39.73 | 376.3 | 48.4 | 283.9 | 18.6 | 25.200 | 188.400 | 50.400 | 334.000 | 107.100 | 40.930 | 93.10 | 13.170 | 73.80 | 13.98 | 36.00 | 5.220 | 35.39 | 5.090 | 4.880 | 11.350 | 1.380 | 1.940 | 5.140 | 4.120 |
| 9958a | 3 | 6 | 7480000 | 33.1 | 25.6 | 50.20 | 519.2 | 58.2 | 319.5 | 22.4 | 40.470 | 266.500 | 68.560 | 457.000 | 145.000 | 54.180 | 130.20 | 18.350 | 105.50 | 19.82 | 50.29 | 7.140 | 47.11 | 6.640 | 6.440 | 9.690 | 1.105 | 1.330 | 2.400 | 3.690 |
| 9958a | 6 | 1 | 7020000 | 34.7 | 26.7 | 229.00 | 495.0 | 76.8 | 347.0 | 23.7 | 71.100 | 384.000 | 83.600 | 510.000 | 146.900 | 57.200 | 132.20 | 18.200 | 100.40 | 18.74 | 47.20 | 6.720 | 45.30 | 6.410 | 7.250 | 16.500 | 1.170 | 1.350 | 0.896 | 4.350 |
| 9958a | 8 | 6 | 7010000 | 35.5 | 25.7 | 71.70 | 62.8 | 207.0 | 32.5 | 18.3 | 63.650 | 502.300 | 118.060 | 647.300 | 100.900 | 31.280 | 47.27 | 4.040 | 16.22 | 2.67 | 5.97 | 0.753 | 4.58 | 0.662 | 9.460 | 1.344 | 0.730 | 2.480 | 28.450 | 3.530 |
| 9958a | 9 | 6 | 6490000 | 38.6 | 26.2 | 111.00 | 39.7 | 85.7 | 8.2 | 14.4 | 51.500 | 392.600 | 90.200 | 475.000 | 70.900 | 22.650 | 32.89 | 2.759 | 10.34 | 1.70 | 3.61 | 0.405 | 2.62 | 0.461 | 3.770 | 0.381 | 0.274 | 1.710 | 10.750 | 1.311 |
| 9958a | 10 | 6 | 7480000 | 32.3 | 25.4 | 33.08 | 146.2 | 162.1 | 68.3 | 31.2 | 225.500 | 1572.000 | 342.000 | 1774.000 | 271.500 | 72.070 | 123.50 | 10.260 | 38.50 | 5.83 | 12.42 | 1.546 | 10.13 | 1.827 | 4.630 | 1.891 | 3.720 | 5.790 | 135.200 | 27.720 |
| 9958a | 11 | 6 | 7610000 | 32.6 | 25.2 | 45.20 | 91.6 | 118.7 | 55.2 | 19.9 | 45.220 | 361.300 | 87.480 | 490.100 | 81.400 | 24.930 | 43.83 | 4.250 | 19.54 | 3.68 | 9.24 | 1.340 | 8.68 | 1.238 | 6.750 | 1.986 | 3.420 | 2.590 | 16.610 | 2.048 |

Modes of Occurrence (= Type)

1: Equant/sub-equant crystal with some euhedral faces
2: Equant overgrowth usually with some euhedral faces
3: Sub-equant overgrowth
4: Discontinuous sub-equant overgrowth
5: Interstitial overgrowth (no LA-ICP-MS analyses)
6: Interstitial grain
7: Small irregular discrete crystals
8: Equant crystal exsolving rutile
9: Replacive
10: Intergrowth of titanite + rutile, replacement of rutile by titanite
11: Corona or discontinuous corona (no LA-ICP-MS analyses)

# Table 4-1.2: LA-ICP-MS trace element analyses for rutile.



| Sample | Position | Ti cps | SiO2 | CaO | Sr | Y | Zr | Nb | Sn | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9928b | OG8 | 16730000 | | 0.03 | 1.12 | 0.10 | 17.9 | 223.0 | 17.50 | | | | | | | | 0.002 | | | | | 0.003 | 0.001 | 0.61 | 4.51 | 15.60 | 0.015 | | 0.054 |
| 9956a | 1 | 17610000 | 0.03 | 0.01 | 0.94 | 0.08 | 38.3 | 806.0 | 20.78 | | | | | | | | | | | | | | | 2.70 | 28.74 | 0.83 | 0.027 | 0.287 | 1.253 |
| 9956a | 15 | 17970000 | | 0.04 | 4.87 | 0.24 | 4.6 | 39.1 | 3.15 | | 0.002 | | | | | | | | 0.001 | 0.032 | | 0.030 | 0.006 | 0.17 | 0.82 | 3.12 | 0.216 | 0.184 | 0.382 |
| 9956a | 16 | 18100000 | | 0.05 | 6.59 | 0.35 | 4.5 | 33.2 | 3.12 | | 0.013 | | | | | 0.016 | 0.003 | 0.032 | 0.005 | 0.032 | 0.007 | 0.024 | 0.014 | 0.20 | 0.63 | 1.45 | 0.227 | 0.644 | 0.725 |
| 9956a | 18 | 18210000 | 0.04 | 0.06 | 6.20 | 0.22 | 15.3 | 44.1 | 3.19 | 0.005 | 0.004 | | 0.021 | | 0.004 | 0.023 | | 0.010 | 0.001 | 0.032 | 0.003 | 0.034 | 0.003 | 0.41 | 1.40 | 14.50 | 0.620 | 0.156 | 0.349 |
| 9956a | 60 | 17030000 | 0.02 | 0.02 | 2.08 | 7.97 | 233.7 | 1328.0 | 157.70 | 17.950 | 41.200 | 4.770 | 18.280 | 3.510 | 0.257 | 2.850 | 0.433 | 2.020 | 0.397 | 1.090 | 0.137 | 0.980 | 0.162 | 16.83 | 67.00 | 44.20 | 0.489 | 8.620 | 167.000 |
| 9956a | 61 | 16240000 | 0.15 | 0.10 | 3.62 | 7.20 | 78.0 | 726.1 | 99.90 | 16.100 | 31.900 | 3.610 | 14.100 | 2.640 | 0.160 | 2.000 | 0.297 | 1.840 | 0.365 | 0.870 | 0.140 | 0.940 | 0.125 | 4.76 | 26.89 | 13.00 | 0.510 | 6.110 | 62.300 |
| 9956a | 74 | 16000000 | 0.09 | 0.03 | 8.27 | 0.15 | 2.1 | 113.5 | 4.01 | | | | | | | | 0.003 | | 0.004 | 0.014 | 0.004 | 0.028 | 0.007 | 0.14 | 4.31 | 3.05 | 0.540 | 0.121 | 0.235 |
| 9956b | 11 | 16400000 | 0.16 | 0.05 | 2.05 | 0.71 | 6500.0 | 908.0 | 26.35 | 0.134 | 0.209 | 0.026 | 0.082 | 0.070 | 0.008 | 0.068 | 0.005 | 0.098 | 0.017 | 0.070 | 0.003 | 0.040 | 0.008 | 191.20 | 33.77 | 1.48 | 0.110 | 0.810 | 26.700 |
| 9956b | 19 | 17400000 | | 0.01 | 1.43 | 0.22 | 2369.0 | 388.0 | 18.65 | 0.034 | 0.090 | 0.008 | 0.013 | | | | 0.004 | 0.020 | 0.010 | 0.024 | | 0.063 | 0.023 | 59.20 | 6.48 | 0.30 | 0.349 | 0.021 | 5.500 |
| 9956b | 20 | 16600000 | 0.04 | | 0.76 | 0.13 | 6347.0 | 840.0 | 35.05 | | 0.003 | | | | | | | | 0.004 | 0.012 | | 0.036 | 0.017 | 185.80 | 31.23 | 2.34 | 0.041 | 0.009 | 40.830 |
| 9956b | 33 | 16740000 | 0.16 | 0.07 | 0.99 | 0.30 | 31.2 | 284.4 | 117.80 | 0.042 | 0.052 | 0.004 | | | | | | 0.026 | 0.011 | 0.022 | 0.004 | 0.003 | | 2.03 | 8.43 | 0.68 | 0.238 | 0.005 | 0.659 |
| 9956b | 34 | 17440000 | 0.03 | 0.01 | 0.82 | 0.16 | 38.2 | 247.5 | 127.00 | 0.008 | 0.045 | | 0.015 | | | | | 0.026 | 0.006 | 0.016 | | | 0.002 | 1.79 | 10.33 | 0.40 | 0.067 | 0.024 | 1.126 |
| 9956b | 65 | 16920000 | 0.04 | 0.02 | 1.54 | 0.34 | 3390.0 | 1709.0 | 30.10 | 0.560 | 1.160 | 0.123 | 0.470 | 0.049 | 0.018 | 0.032 | 0.006 | 0.058 | 0.010 | 0.036 | 0.003 | 0.024 | 0.005 | 112.30 | 120.90 | 1.85 | 0.204 | 0.520 | 10.980 |
| 9956c | 1 | 16080000 | | 0.02 | 9.40 | 0.08 | 0.4 | 4.1 | 1.91 | | | | | | | | | | | | | | | | 0.18 | 1.59 | 0.289 | 0.097 | 0.178 |
| 9956c | 9 | 16610000 | 0.06 | 0.10 | 5.98 | 4.39 | 660.0 | 396.0 | 50.90 | 1.020 | 2.440 | 0.352 | 1.650 | 0.620 | 0.189 | 1.050 | 0.164 | 1.080 | 0.223 | 0.453 | 0.074 | 0.424 | 0.045 | 25.20 | 17.00 | 55.70 | 0.219 | 3.420 | 38.400 |
| 9956c | 11 | 16230000 | 0.03 | | 0.86 | 0.12 | 2485.0 | 470.5 | 18.22 | | | | | | | | | 0.022 | 0.007 | | 0.002 | 0.035 | 0.005 | 84.20 | 17.42 | 0.41 | 0.008 | | 5.400 |
| 9956c | 21 | 16050000 | 0.04 | 0.00 | 0.86 | 0.08 | 5030.0 | 1267.0 | 29.47 | | | | | | | | | | | 0.016 | 0.006 | 0.017 | 0.010 | 130.10 | 22.31 | 8.38 | 0.038 | 0.034 | 40.390 |
| 9956c | 22 | 16270000 | 0.04 | | 0.78 | 0.06 | 4229.0 | 1016.0 | 28.60 | | | | | | | | 0.003 | | | | | 0.007 | 0.005 | 118.80 | 23.88 | 3.57 | 0.004 | | 20.910 |
| 9956c | 23 | 16190000 | | 0.02 | 2.96 | 0.12 | 6396.0 | 959.0 | 35.60 | 0.006 | 0.055 | 0.001 | | | | | | 0.010 | 0.001 | 0.011 | | 0.019 | 0.018 | 177.10 | 29.76 | 3.66 | 0.360 | 0.011 | 43.400 |
| 9956c | 24 | 16380000 | 0.09 | | 1.18 | 0.39 | 5630.0 | 785.0 | 32.00 | 0.109 | 0.205 | 0.009 | 0.032 | | | 0.032 | | 0.074 | 0.006 | 0.048 | 0.006 | 0.058 | 0.020 | 156.90 | 27.52 | 2.39 | 0.090 | 0.031 | 37.600 |
| 9956c | 29 | 16640000 | | 0.02 | 0.87 | 0.34 | 14.0 | 177.0 | 38.70 | 0.136 | 0.272 | 0.045 | 0.097 | 0.054 | 0.018 | 0.081 | 0.007 | 0.082 | 0.010 | 0.019 | 0.005 | 0.019 | | 0.65 | 16.26 | 2.32 | 0.058 | 0.535 | 5.290 |
| 9956c | 38 | 16180000 | | 0.01 | 0.75 | 0.06 | 1919.0 | 300.5 | 25.14 | | | | | | | | | | | 0.002 | | 0.031 | 0.005 | 58.95 | 8.66 | 0.36 | 0.031 | 0.027 | 7.580 |
| 9956c | 45 | 16390000 | 0.03 | 0.01 | 1.65 | 2.67 | 326.4 | 677.0 | 124.30 | 5.840 | 12.790 | 1.509 | 5.420 | 0.880 | 0.075 | 0.860 | 0.131 | 0.680 | 0.142 | 0.397 | 0.057 | 0.424 | 0.060 | 16.99 | 35.30 | 20.48 | 0.872 | 4.060 | 53.400 |
| 9956c | 58 | 15940000 | 0.05 | 0.00 | 1.19 | 0.23 | 4670.0 | 1466.0 | 36.20 | 0.327 | 0.840 | 0.090 | 0.318 | 0.049 | | 0.038 | 0.008 | 0.031 | 0.009 | 0.023 | | 0.076 | 0.005 | 158.50 | 61.20 | 6.42 | 0.075 | 0.476 | 26.600 |
| 9956c | 72 | 15870000 | 0.05 | 0.04 | 2.88 | 1.27 | 413.0 | 2646.0 | 63.20 | 1.820 | 4.040 | 0.432 | 1.870 | 0.231 | 0.019 | 0.381 | 0.041 | 0.269 | 0.061 | 0.173 | 0.034 | 0.236 | 0.018 | 18.53 | 77.10 | 7.68 | 0.760 | 2.250 | 21.800 |
| 9956c | 75 | 15760000 | 0.12 | 0.13 | 0.95 | 0.28 | 2790.0 | 576.6 | 21.42 | 0.004 | 0.004 | 0.002 | | | | | 0.001 | 0.024 | 0.008 | 0.033 | 0.008 | 0.046 | 0.012 | 86.80 | 54.06 | 1.03 | 0.095 | 0.069 | 10.040 |
| 9956d | 35 | 14580000 | 0.05 | 0.02 | 2.84 | 6.96 | 218.1 | 508.0 | 227.00 | 7.250 | 42.900 | 8.410 | 43.800 | 12.890 | 1.470 | 8.230 | 0.949 | 3.870 | 0.473 | 0.850 | 0.064 | 0.316 | 0.029 | 22.62 | 15.90 | 9.79 | 0.497 | 9.010 | 12.660 |
| 9956d | 36 | 15940000 | 0.14 | 0.11 | 2.49 | 1.61 | 38.8 | 536.0 | 26.43 | 3.000 | 3.000 | 0.273 | 0.930 | 0.126 | 0.057 | 0.216 | 0.017 | 0.313 | 0.086 | 0.321 | 0.071 | 0.232 | 0.035 | 2.45 | 19.03 | 0.90 | 2.520 | 0.919 | 1.547 |
| 9956d | 42 | 15470000 | 0.03 | 0.02 | 0.82 | 0.20 | 819.0 | 2015.0 | 123.70 | 0.489 | 1.110 | 0.114 | 0.360 | 0.034 | | 0.030 | 0.012 | 0.023 | 0.015 | 0.005 | | 0.025 | 0.014 | 37.30 | 117.90 | 15.70 | 0.034 | 0.660 | 26.900 |
| 9956d | 43 | 15540000 | 0.03 | 0.00 | 0.97 | 0.08 | 5170.0 | 1275.0 | 33.15 | | | | | | | | 0.003 | | | | 0.002 | 0.027 | 0.008 | 117.30 | 17.30 | 7.72 | 0.169 | 0.047 | 50.340 |
| 9956d | 44 | 15950000 | 0.01 | 0.01 | 0.89 | 0.54 | 2280.0 | 998.0 | 126.00 | 1.350 | 2.710 | 0.270 | 1.140 | 0.238 | 0.006 | 0.059 | 0.019 | 0.140 | 0.027 | 0.057 | 0.014 | 0.073 | 0.009 | 75.70 | 23.90 | 67.00 | 0.072 | 1.680 | 135.000 |

# Appendix 5: SEM-BSE images of the location of laser ablation rutile geochronology (syenites: samples 9928, 9956).

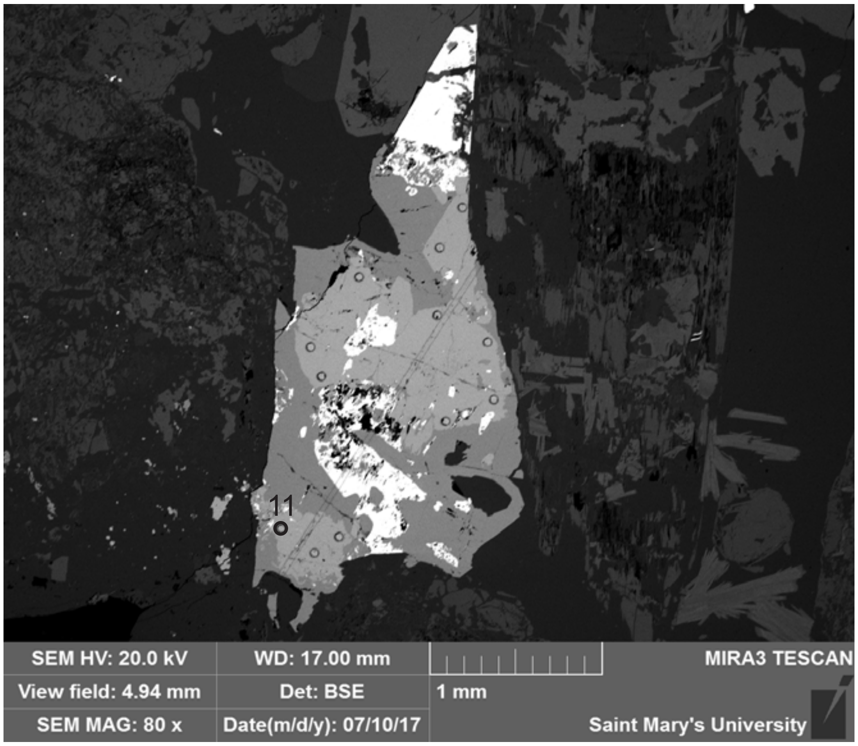



Figure 5.1: Sample 9928a. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

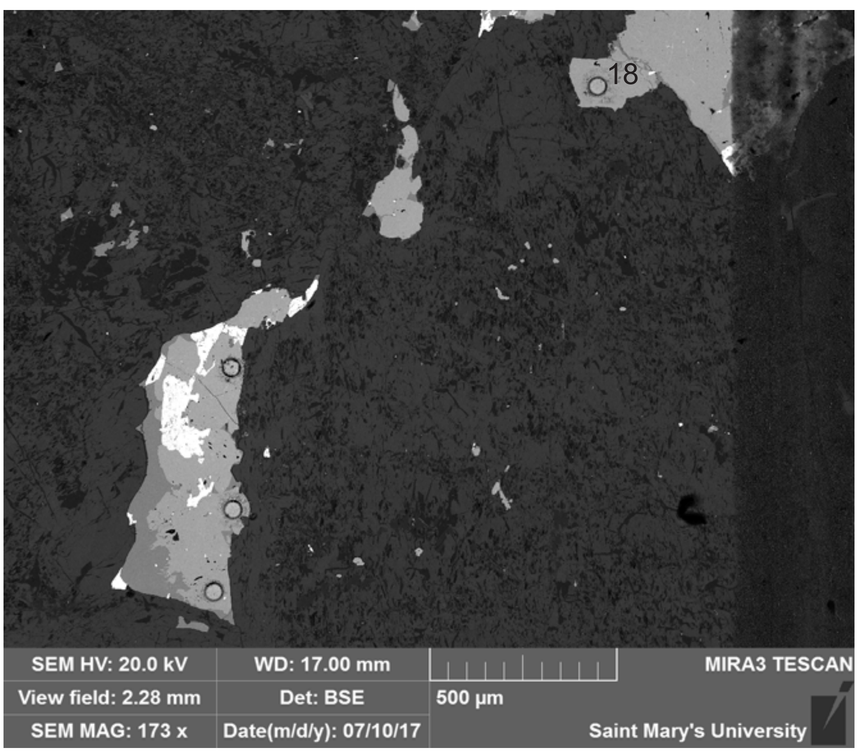



Figure 5.2: Sample 9928a. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

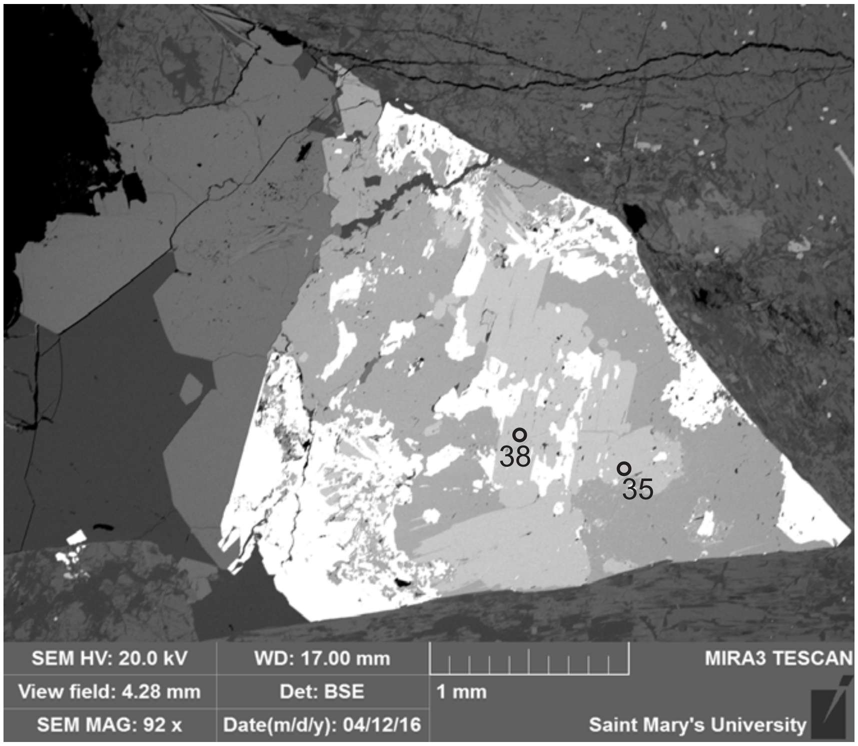



Figure 5.4: Sample 9928a. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

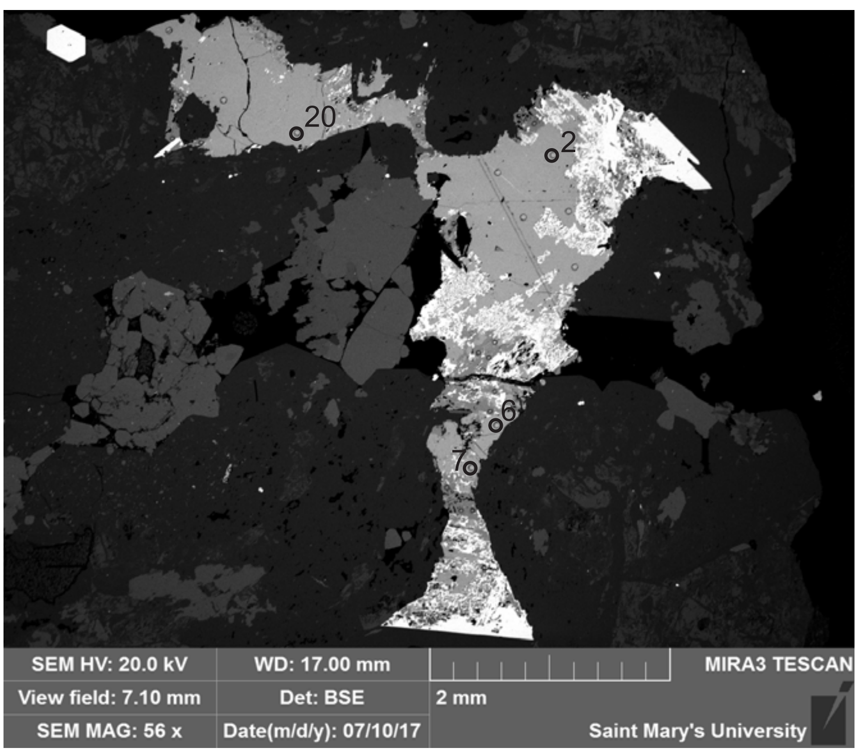



Figure 5.5: Sample 9956b. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

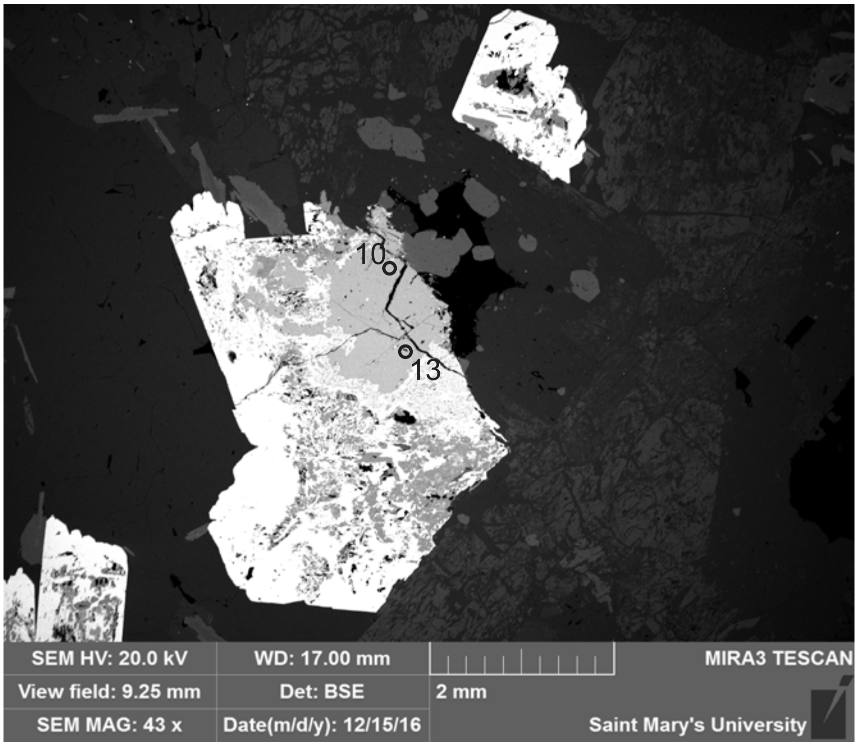



Figure 5.6: Sample 9956b. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

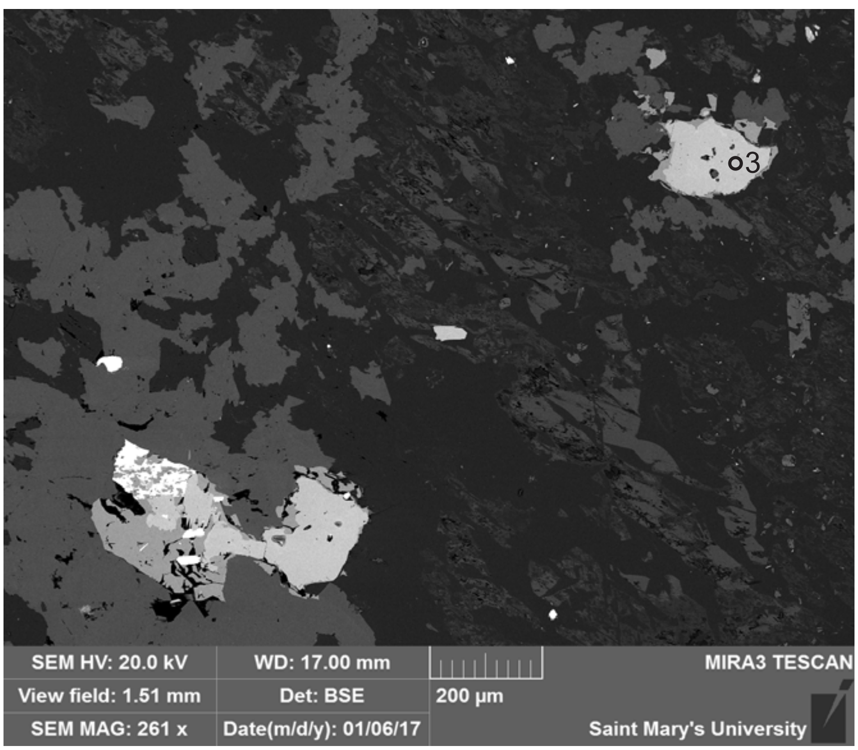



Figure 5.7: Sample 9956c. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

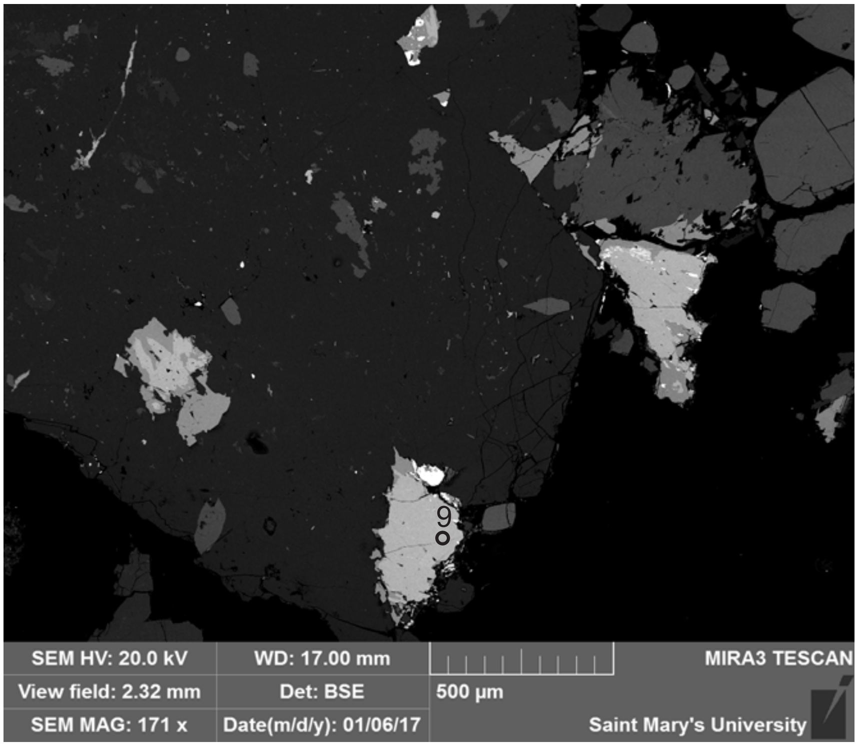



Figure 5.8: Sample 9956c. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

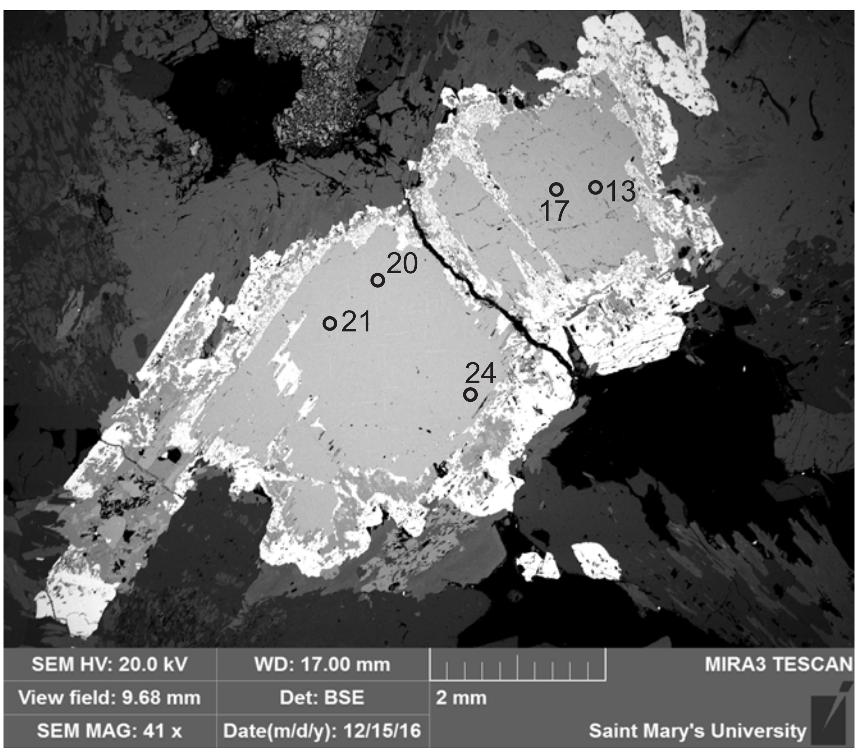



Figure 5.9: Sample 9956c. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

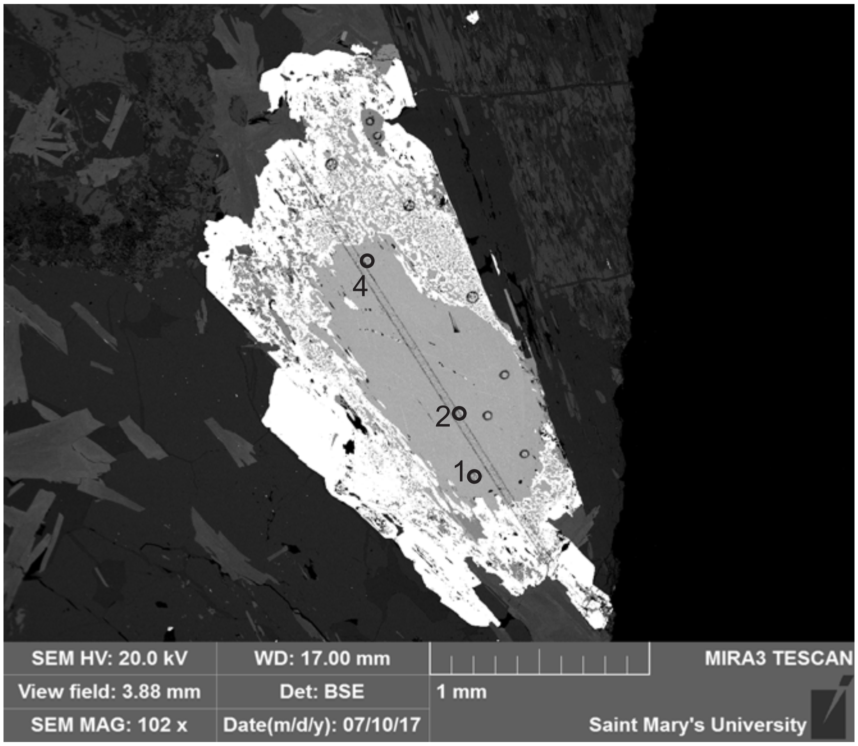



Figure 5.10: Sample 9956d. Location of laser ablation analyses for geochronology. Numbers correspond to Sample No. in Supplementary Table 2 of Pe-Piper et al. (2019).

# Appendix 6: Mineral Rutile: SEM-BSE images of location of analyzed spots and the raster data for syenite samples.

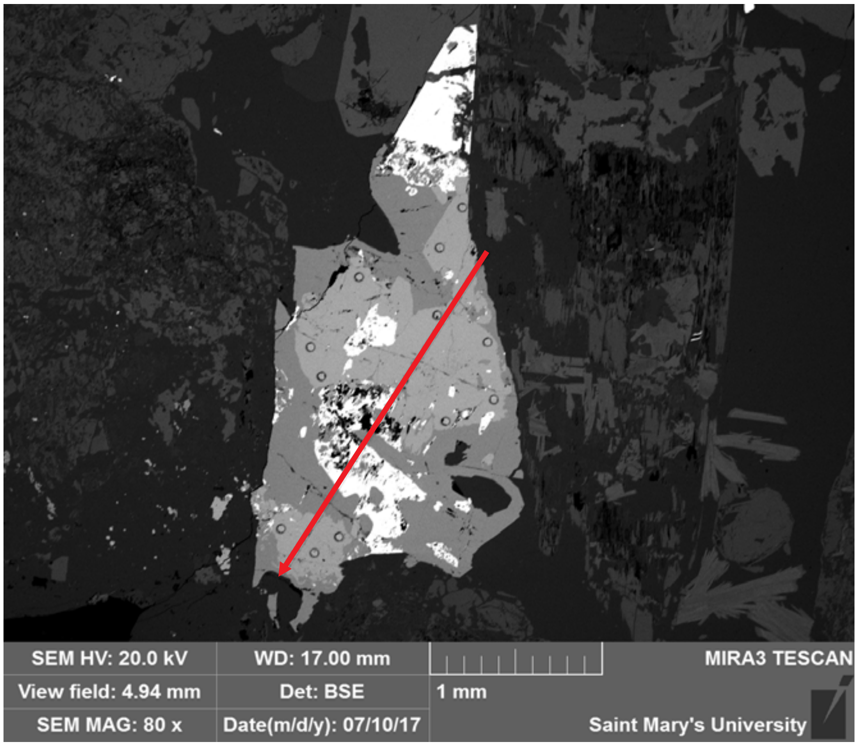


Figure 6.1: Sample 9928a. Location of raster analysis 1.

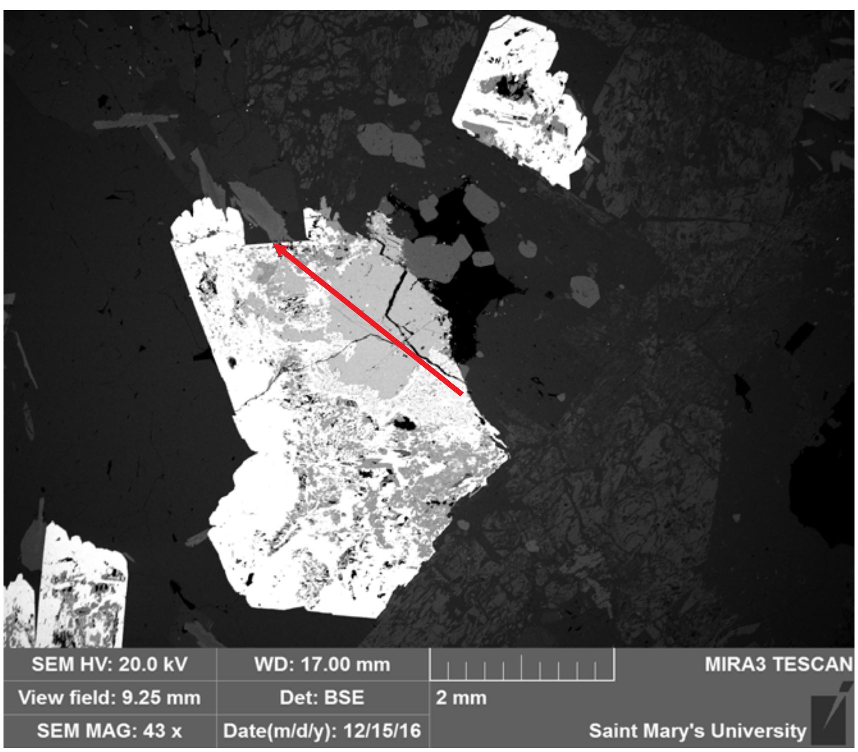


Figure 6.2: Sample 9956b. Location of raster analysis 1.

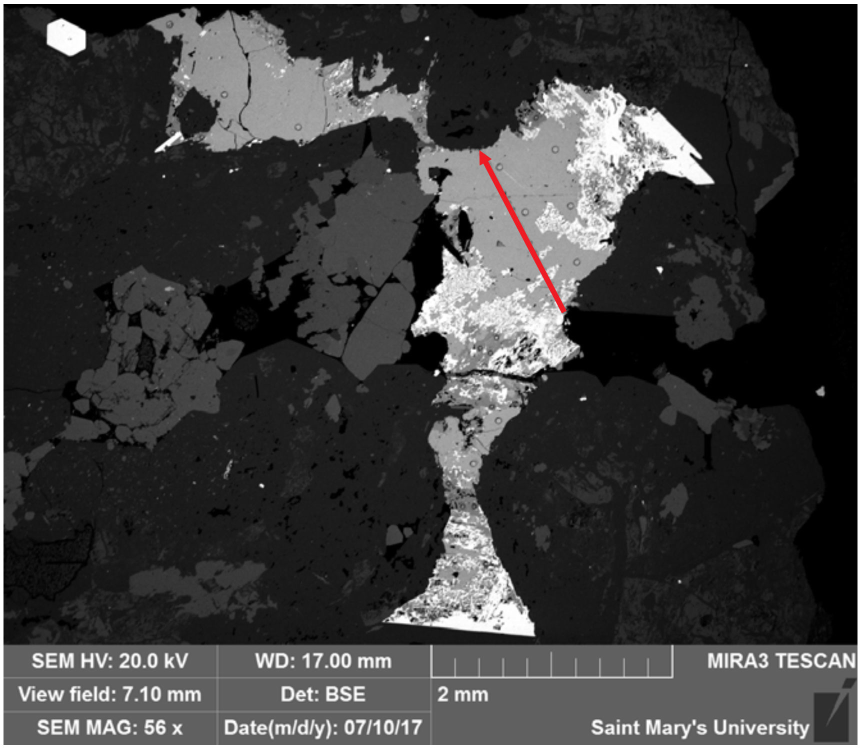



Figure 6.3: Sample 9956b. Location of raster analysis 2.

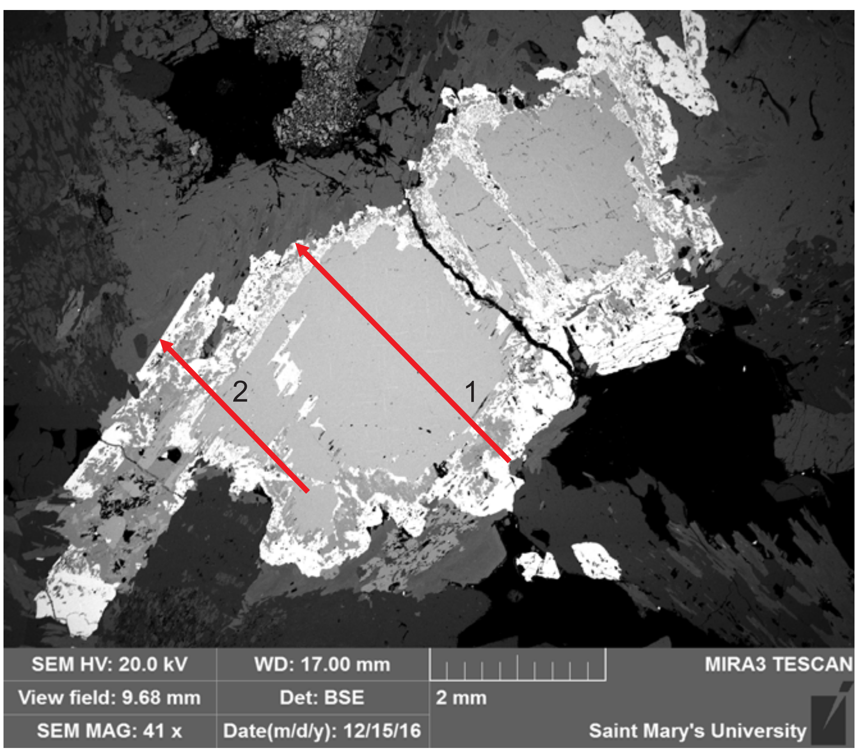



Figure 6.4: Sample 9956c. Location of raster analysis 1 and 2.

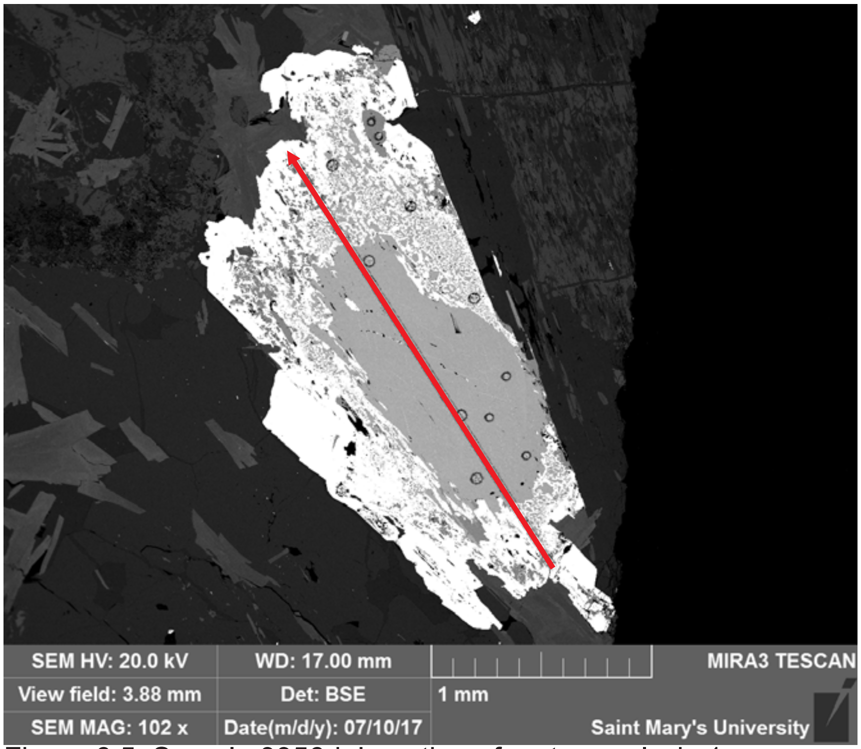
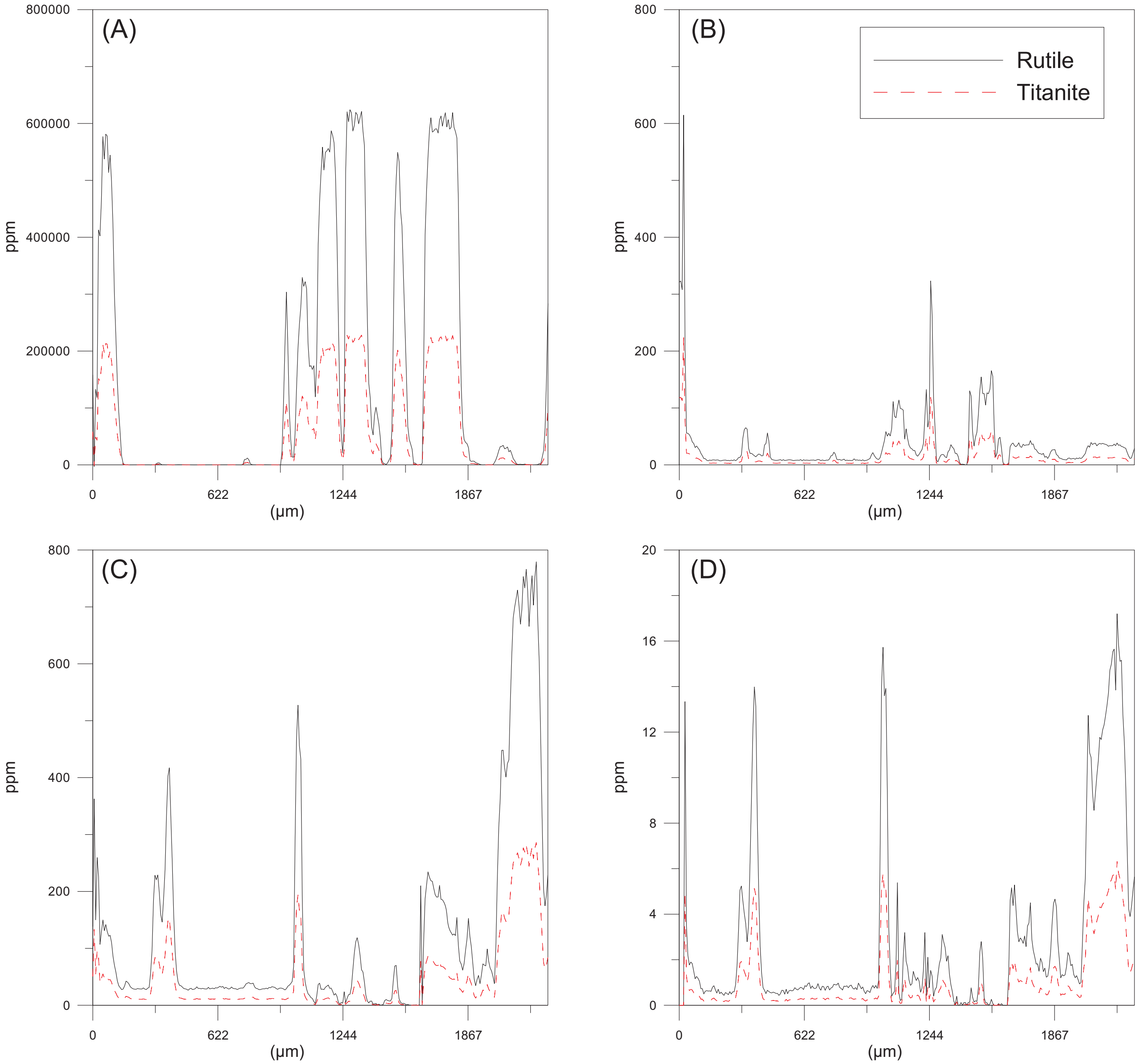
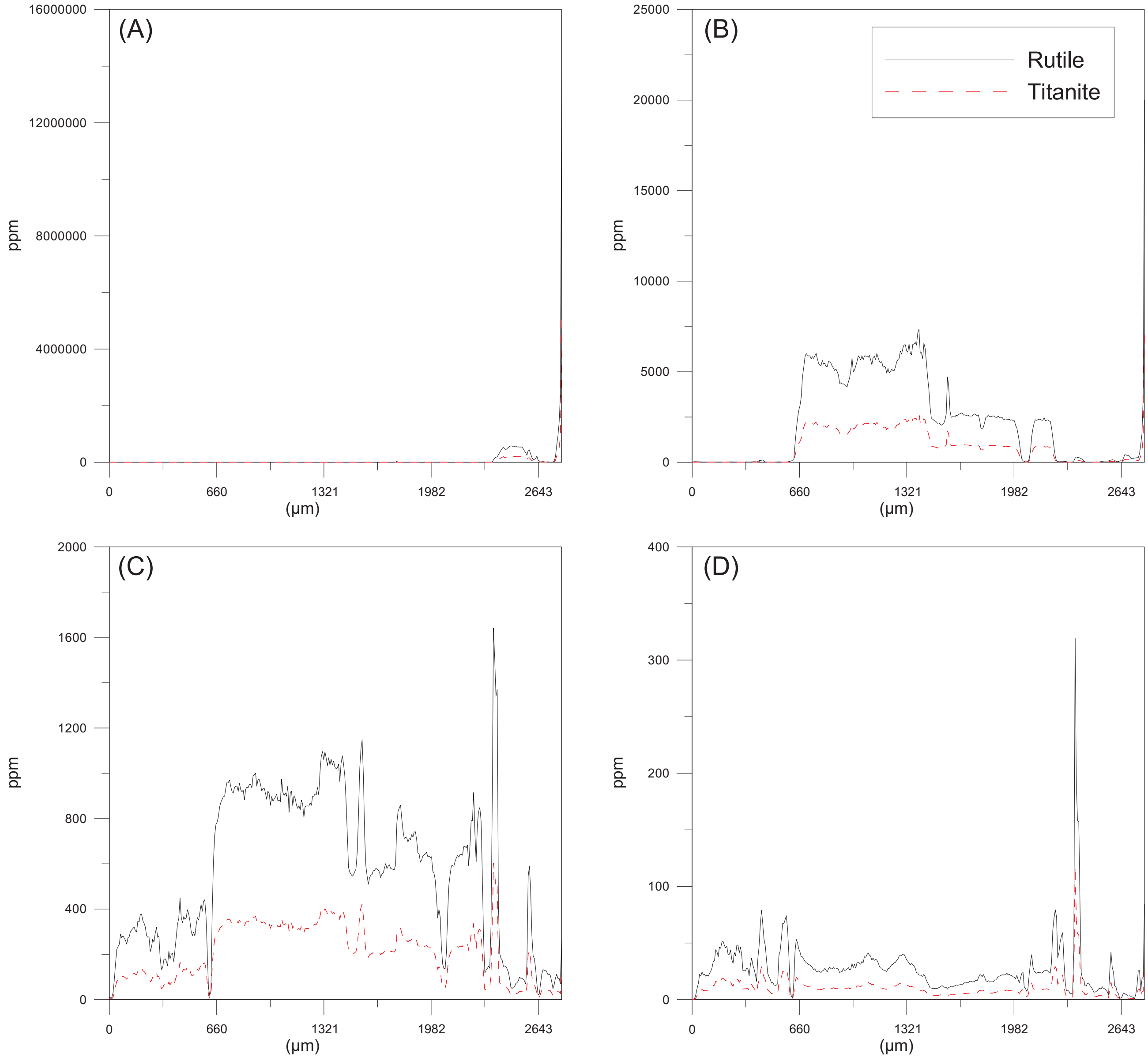


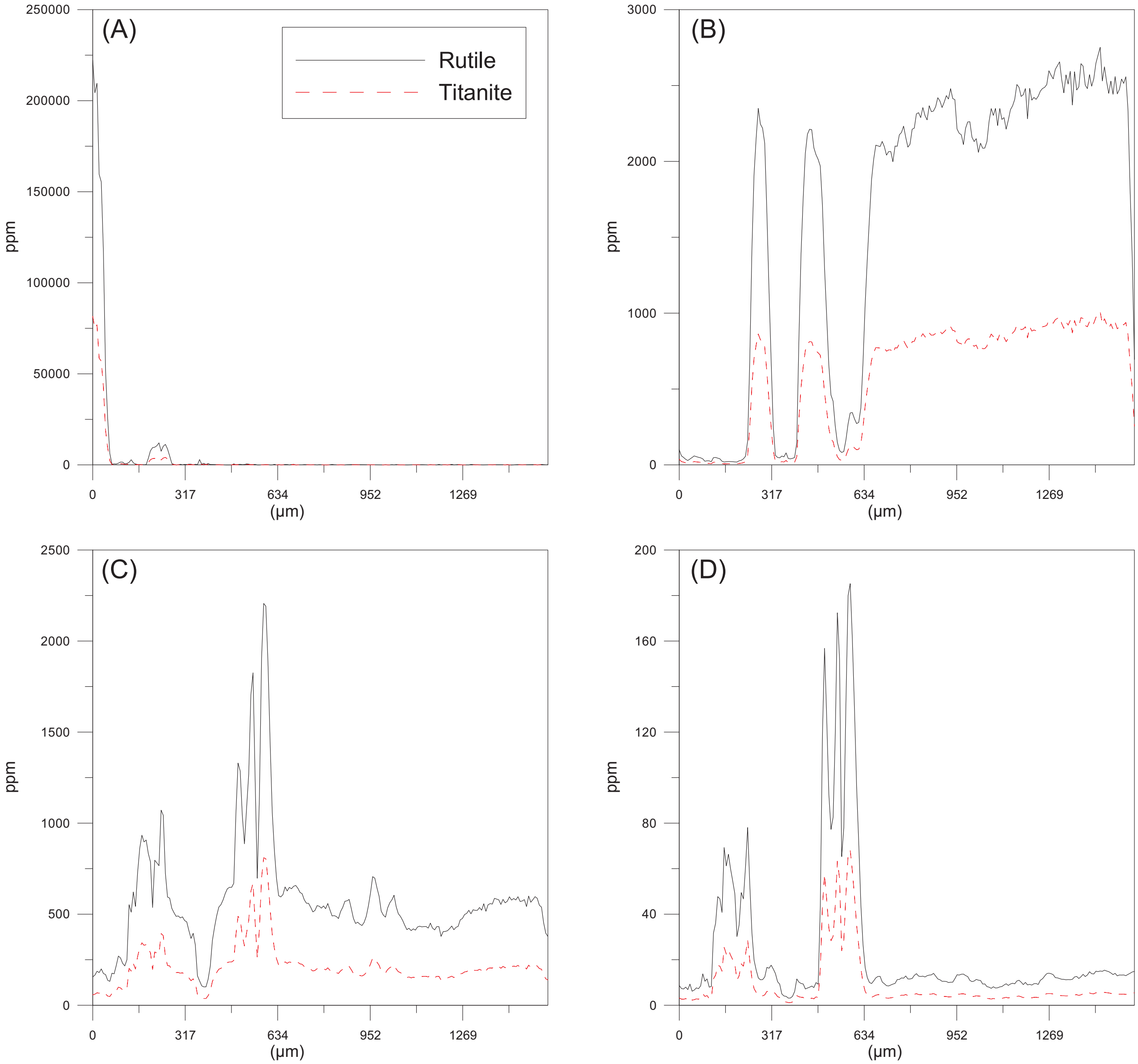
Figure 6.5: Sample 9956d. Location of raster analysis 1.



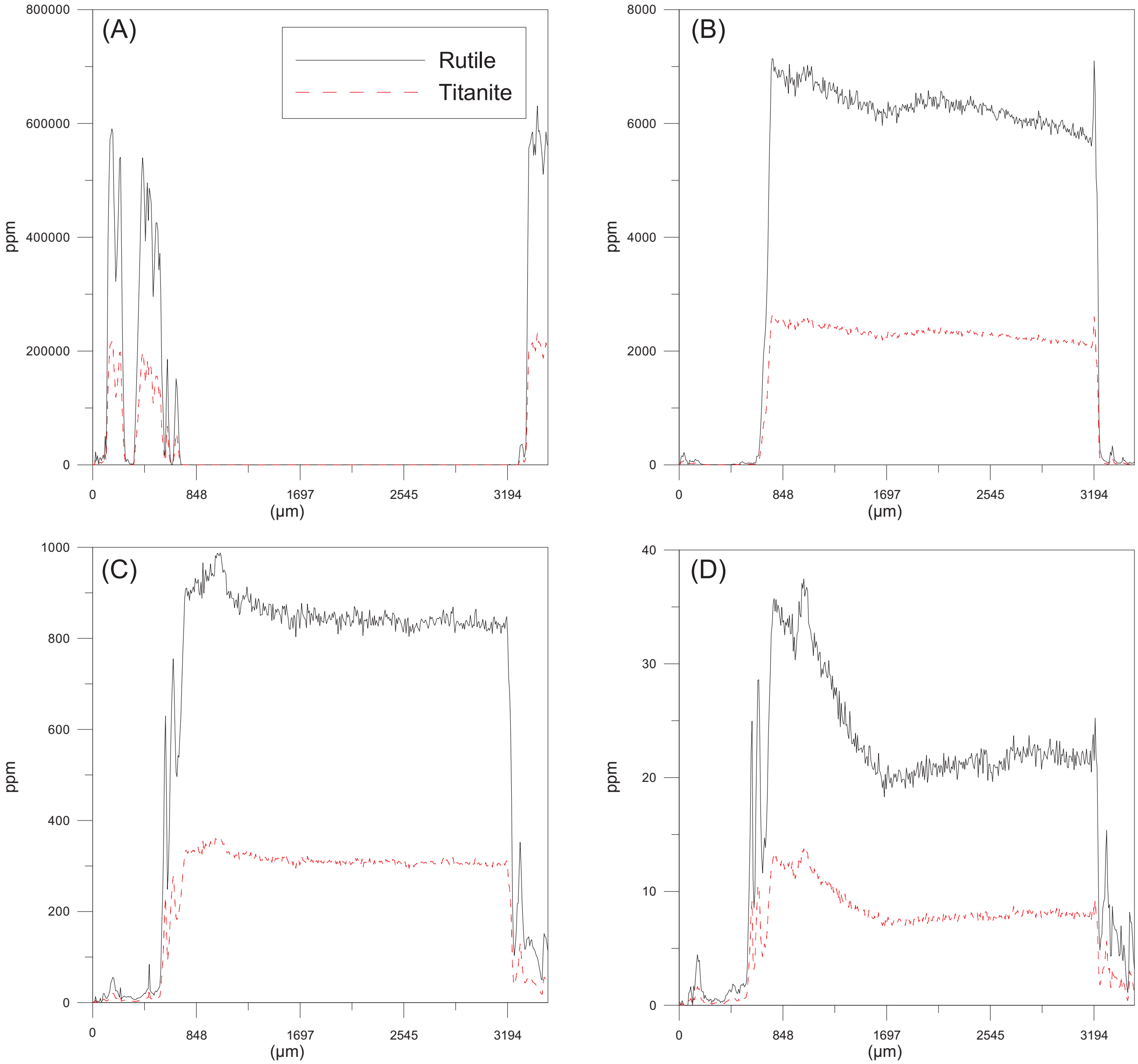

Raster data of titanite (red) and rutile (black) in sample 9928a (Fig. 1).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta



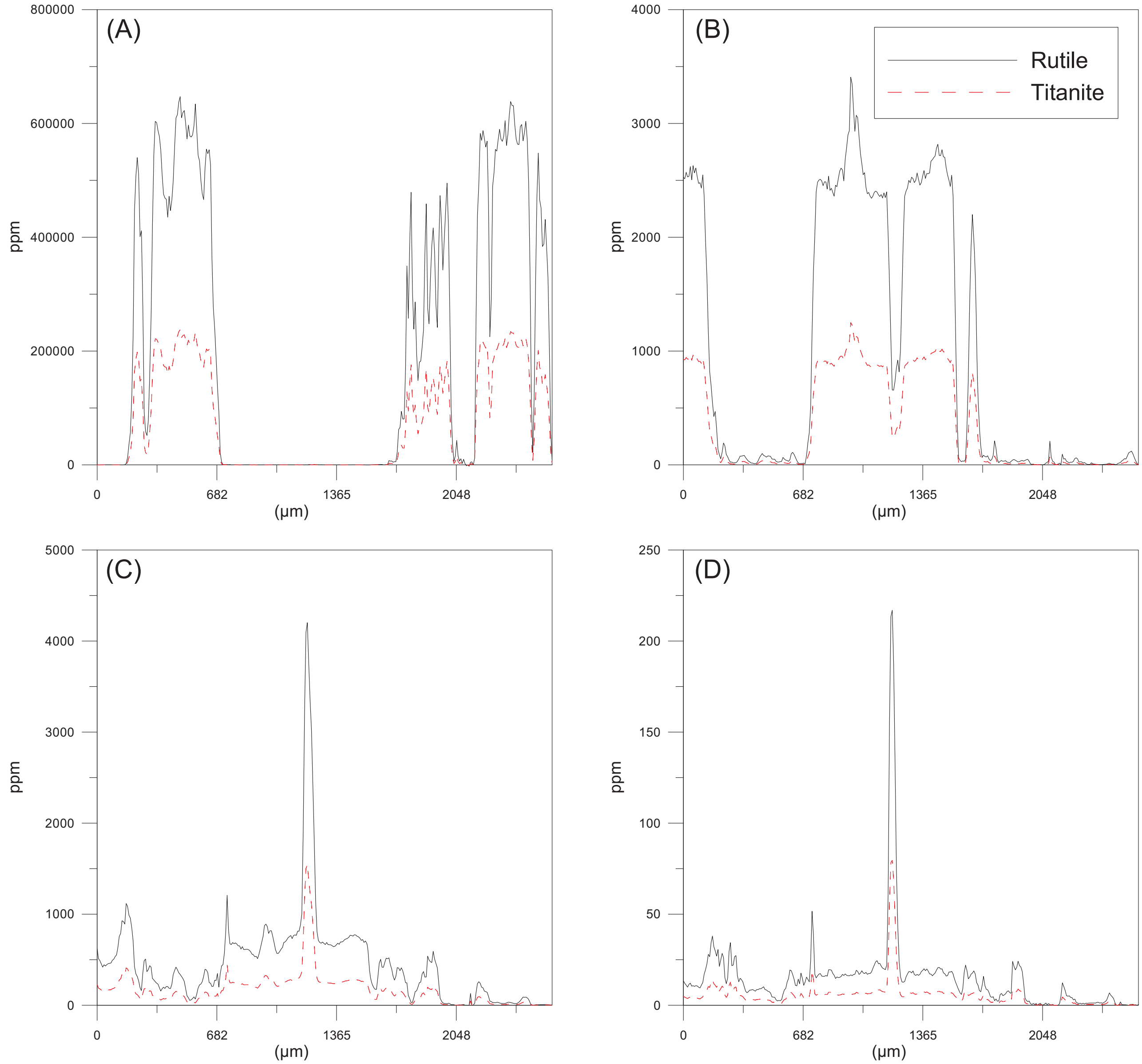

Raster data of titanite (red) and rutile (black) in sample 9956b-1 (Fig. 2).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta



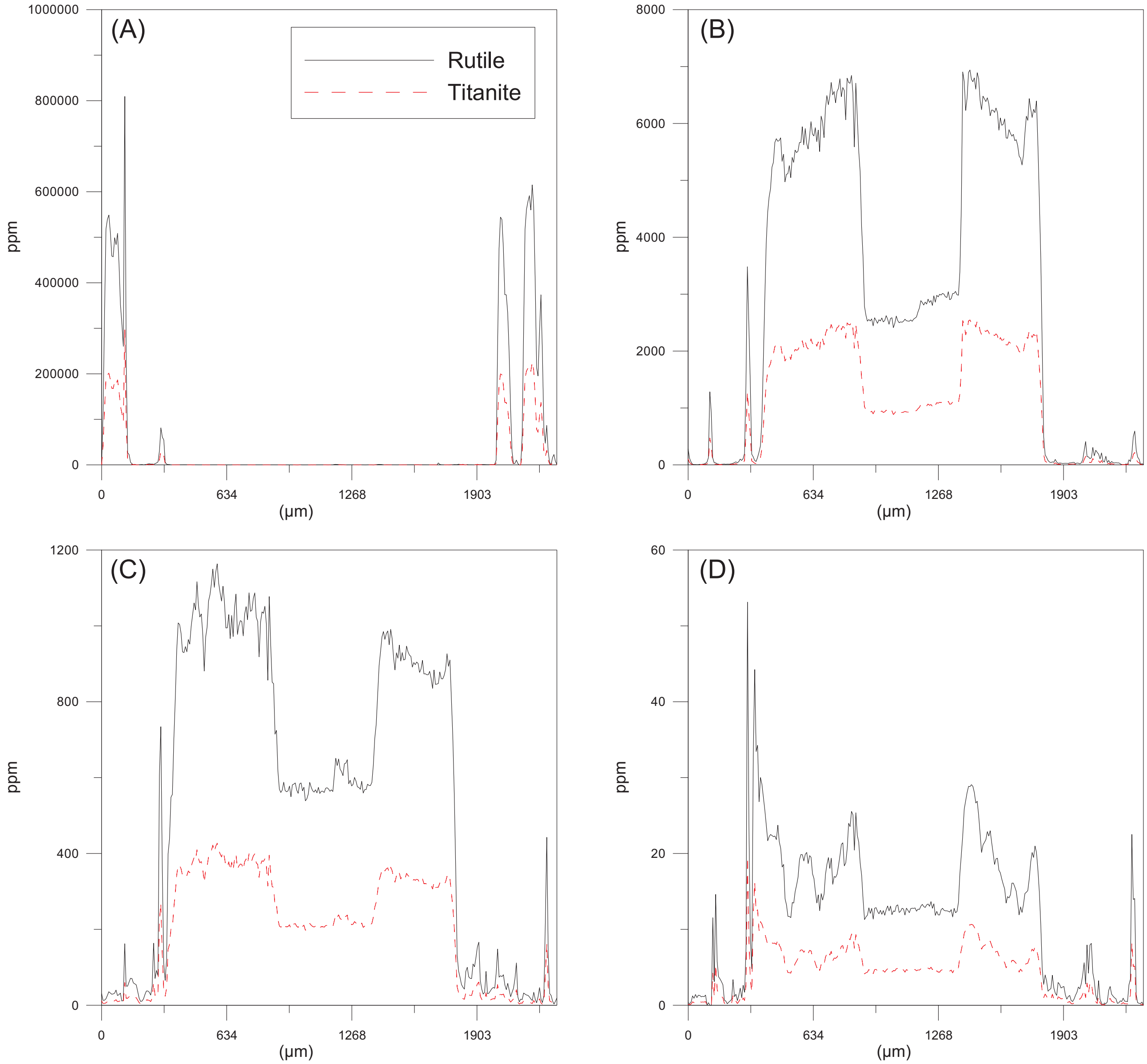

Raster data of titanite (red) and rutile (black) in sample 9956b-2 (Fig. 3).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta




Raster data of titanite (red) and rutile (black) in sample 9956c-1 (Fig. 4).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta




Raster data of titanite (red) and rutile (black) in sample 9956c-2 (Fig. 5).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta




Raster data of titanite (red) and rutile (black) in sample 9956d-1 (Fig. 6).
**A:** Ca
**B:** Zr
**C:** Nb
**D:** Ta

# Appendix 7: Mineral Rutile: Raman spectroscopy spectra and SEM-BSE images of the location of analyzed spots.

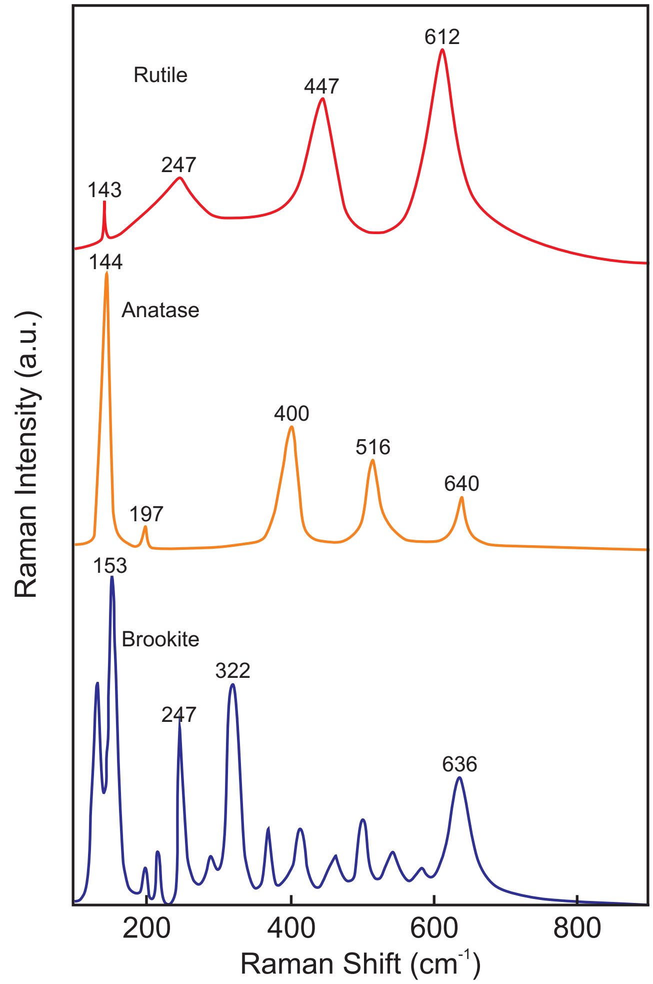
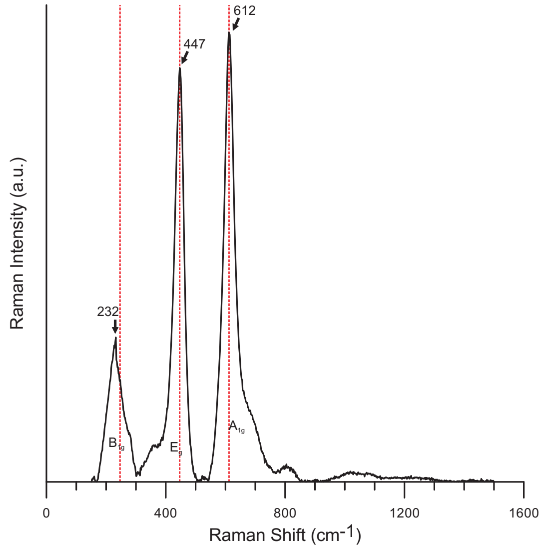



Figure 7.1: Reference titania polymorph Raman spectra (after Meinhold, G. (2010)). Rutile has a strong wavelength peak at 247 $cm^{-1}$, 447 $cm^{-1}$, and 612 $cm^{-1}$. These reference peaks appear as dashed red lines in the analysed data from Clarke Head.



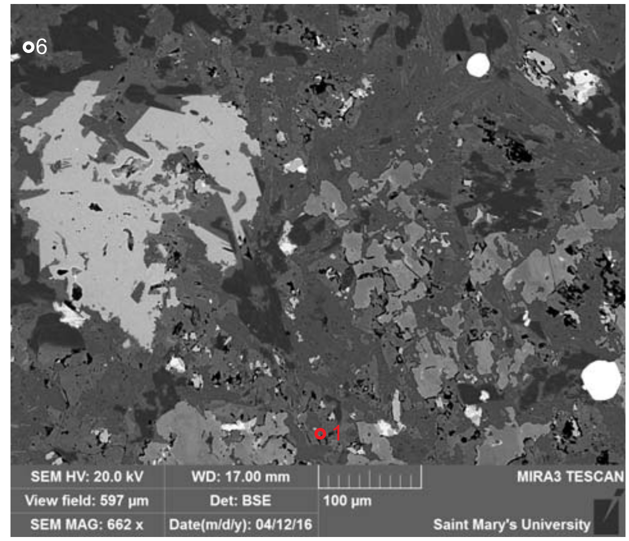
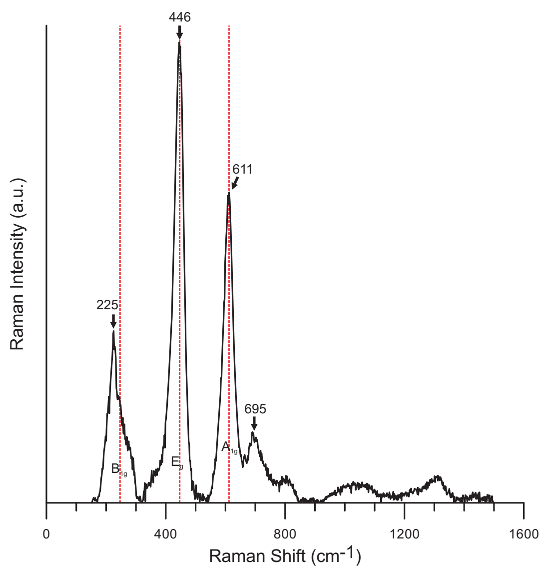




Figure 7.2: Sample 9927(1) site 7.



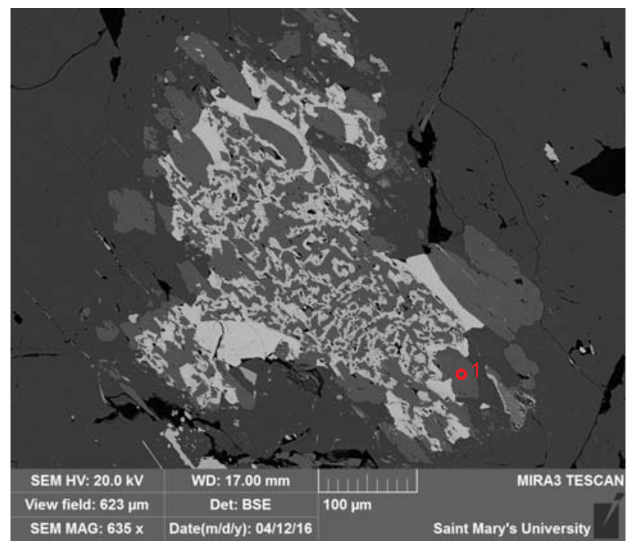
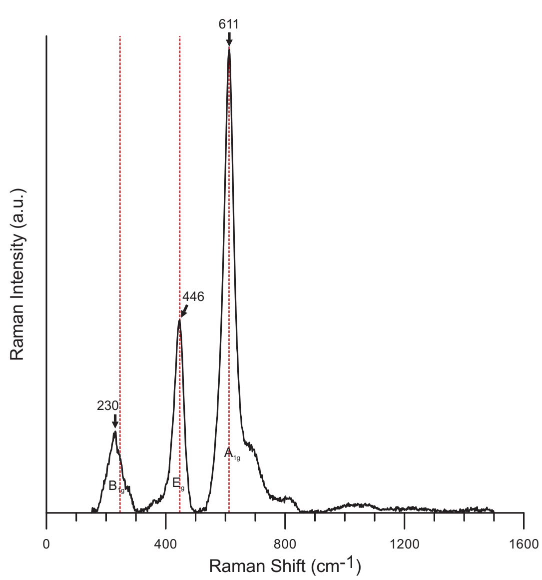




Figure 7.3: Sample 9928a site 2.



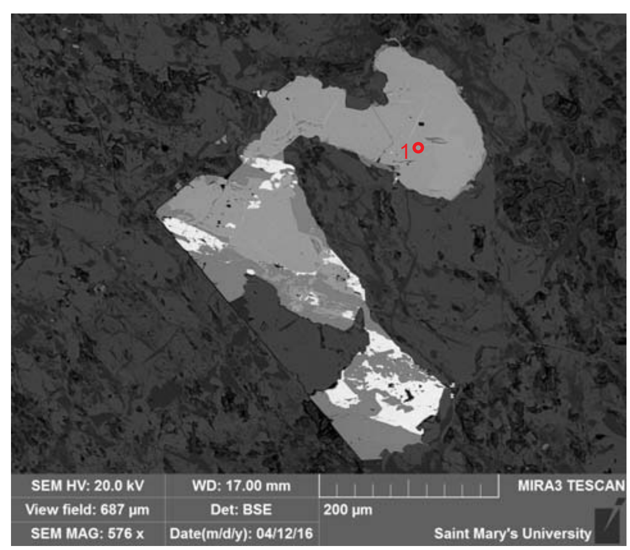
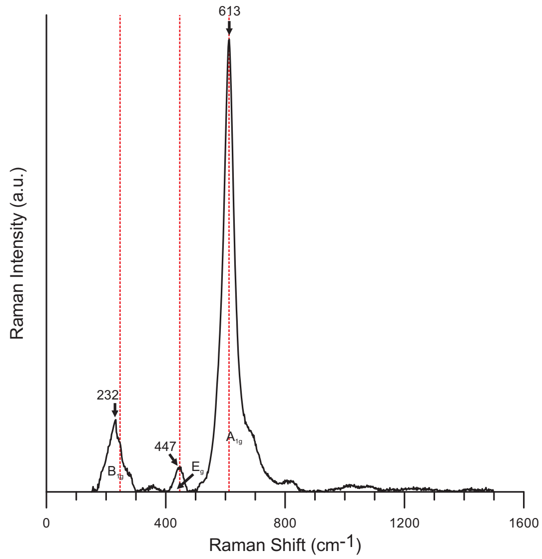




Figure 7.4: Sample 9928a site 4.



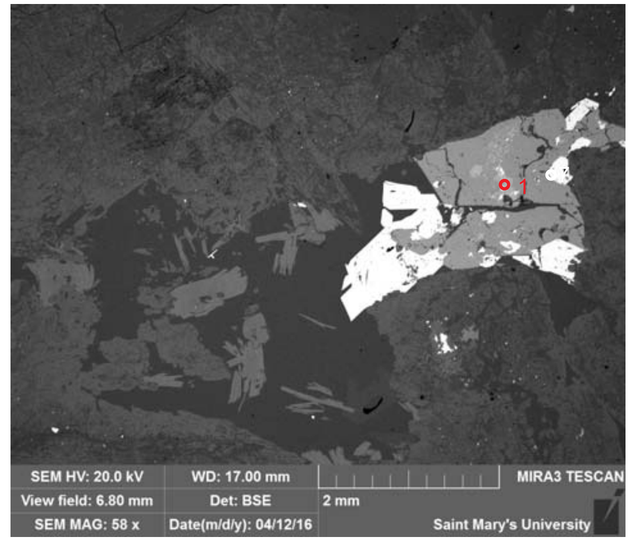
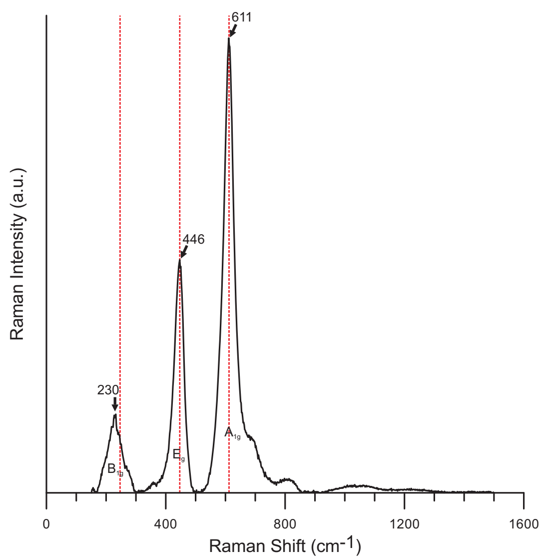




Figure 7.5: Sample 9928a site 6.



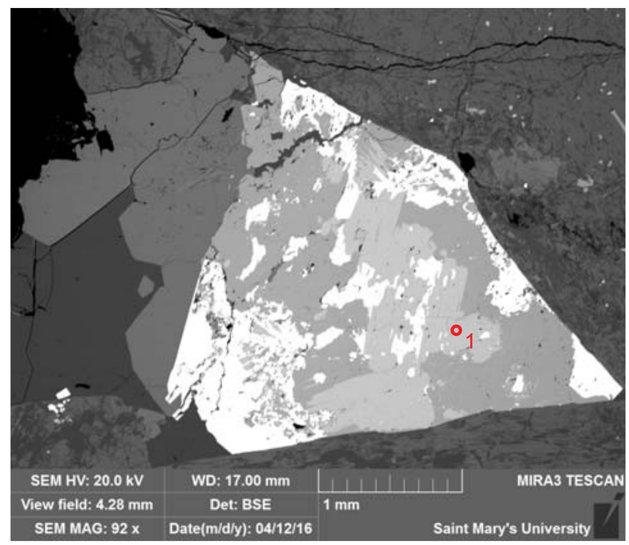
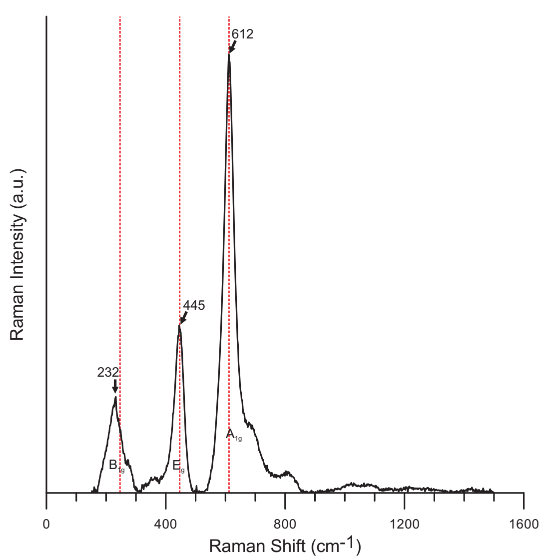




Figure 7.6: Sample 9928a site 7.



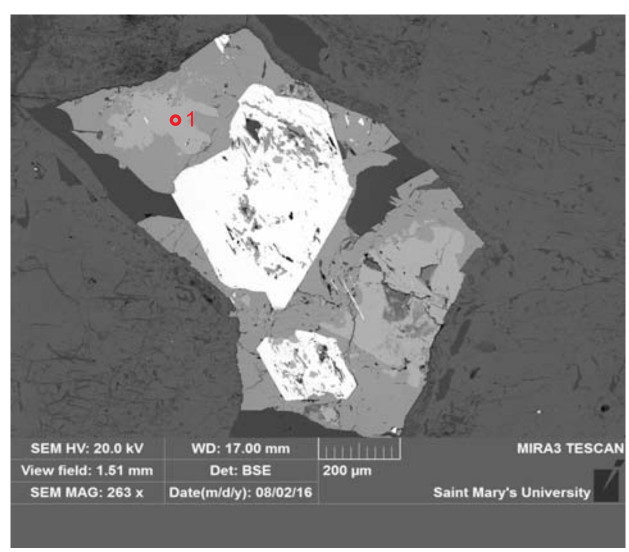
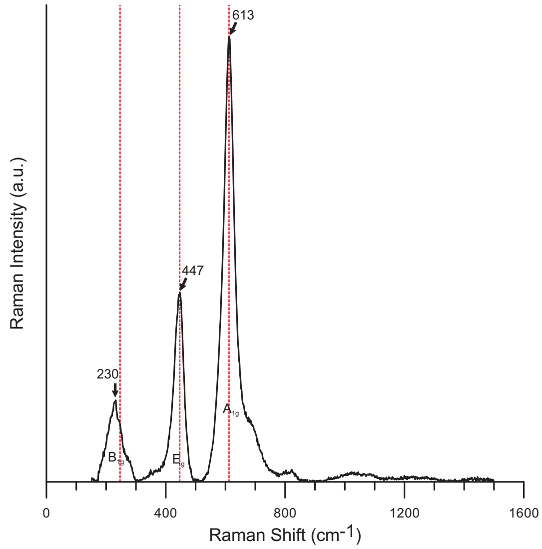




Figure 7.7: Sample 9928a site 13.



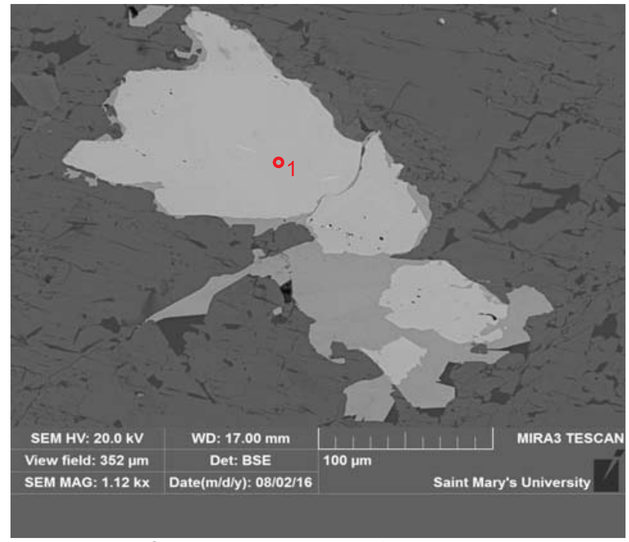
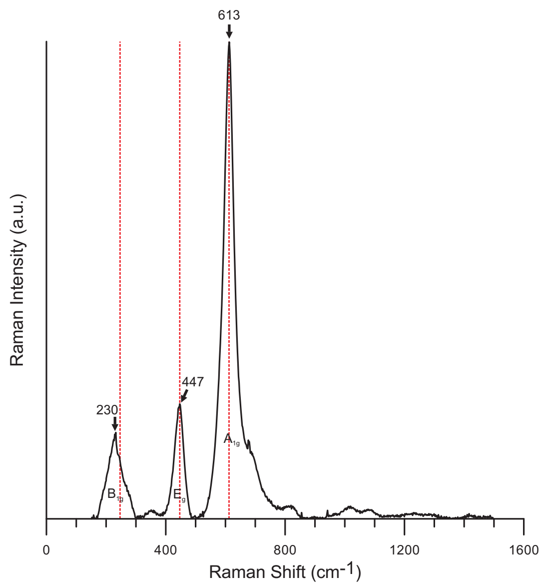




Figure 7.8: Sample 9928a site 14.



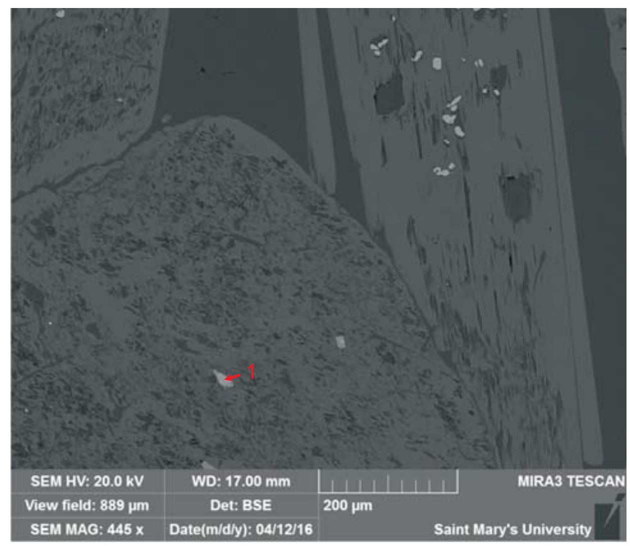
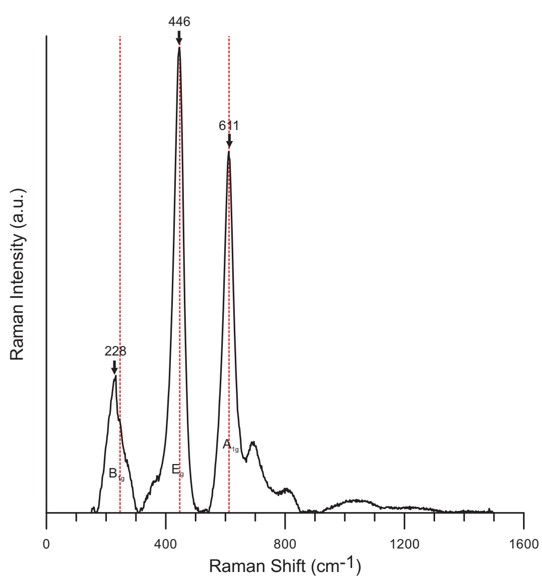




Figure 7.9: Sample 9928b site 22.



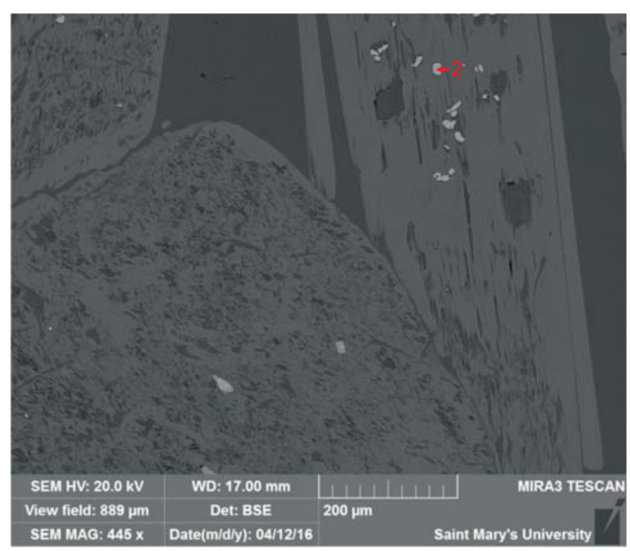




Figure 7.10: Sample 9928b site 22.

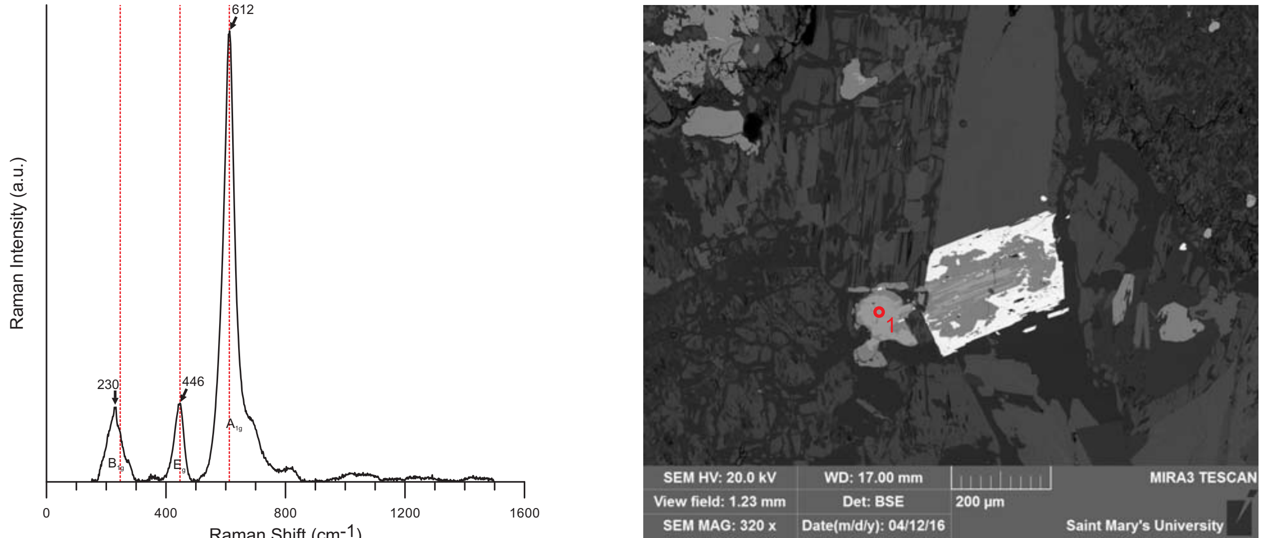


Figure 7.11: Sample 9928b site 26.

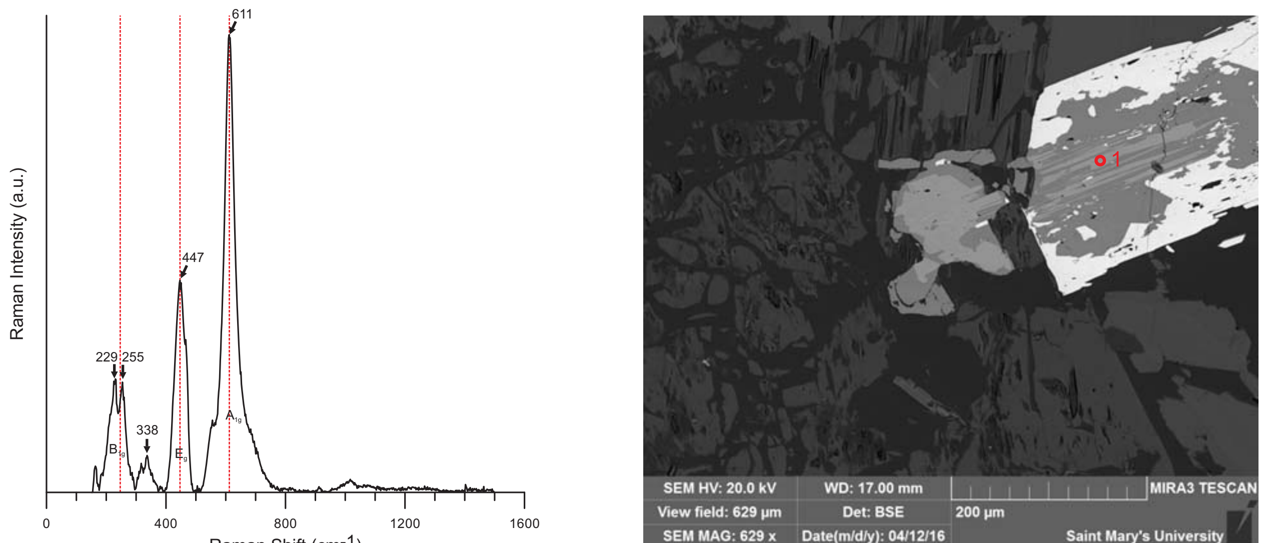


Figure 7.12: Sample 9928b site 27.

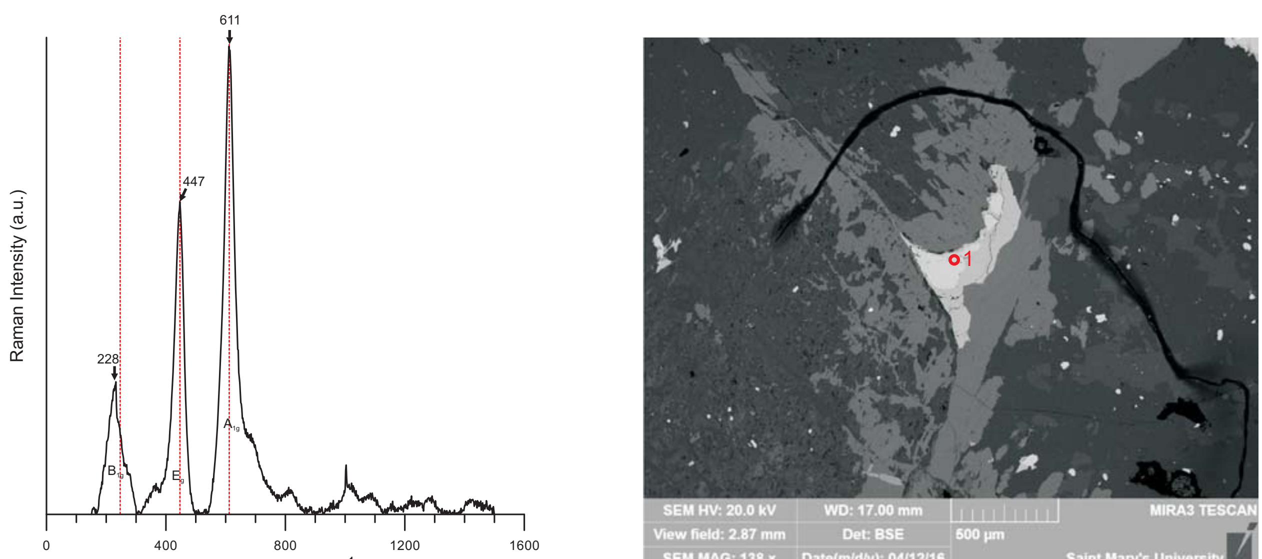


Figure 7.13: Sample 9928b site 29.

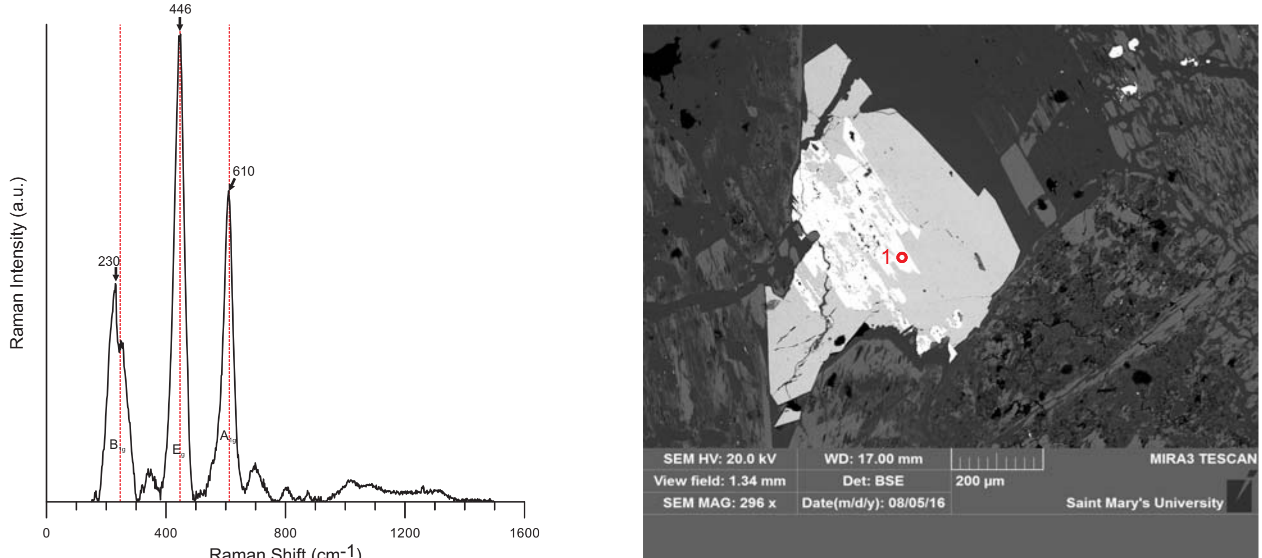


Figure 7.14: Sample 9928b site 34.

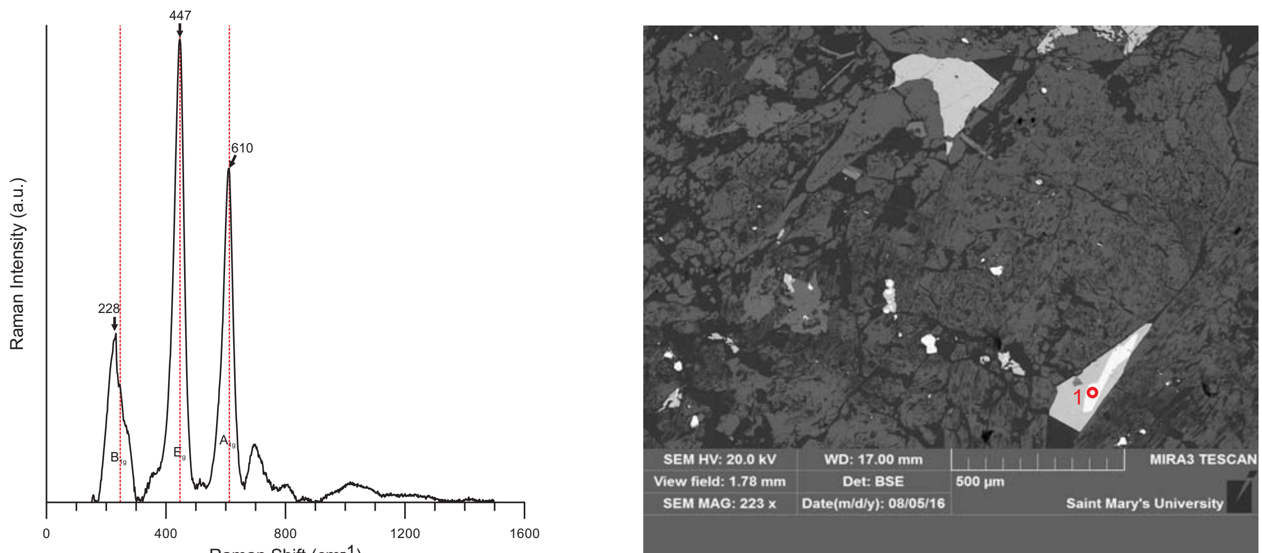


Figure 7.15: Sample 9928b site 39.

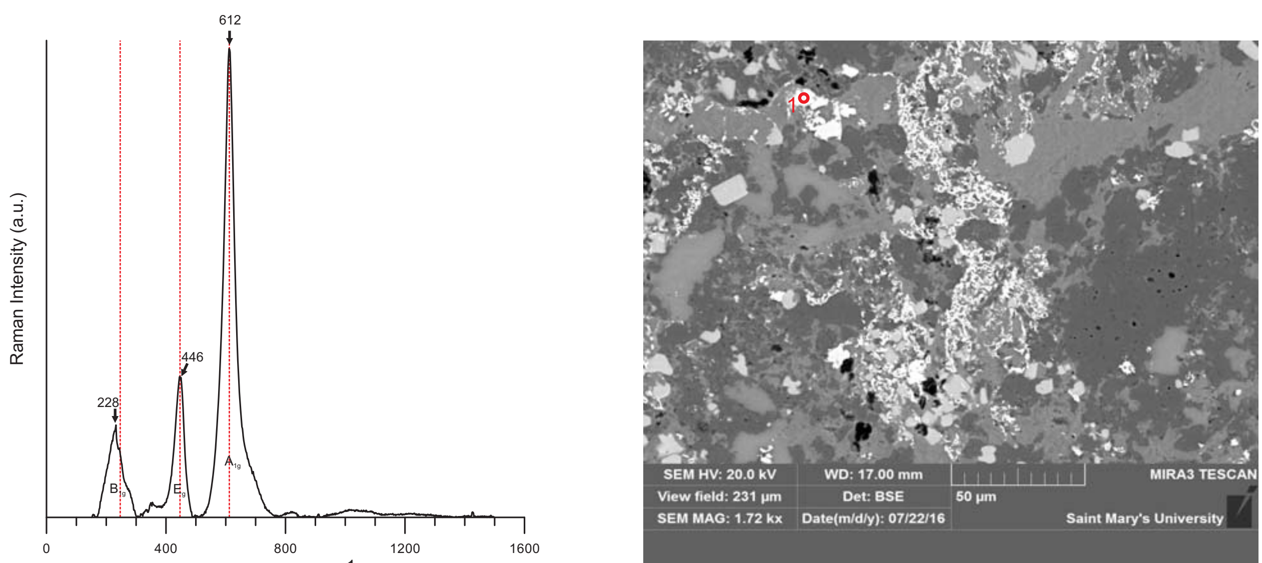
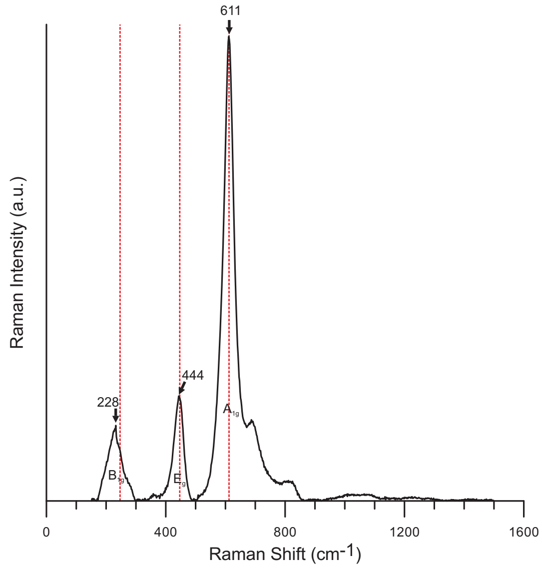


Figure 7.16: Sample 9937 site 4.



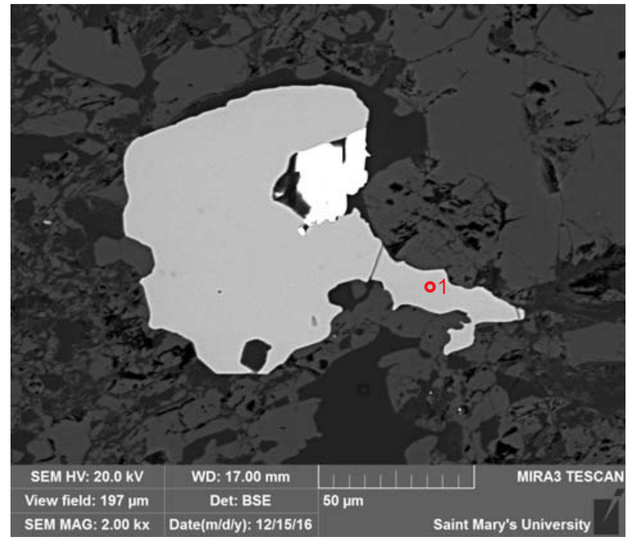
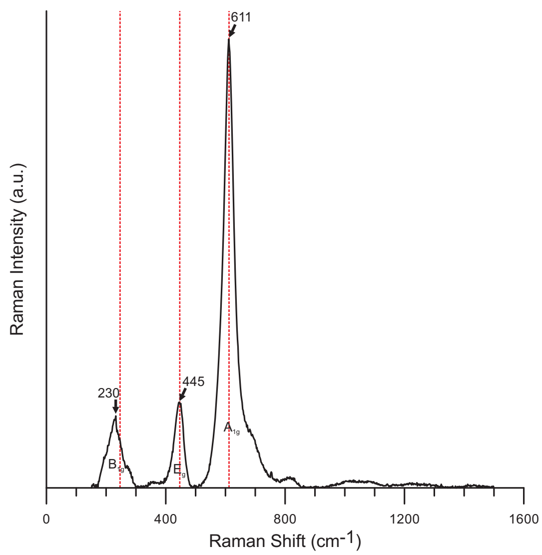




Figure 7.17: Sample 9956a site 1.



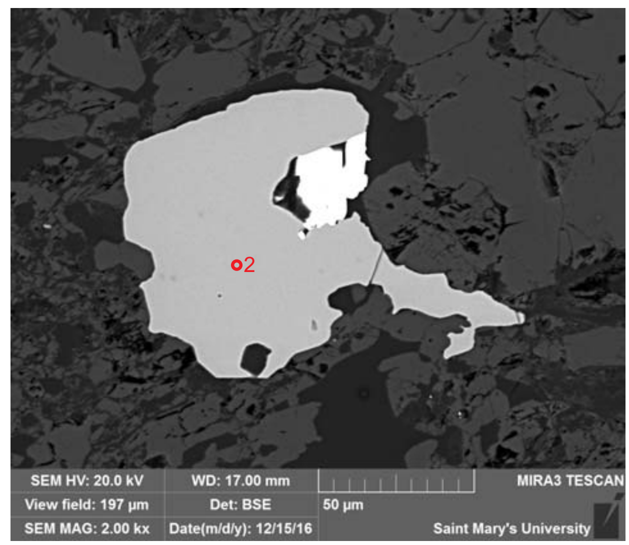
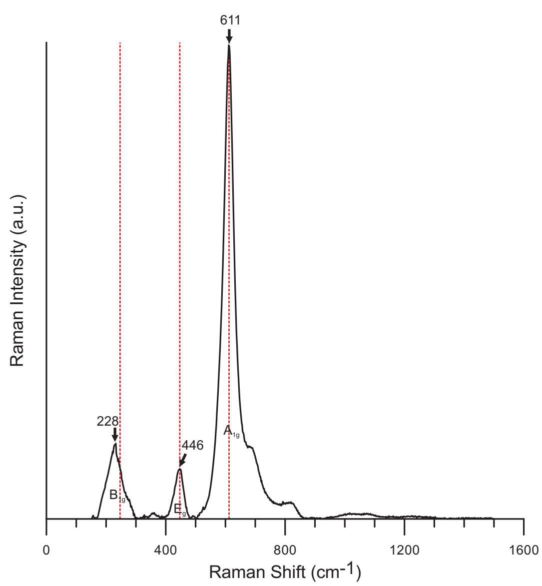




Figure 7.18: Sample 9956a site 1.



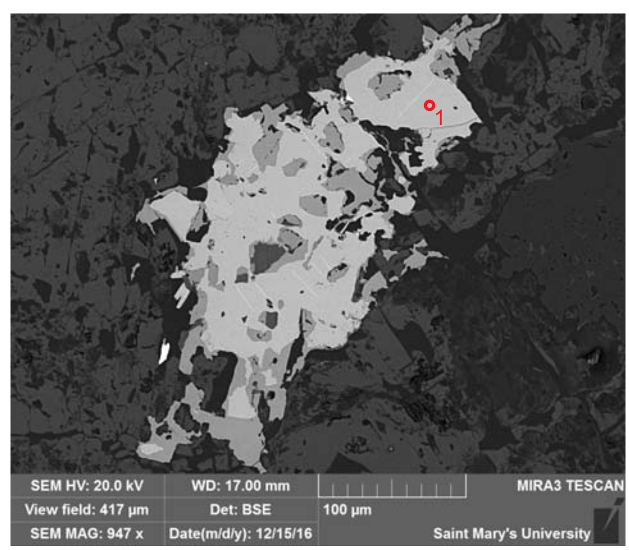




Figure 7.19: Sample 9956a site 2.

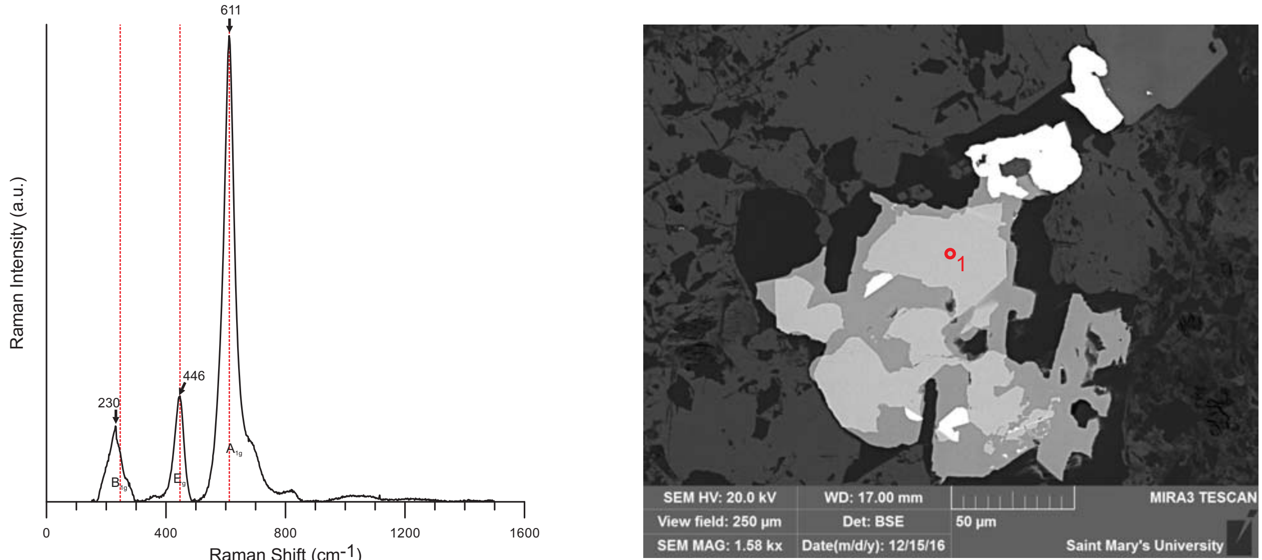


Figure 7.20: Sample 9956a site 4.

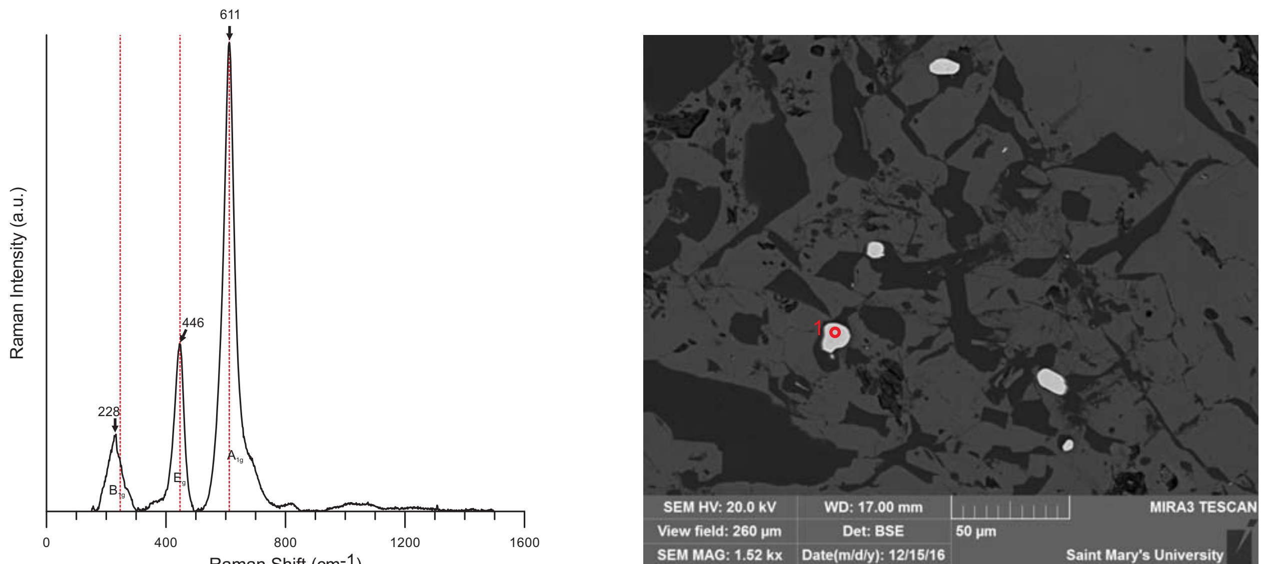


Figure 7.21: Sample 9956a site 6.

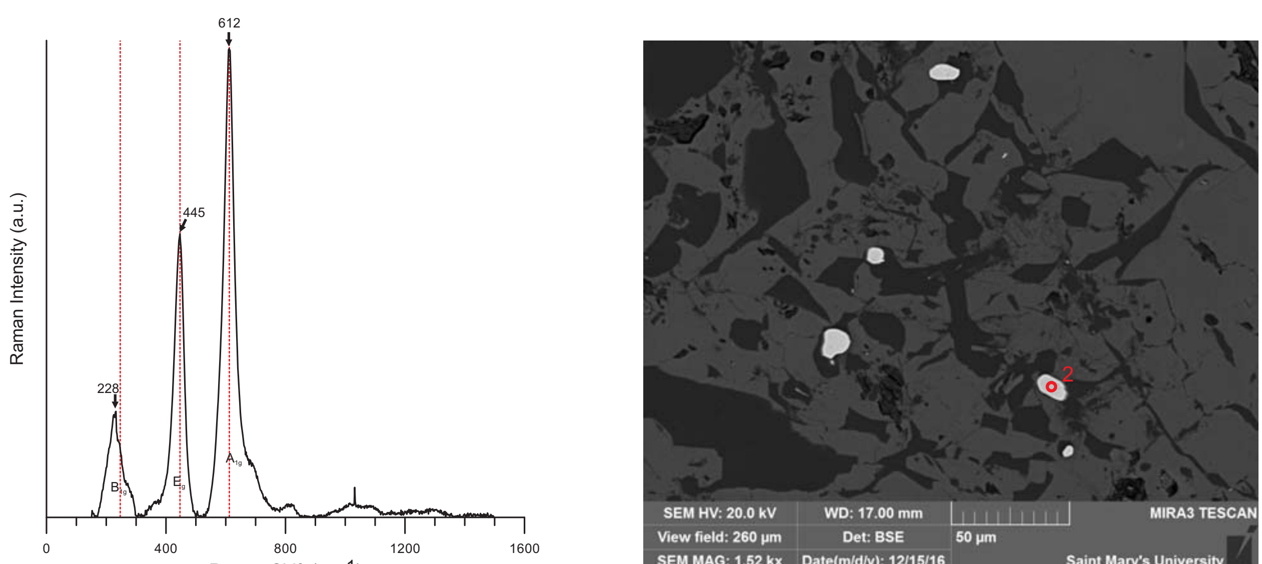
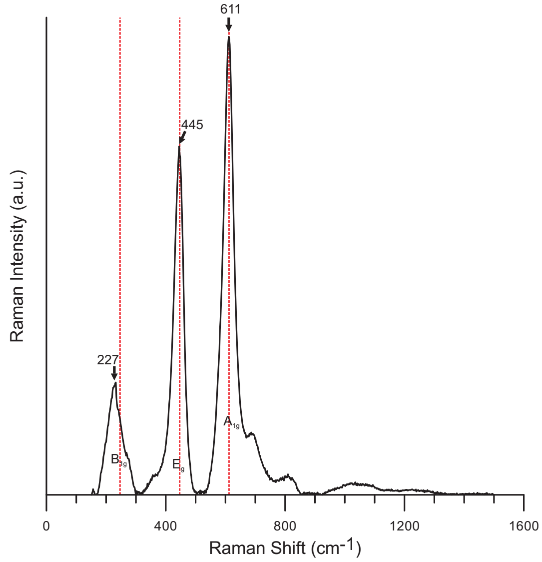


Figure 7.22: Sample 9956a site 6.



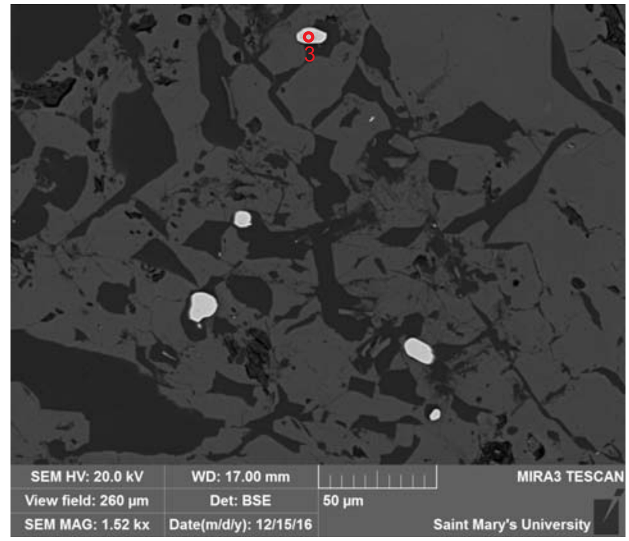
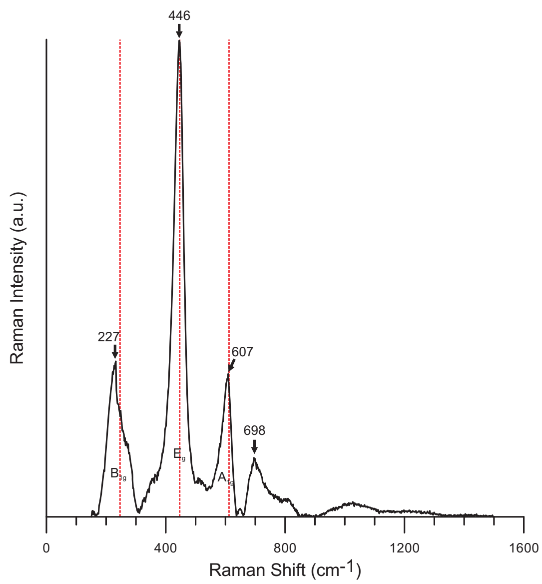




Figure 7.23: Sample 9956a site 6.



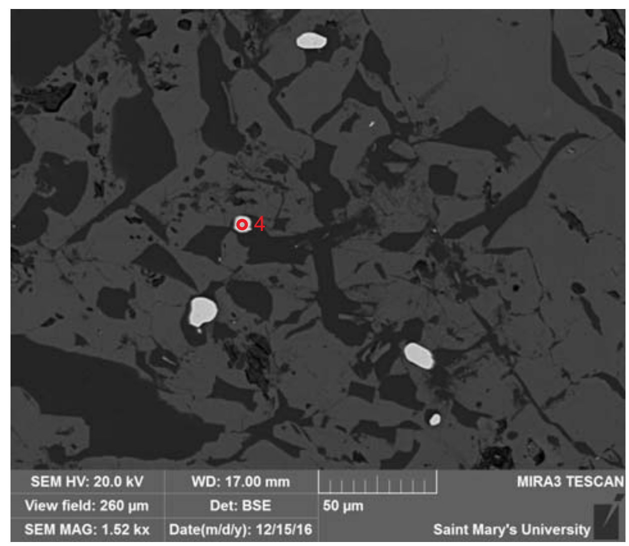
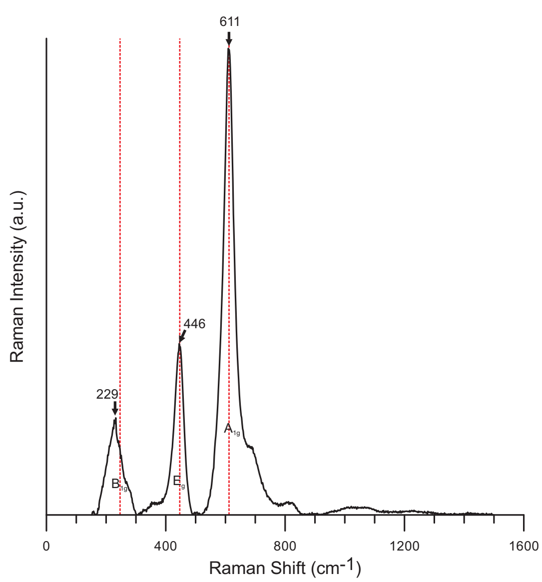




Figure 7.24: Sample 9956a site 6.



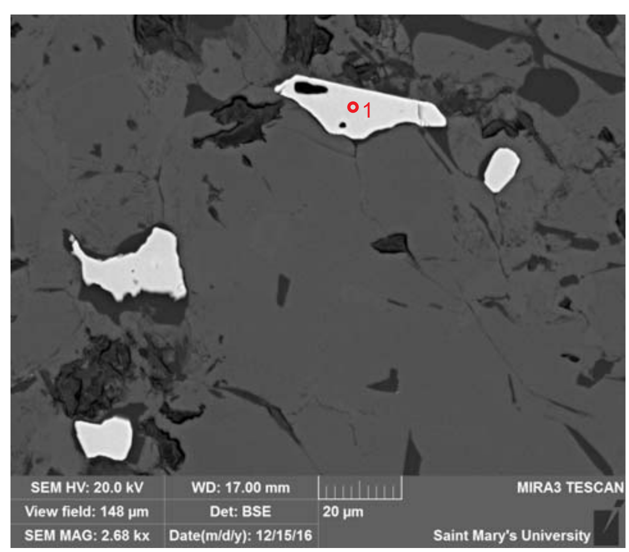
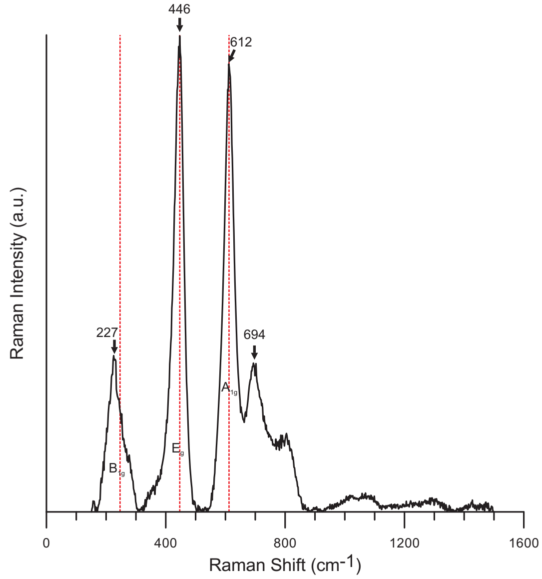




Figure 7.25: Sample 9956a site 11.



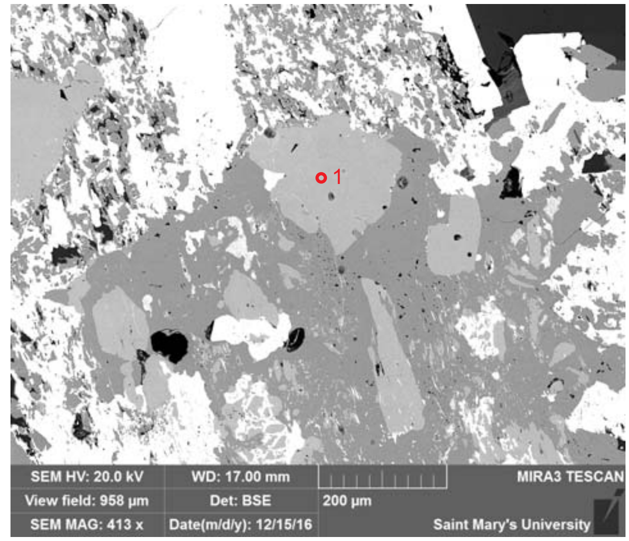
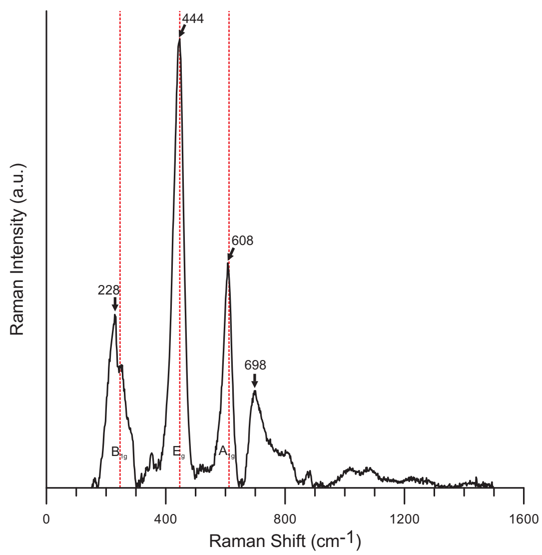




Figure 7.26: Sample 9956a site 12.



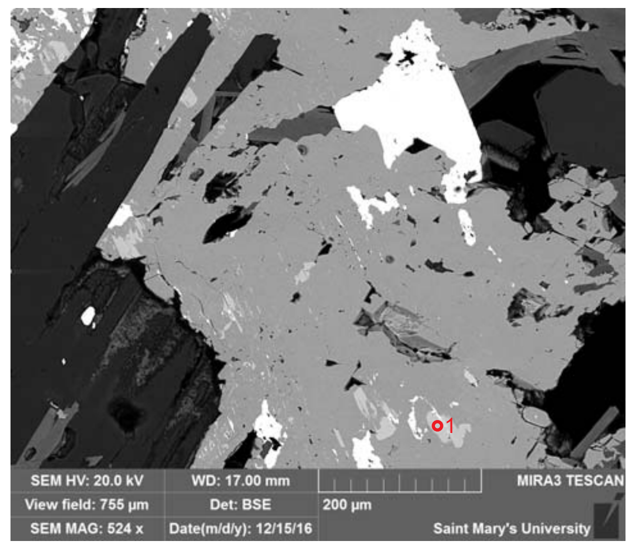
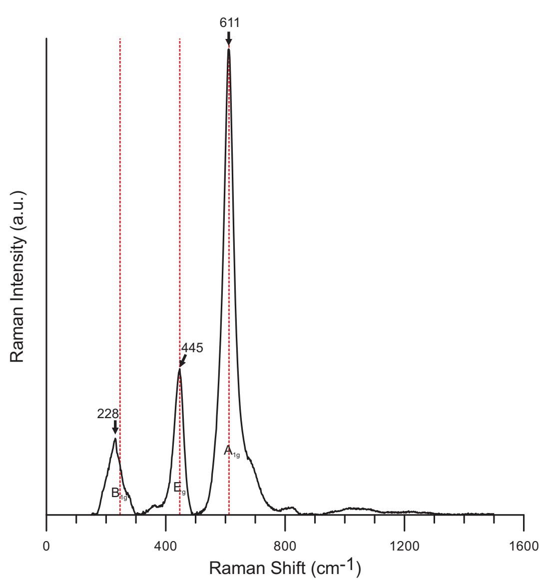




Figure 7.27: Sample 9956a site 14.



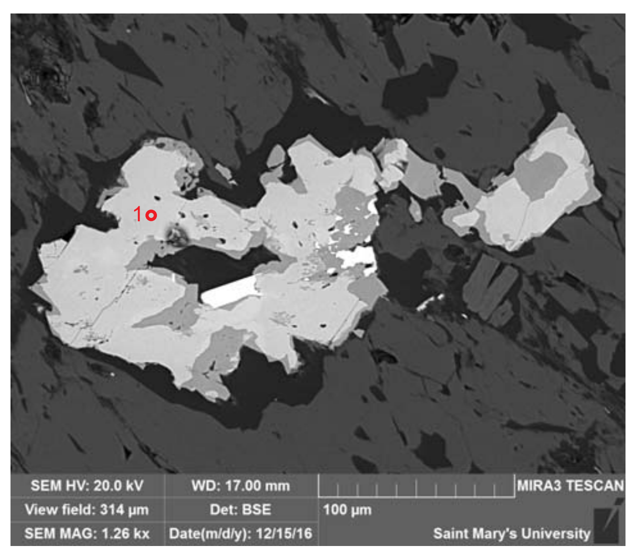




Figure 7.28: Sample 9956a site 16.

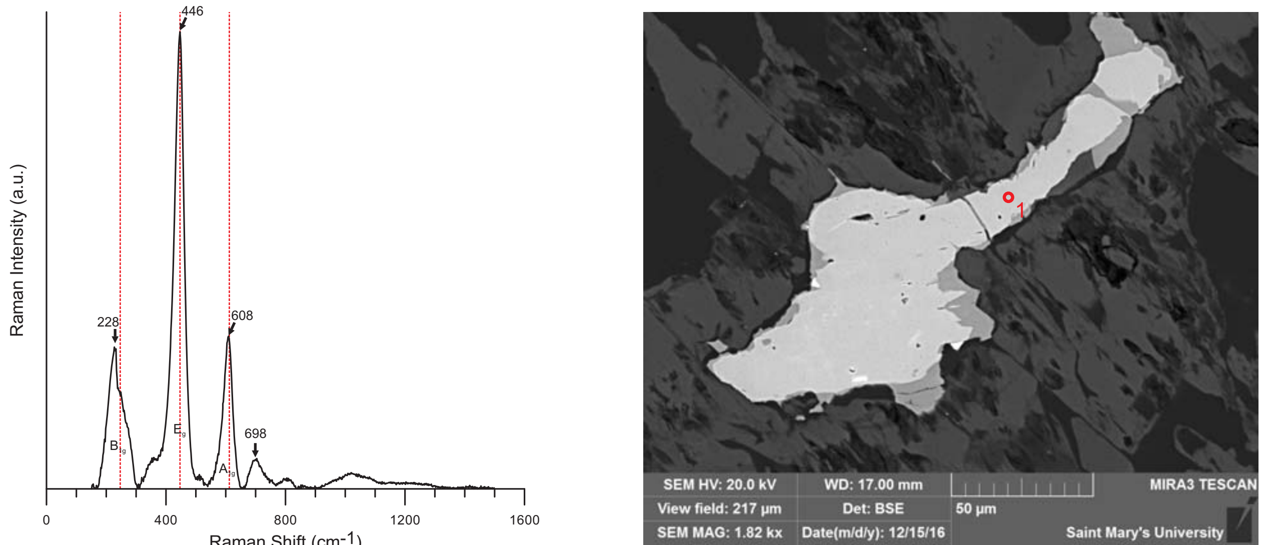


Figure 7.29: Sample 9956a site 17.

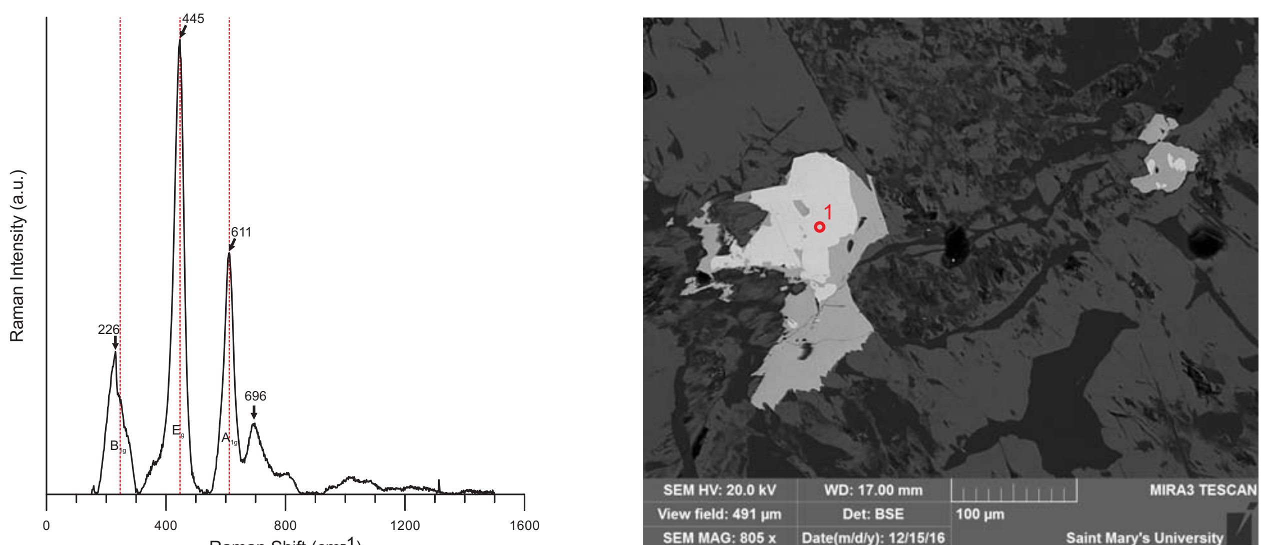


Figure 7.30: Sample 9956a site 18.

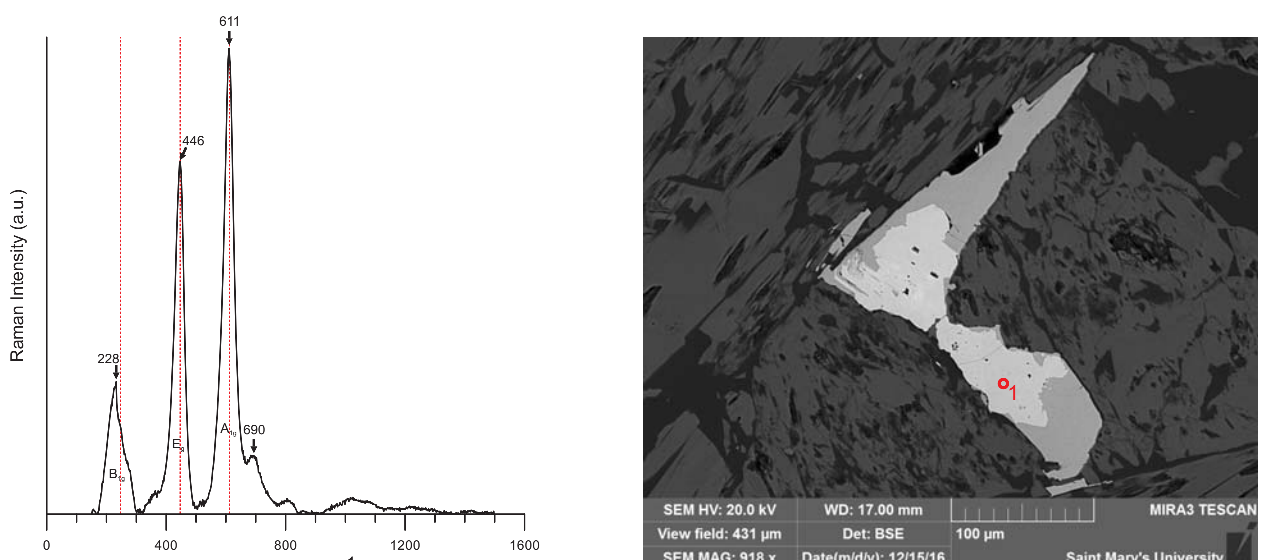
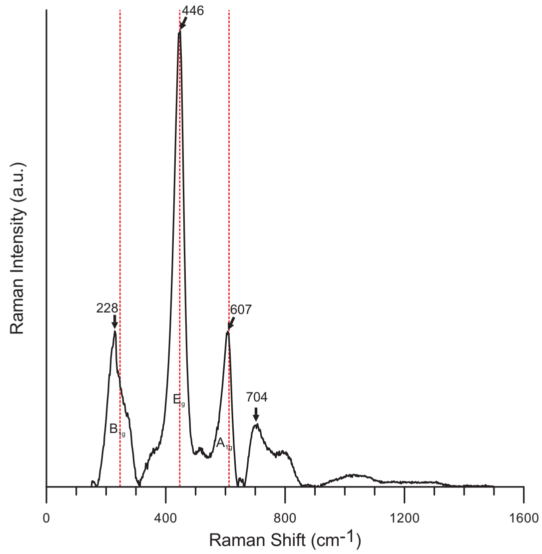


Figure 7.31: Sample 9956a site 20.



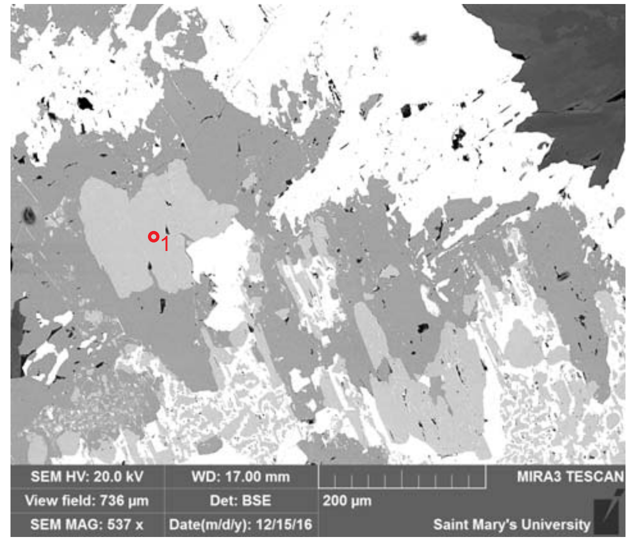
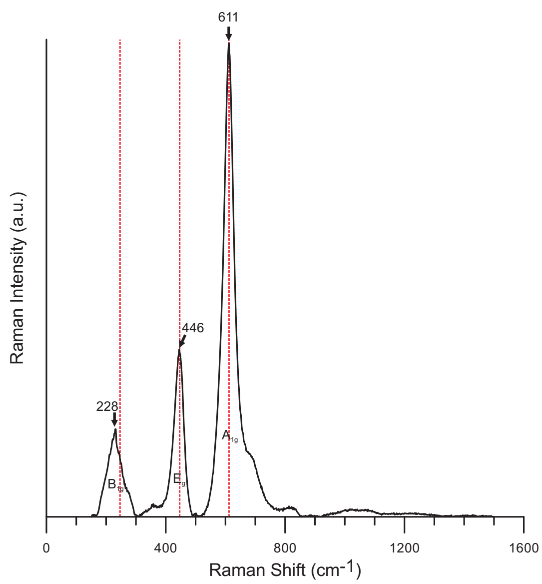




Figure 7.32: Sample 9956a site 21.



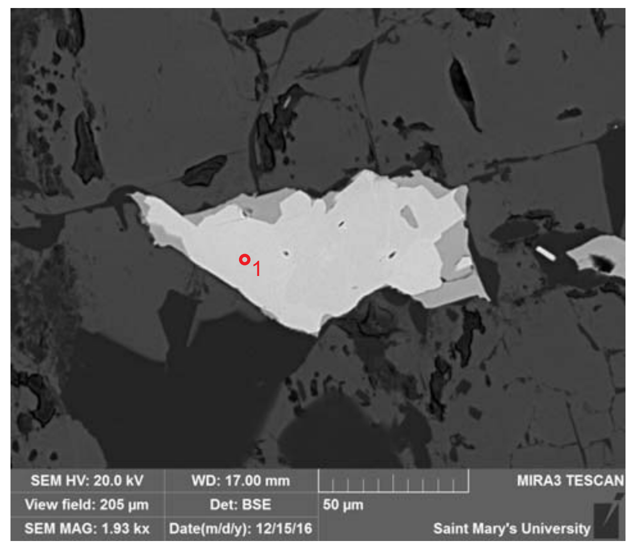
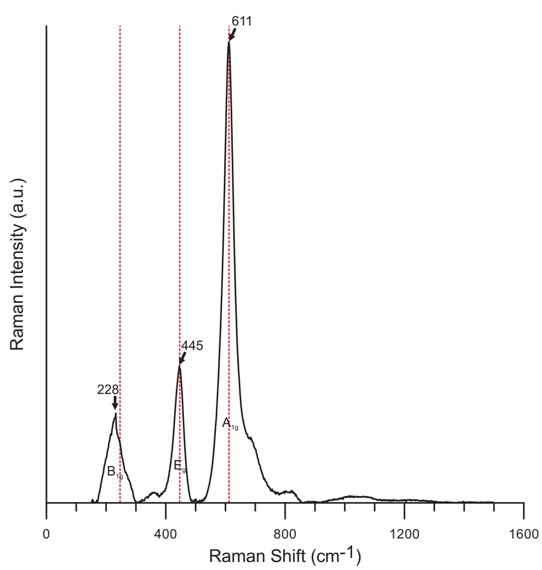




Figure 7.33: Sample 9956a site 25.



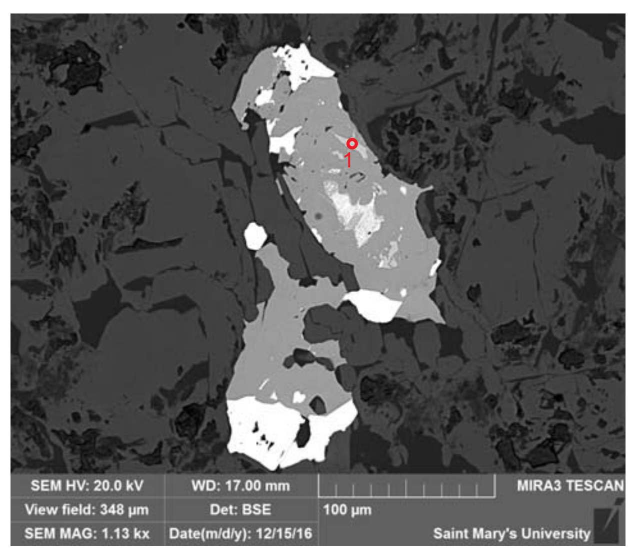
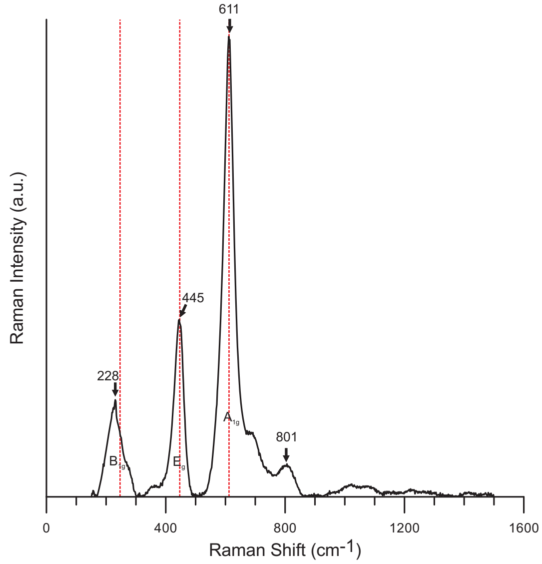




Figure 7.34: Sample 9956a site 26.



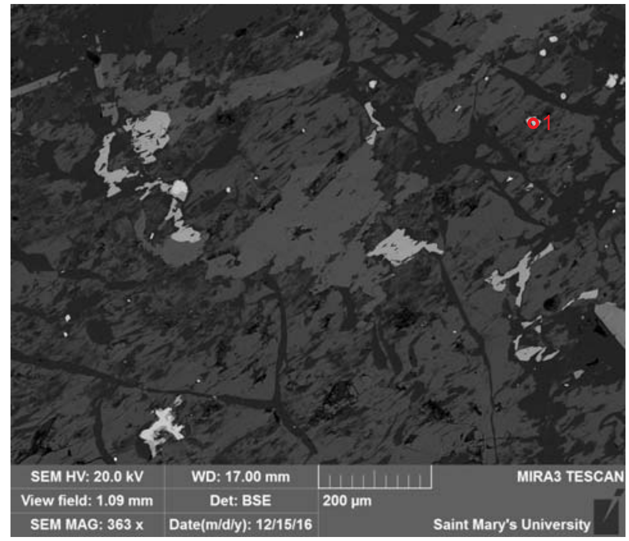
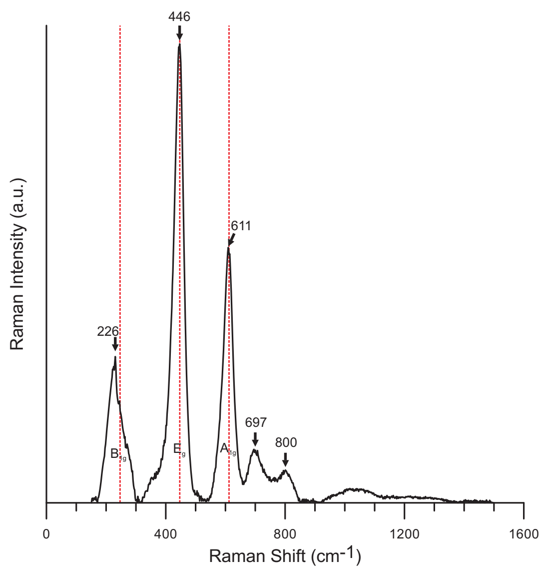




Figure 7.35: Sample 9956a site 29.



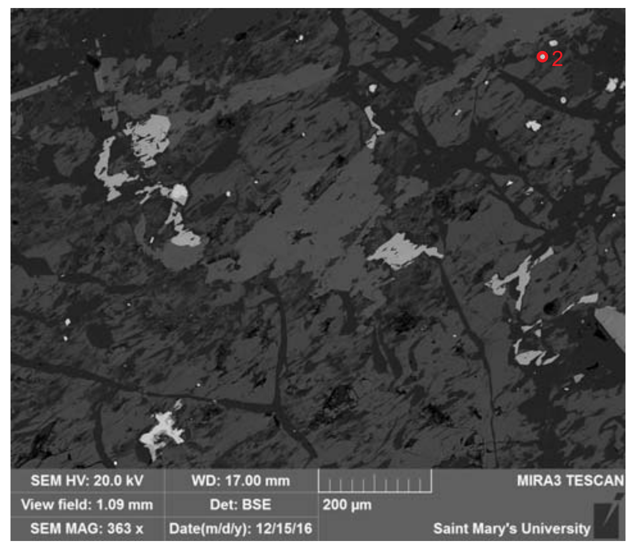
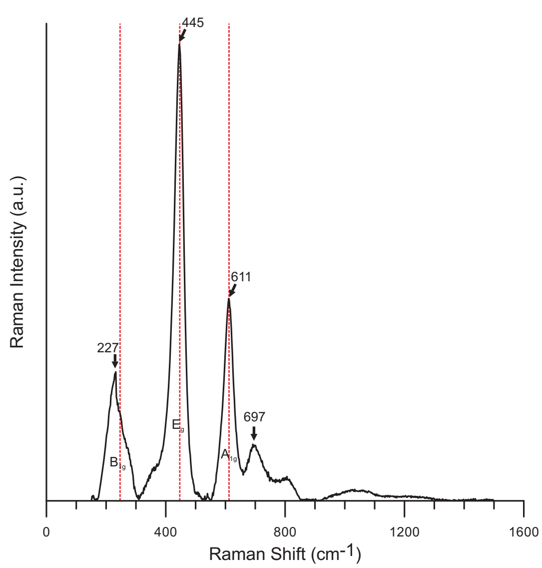




Figure 7.36: Sample 9956a site 29.



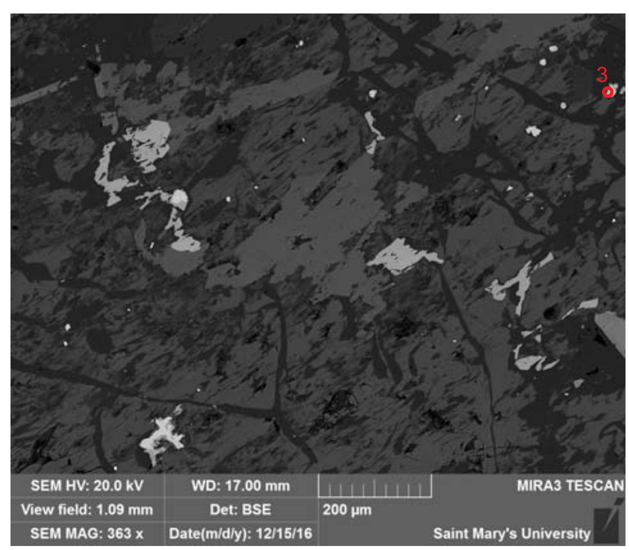




Figure 7.37: Sample 9956a site 29.

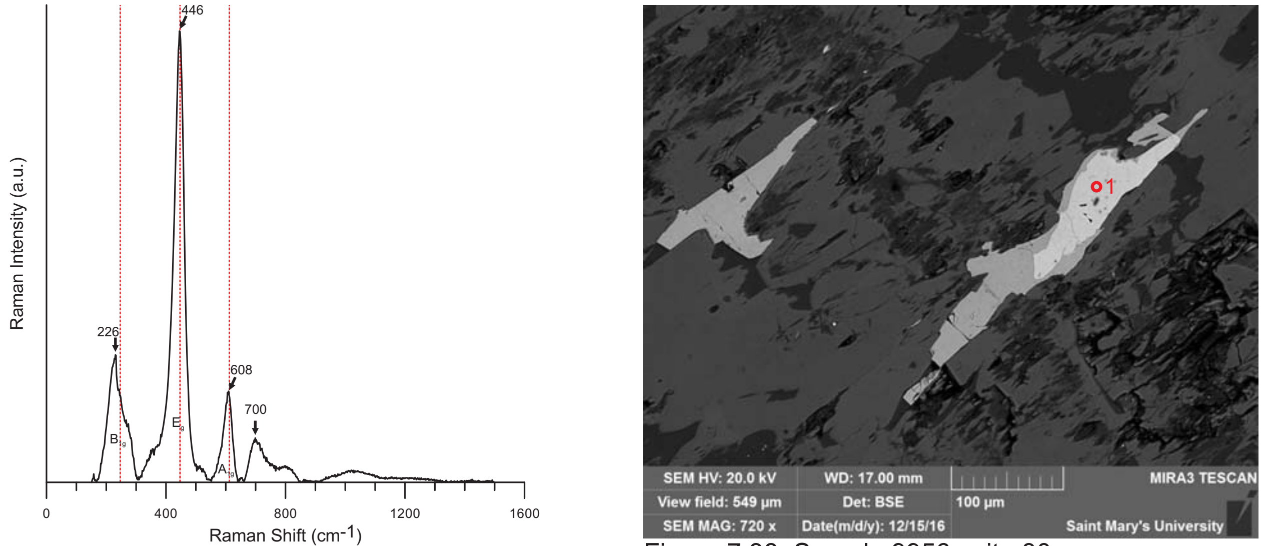


Figure 7.38: Sample 9956a site 30.

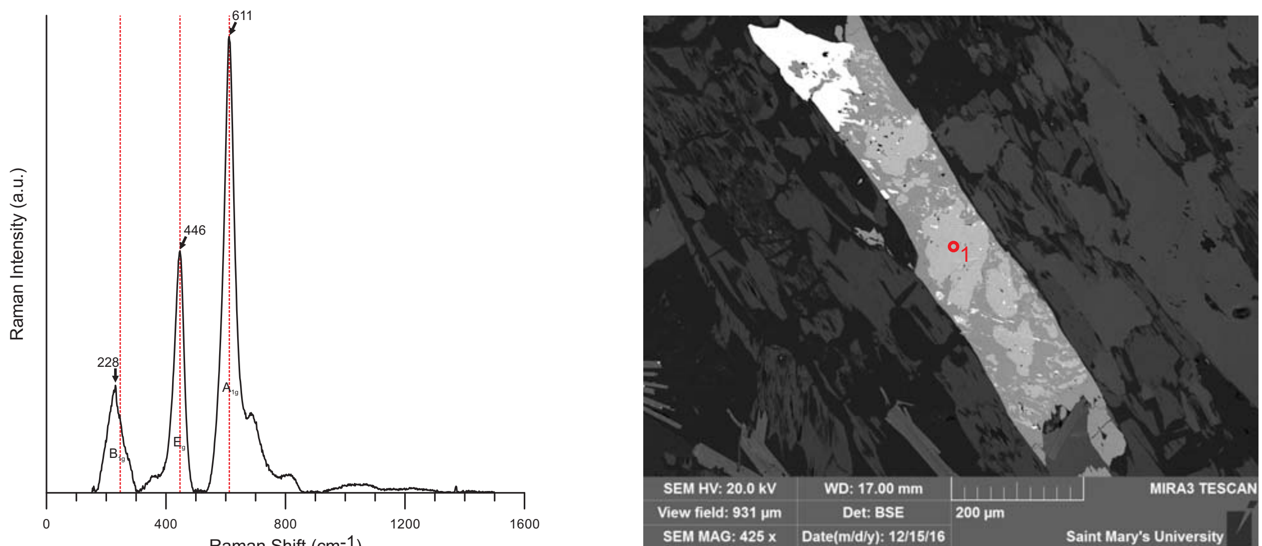


Figure 7.39: Sample 9956a site 32.

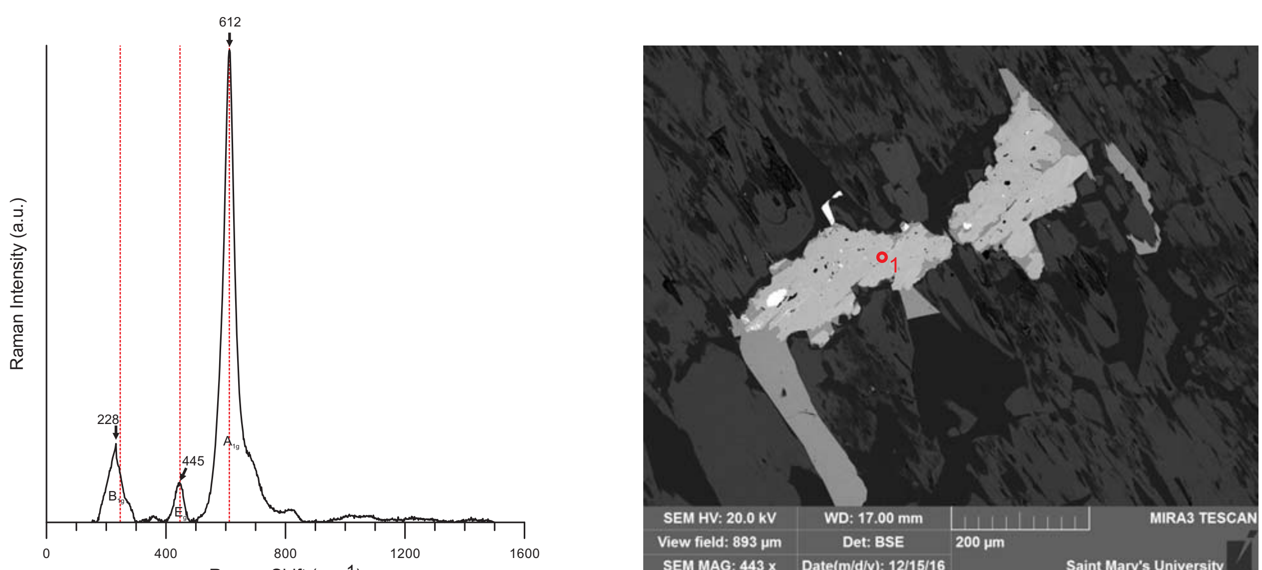


Figure 7.40: Sample 9956a site 33.

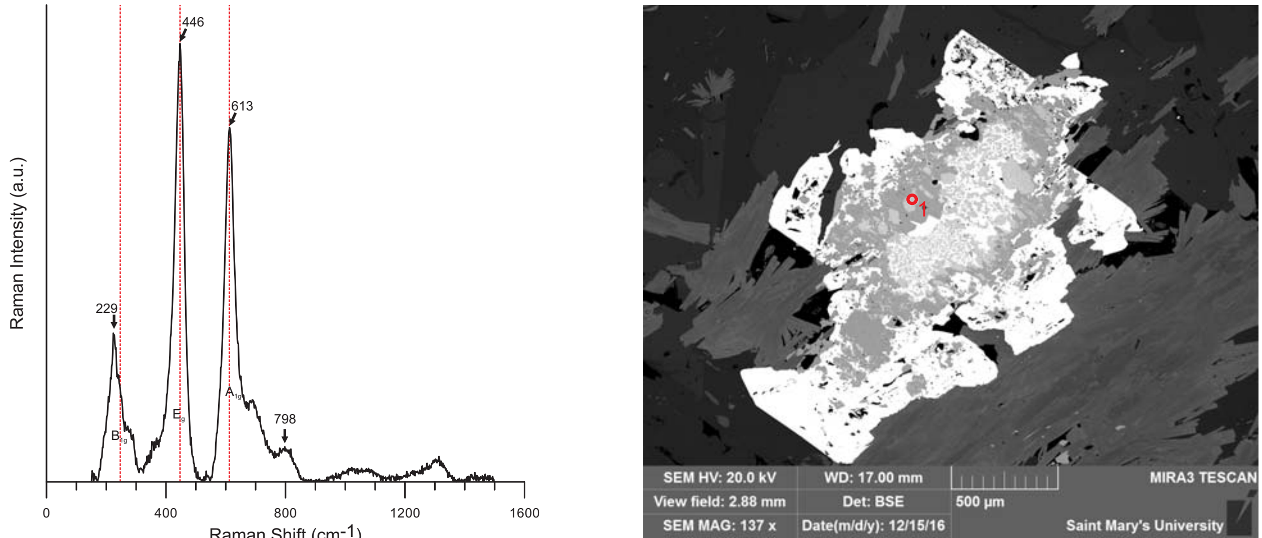


Figure 7.41: Sample 9956a site 38.

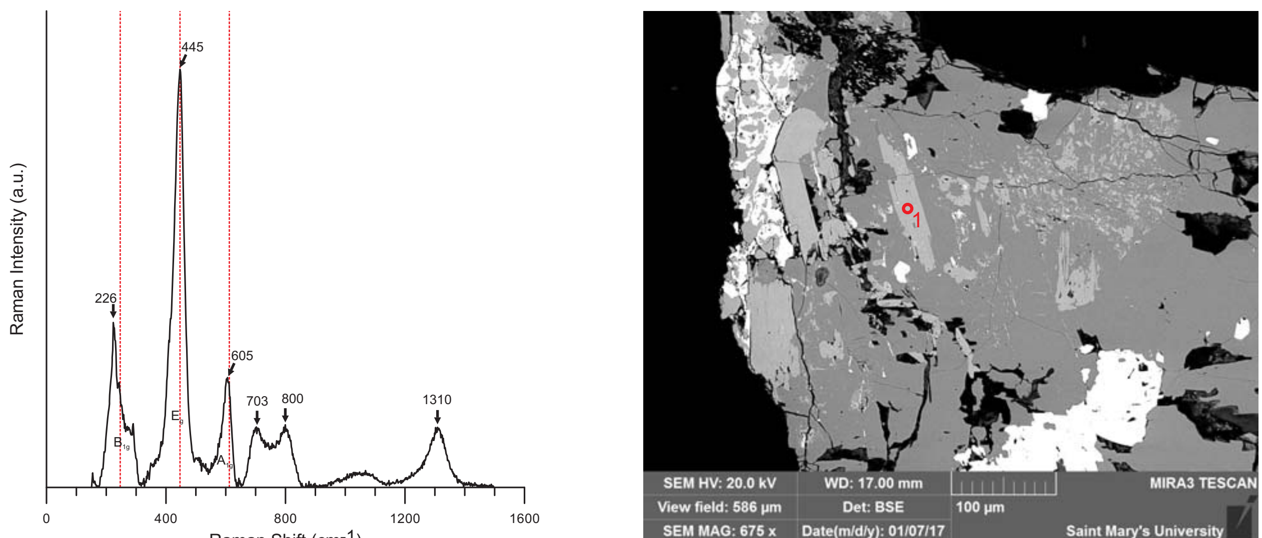


Figure 7.42: Sample 9956d site 1.

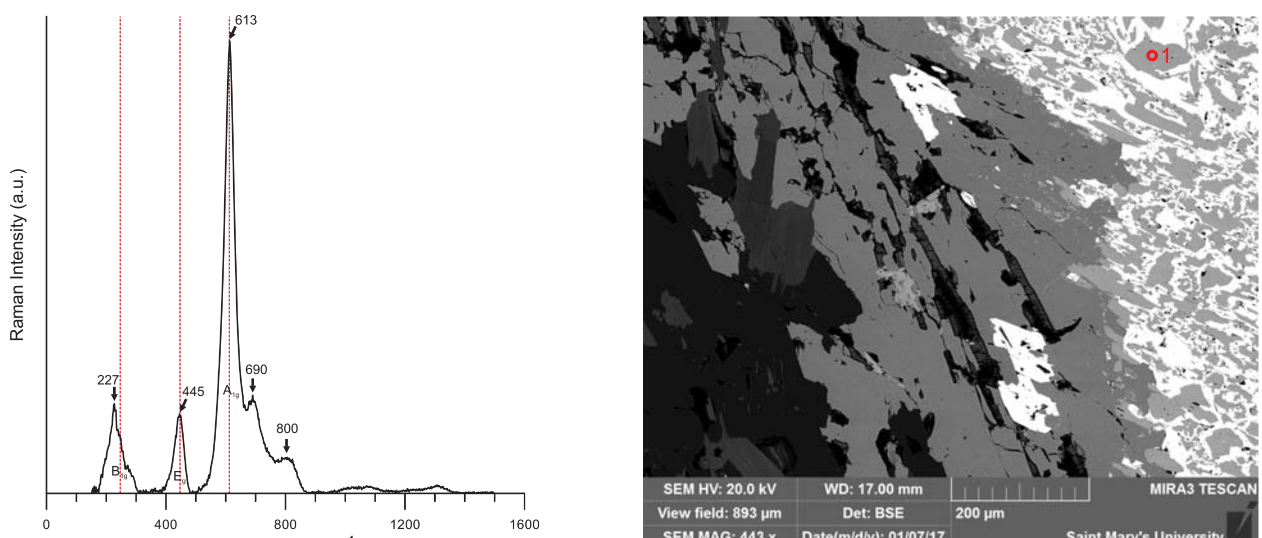
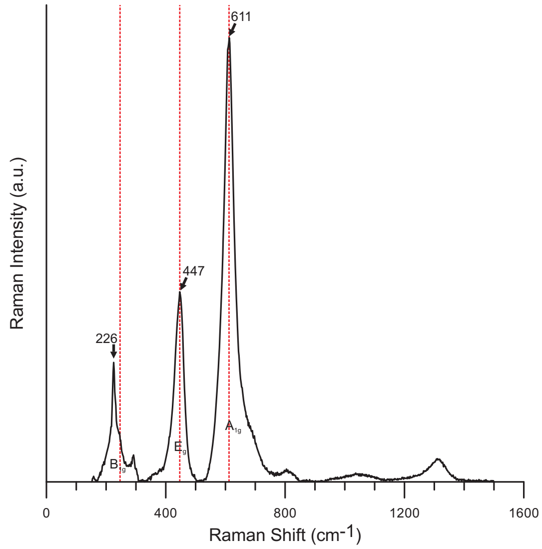


Figure 7.43: Sample 9956d site 2.



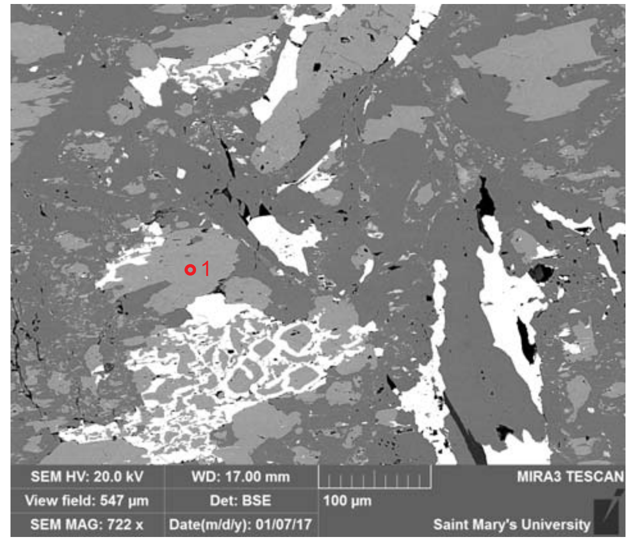
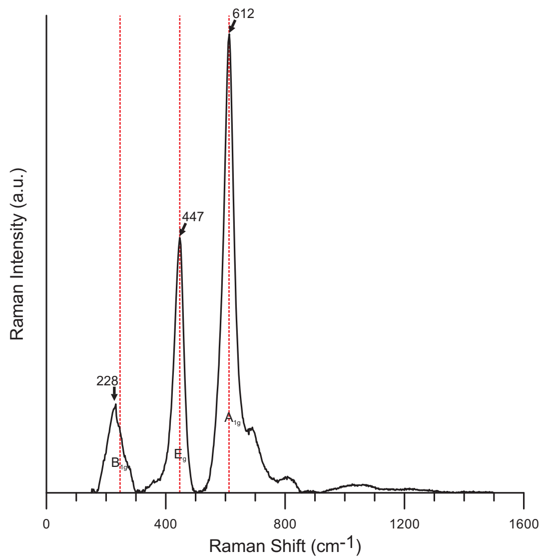




Figure 7.44: Sample 9956d site 6.



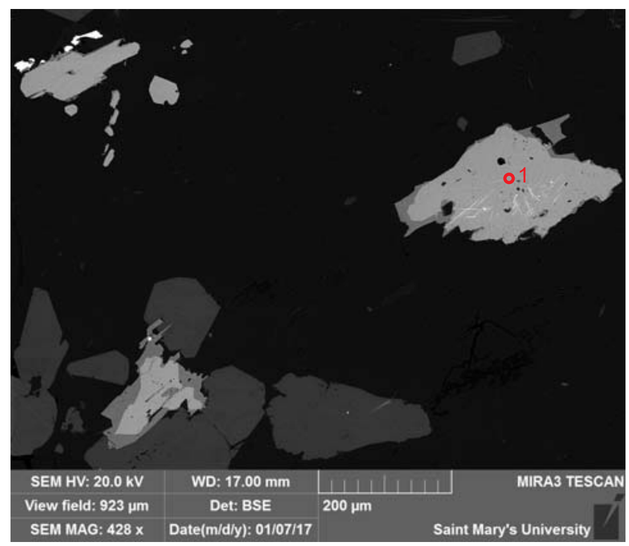
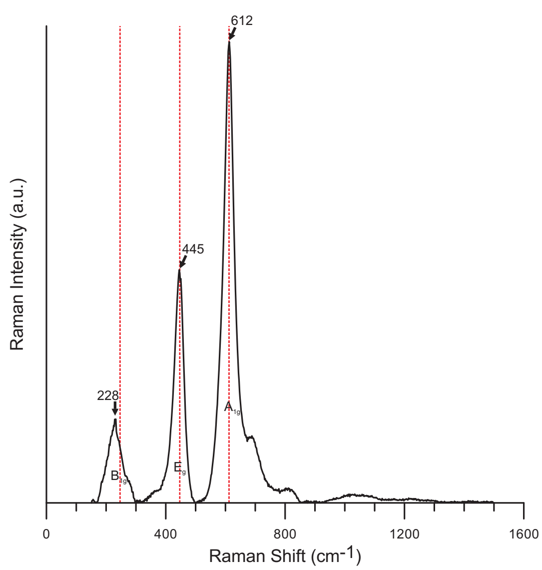




Figure 7.45: Sample 9956d site 10.



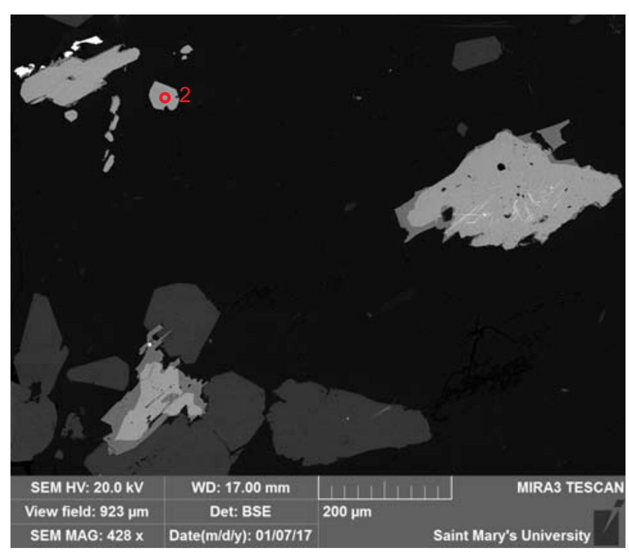




Figure 7.46: Sample 9956d site 10.

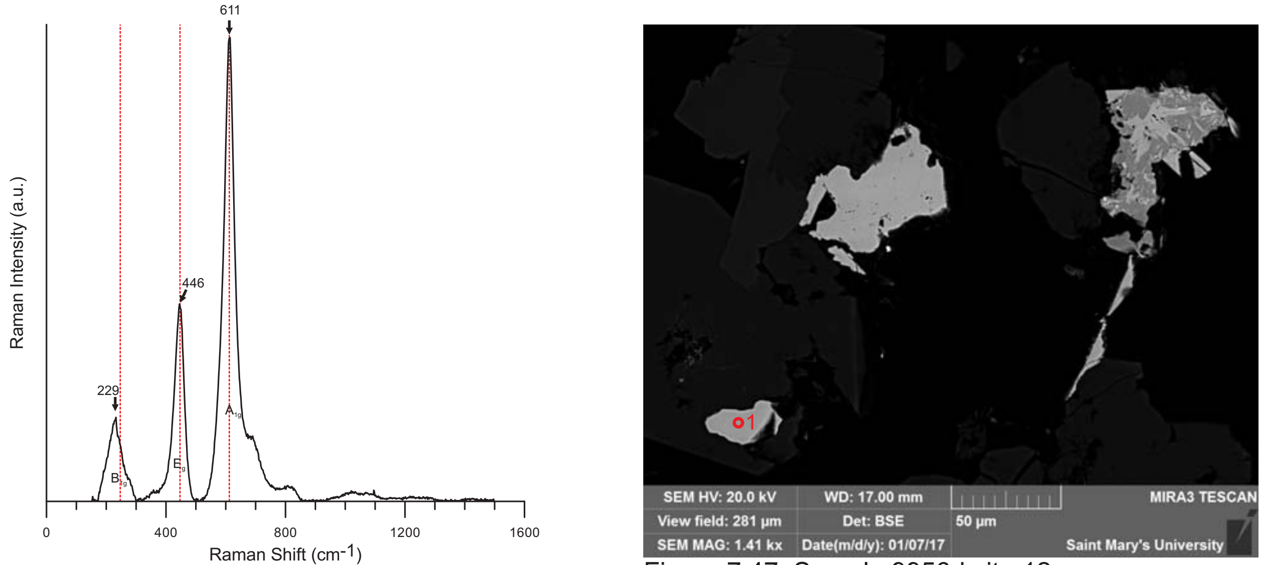


Figure 7.47: Sample 9956d site 12.

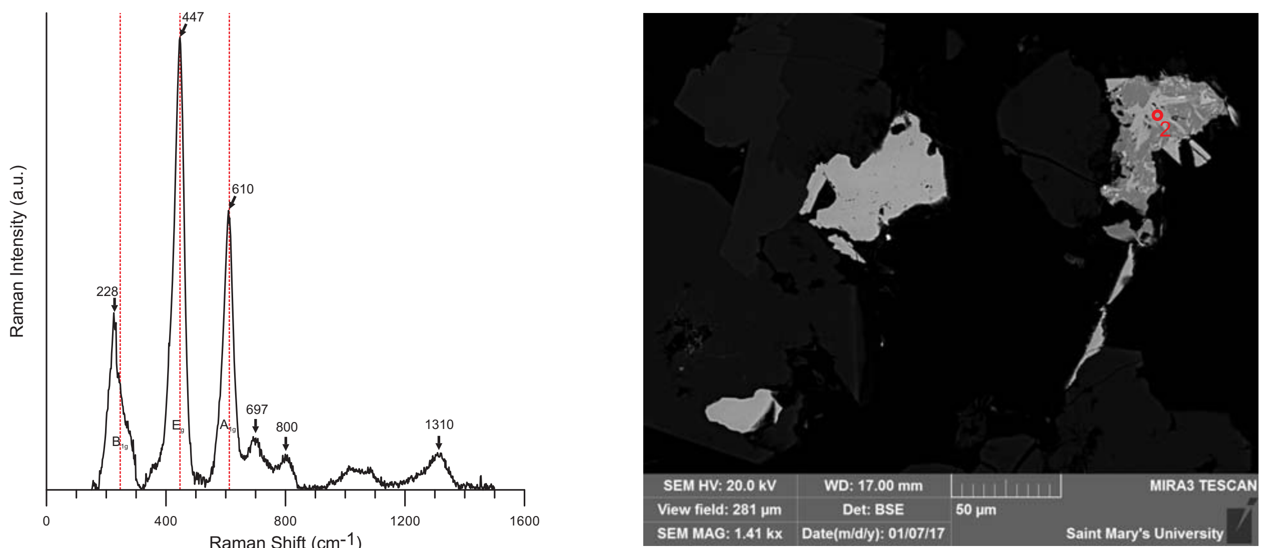


Figure 7.48: Sample 9956d site 12.

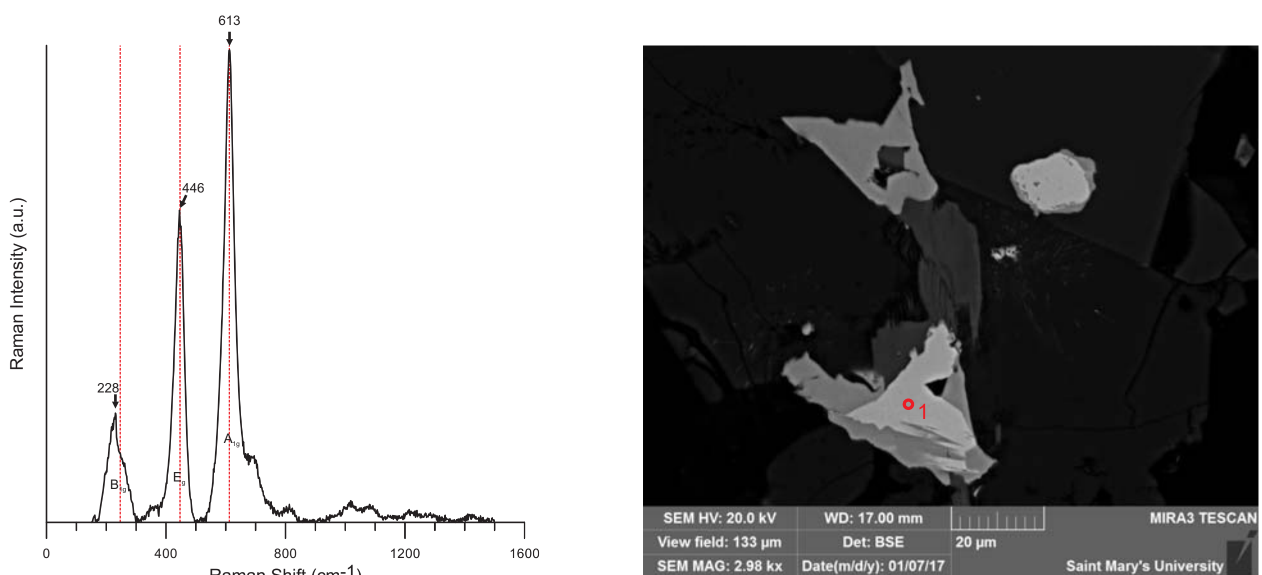
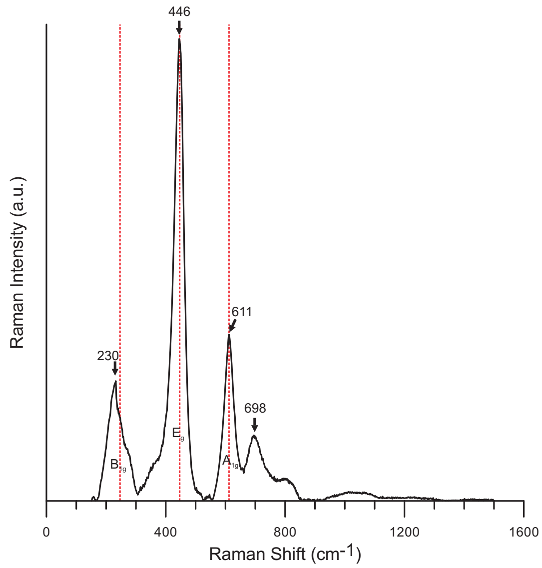


Figure 7.49: Sample 9956d site 13.



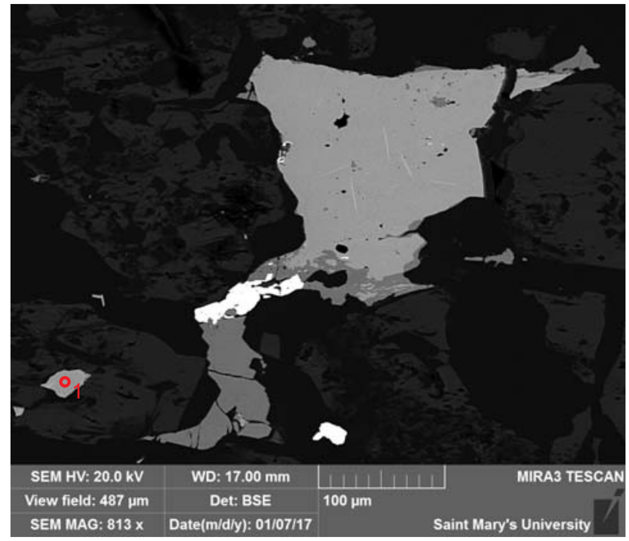
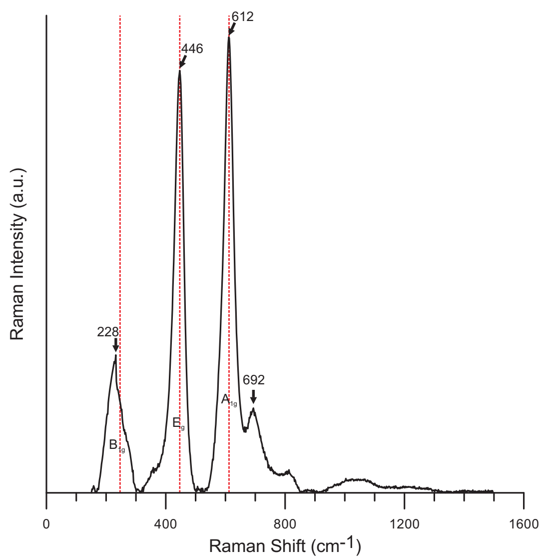




Figure 7.50: Sample 9956d site 18.



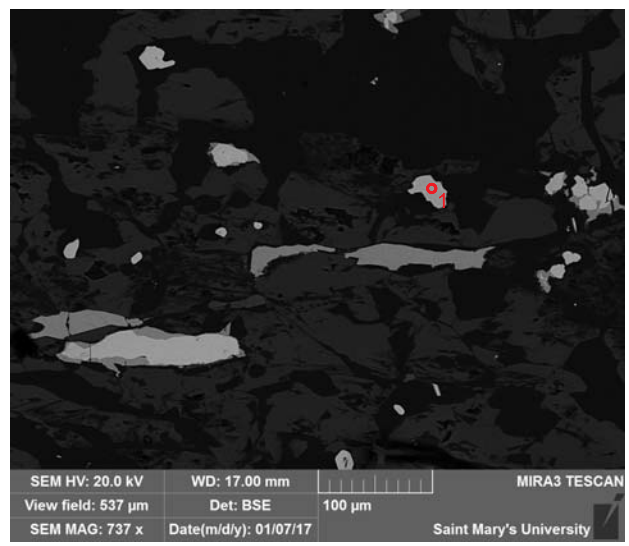
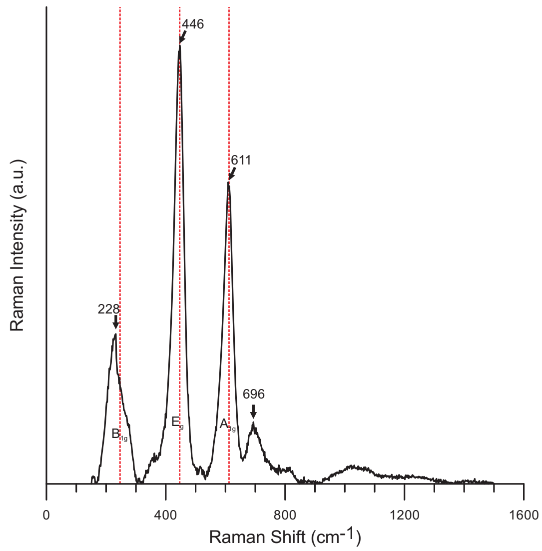




Figure 7.51: Sample 9956d site 20.



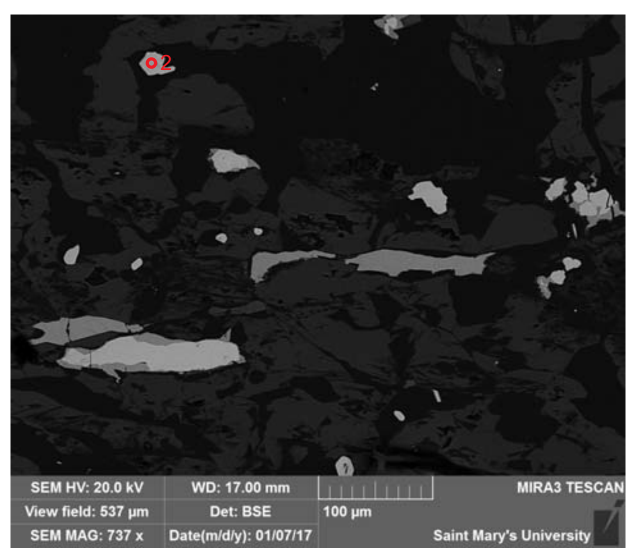




Figure 7.52: Sample 9956d site 20.

# Appendix 8: SEM-BSE images indicating the location of analyzed spots for REE patterns in Rutile and the actual REE patterns.

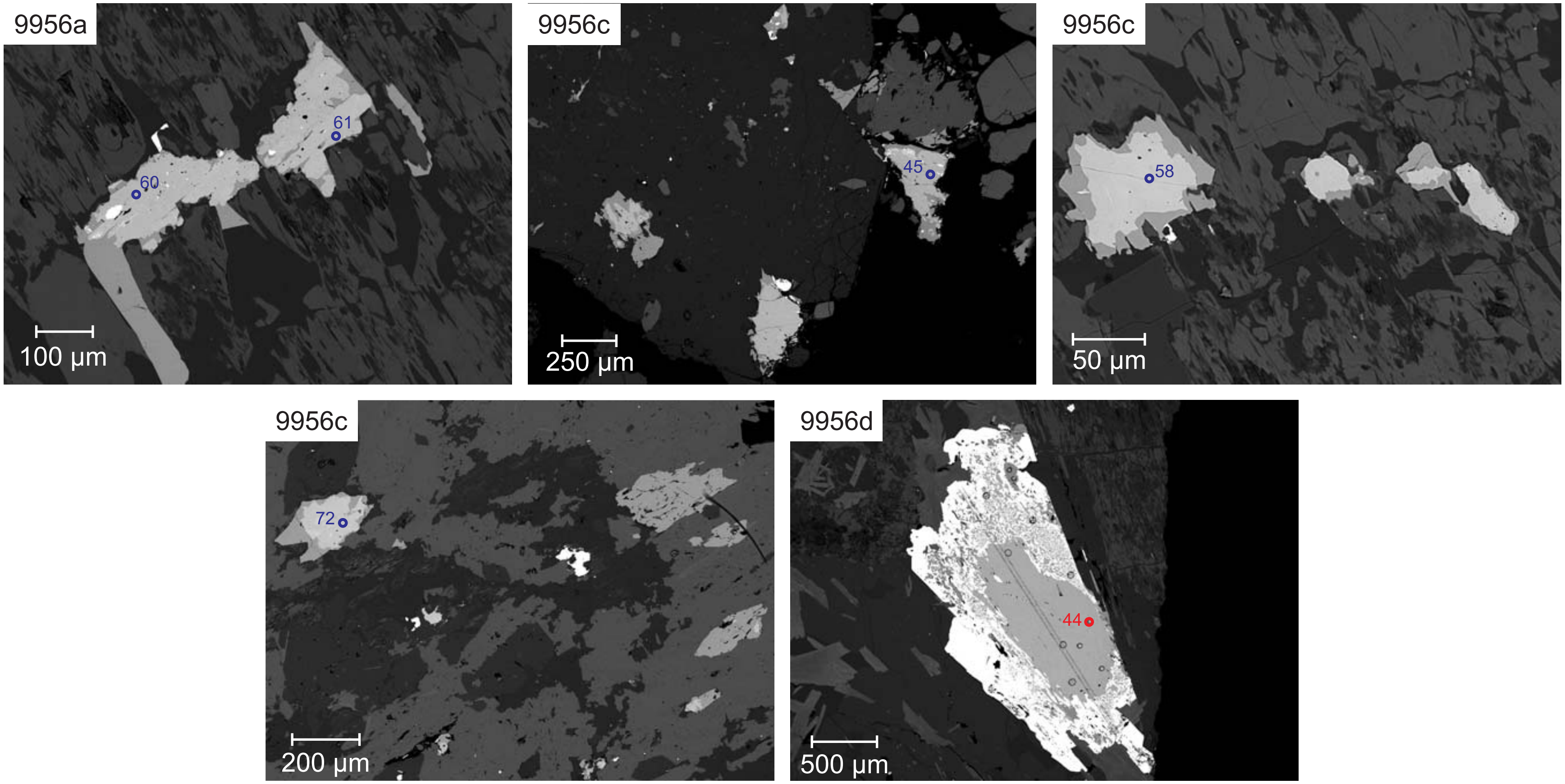


Figure 8.1: BSE images of all analysed grains (trace elements) for rutile type 1 REE patterns. The numbers indicate the analyses in Table 4-1.2. See Figure 8.6 A for REE pattern. The red labels indicate equant grains and the blue labels indicated interstitial grains.

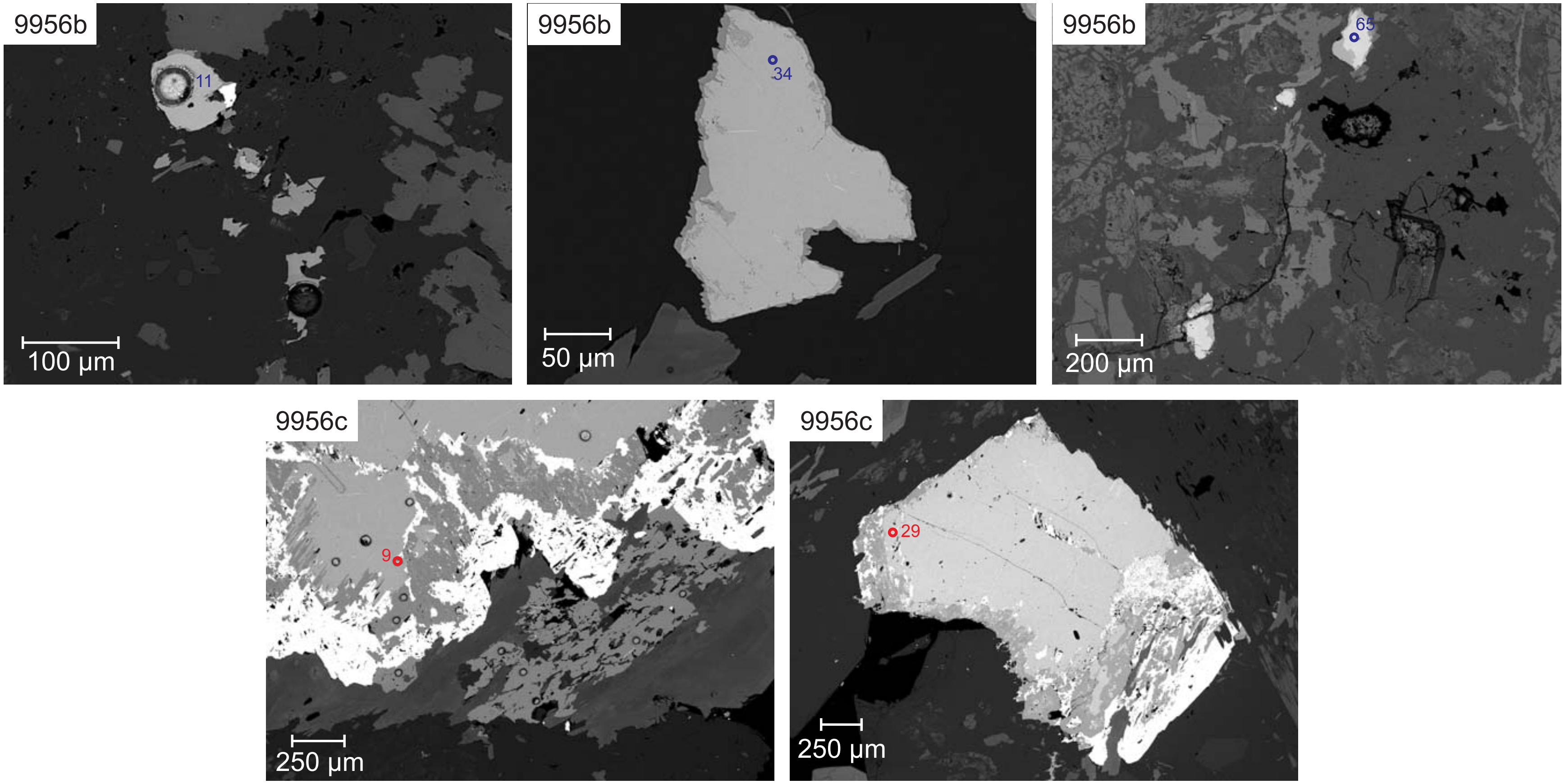



Figure 8.2: BSE images of all analysed grains (trace elements) for rutile type 2 REE patterns. The numbers indicate the analyses in Table 4-1.2. See Figure 8.6 B for REE pattern. The red labels indicate equant grains and the blue labels indicated interstitial grains.

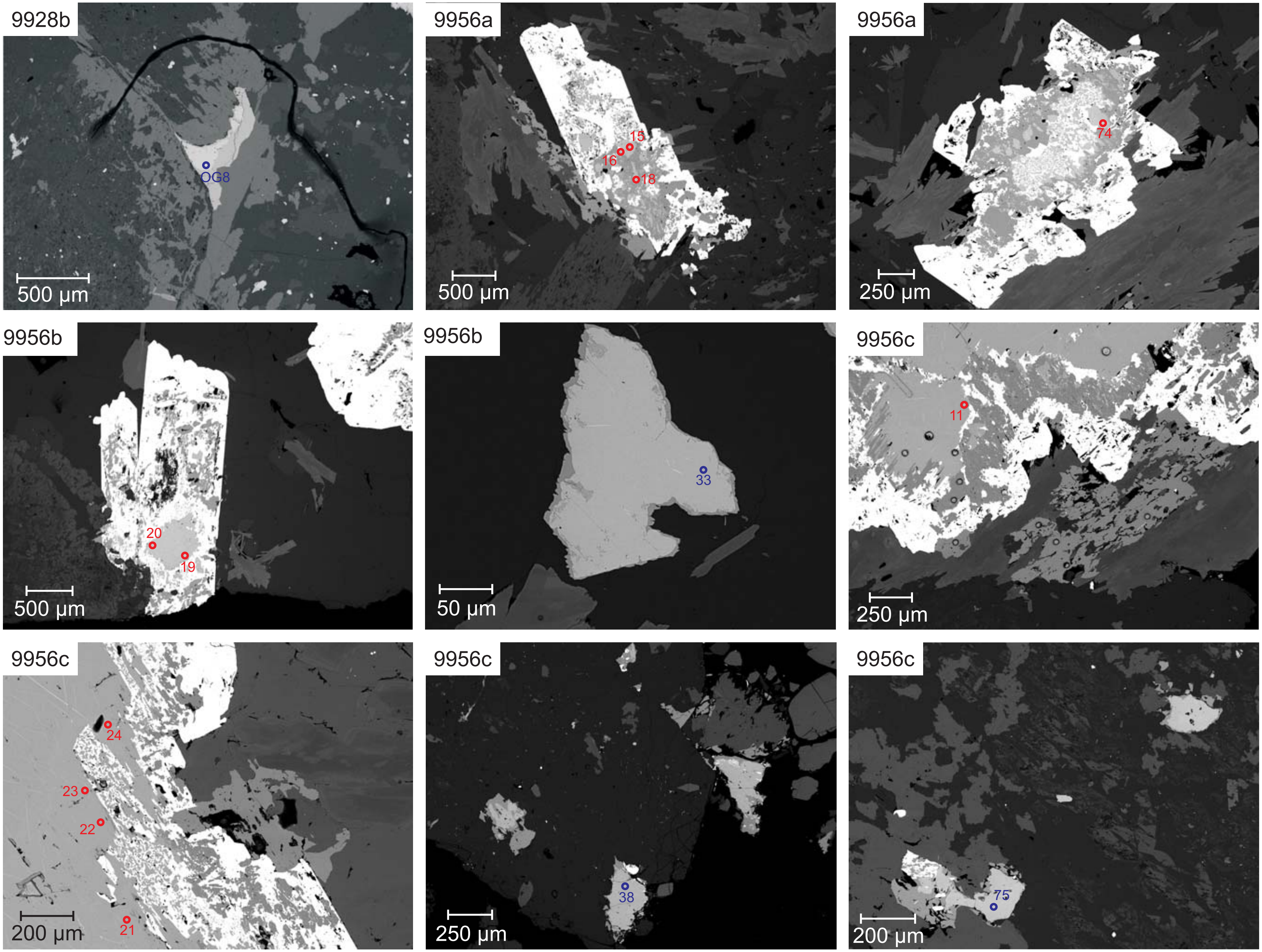



Figure 8.3: BSE images of all analysed grains (trace elements) for rutile type 3 REE patterns. The numbers indicate the analyses in Table 4-1.2. See Figure 8.6 C,D for REE pattern. The red labels indicate equant grains and the blue labels indicated interstitial grains.

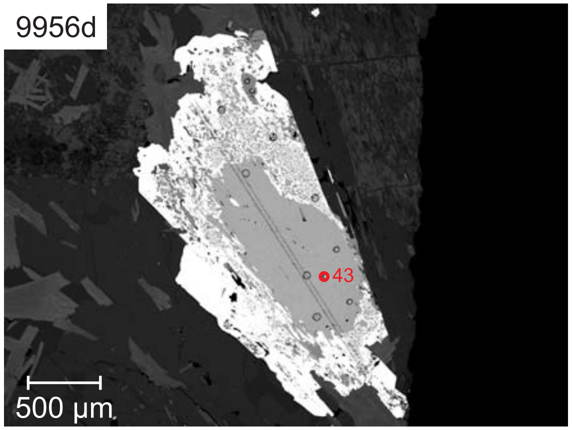



Figure 8.4: BSE images of all analysed grains (trace elements) for rutile type 3 REE patterns. The numbers indicate the analyses in Table 4-1.2. See Figure 8.6 C,D for REE pattern. The red labels indicate equant grains and the blue labels indicated interstitial grains.

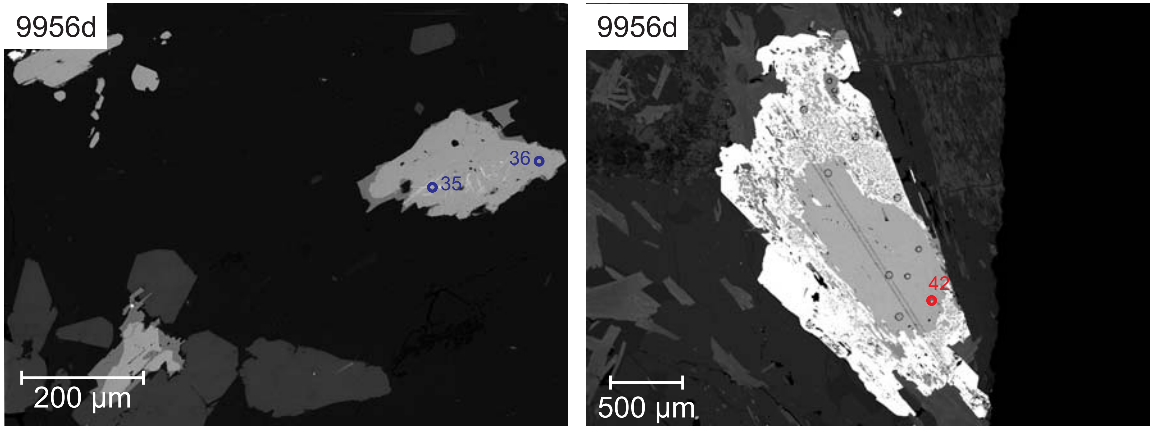



Figure 8.5: BSE images of all analysed grains (trace elements) for rutile of unclasified REE patterns. The numbers indicate the analyses in Table 4-1.2. See Figure 8.6 E for REE pattern. The red labels indicate equant grains and the blue labels indicated interstitial grains.

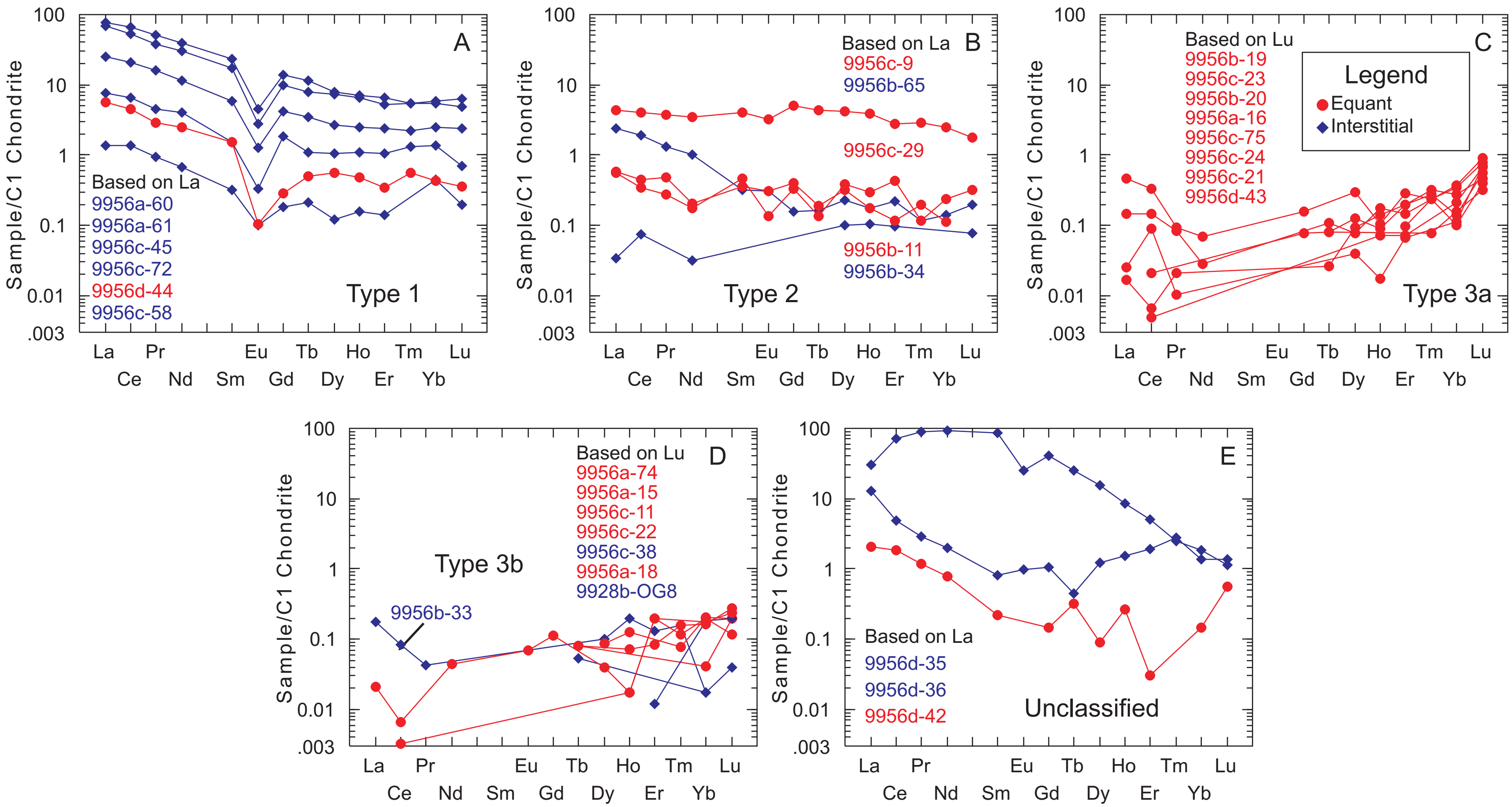



Figure 8.6: REE patterns of different types of rutile. Each of these figures (A-E) contains sample number and analyzed spot numbers as in Table 4-1.2.

# Appendix 9: REE patterns for representative titanite samples.

**Modes of Occurrence of Titanite**

● **Type 1:** Equant/sub-equant crystal with some euhedral faces
■ **Type 2:** Equant overgrowth usually with some euhedral faces
◆ **Type 3:** Sub-equant overgrowth
▲ **Type 4:** Discontinuous sub-equant overgrowth
▼ **Type 6:** Interstitial grain
◀ **Type 7:** Small irregular discrete crystals
▶ **Type 8:** Equant crystal exsolving rutile
+ **Type 9:** Replacive
○ **Type 10:** Intergrowth of titanite + rutile, replacement of rutile by titanite
▽ **Type 6 Diorite:** Interstitial grain
+ **Type 9 Diorite:** Replacive
◒ **Type 1 Gabbro:** Equant sub-equant crystal with some euhedral faces
**Types 5 and 11:** No LA-ICP-MS analyses

Note

Each of the figures in this appendix contains a legend that gives the type of titanite. The chemical analyses for these REE patterns are also in Appendix 4.

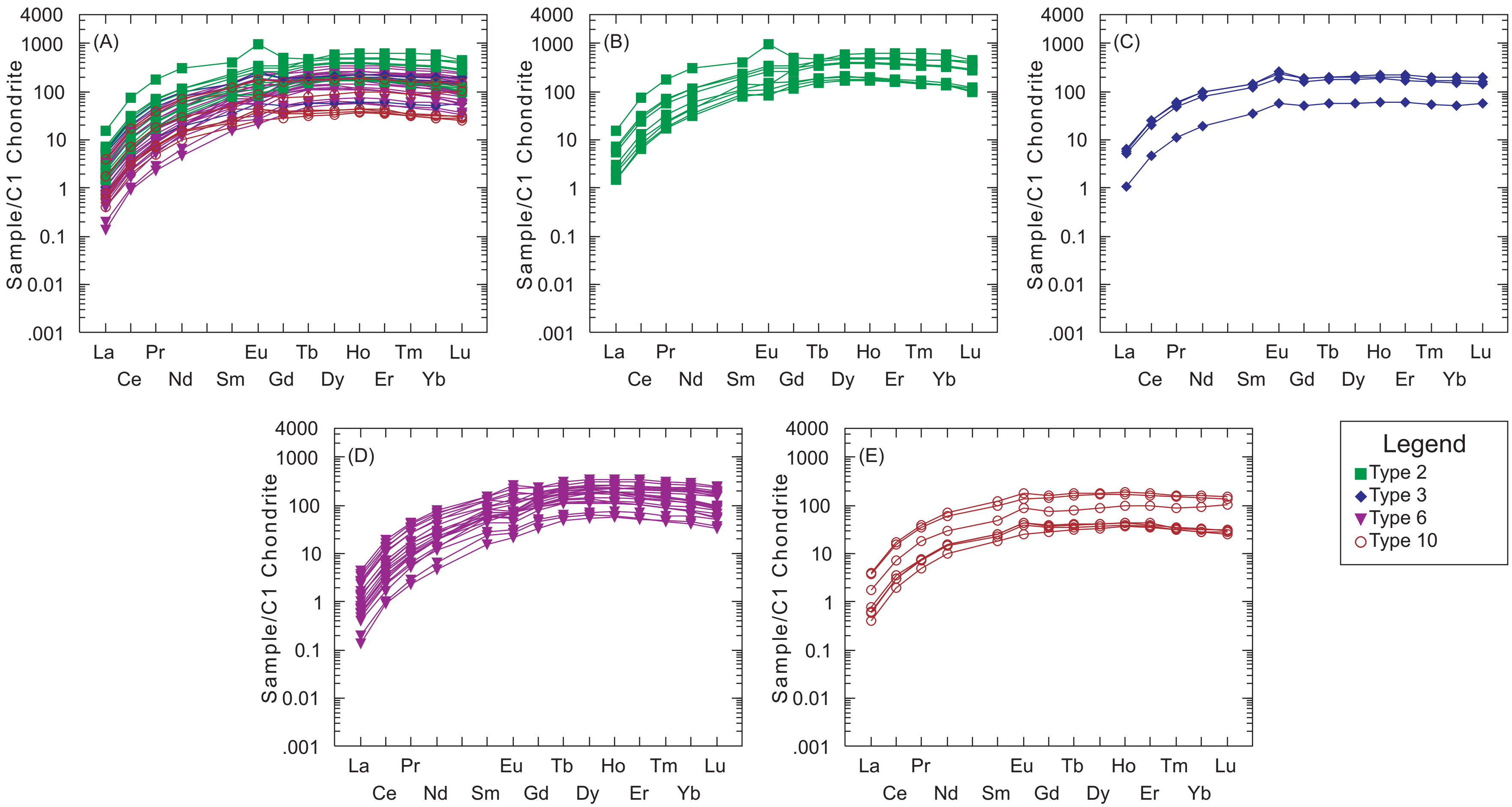



Figure 9.1: REE patterns of class A: Plot A: All REE patterns with flat MREE-HREE, a positive Eu anomaly, less LREE fractionation, and Lu>20. Plots B-E: Indicate modes of occurrence of analyzed titanite.

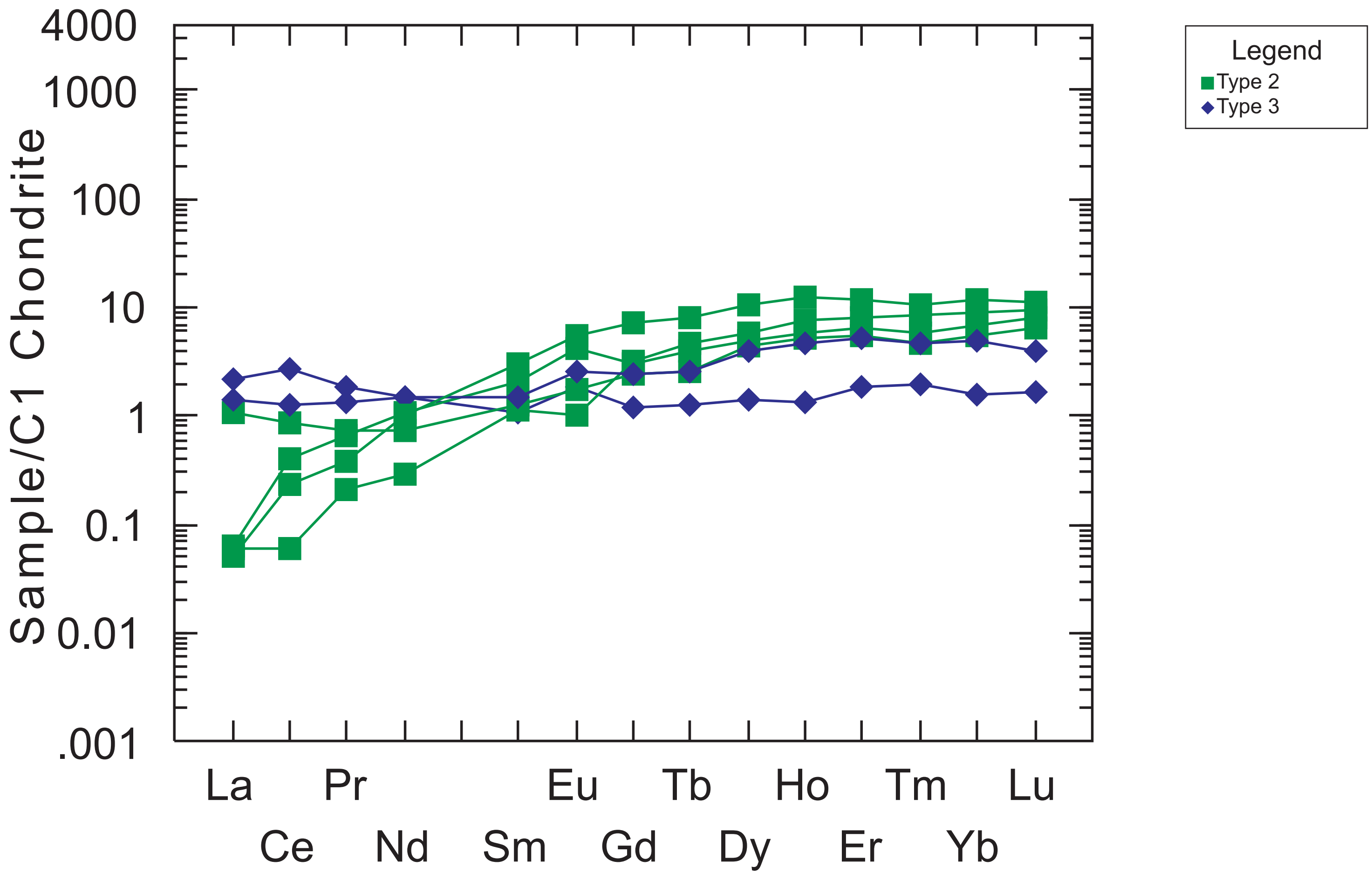



Figure 9.2: REE patterns of class B. Rather flat REE spectra and HREE>LREE.

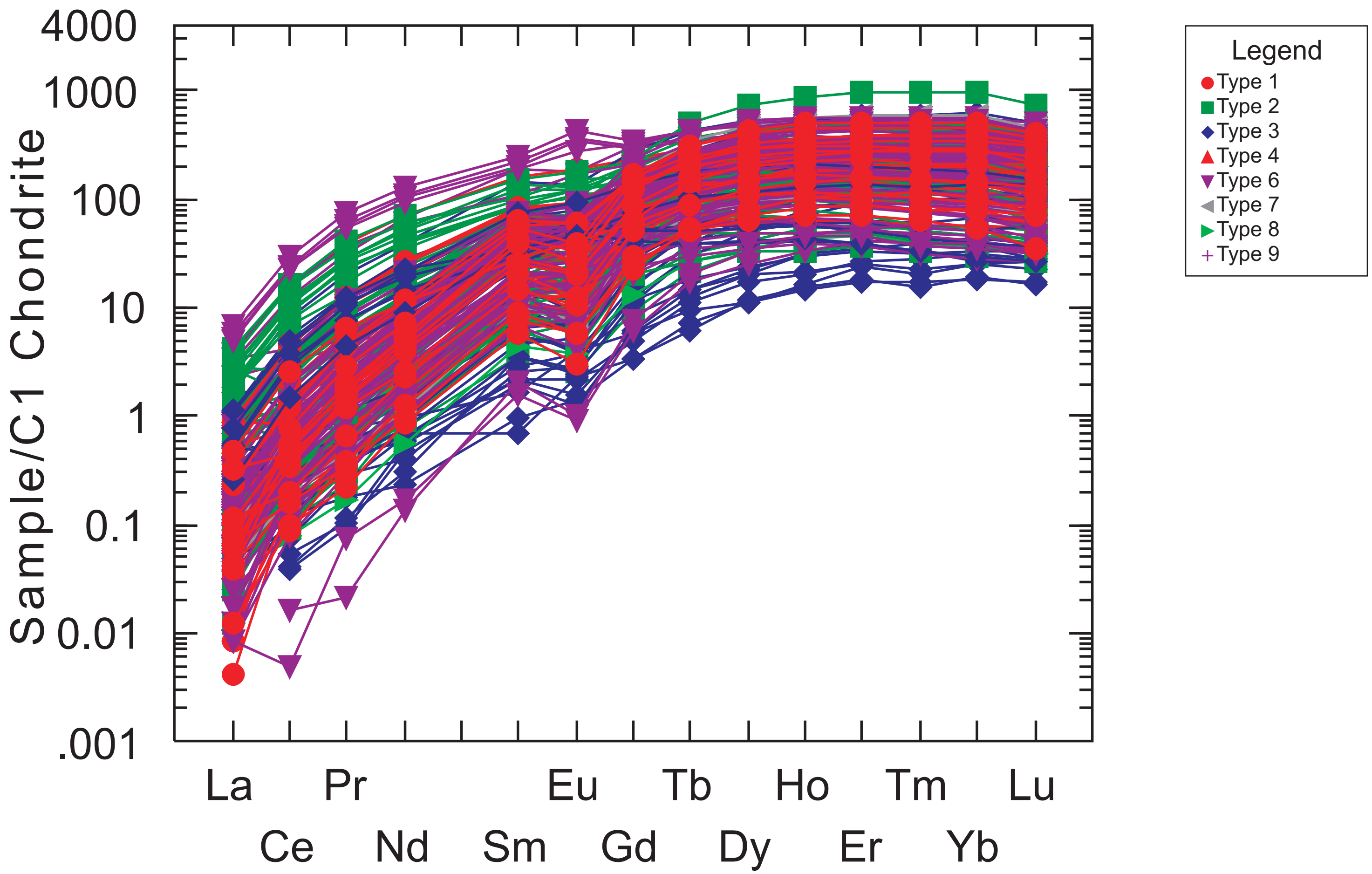



Figure 9.3A: REE patterns of class C. Fractionated LREE-MREE, flat HREE, negative Eu anomaly, greater where ΣREE is lowest.

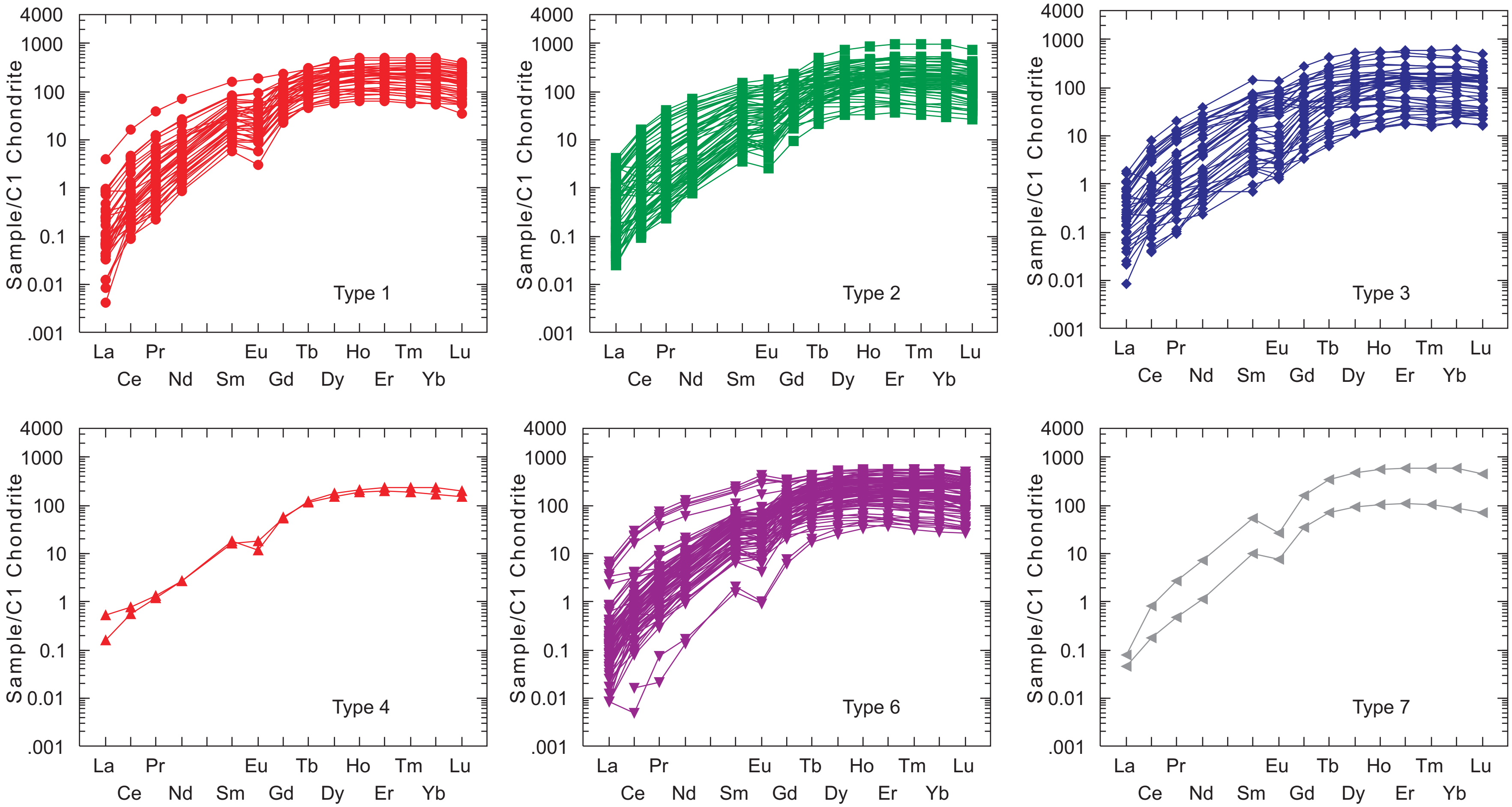



Figure 9.3B: REE patterns of class C. All types of titanite that make up the REE pattern in Figure 9.3A.

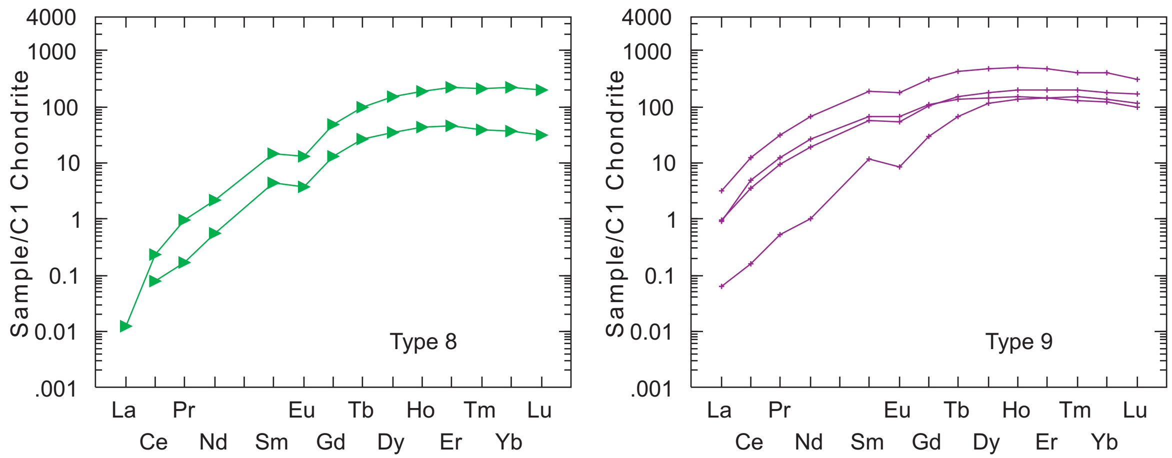



Figure 9.3C: REE patterns of class C. All types of titanite that make up the REE pattern in Figure 9.3A.

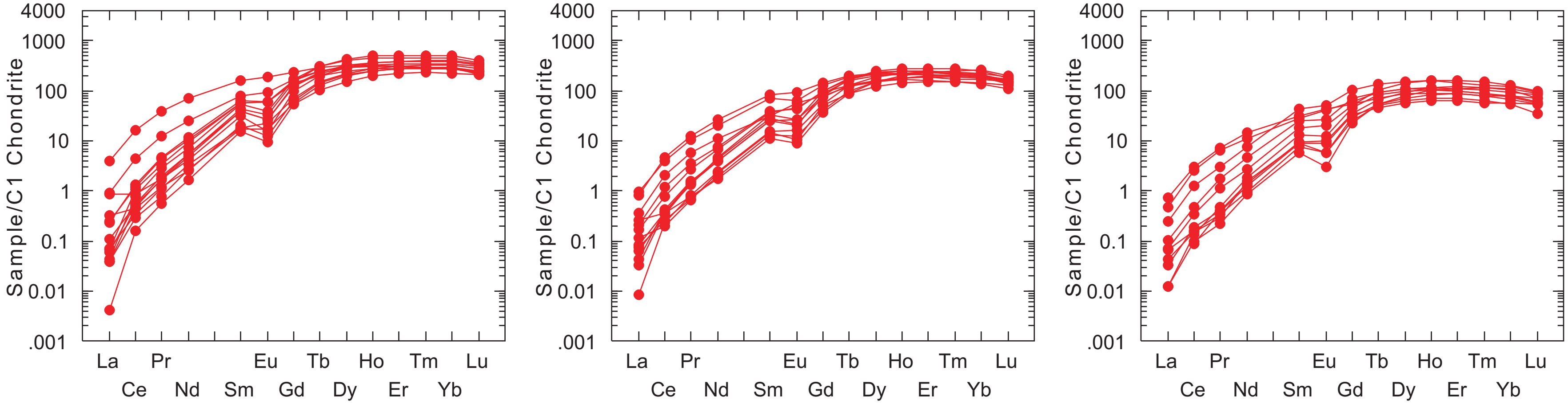



Figure 9.3D: REE patterns of class C. Type 1 titanite from Figure 9.3B.

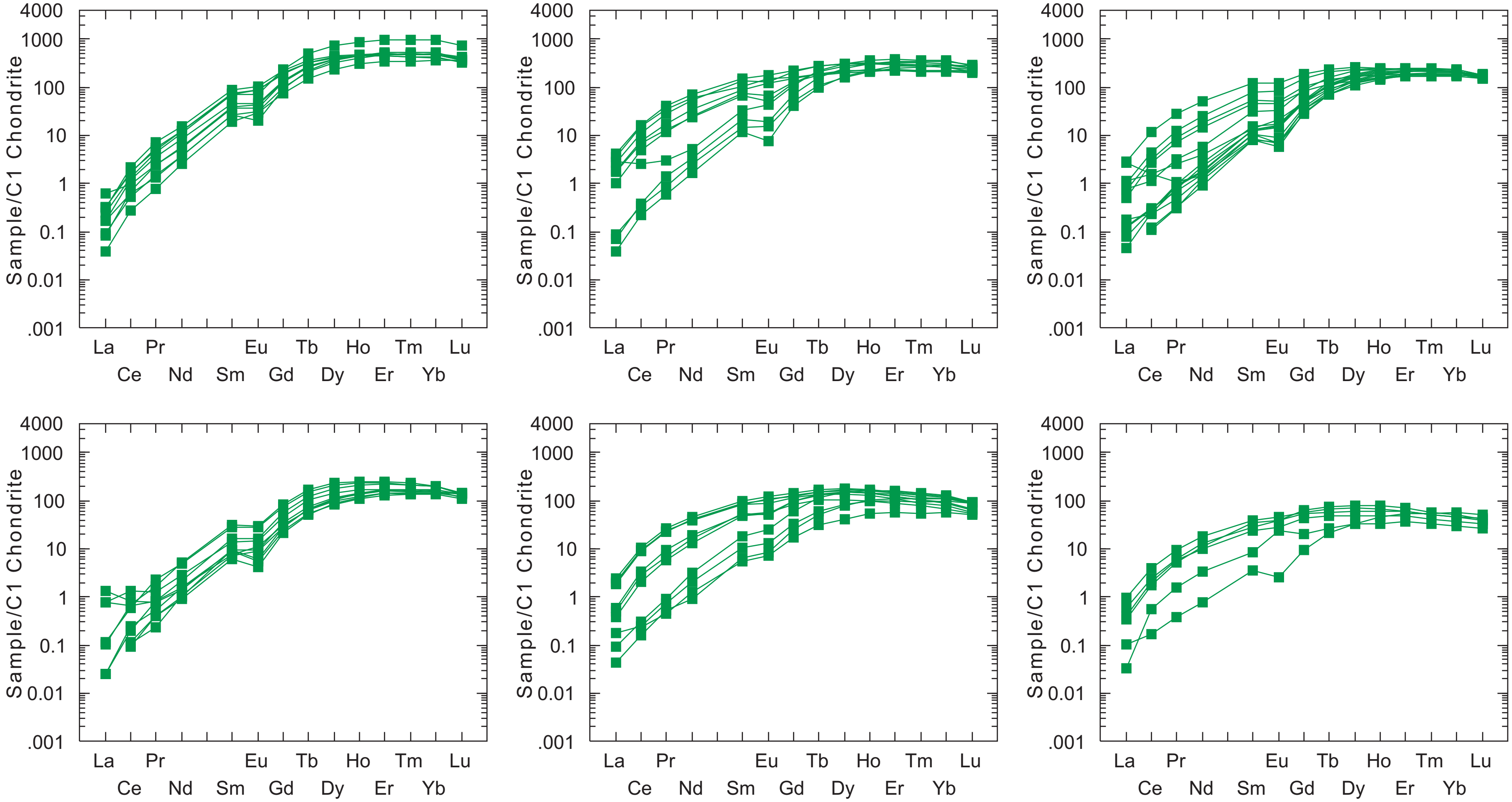



Figure 9.3E: REE patterns of class C. Type 2 titanite from Figure 9.3B.

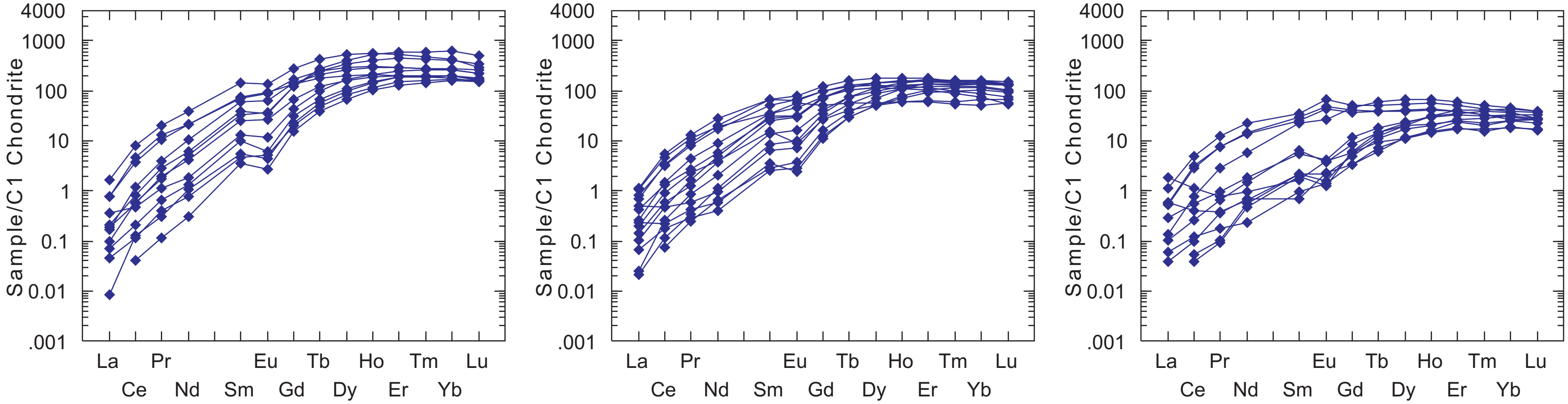



Figure 9.3F: REE patterns of class C. Type 3 titanite from Figure 9.3B.

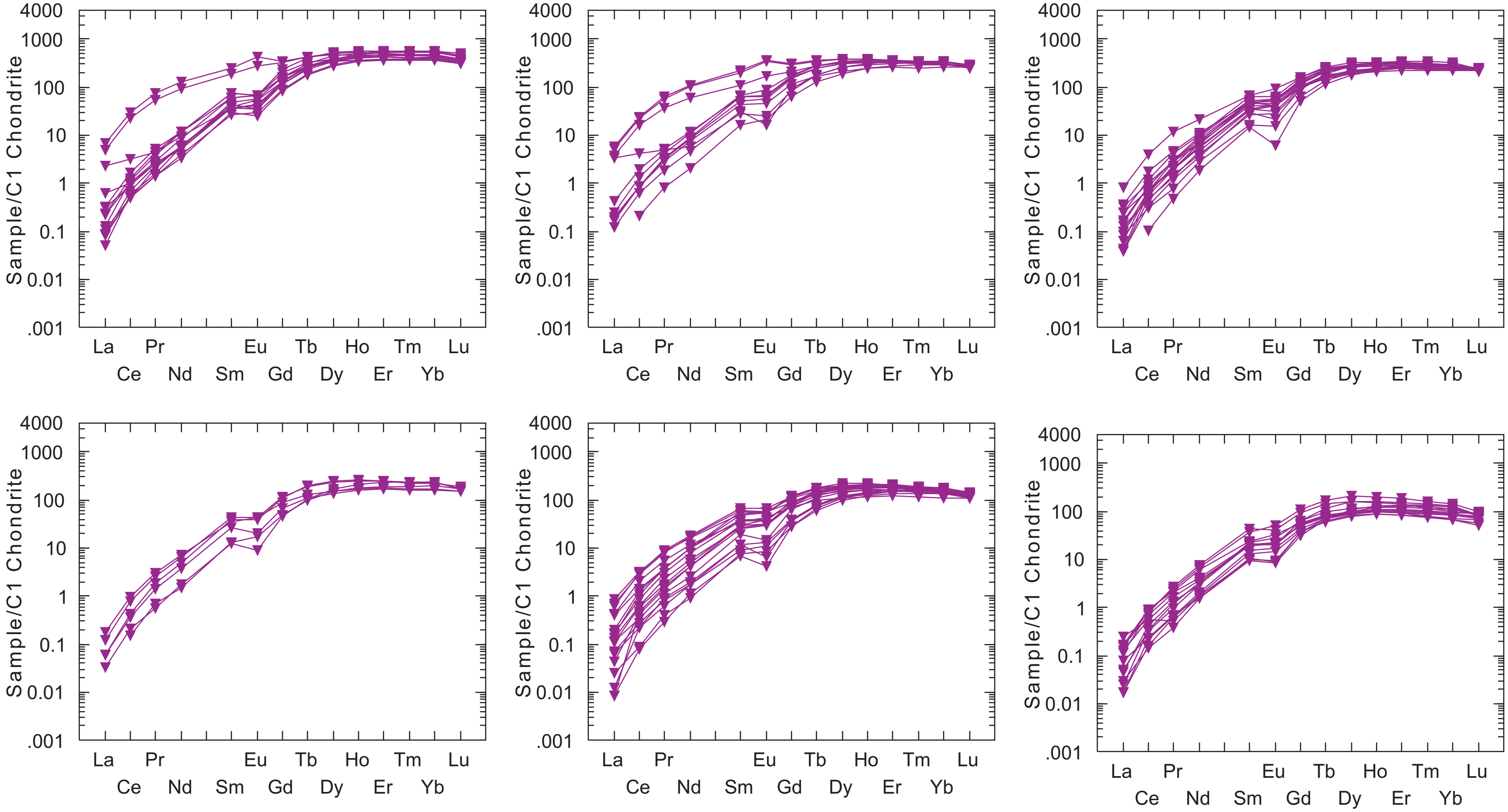



Figure 9.3G: REE patterns of class C. Type 6 titanite from Figure 9.3B.

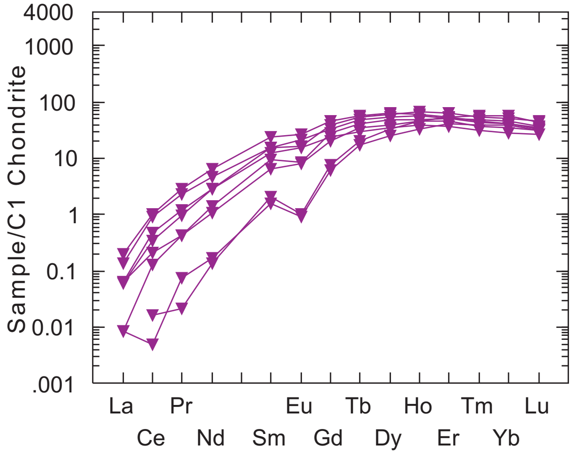



Figure 9.3H: REE patterns of class C. Type 6 titanite from Figure 9.3B.

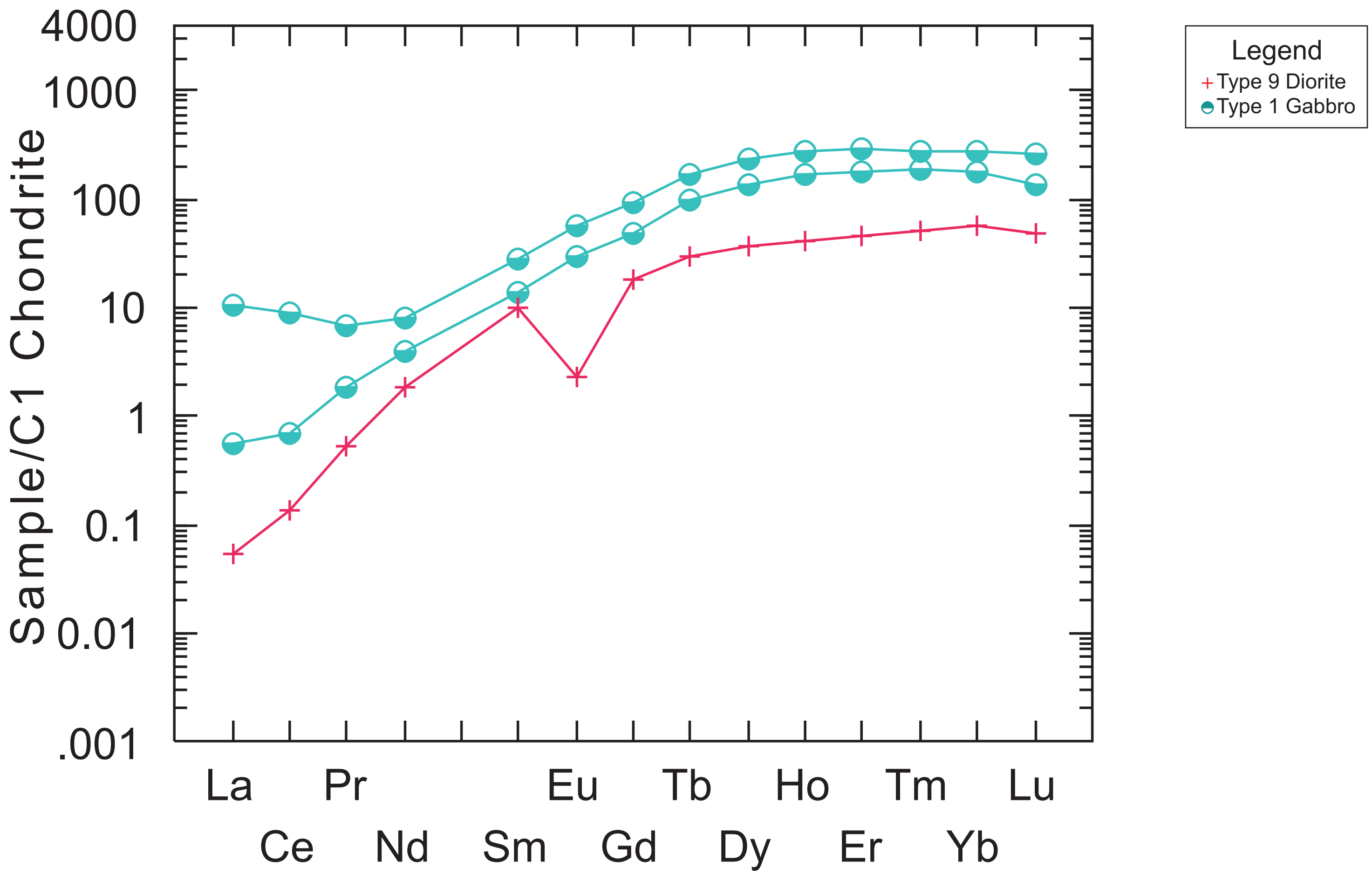



Figure 9.4: REE patterns of class D.

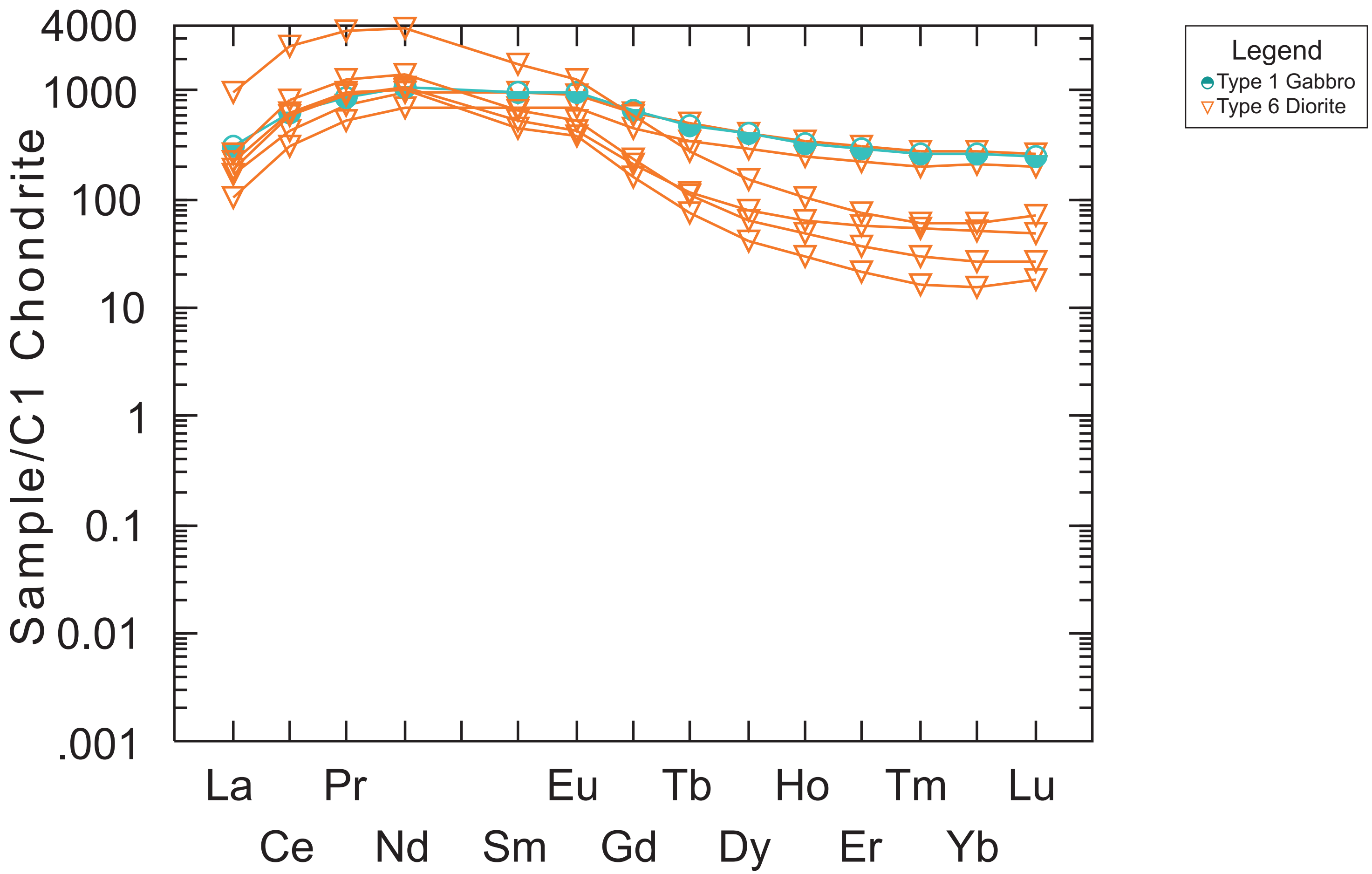



Figure 9.5: REE patterns of class E.

# Appendix 10: Microphotographs of scapolite from representative diorite samples.

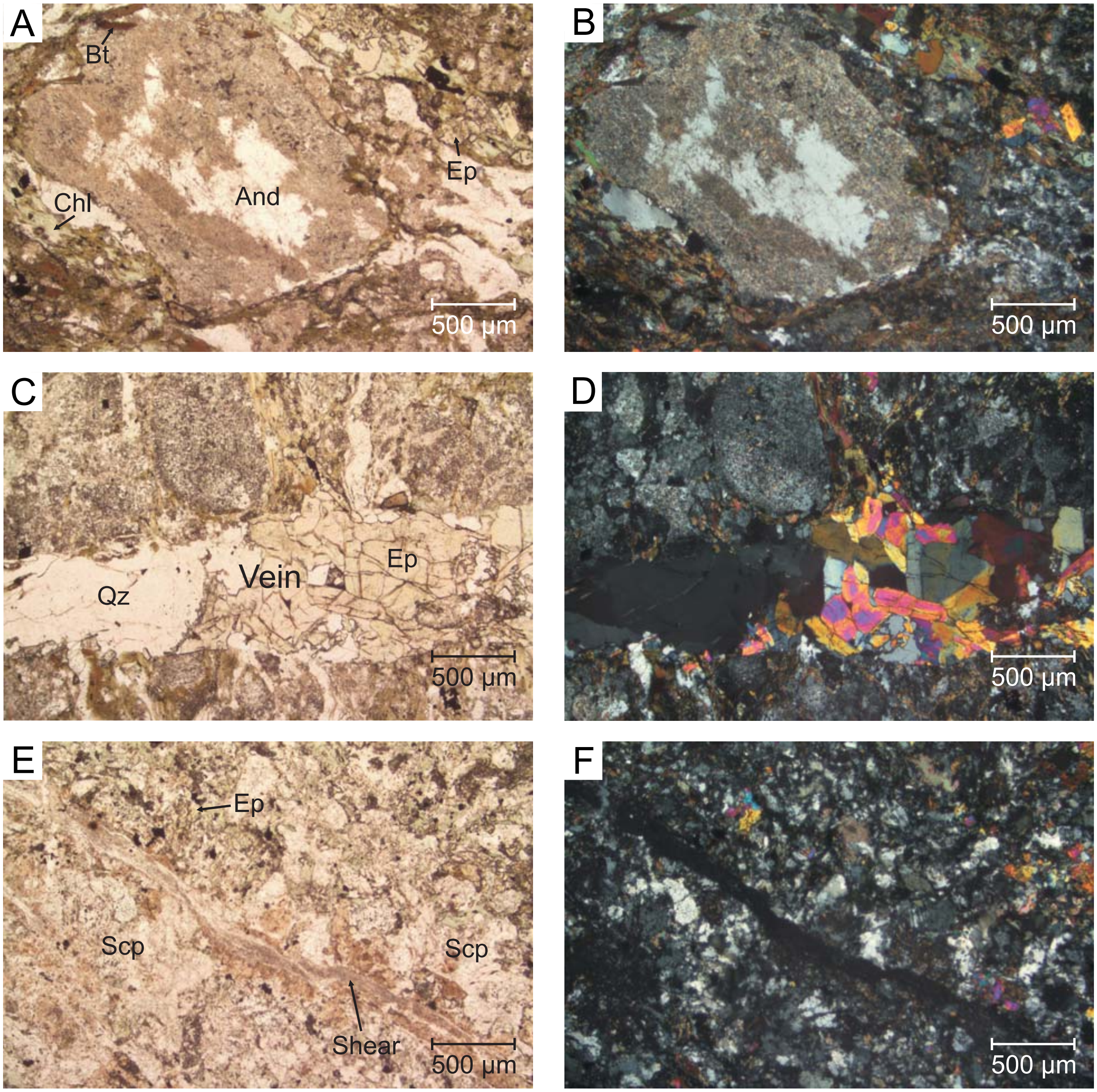



Figure 10.1: Microphotographs showing petrographical features of representative diorites. Symbols: Bt = biotite, Chl = chlorite, Ep = epidote, And = Andesine, Qz = quartz, Scp = scapolite.
Sample 9954a:
**A:** Porphyritic texture with andesine phenocrysts and ferromagnesian minerals, now altered to epidote, as microphenocrysts. 4x ppl.
**B:** As in A but in xpl.
Sample 9954b:
**C:** Quartz + epidote vein cutting the diorite. 4x ppl.
**D:** As in C but xpl.
Sample 9957:
**E:** Diorite with scapolite patches and a shear. 4x ppl.
**F:** As in E but xpl.

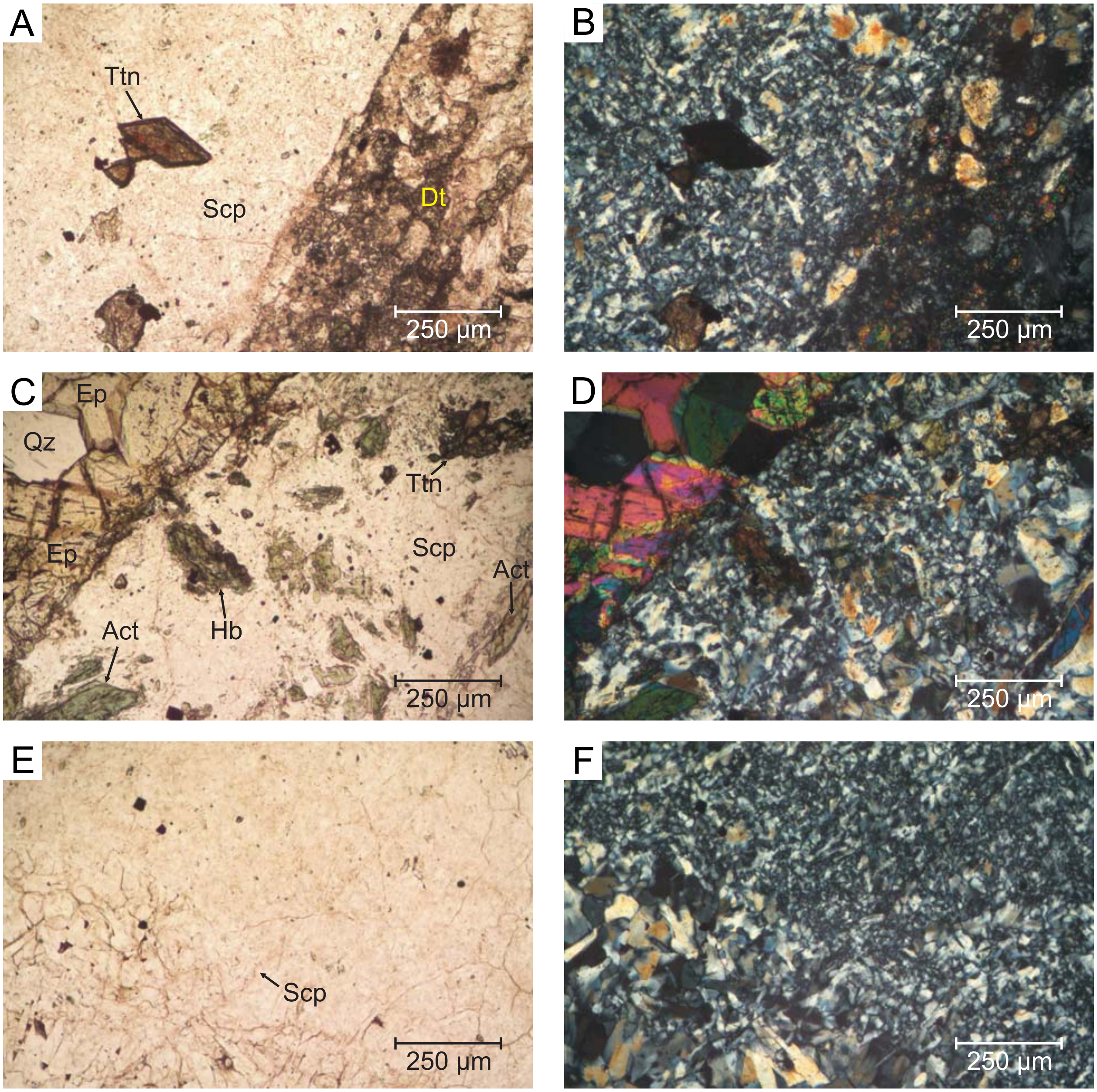



Figure 10.2: Microphotographs showing petrographical features of representative diorites (Dt) (Sample 9958a). Symbols: Act = actinolite, Ep = epidote, Hb = hornblende, Qz = quartz, Scp = scapolite, Ttn = titanite.

**A:** Scapolite vein cutting the diorite sample. The vein also contains scattered xenoliths from the host rock, and probably hydrothermal titanite. 10x ppl.

**B:** As in A but in xpl.

**C:** Scapolite vein that appears to be cut by an epidote - quartz vein. This sample contains several partly disaggregated minerals from the host diorite (mostly actinolite and rare hornblende). 10x ppl.

**D:** As in C but xpl.

**E:** Scapolite veinlet in scapolite vein. 10x ppl.

**F:** As in E but xpl. Shows the difference in grain size, grain reduction, within the scapolite vein due to cataclastic deformation.

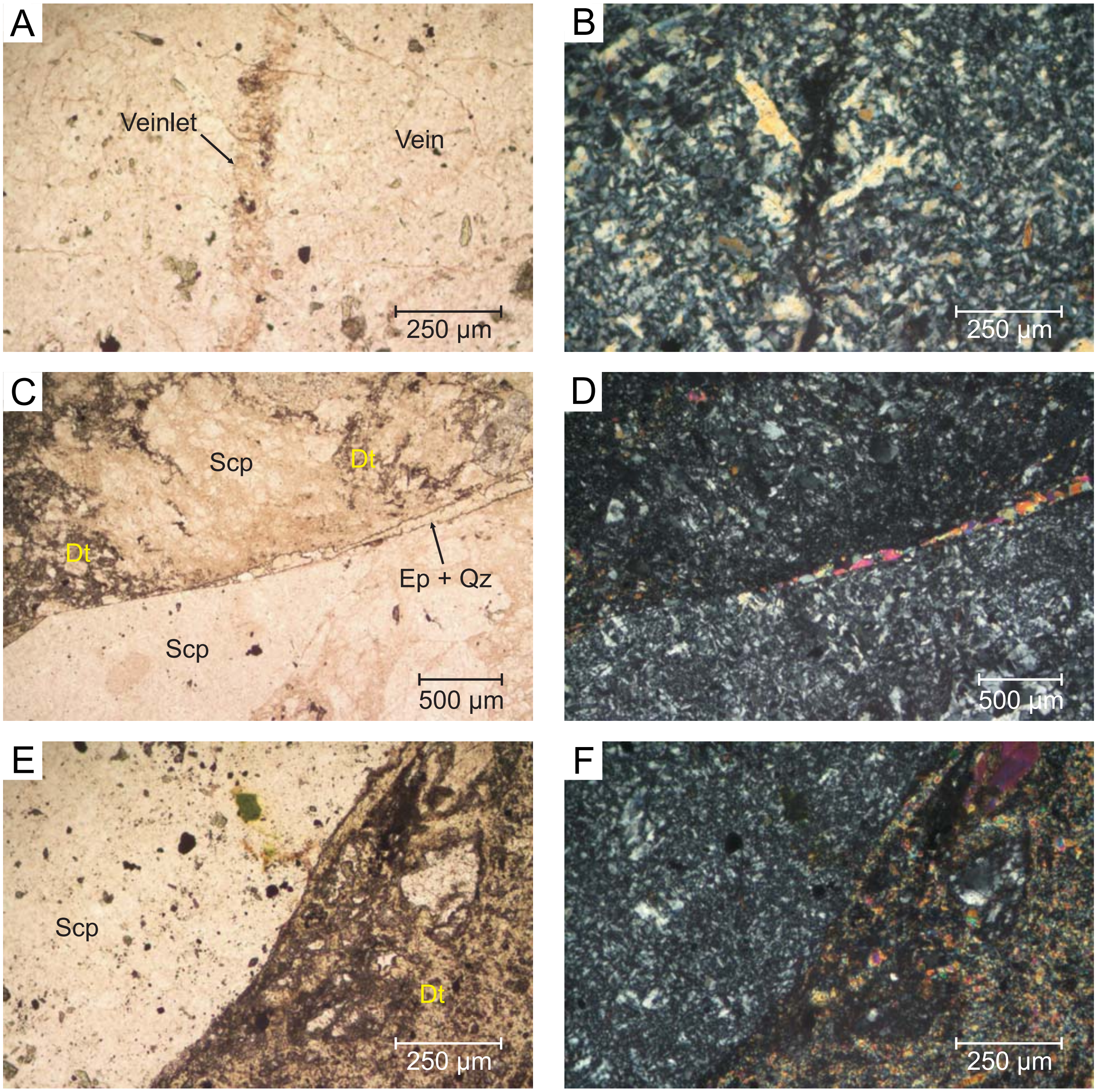



Figure 10.3: Microphotographs showing petrographical features of representative diorites (Dt). Symbols: Ep = epidote, Qz = quartz, Scp = scapolite.
Sample 9958a:
**A:** Scapolite vein with scapolite veinlet and variable grain size probably due to cataclastic deformation. 10x ppl.
**B:** As in A but in xpl.
Sample 9958b:
**C:** Epidote + quartz vein along the contact between the partly scapolized diorite and the scapolite vein in the diorite. 4x ppl.
**D:** As in C but xpl.
**E:** Contact between the diorite and the scapolite vein. 10x ppl.
**F:** As in E but xpl.

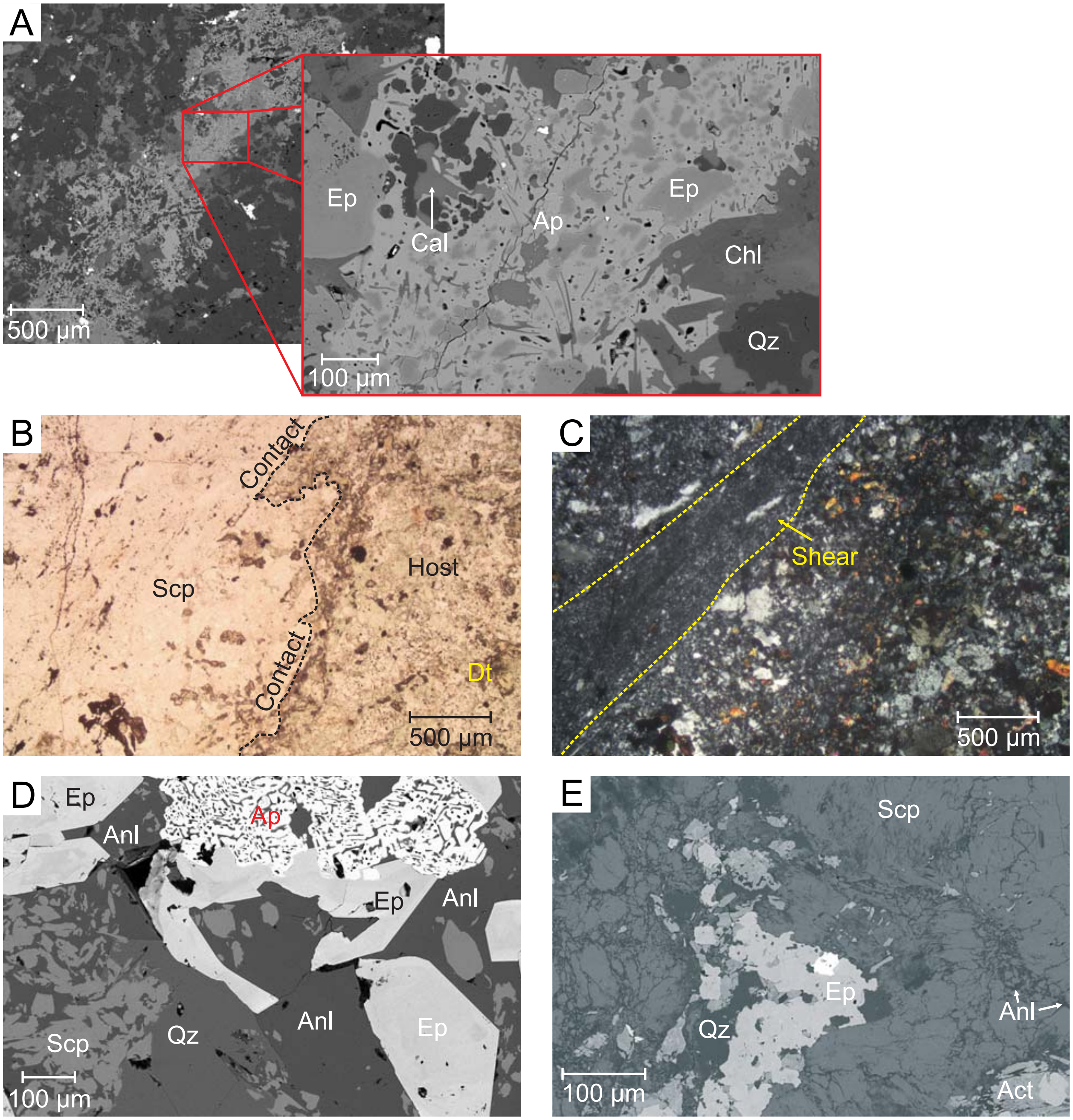



Figure 10.4: Representative BSE images and microphotographs of scapolite from samples 9957 and 9958a.

**A:** Sample 9957 (diorite) (10-1). An epidote and apatite vein cuts across the host, with apatite probably replacing epidote.

**B:** Sample 9957 (diorite) (10-1). Contact between the scapolite patch and the host diorite. Relics of the host are found within the patch. 4x ppl.

**C:** Sample 9957 (diorite) (10-1). Difference in grain size in the scapolite patch. Brittle deformation is most likely responsible for this. 4x xpl.

**D:** Sample 9958a (diorite) (10-2). Scapolite and analcime appear to predate quartz + epidote. Apatite postdates epidote.

**E:** Sample 9958a (diorite) (10-2). Analcime appears to fill voids and following grain broundries in the scapolite. Epidote and quartz appear to be synchronous and postdate the analcime + scapolite, and are replacing actinolite crystals.

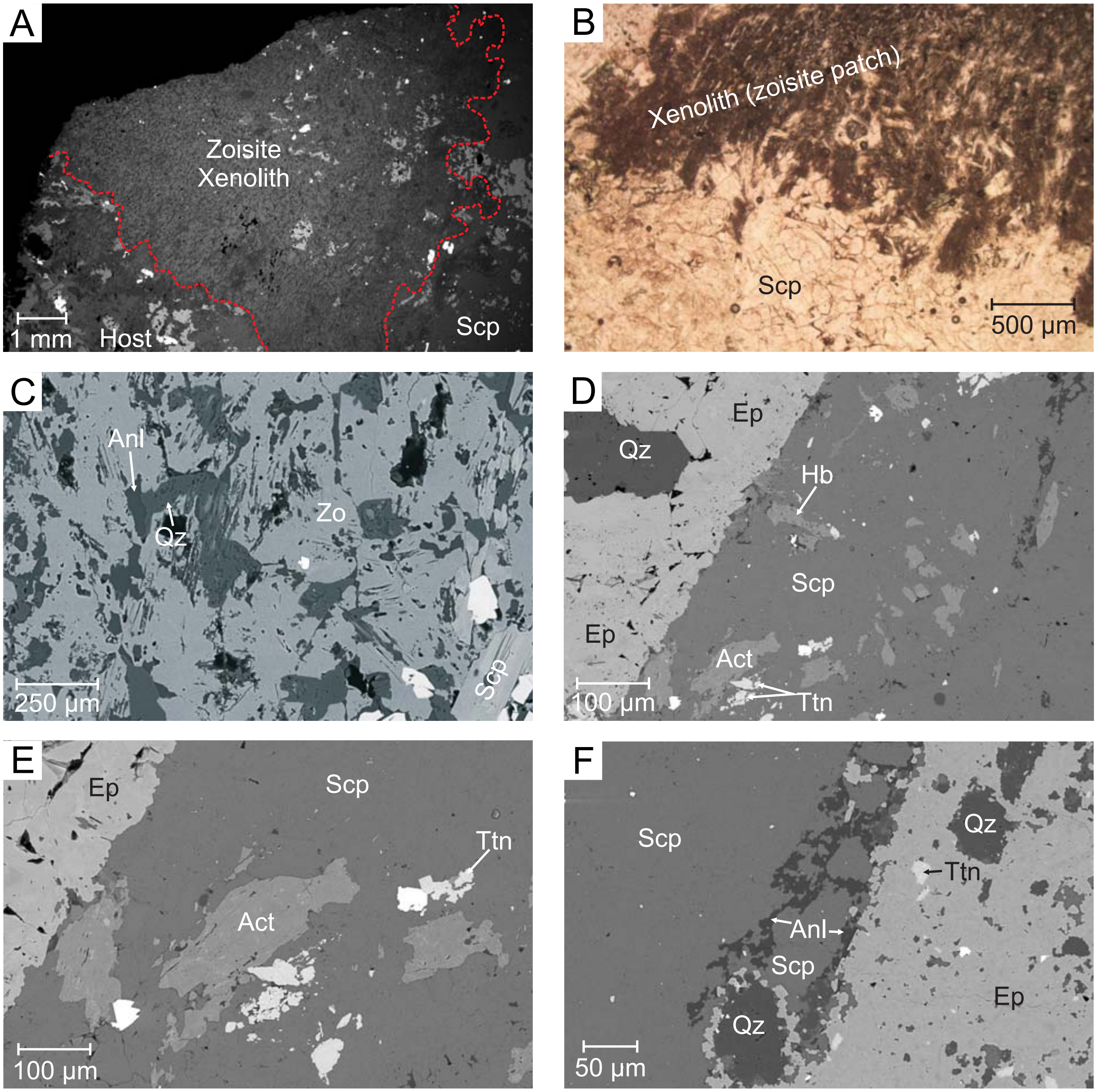



Figure 10.5: Representative BSE images and microphotographs of scapolite from 9958a and 9958b.
**A:** Sample 9958a (diorite) (10-2). This image shows the contact between the large zoisite xenolith and the scapolite vein.
**B:** Sample 9958a (diorite) (10-2). Microphotograph of the zoisite xenolith in contact with the scapolite vein. 4x ppl.
**C:** Sample 9958a (diorite) (10-2). Zoisite appears to be replaced by scapolite, analcime, and quartz.
**D:** Sample 9958a (diorite) (10-2). Contact between the scapolite vein and the host rock (diorite).
**E:** Sample 9958a (diorite) (10-2). Zoom in of Figure 5D. The scapolite vein contains relic actinolite crystals and titanite postdates the scapolite because it fills voids.
**F:** Sample 9958b (diorite) (10-3). A scapolite vein cuts the host diorite that has been epidotized. Quartz appears to predate epidote and analcime rims scapolite fragments.

# Appendix 11: Additional SEM-BSE images and EDS geochemical analyses of the scapolite in the diorites.

# Appendix 11-1: SEM-BSE images and EDS mineral analyses for sample 9957.

**Sample 9957**

**Host: Altered Diorite**

Magmatic minerals seen: K-feldspar, albite, quartz

Accessory and alteration minerals: analcime, apatite, calcite, chlorite, epidote, Fe-oxides, titanite

**Types of Alteration:**

a) Calcite ± Chlorite

b) Epidote ± Apatite

c) Scapolite

**Sequence of alteration in diorite:**

Scapolite, Analcime → Calcite ± Chlorite → Epidote → Apatite ± Titanite → Fe-oxides/hydroxides ± Titanite?

**Notes:**

1. Epidote cross-cuts older minerals such as calcite, quartz, and albite (Fig. 11-1.3).

2. Calcite and chlorite appear to fill voids in the quartz and albite (Fig. 11-1.5,7)

3. Apatite appears to replace epidote (Fig. 11-1.9) and calcite (Fig. 11-1.5).

4. Scapolite appears to occur as a large patch and/or replace K-feldspar (Fig. 11-1.11).

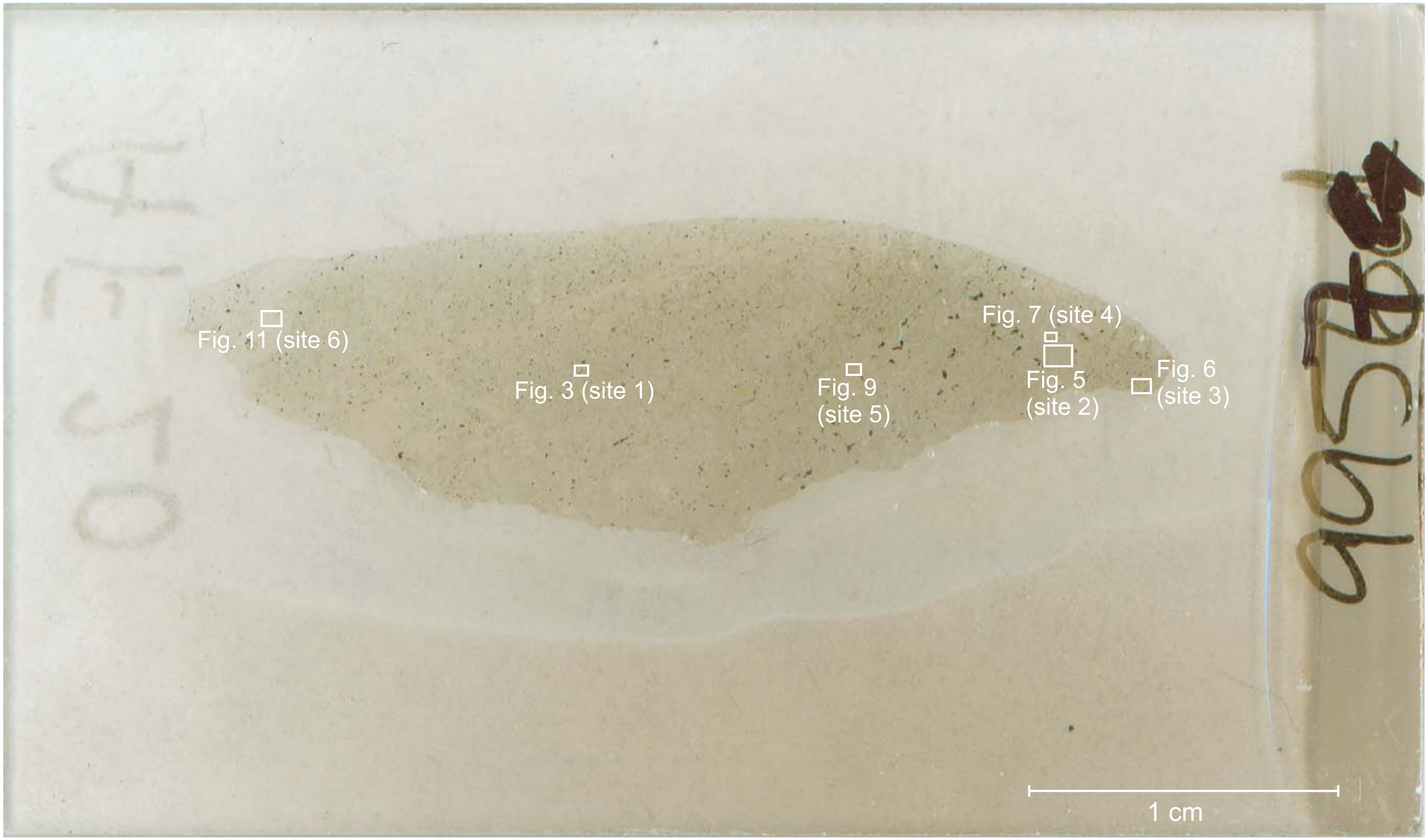



Figure 11-1.1: Scanned thin section of sample 9957 (diorite) showing the location of analyzed sites. This sample consists of a chilled margin against grey sandstone xenolith.

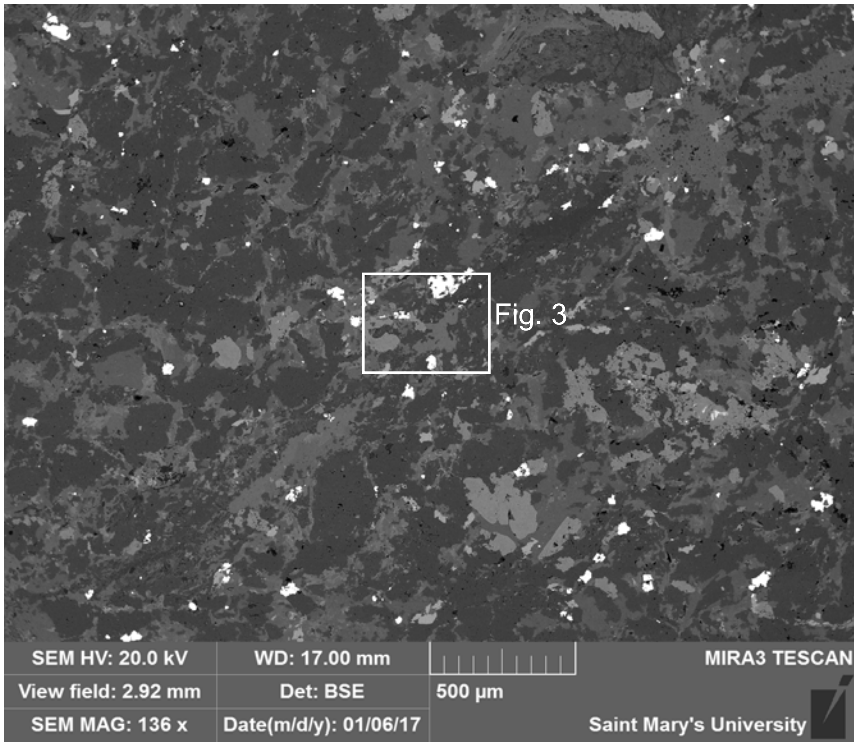
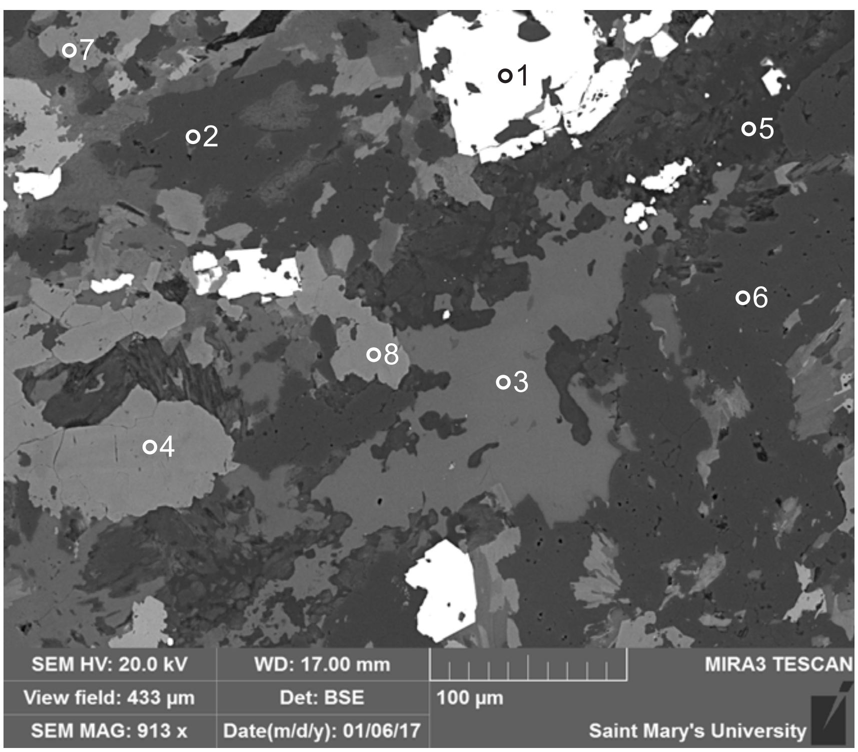



Figure 11-1.2: Sample 9957 (SEM).




1:Limonite
2:Albite
3:Calcite
4:Epidote
5:Analcime?
6:Albite
7:Epidote
8:Epidote

Figure 11-1.3: Sample 9957 site 1 (SEM). This site consists of albite (2,6), calcite (3), and analcime (5). Epidote (4,7-8) cross-cuts calcite, albite, and probably analcime. Fe-oxides/hydroxides (1) are the latest minerals to form.

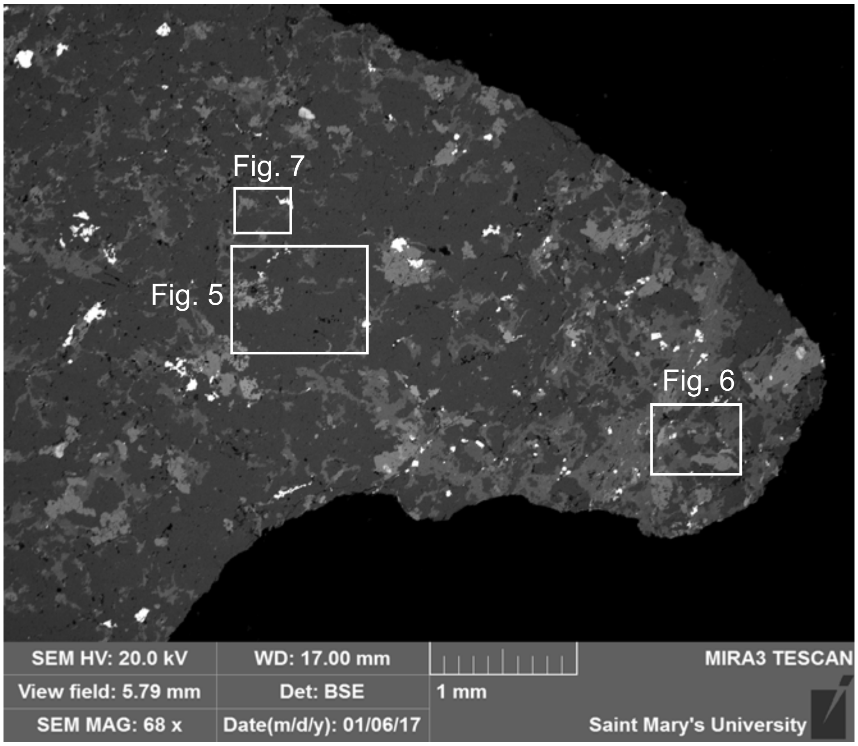



Figure 11-1.4: Sample 9957 (SEM).

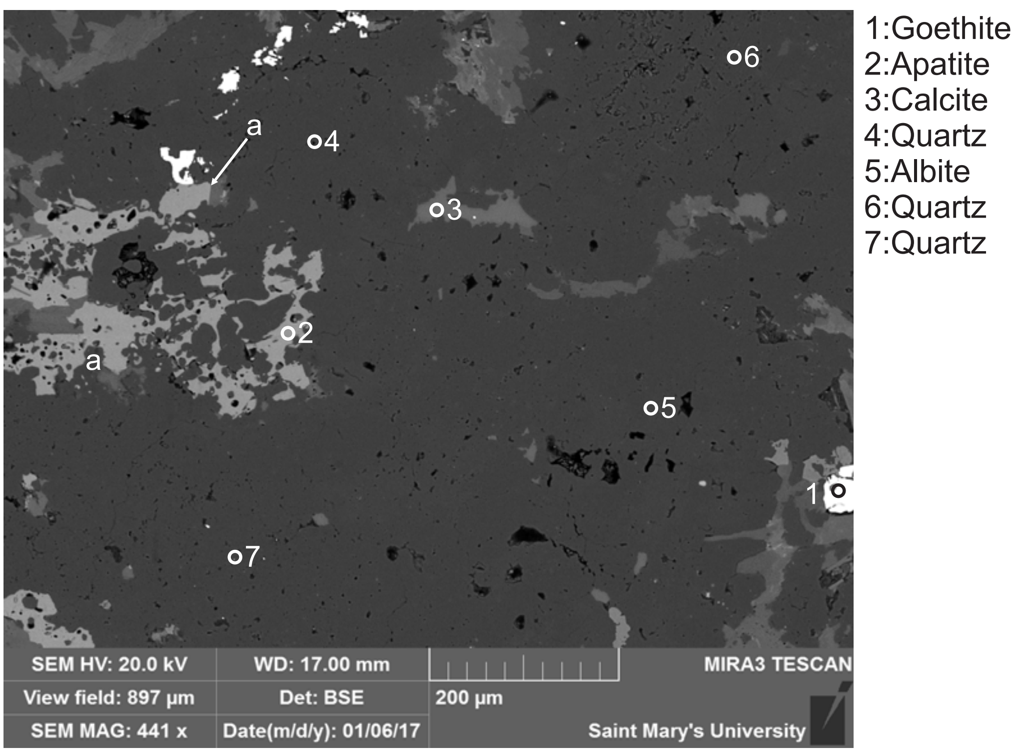
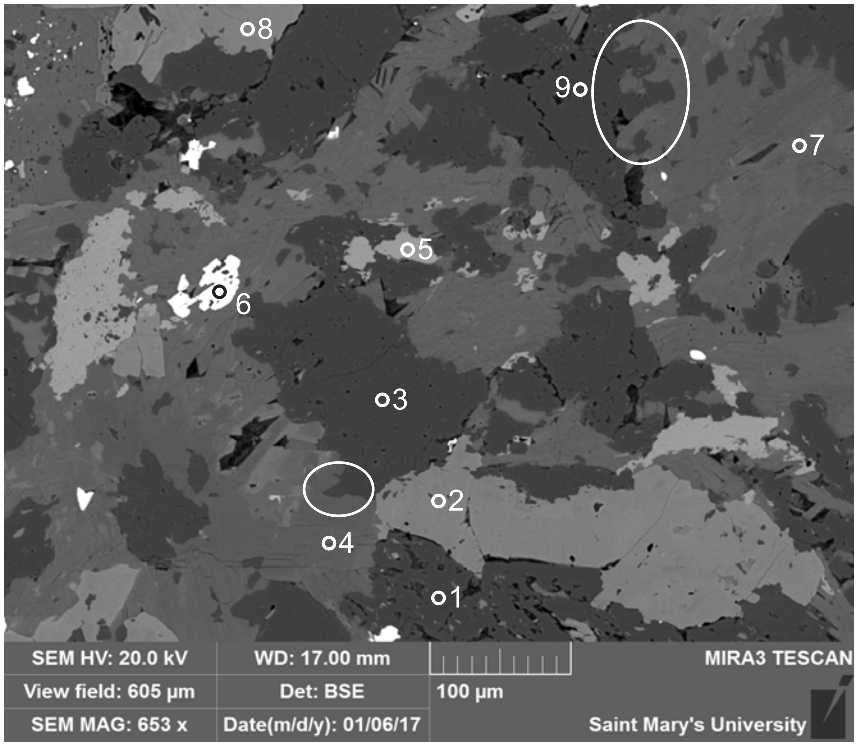
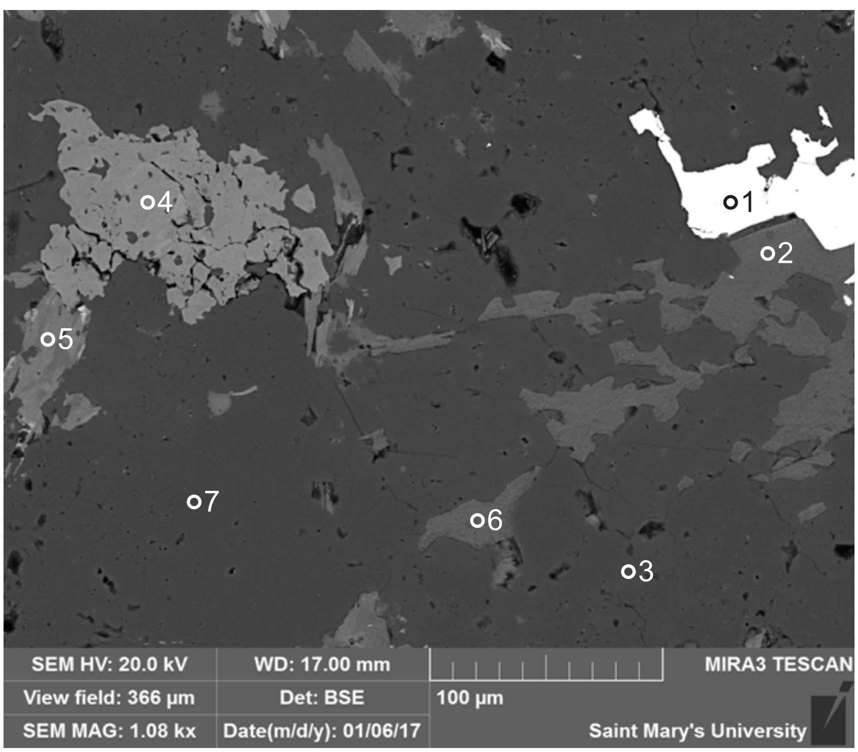



Figure 11-1.5: Sample 9957 site 2 (SEM). This site consists of quartz (4,6-7) and albite (5) with calcite (3) partially filling voids. Apatite (2) appears to replace the calcite or co-precipitate with it (positions a). Fe-oxides/hydroxides (1) are the latest mineral to form.




1:Quartz
2:Epidote
3:Quartz
4:Chlorite
5:Titanite
6:Limonite
7:Chlorite
8:Epidote
9:Quartz

Figure 11-1.6: Sample 9957 site 3 (SEM). Chlorite (4,7) invades quartz (1,3,9) (circles). Later epidote (2,8) and titanite (5) cross-cut chlorite and quartz. Fe-oxides/hydroxides (6) are the latest mineral to form.




1:Goethite
2:Chlorite
3:Albite
4:Epidote
5:Chlorite
6:Chlorite
7:Quartz

Figure 11-1.7: Sample 9957 site 4 (SEM). This site consists of quartz (7) and albite (3). Chlorite (2,5-6) and epidote (4) appear to cut quartz and albite. Fe-oxides/hydroxides (1) are the latest minerals to form.

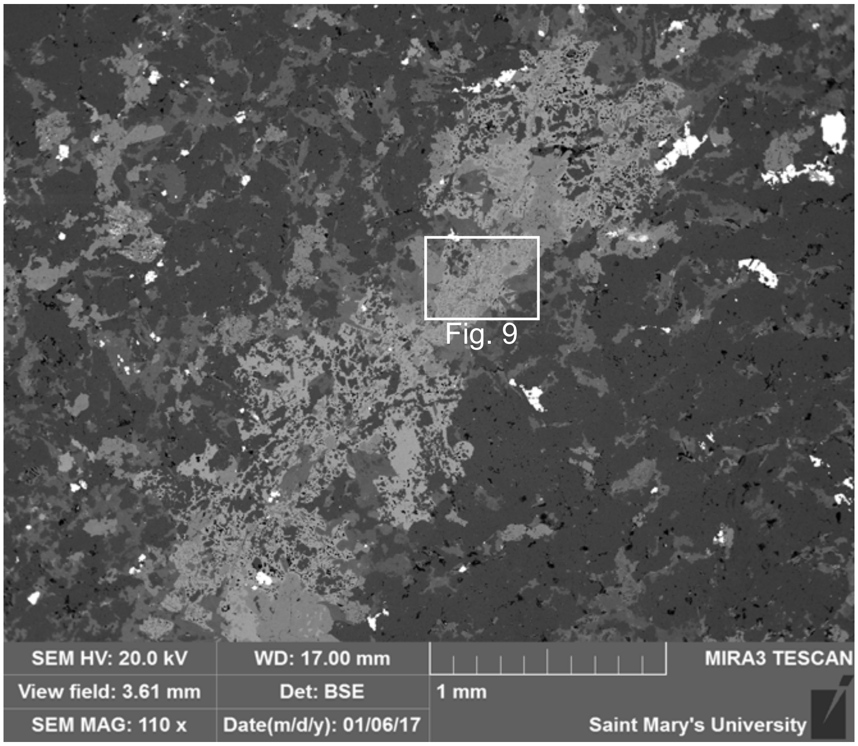



Figure 11-1.8: Sample 9957 (SEM).

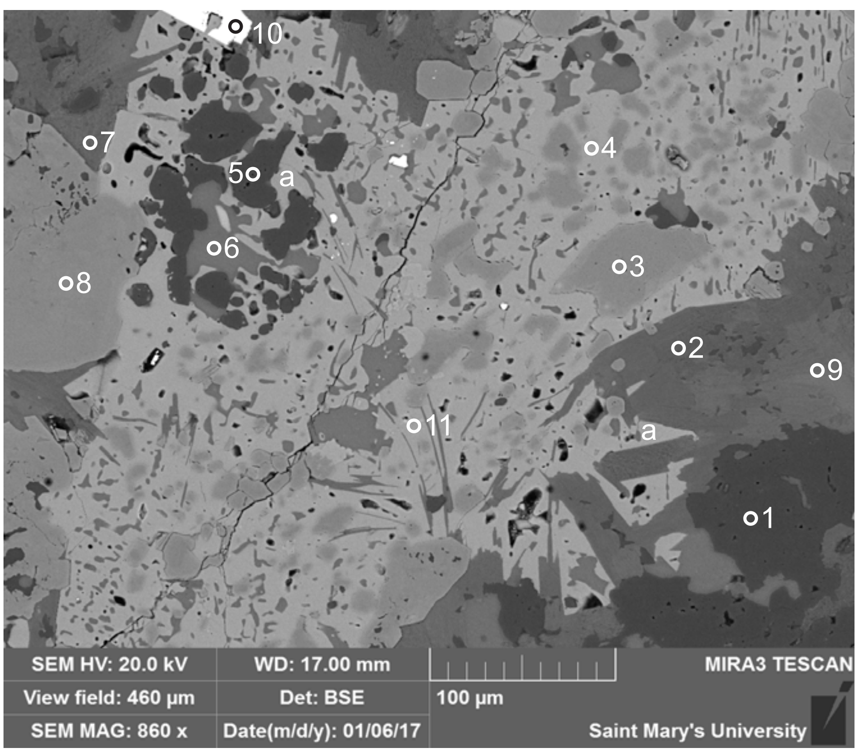



Figure 11-1.9: Sample 9957 site 5 (SEM). This site consists of an epidote (3,8) and apatite (4,11) vein, probably with apatite replacing epidote and quartz (positions a). Patches of quartz (5) and calcite (6) are found within the epidote-apatite vein. Towards the margins of the vein, host rock minerals such as chlorite (2,7), calcite (9), and quartz (1) are found.

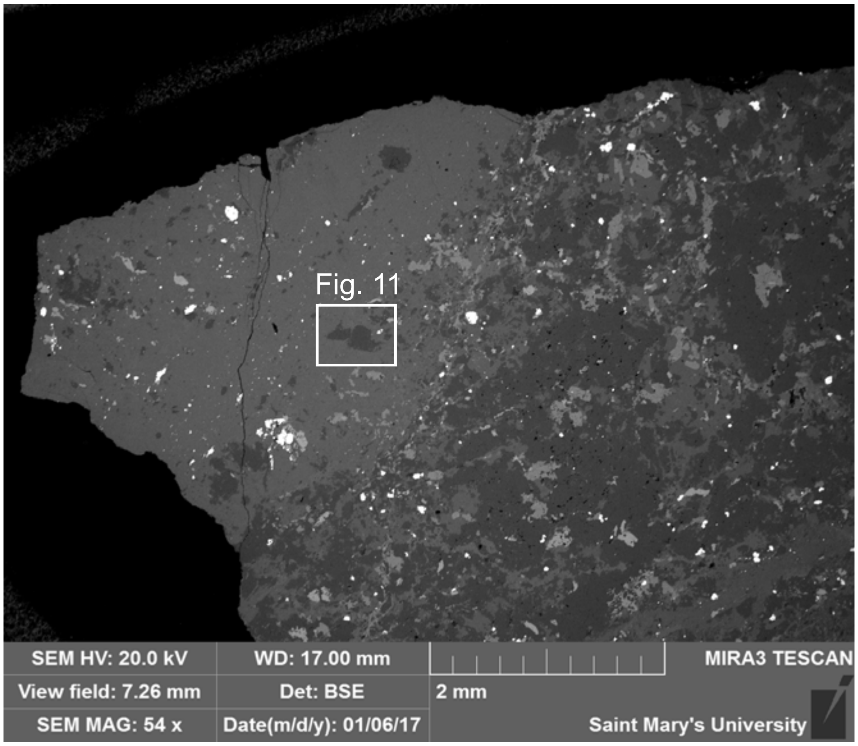
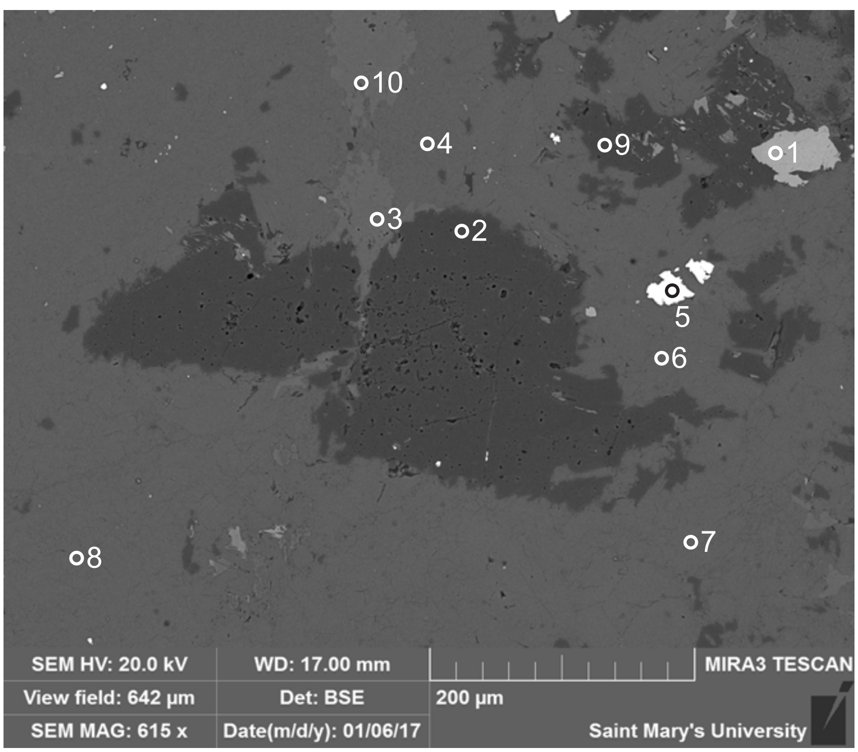



Figure 11-1.10: Sample 9957 (SEM).




1:Titanite
2:Quartz
3:K-feldspar
4:Scapolite
5:Goethite
6:Scapolite
7:Scapolite
8:Scapolite
9:Quartz
10:K-feldspar

Figure 11-1.11: Sample 9957 site 6 (SEM). This site consists of a scapolite (4,6-8) patch with inclusions of quartz (2,9) and K-feldspar (3,10). Titanite (1) appears later cross-cutting quartz and scapolite. Scapolite appears to be replacing the K-feldspar (3,10).

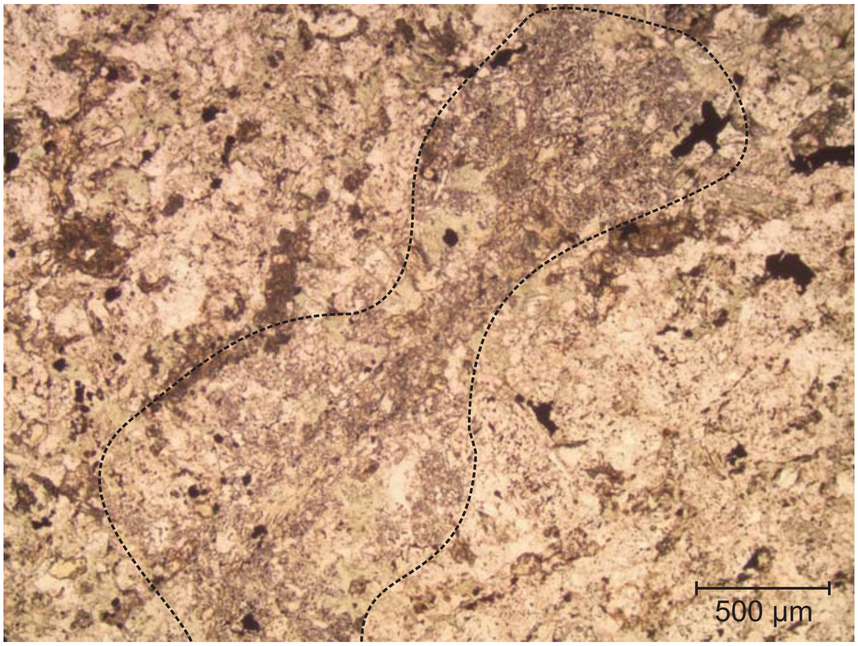



Figure 11-1.12: Microphotograph of Figure 11-1.8 and 11-1.9. Probably of vein made up of apatite, epidote, calcite, and quartz vein. 4x ppl.

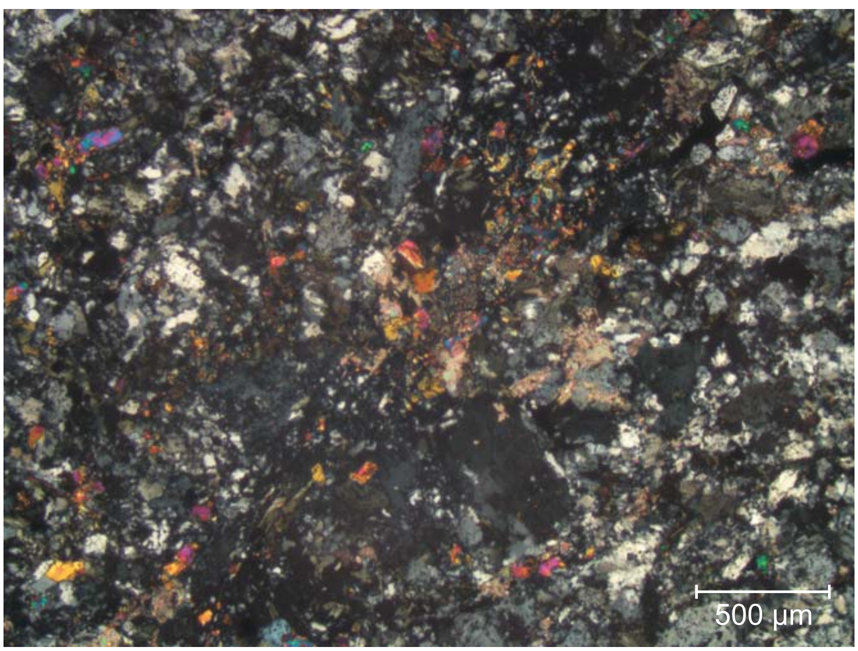



Figure 11-1.13: Same as Figure 11-1-12 but xpl.

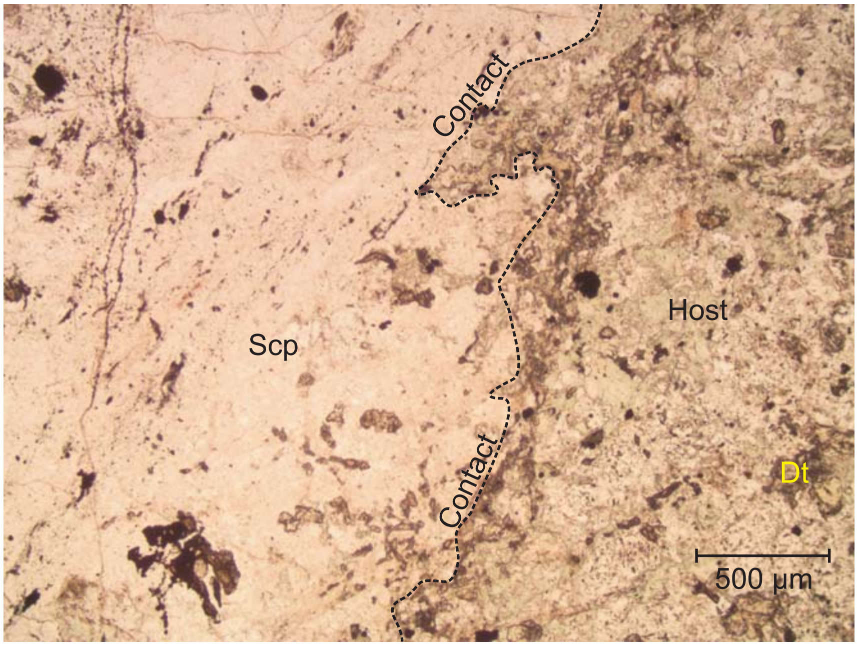


Figure 11-1.14: Contact between scapolite patch and host diorite rock. 4x ppl.

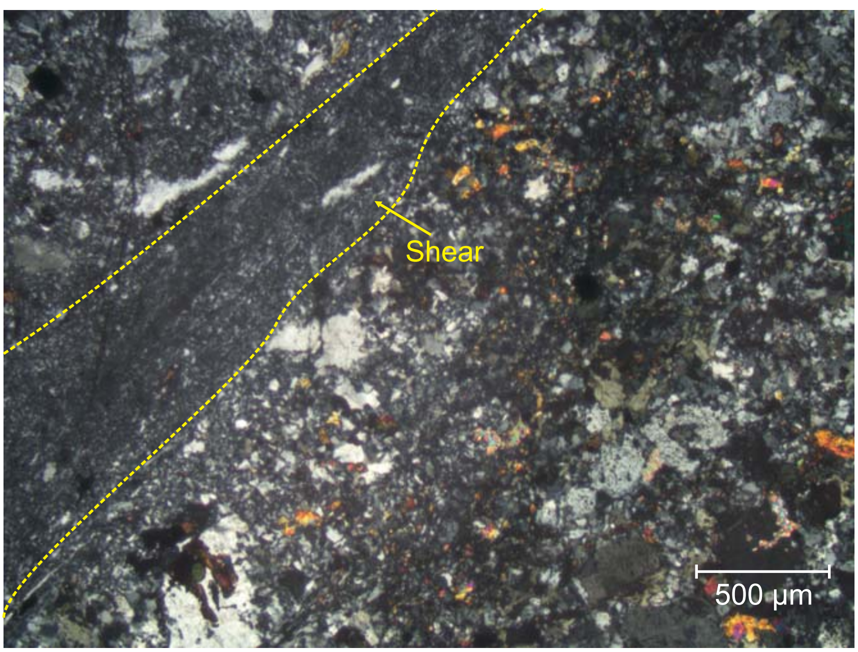


Figure 11-1.15: Same as Figure 11-1.14 but xpl. Brittle deformation is probably responsible for difference in grain size of the scapolite.

Table 11-1.1: EDS analyses from sample 9957. 

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | F | Cl | V2O5 | WO3 | Total | Actual Total | Caculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9957 | 1 | 1 | Lm | | | | 99.64 | | | | | | | | | 0.36 | | 100 | 94 | 79 |
| 9957 | 1 | 2 | Ab | 68.34 | | 19.55 | | | | 0.95 | 11.17 | | | | | | | 100 | 118 | |
| 9957 | 1 | 3 | Cal | | | | | | | 56.00 | | | | | | | | 56 | 57 | |
| 9957 | 1 | 4 | Ep | 40.29 | | 24.08 | 9.92 | | | 22.25 | | | 0.47 | | | | | 97 | 109 | |
| 9957 | 1 | 5 | Anl? | 58.96 | | 20.01 | | | | 0.15 | 11.88 | | | | | | | 91 | 107 | |
| 9957 | 1 | 6 | Ab | 68.67 | | 19.23 | | | | 0.63 | 11.47 | | | | | | | 100 | 120 | |
| 9957 | 1 | 7 | Ep | 42.10 | | 21.76 | 11.13 | | 1.38 | 20.64 | | | | | | | | 97 | 104 | |
| 9957 | 1 | 8 | Ep | 39.92 | | 24.28 | 9.83 | | | 22.27 | | | 0.71 | | | | | 97 | 109 | |
| 9957 | 2 | 1 | Gth | 0.63 | | | 99.37 | | | | | | | | | | | 100 | 96 | 81 |
| 9957 | 2 | 2 | Ap | | | | | | | 49.42 | | | 44.91 | 5.03 | 0.64 | | | 100 | 118 | |
| 9957 | 2 | 3 | Cal | 0.50 | | | | | | 55.50 | | | | | | | | 56 | 55 | |
| 9957 | 2 | 4 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 116 | |
| 9957 | 2 | 5 | Ab | 68.65 | | 19.32 | | | | 0.78 | 11.25 | | | | | | | 100 | 116 | |
| 9957 | 2 | 6 | Qz | 97.69 | | 1.20 | | | | 0.22 | 0.89 | | | | | | | 100 | 115 | |
| 9957 | 2 | 7 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 118 | |
| 9957 | 3 | 1 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 120 | |
| 9957 | 3 | 2 | Ep | 40.56 | | 25.10 | 9.17 | | | 22.17 | | | | | | | | 97 | 108 | |
| 9957 | 3 | 3 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 119 | |
| 9957 | 3 | 4 | Chl | 29.65 | | 18.40 | 15.44 | | 21.51 | | | | | | | | | 85 | 100 | |
| 9957 | 3 | 5 | Ttn | 33.32 | 36.36 | 1.62 | 1.01 | | | 27.68 | | | | | | | | 100 | 107 | |
| 9957 | 3 | 6 | Lm | | | | 99.63 | | | | | | | | | 0.37 | | 100 | 92 | 77 |
| 9957 | 3 | 7 | Chl | 28.86 | | 19.08 | 17.41 | | 19.65 | | | | | | | | | 85 | 98 | |
| 9957 | 3 | 8 | Ep | 40.45 | | 24.06 | 10.42 | | | 22.07 | | | | | | | | 97 | 104 | |
| 9957 | 3 | 9 | Qz | 99.86 | | | | | | | | | | | 0.14 | | | 100 | 116 | |
| 9957 | 4 | 1 | Gth | 0.62 | | | 99.38 | | | | | | | | | | | 100 | 97 | 81 |
| 9957 | 4 | 2 | Chl | 29.34 | | 18.45 | 16.13 | | 21.08 | | | | | | | | | 85 | 99 | |
| 9957 | 4 | 3 | Ab | 69.28 | | 19.20 | | | | 0.60 | 10.92 | | | | | | | 100 | 122 | |
| 9957 | 4 | 4 | Ep | 40.35 | | 23.65 | 10.83 | | | 22.16 | | | | | | | | 97 | 110 | |
| 9957 | 4 | 5 | Chl | 30.03 | | 17.21 | 20.16 | 0.52 | 16.92 | 0.17 | | | | | | | | 85 | 100 | |
| 9957 | 4 | 6 | Chl | 30.38 | | 17.65 | 15.50 | | 21.47 | | | | | | | | | 85 | 99 | |

Table 11-1.1: EDS analyses from sample 9957.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | F | Cl | V2O5 | WO3 | Total | Actual Total | Caculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9957 | 4 | 7 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 122 | |
| 9957 | 5 | 1 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 124 | |
| 9957 | 5 | 2 | Chl | 28.74 | | 19.75 | 14.43 | | 21.90 | 0.18 | | | | | | | | 85 | 102 | |
| 9957 | 5 | 3 | Ep | 40.18 | | 23.90 | 10.37 | | | 22.55 | | | | | | | | 97 | 110 | |
| 9957 | 5 | 4 | Ap | 2.29 | | 1.61 | 0.62 | | | 49.62 | | | 39.66 | 6.19 | | | | 100 | 116 | |
| 9957 | 5 | 5 | Qz | 98.31 | | | | | | 0.49 | 0.25 | 0.17 | | | 0.78 | | | 100 | 120 | |
| 9957 | 5 | 6 | Cal | | | | | | | 56.00 | | | | | | | | 56 | 56 | |
| 9957 | 5 | 7 | Chl | 30.02 | | 18.37 | 16.35 | 0.21 | 19.75 | 0.31 | | | | | | | | 85 | 99 | |
| 9957 | 5 | 8 | Ep | 40.04 | | 23.63 | 10.81 | | | 22.52 | | | | | | | | 97 | 109 | |
| 9957 | 5 | 9 | Cal + | 1.05 | | 0.67 | 0.76 | | 0.79 | 52.73 | | | | | | | | 56 | 59 | |
| 9957 | 5 | 10 | Lm | 0.64 | | | 99.36 | | | | | | | | | | | 100 | 94 | 79 |
| 9957 | 5 | 11 | Ap | | | | | | | 48.17 | | | 44.16 | 6.66 | | | 1.01 | 100 | 126 | |
| 9957 | 6 | 1 | Ttn | 33.23 | 36.74 | 1.47 | 0.81 | | | 27.75 | | | | | | | | 100 | 112 | |
| 9957 | 6 | 2 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 123 | |
| 9957 | 6 | 3 | Kfs | 66.53 | | 17.93 | | | | | | 15.55 | | | | | | 100 | 118 | |
| 9957 | 6 | 4 | Scp | 57.55 | | 21.92 | | | | 6.61 | 10.07 | 0.48 | | | 3.36 | | | 100 | 118 | |
| 9957 | 6 | 5 | Gth | 1.12 | | | 98.88 | | | | | | | | | | | 100 | 95 | 80 |
| 9957 | 6 | 6 | Scp | 57.60 | | 21.84 | | | | 5.94 | 10.31 | 0.54 | | | 3.77 | | | 100 | 120 | |
| 9957 | 6 | 7 | Scp | 57.35 | | 21.98 | | | | 6.22 | 10.20 | 0.57 | | | 3.68 | | | 100 | 122 | |
| 9957 | 6 | 8 | Scp | 57.24 | | 21.98 | | | | 6.63 | 10.10 | 0.49 | | | 3.56 | | | 100 | 118 | |
| 9957 | 6 | 9 | Qz | 98.81 | | 0.63 | | | | | 0.41 | | | | 0.15 | | | 100 | 120 | |
| 9957 | 6 | 10 | Kfs | 66.38 | | 17.91 | | | | | 0.47 | 15.24 | | | | | | 100 | 116 | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | Oxide total | | | | | | | | | | | | | | | | | |
| | | Mag = | >90% | | | | | | | Average quartz total = 119 | | | | | | | | | | |
| | | Hem = | 85-89% | | | | | | | | | | | | | | | | | |
| | | Gth = | 80-84% | | | | | | | Oxide total = (wt % oxide / Avg. Qz total) * 100 | | | | | | | | | | |
| | | Lm = | <80% | | | | | | | | | | | | | | | | | |
| | | | | Notes | | | | | | | | | | | | | | | | |
| | | | | + = indicates other minerals present | | | | | | | | | | | | | | | | |

# Appendix 11-2: SEM-BSE images and EDS mineral analyses for sample 9958a.

**Sample 9958a**

**Host: Altered Diorite**

Magmatic minerals seen: K-feldspar, hornblende, quartz, albite

Accessory and alteration minerals: apatite, chlorite, Fe-oxides/hydroxides, pyrite, titanite, quartz, albite, xenolith: zoisite

**Types of Alteration + Veins (probably from early to late):**

a) Hornblende → actinolite, ?albite

b) Scapolite + Analcime

c) Epidote + Quartz

d) Titanite, Fe-oxides

**Notes:**

1. This sample is cut by scapolite veins and patches. In the larger scapolitic vein and close to their contacts with the host diorite, there are plenty of half-digested xenoliths of hornblende and actinolite (Figs. 11-2.26,27,29).

2. Analcime occurs interstitially between scapolite crystals (Fig. 11-2.9,16) or along grain boundaries (Figs. 11-2.13,14).

3. Apatite postdates epidote (Fig. 11-2.4).

4. Secondary titanite (Fig. 11-2.19) with well developed crystal facies, appears to fill voids in scapolite patch.

5. A patch probably of zoisite crystals with straight extinction in the fabric direction (Fig. 11-2.29) has been seen in the scapolite vein that cuts the host diorite. The patch has been considered as a xenolith (Figs. 11-2.27,28). The zoisite appears to be cross-cut by scapolite, analcime, quartz, and albite (Fig. 11-2.25b).

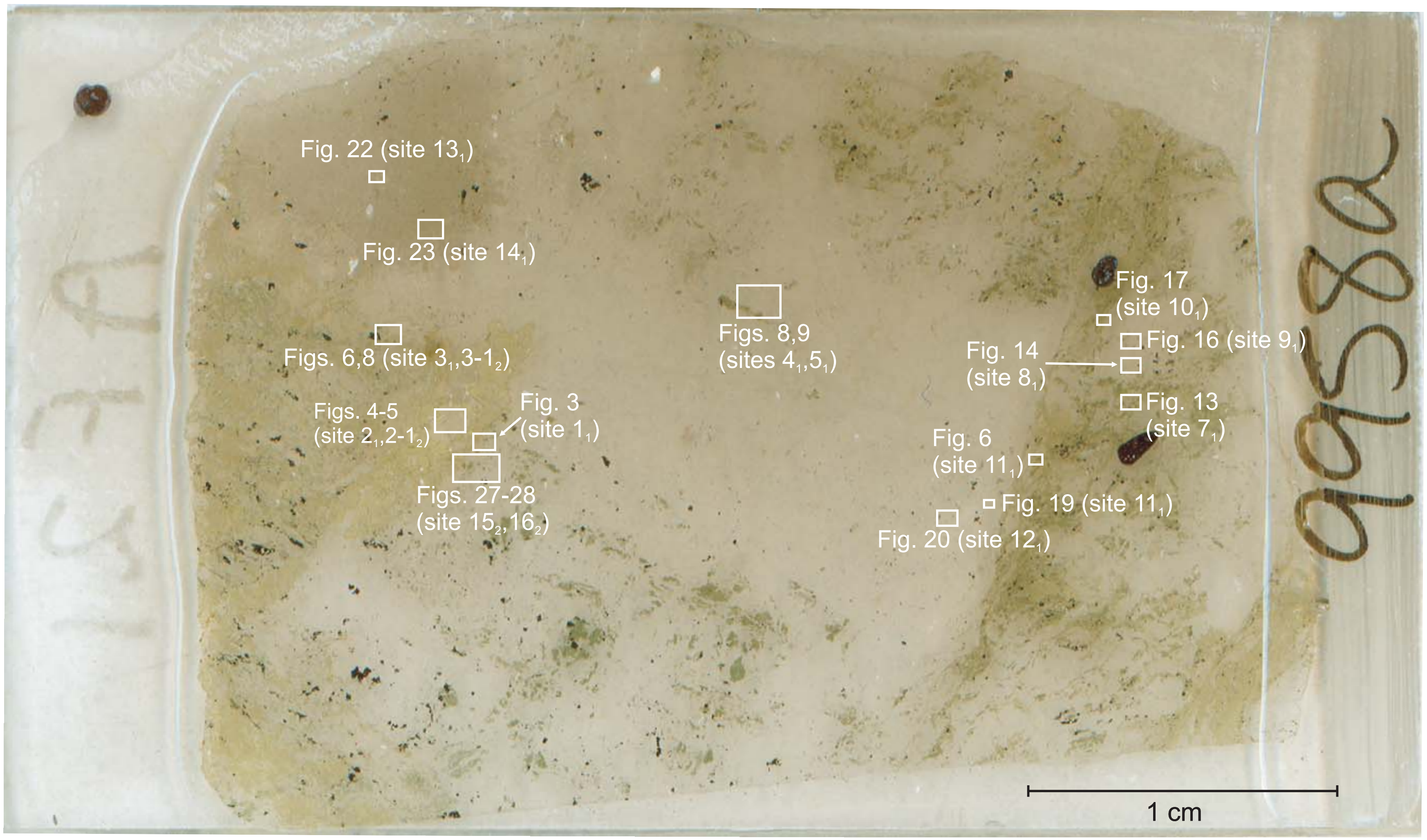



Figure 11-2.1: Scanned thin section of 9958a showing the location of analyzed sites. This sample is mafic rock form a rockfall. This mafic rock is cut by scapolite veins and patches. The subscripts indicate the tables where the sites can be found 1 = Table 11-21.1, 2 = Table 11-21.2.

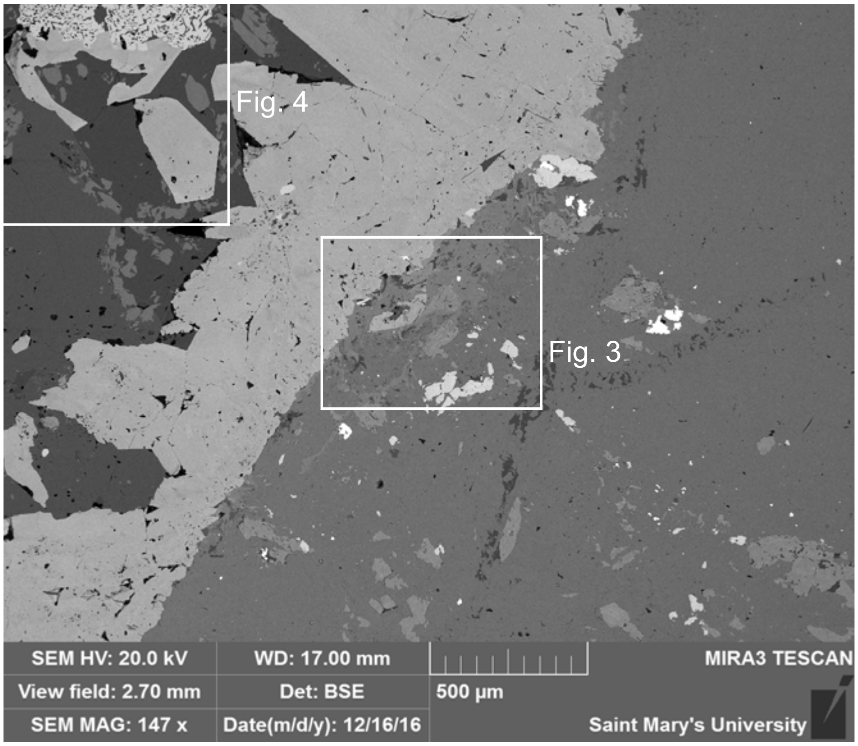



Figure 11-2.2: Sample 9958a (SEM).

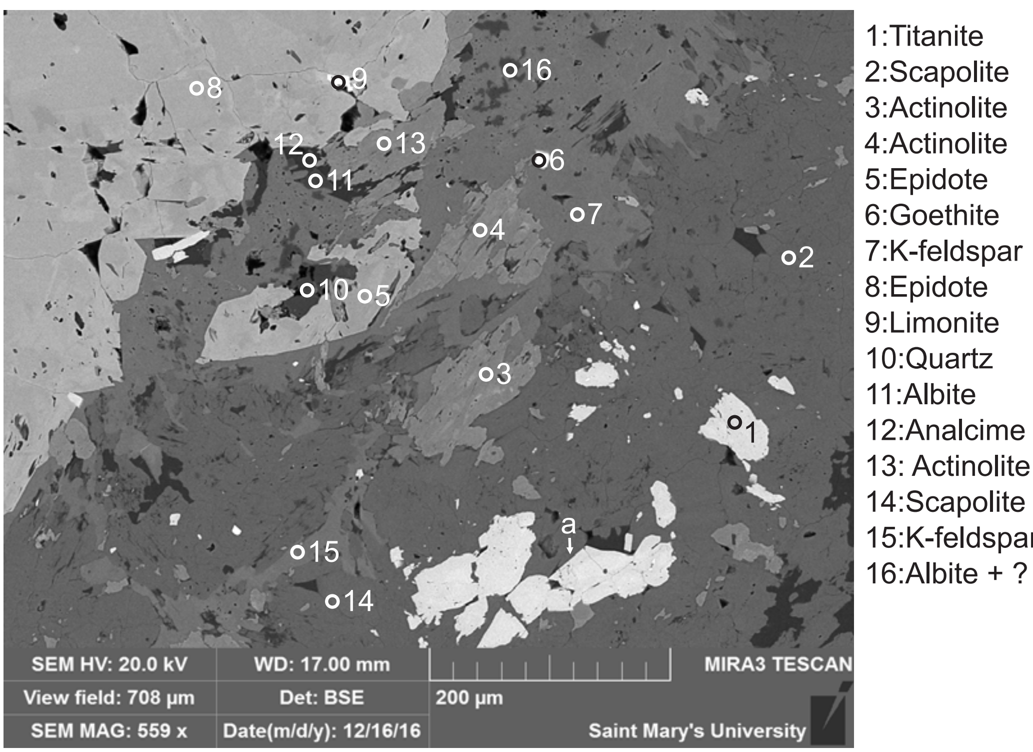



Figure 11-2.3: Sample 9958a site 1 (SEM). (Table 11-2.1). This site consists of actinolite crystals (3-4,12-13) in contact with K-feldspar (7), and scapolite (2,14). Scapolite (14) appears to have replaced K-feldspar (15). Quartz (10), analcime (12) and albite (11,16) appear to fill dissolution voids in K-feldspar, actinolite (13), and epidote (5). Titanite (1, position a) partially fills voids in scapolite.

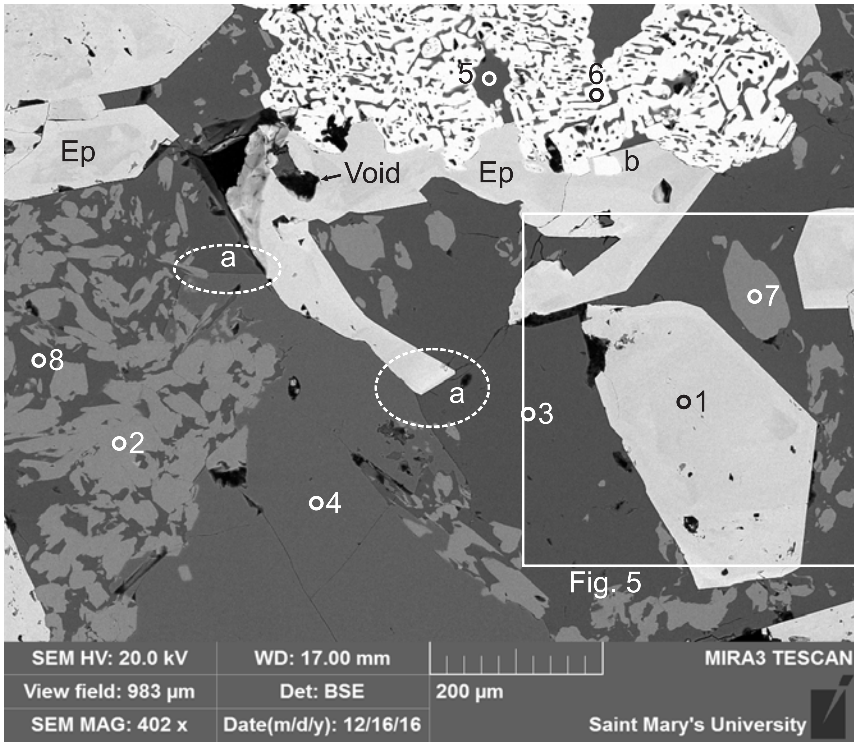



Figure 11-2.4: Sample 9958a site 2 (SEM). (Table 11-2.1). Uncertain relationship between scapolite + analcime and apatite. Apatite postdates epidote (position b). Scapolite and analcime are cut/replaced by euhedral quartz and epidote crystals (note euhedral epidote and quartz termination (positions a)).

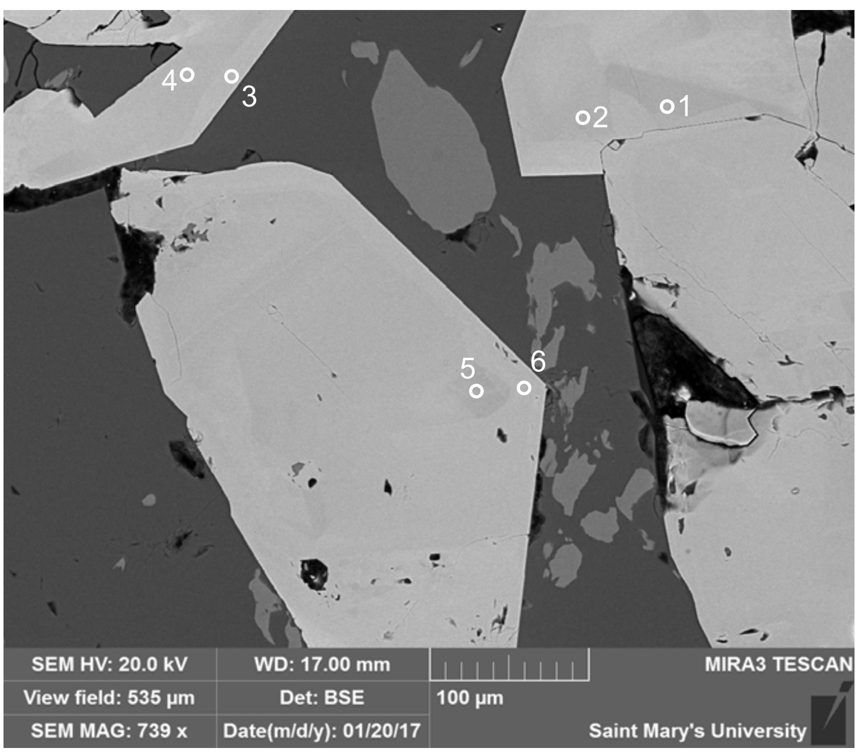



Figure 11-2.5: Sample 9958a site 2-1 (SEM). (Table 11-2.2). This site consists of zoned epidote that becomes more Fe-rich towards rim.

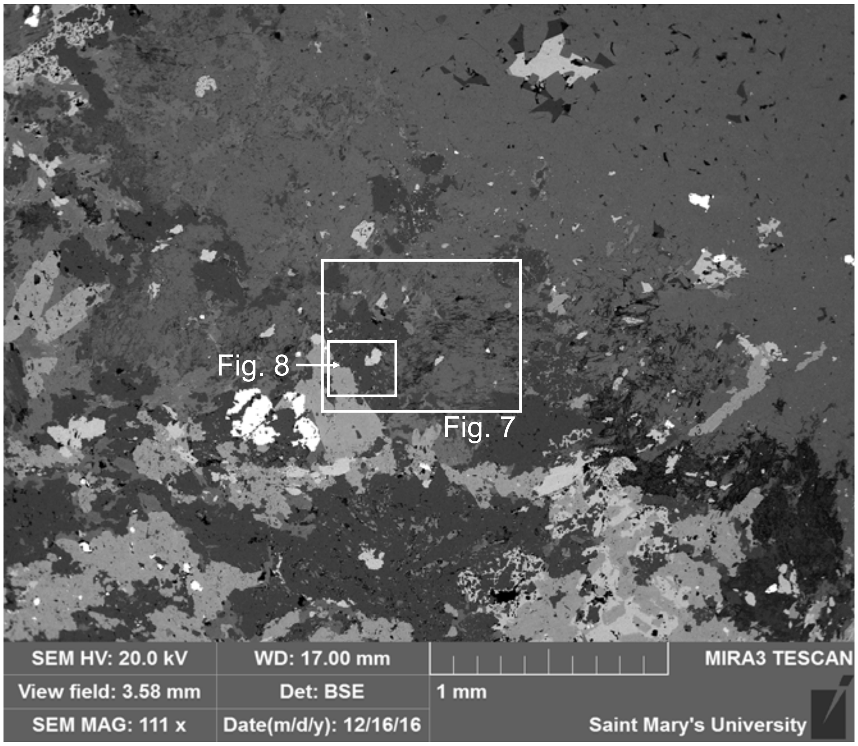
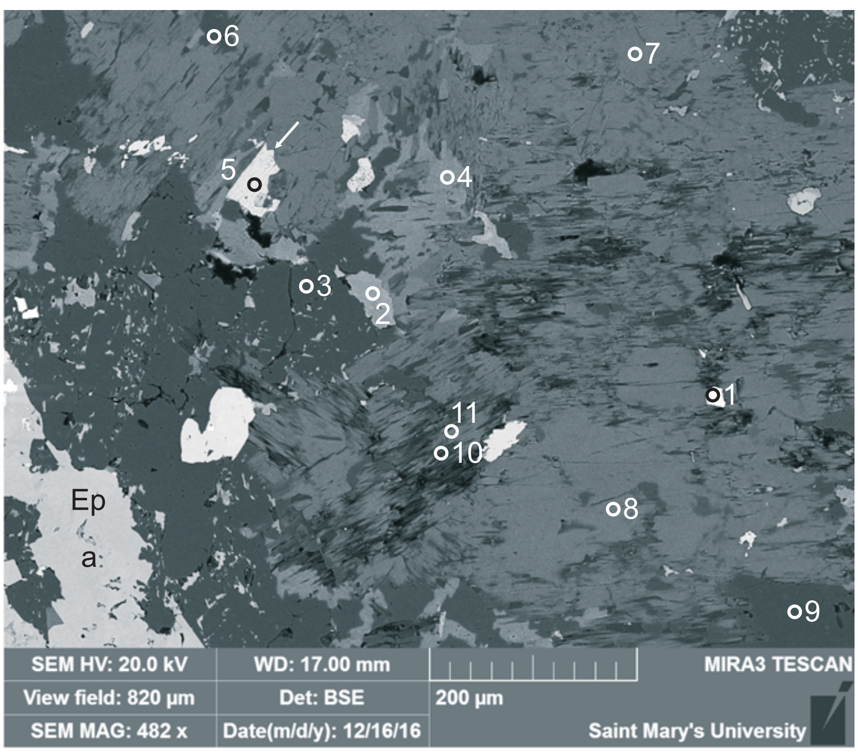



Figure 11-2.6: Sample 9958a (SEM).




1:Goethite
2:Actinolite
3:Quartz
4:K-feldspar
5:Apatite
6:Quartz
7:Scapolite
8:Scapolite
9:Quartz
10:Scapolite
11:Scapolite

Figure 11-2.7: Sample 9958a site 3 (SEM). (Table 11-2.1). Actinolite (2) shows interlocking texture with K-feldspar (4). Scapolite (7-8,11-11) (probably replacing K-feldspar (4)) appears to be invaded by quartz (3,6,9). Quartz appears to be part of a quartz-epidote patch (position a). Apatite (5) cross-cuts scapolite (arrow).

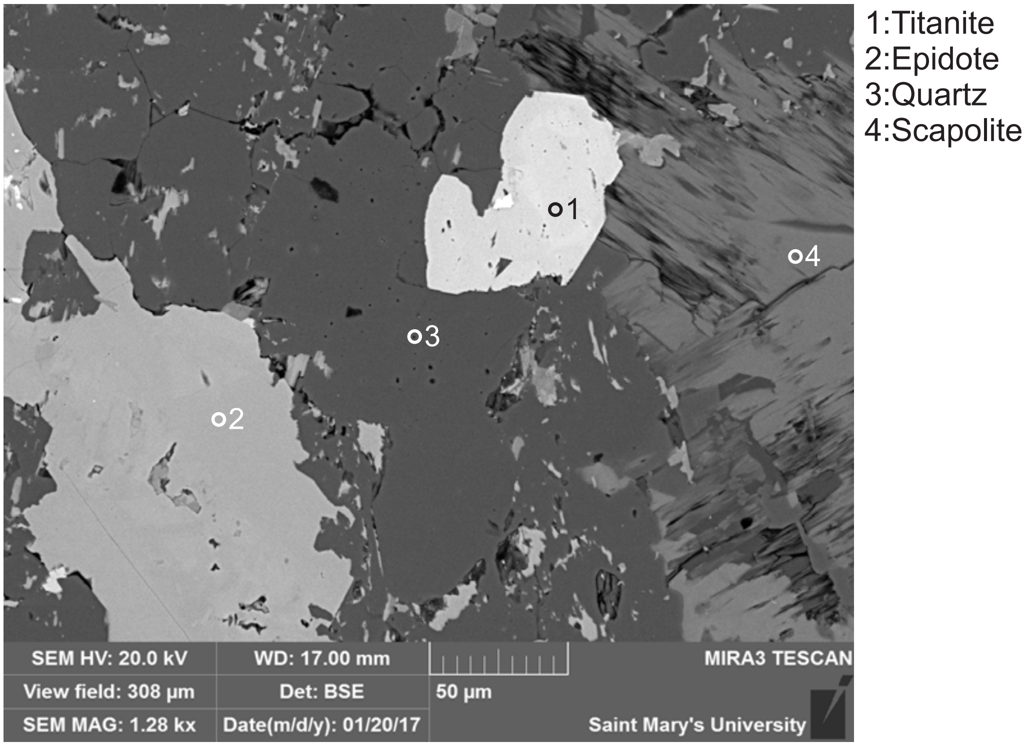



Figure 11-2.8: Sample 9958a site 3-1 (SEM). (Table 11-2.2). Epidote (2) and quartz (3) patch (from Fig. 11-2.6) overprints scapolite (4). Titanite (1) is the latest to form mineral cross-cutting quartz and scapolite.

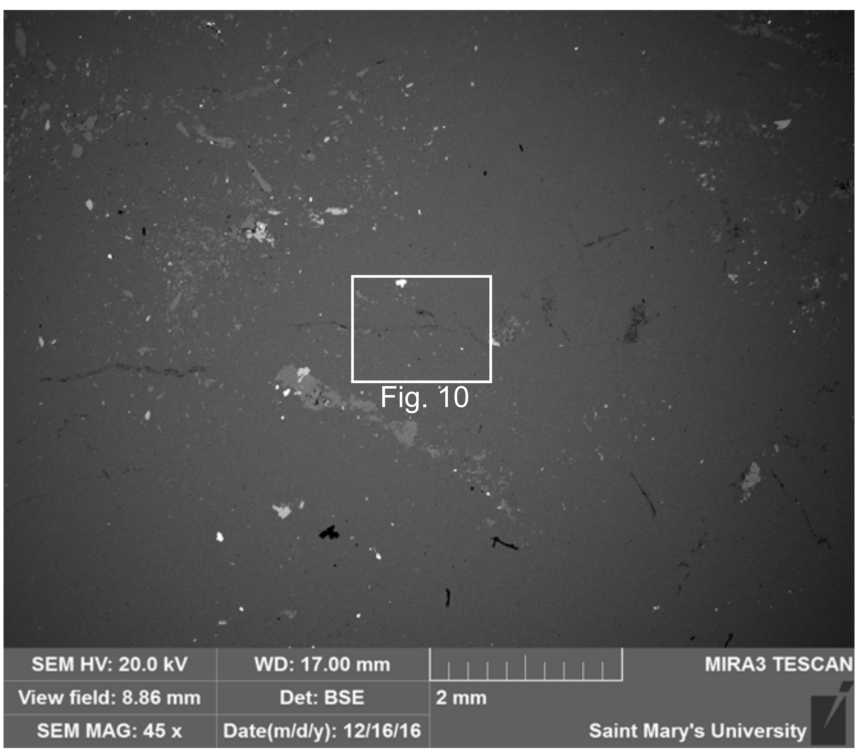
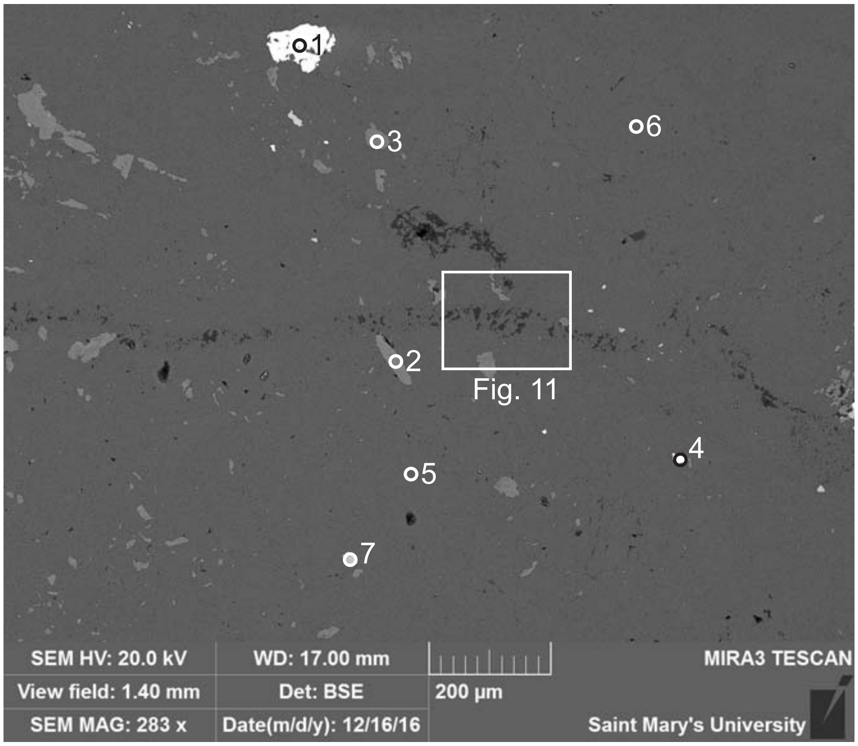
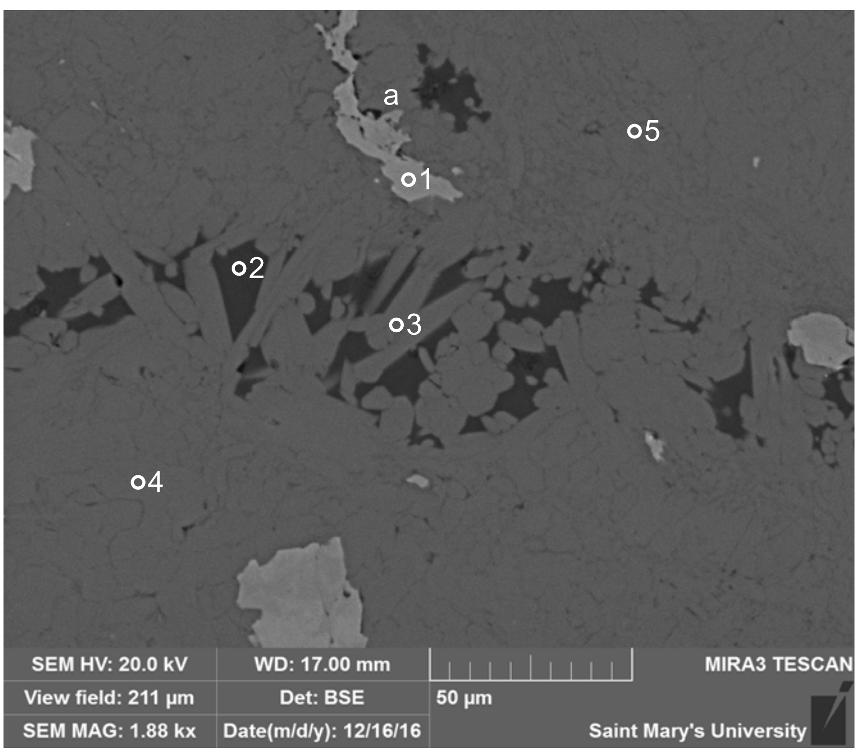



Figure 11-2.9: Sample 9958a (SEM).




1:Limonite
2:Actinolite
3:Actinolite
4:Goethite
5:Scapolite
6:Scapolite
7:Titanite

Figure 11-2.10: Sample 9958a site 4 (SEM). (Table 11-2.1). This site consists of a large scapolite patch, and actinolite (2-3) crystals that may be relic grains. Limonite (1), geothite (4), and titanite (7) are the latest minerals to form.




1:Actinolite
2:Analcime
3:Scapolite
4:Scapolite
5:Scapolite

Figure 11-2.11: Sample 9958a site 5 (SEM). (Table 11-2.1). Zoom in of site 4. Small scapolite laths (3-5) appear to make up the patch. Analcime (2) and actinolite (1) appear to be interstitial or fill voids in the scapolite.

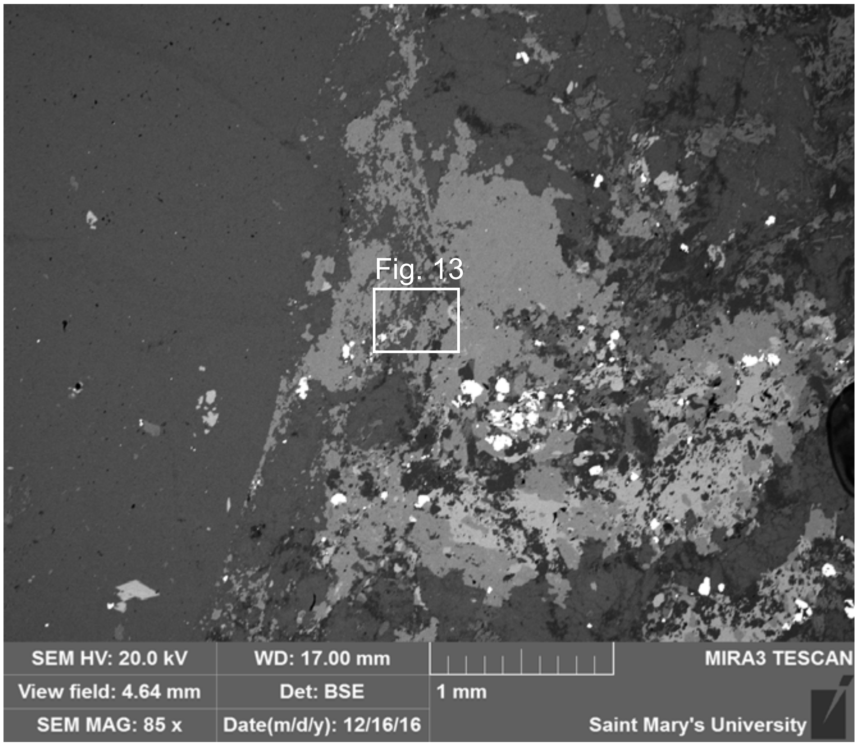



Figure 11-2.12: Sample 9958a (SEM).

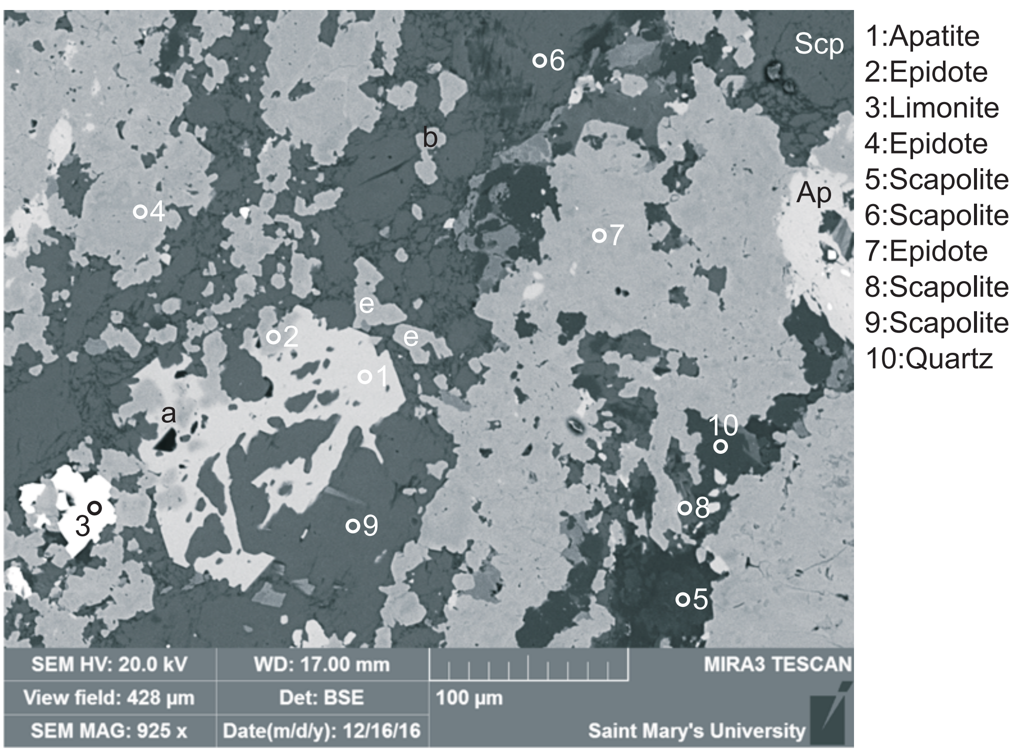



Figure 11-2.13: Sample 9958a site 6 (SEM). (Table 11-2.1). Scapolite (5-6,8-9) contains fractures (possibly filled with analcime) that are cross-cut by epidote (position b). Some of the epidote is euhedral (positions e), some are lobate. Apatite appears to replace some epidote (position a).

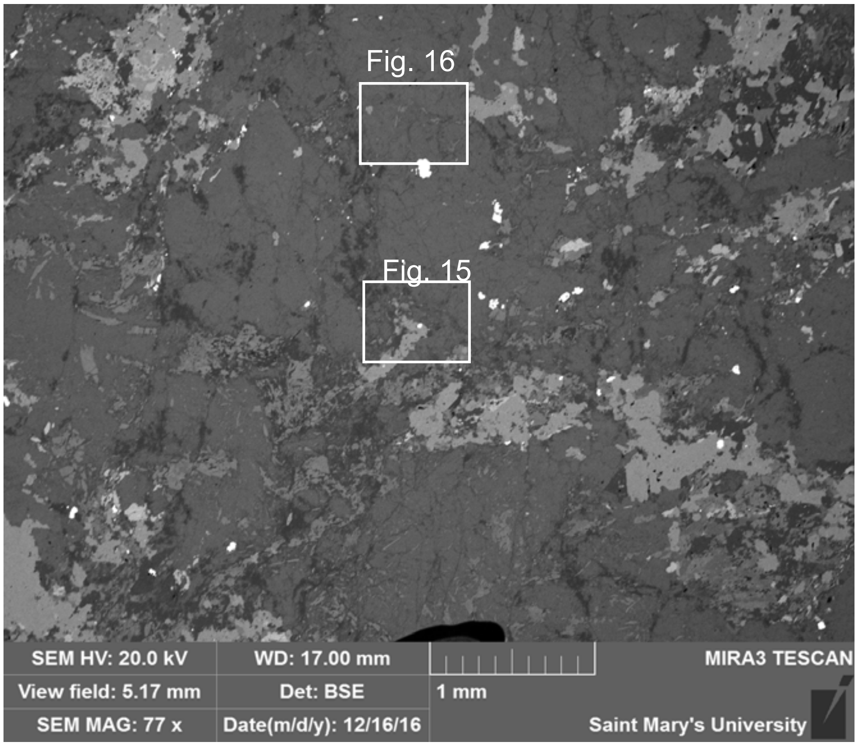



Figure 11-2.14: Sample 9958a (SEM).

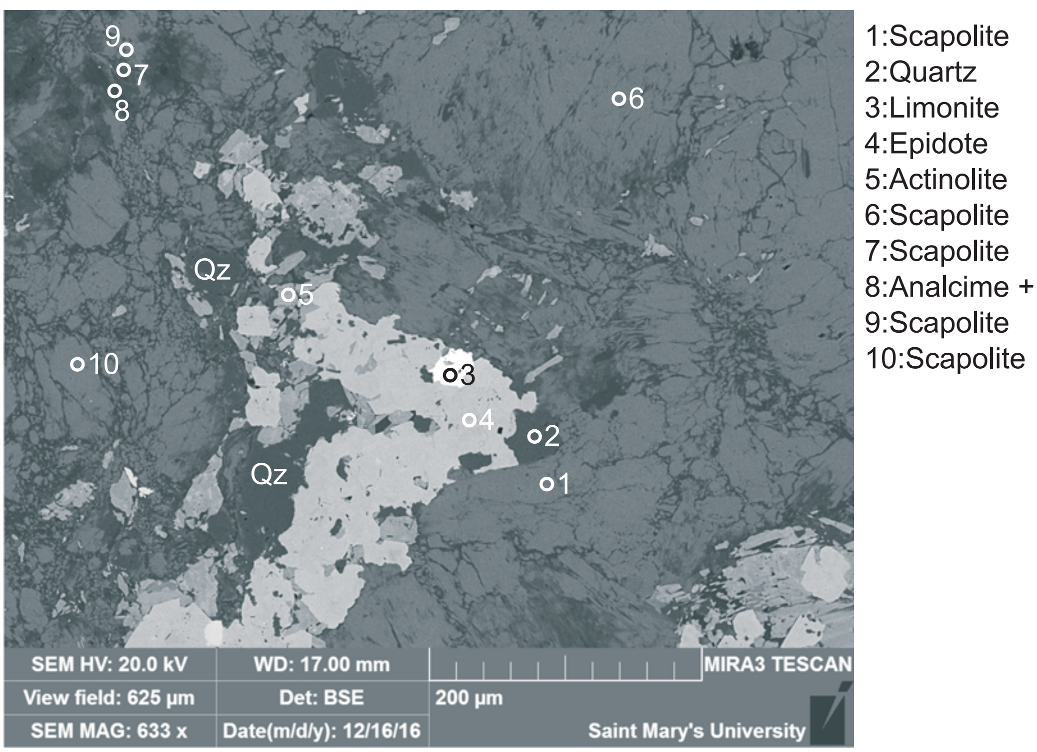
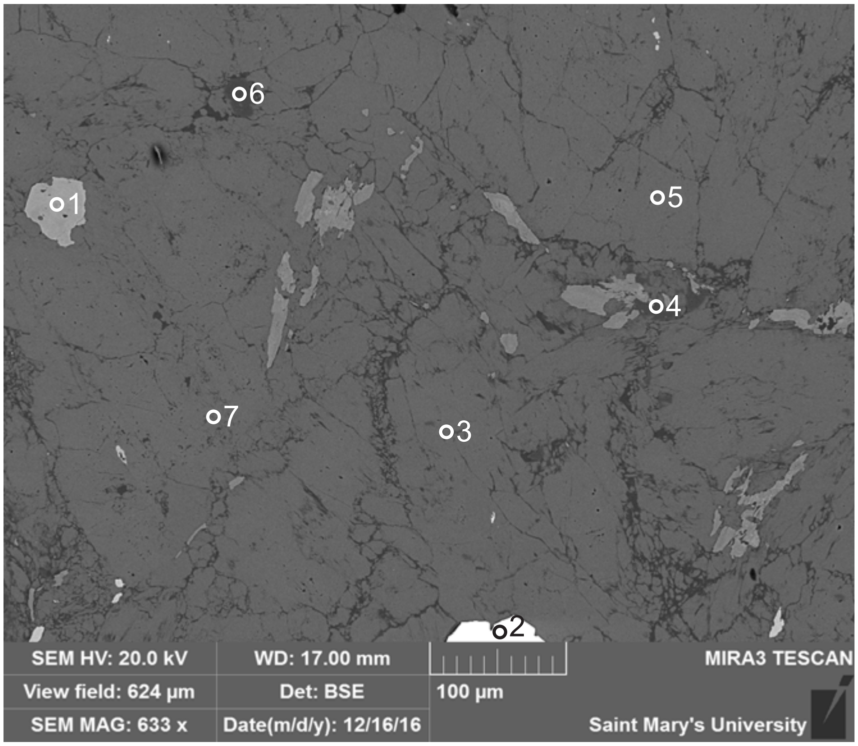



Figure 11-2.15: Sample 9958a site 7 (SEM). (Table 11-2.1). Epidote (4) and quartz (2, qz) appear to be synchronous and are replacing actinolite (5). Analcime (8) appears to fill voids in the scapolite and possibly along grain boundaries as well.




1:Epidote
2:Pyrite
3:Scapolite
4:Quartz
5:Scapolite
6:Quartz
7:Scapolite

Figure 11-2.16: Sample 9958a site 8 (SEM). (Table 11-2.1). This site consists of epidote (1), and quartz (4,6) crystals cutting scapolite. Analcime seems to occur in the fractures between scapolite crystals. Pyrite (2) is the latest mineral to form.

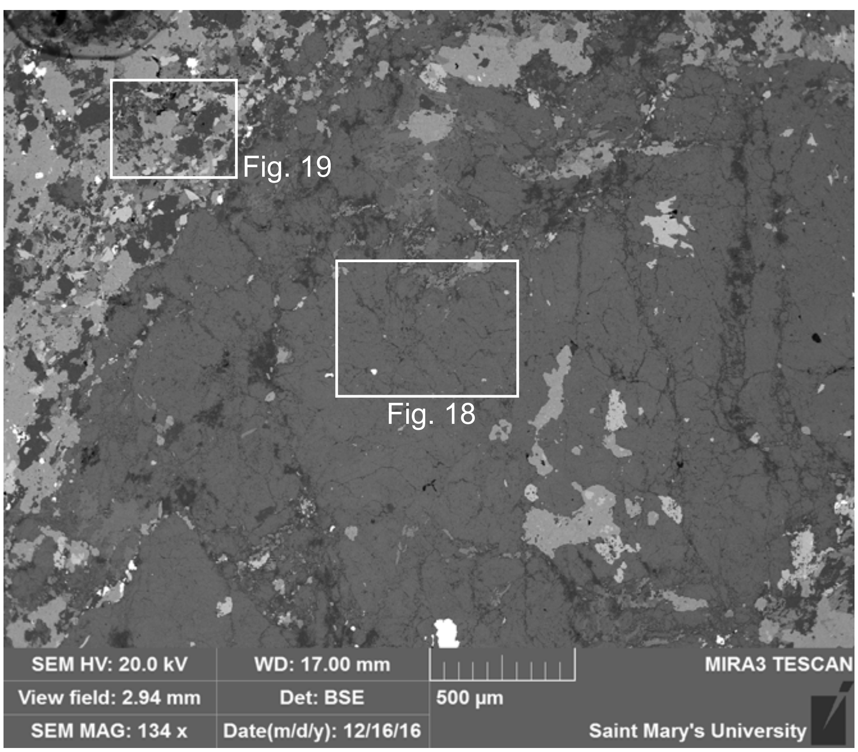
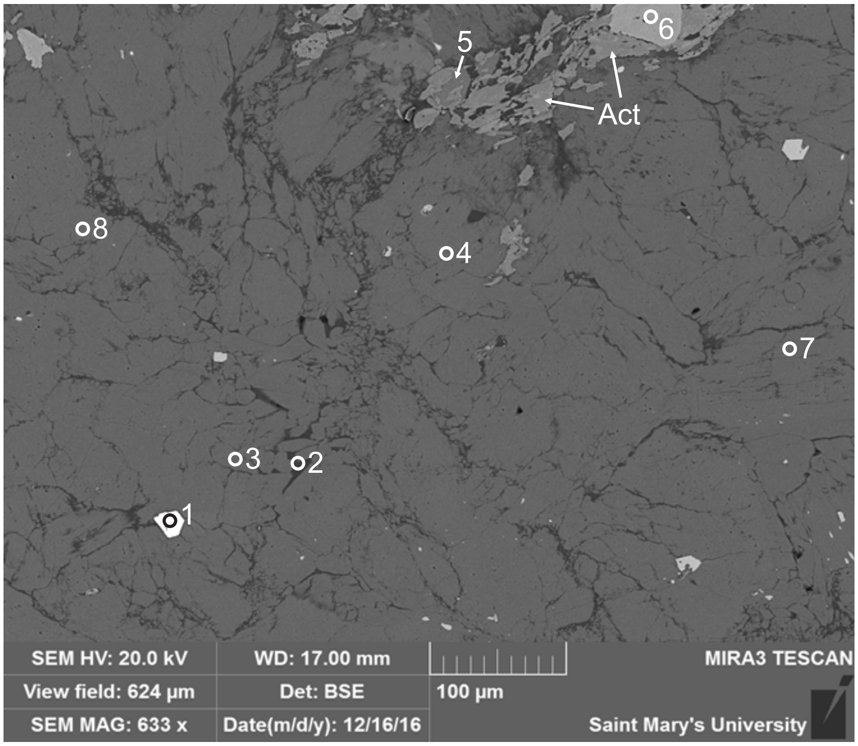
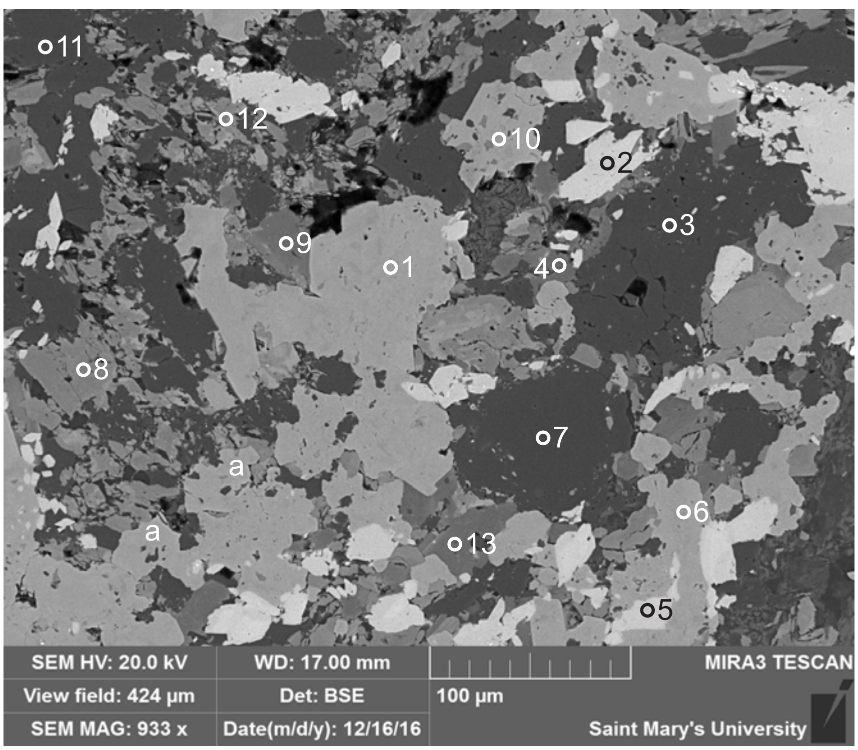



Figure 11-2.17: Sample 9958a (SEM).




1:Limonite
2:Analcime
3:Scapolite
4:Scapolite
5:K-feldspar
6:Epidote
7:Scapolite
8:Scapolite

Figure 11-2.18: Sample 9958a site 9 (SEM). (Table 11-2.1). This site consists of relic K-feldspar (5) and probably actinolite crystals that has been replaced by scapolite (3-4,7-8). Analcime (2) appears to form in between scapolite grains. Epidote (6) appears to cross-cut the actinolite grains. Limonite (1) appears to be the latest mineral to form.




1:Epidote
2:Titanite
3:Quartz
4:Chlorite
5:Titanite
6:Epidote
7:Quartz
8:Actinolite
9:Chlorite
10:Epidote
11:Quartz
12:Actinolite
13:Chlorite

Figure 11-2.19: Sample 9958a site 10 (SEM). (Table 11-2.1). This site consists of chlorite (4,9,13) and actinolite (8,12) that have been cross-cut by epidote (1,6,10) and quartz (3,7,11) (positions a). Titanite (2,5) appears to cross-cut epidote and is the latest mineral to form.

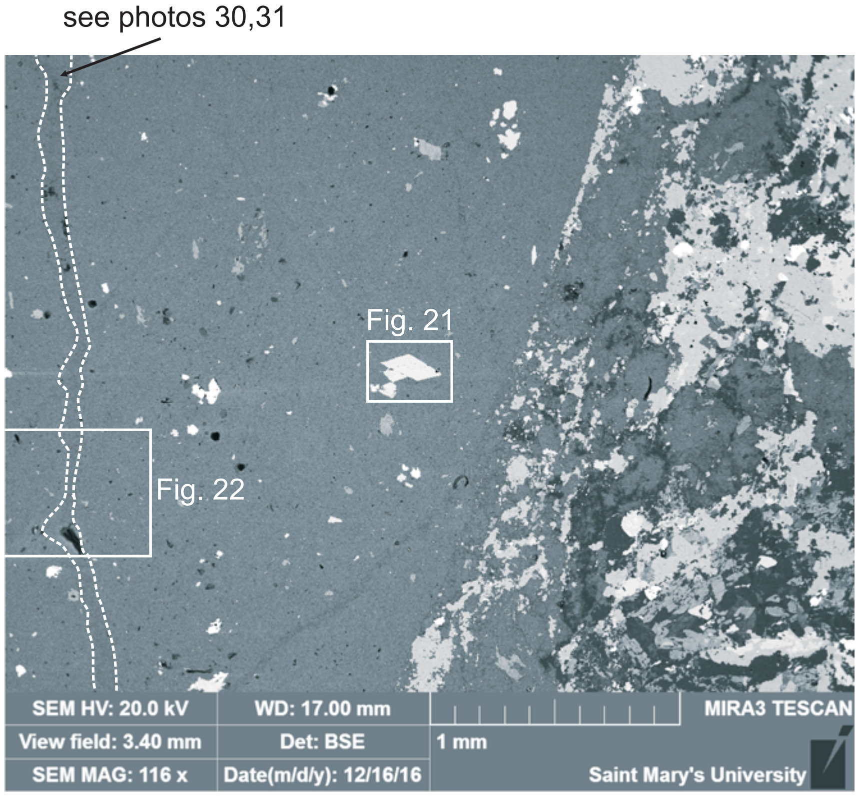



Figure 11-2.20: Sample 9958a (SEM). Complex system of scapolite vein and veinlets. See also photo Fig. 21.

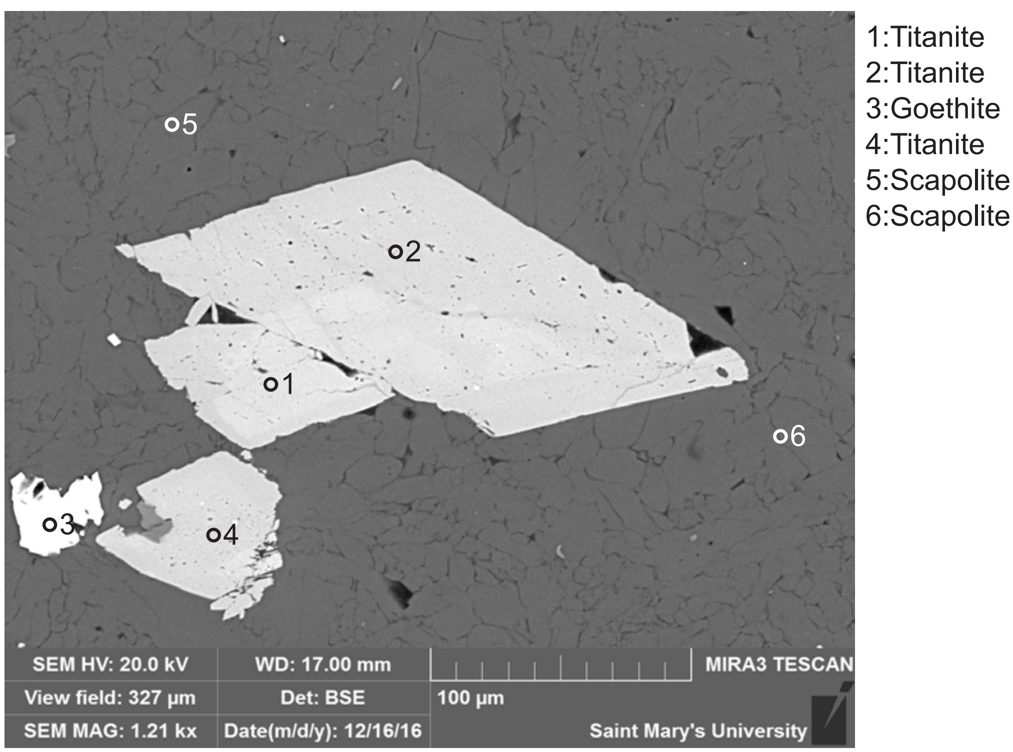



Figure 11-2.21: Sample 9958a site 11 (SEM). (Table 11-2.1). This site consists of euhedral titanite (11-2,4) crystals that appear to be filling voids in the scapolite (5,6) patch. Goethite (3) also appears to be filling a void.

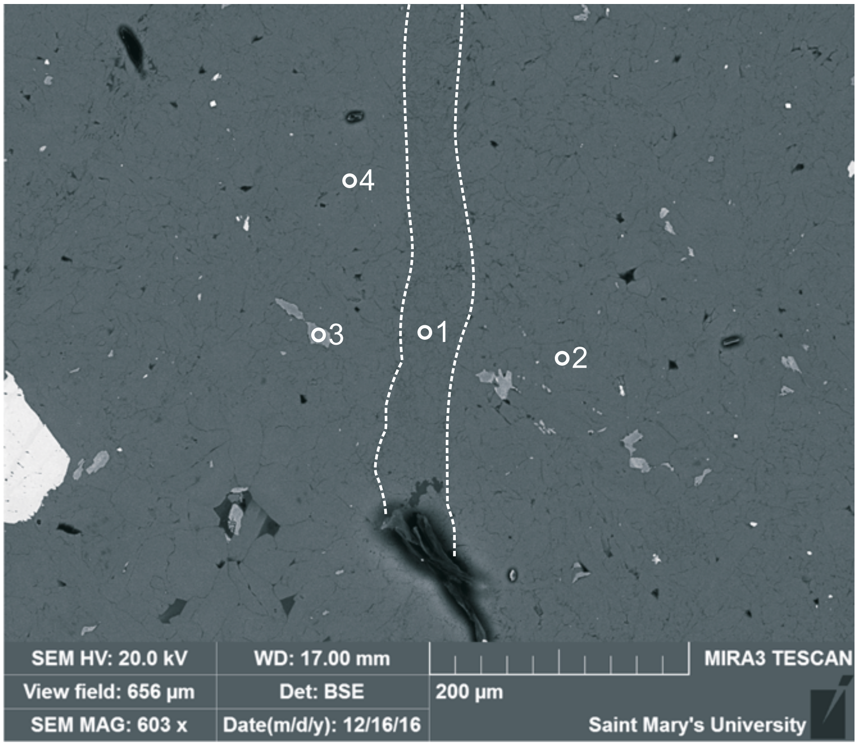



Figure 11-2.22: Sample 9958a site 12 (SEM). (Table 11-2.1). This site consists of the scapolite patch, with crystals of actinolite (3). This site also displays a darker vein of scapolite (easier to see in Figure 11-2.20) outlined in white.

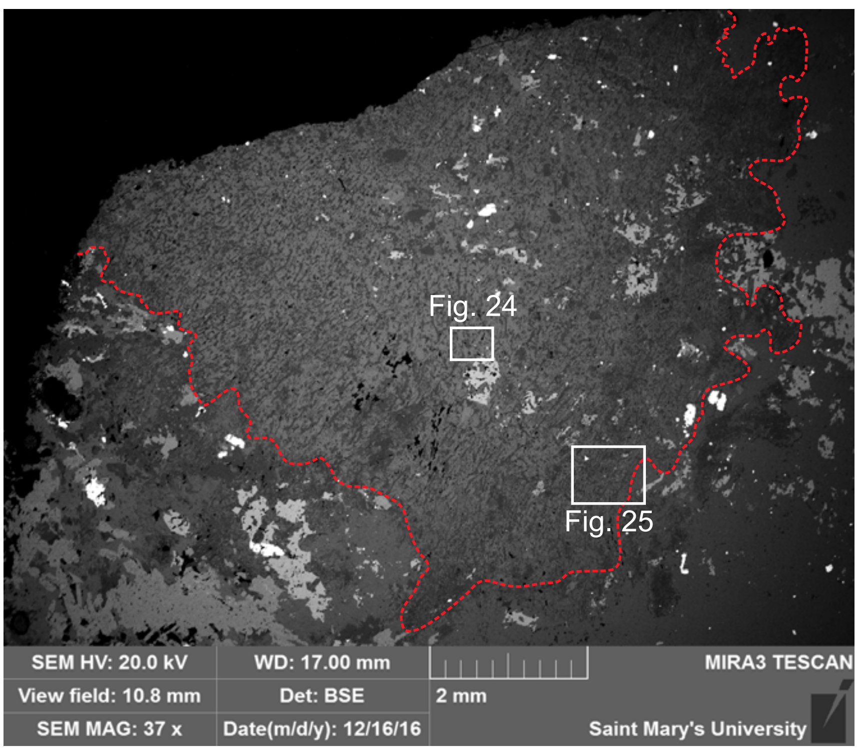
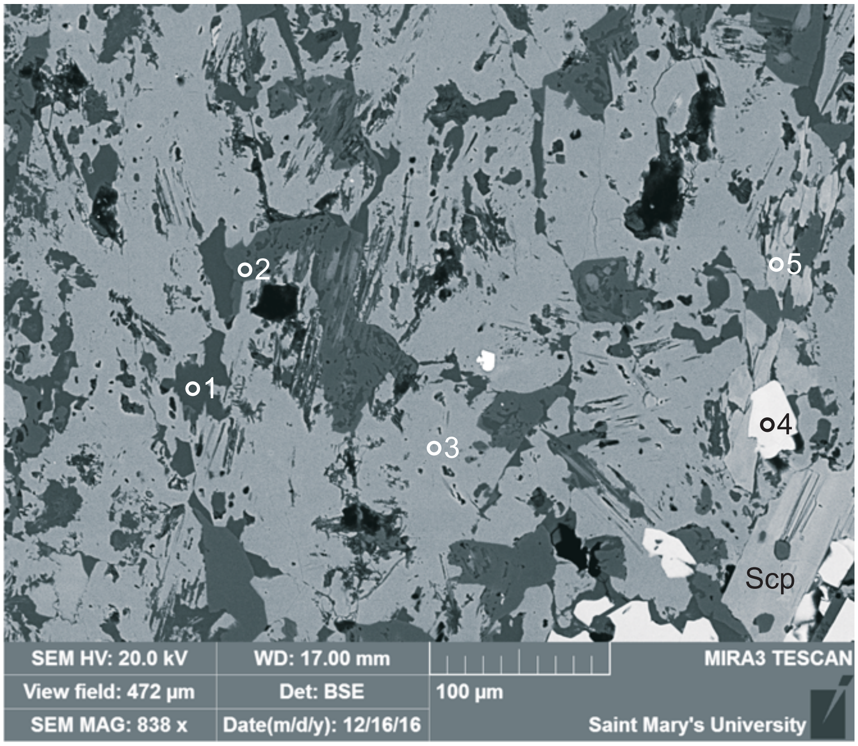
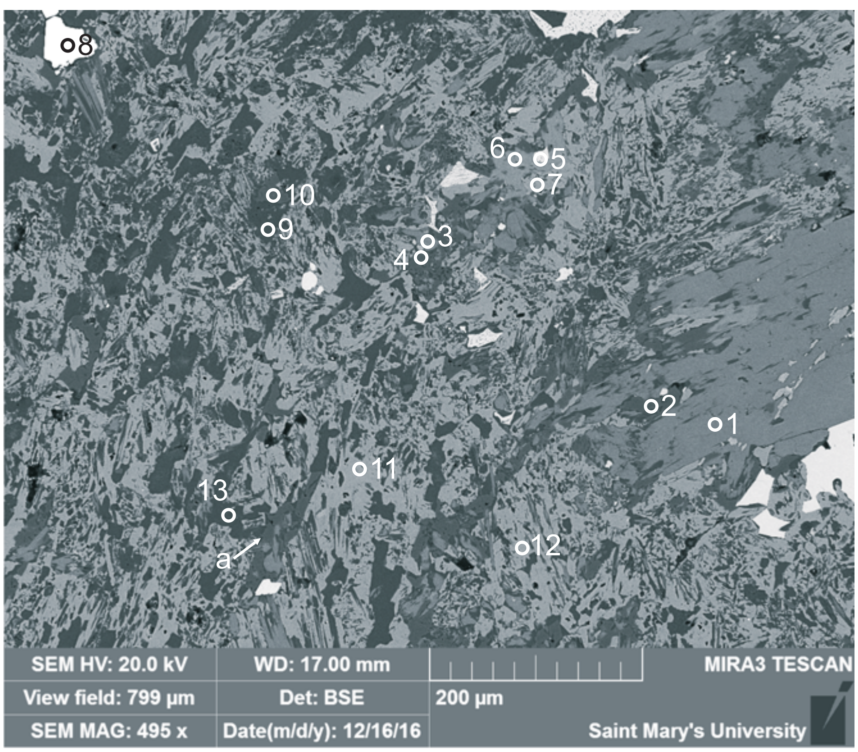



Figure 11-2.23: Sample 9958a (SEM).




1:Analcime
2:Quartz
3:Zoisite
4:Titanite
5:Scapolite

Figure 11-2.24: Sample 9958a site 13 (SEM). (Table 11-2.1). This site consists of a patch of zoisite (3) in a scapolite-analcime rock, that appears to be partly replaced by analcime (1), quartz (2), and scapolite (5). Quartz may be interstitial with the original feldspar or might be later. Titanite (4) is the latest mineral to form.




1:Scapolite
2:Quartz + Scapolite
3:Scapolite
4:Quartz
5:Apatite
6:K-feldspar
7:Zoisite
8:Limonite
9:Analcime
10:Albite
11:Zoisite
12:Zoisite
13:Analcime

Figure 11-2.25a: Sample 9958a site 14 (SEM). (Table 11-2.1). This site consists of scapolite (1), analcime (9,12), albite (10) and quartz (2,4) replacing zoisite (7,11-12). Analcime appears to be ?replacing or co-precipitating with quartz (position a). Zoisite appears to have replaced K-feldspar (6).

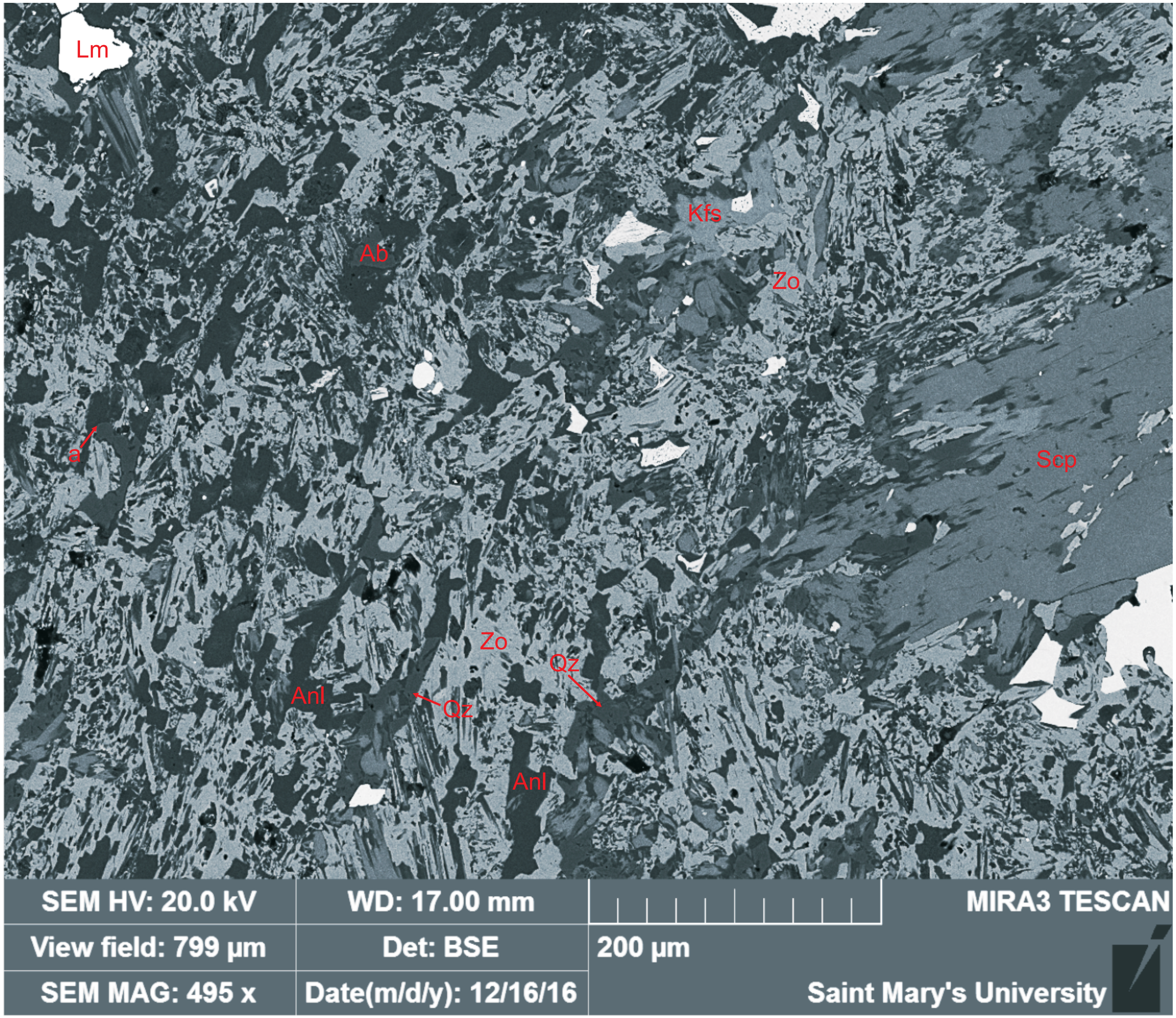



Figure 11-2.25b: Figure 11-2.25a enlarged (see caption of Fig. 11-2.25a).

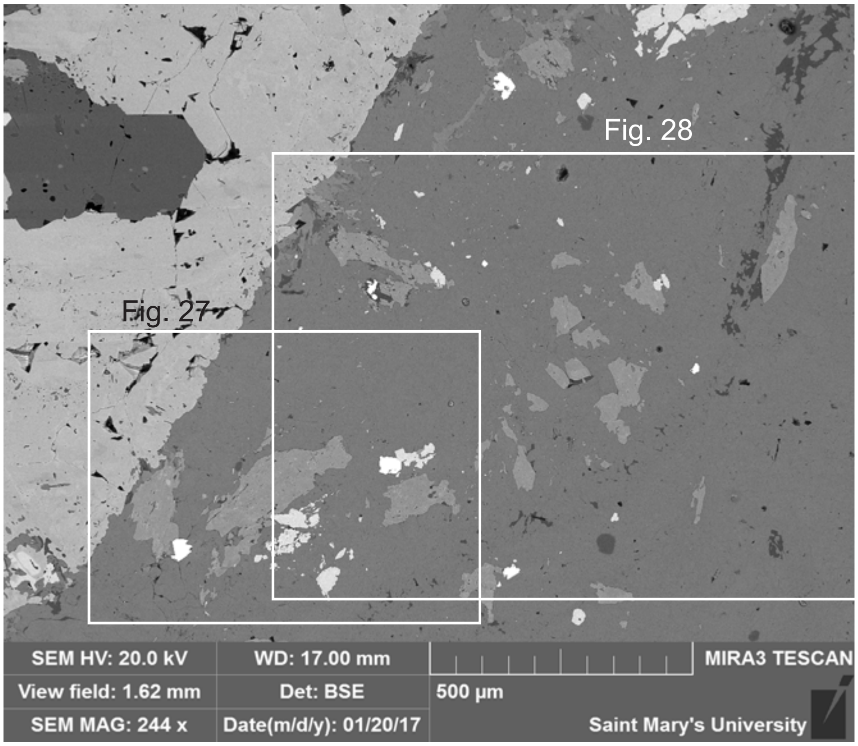
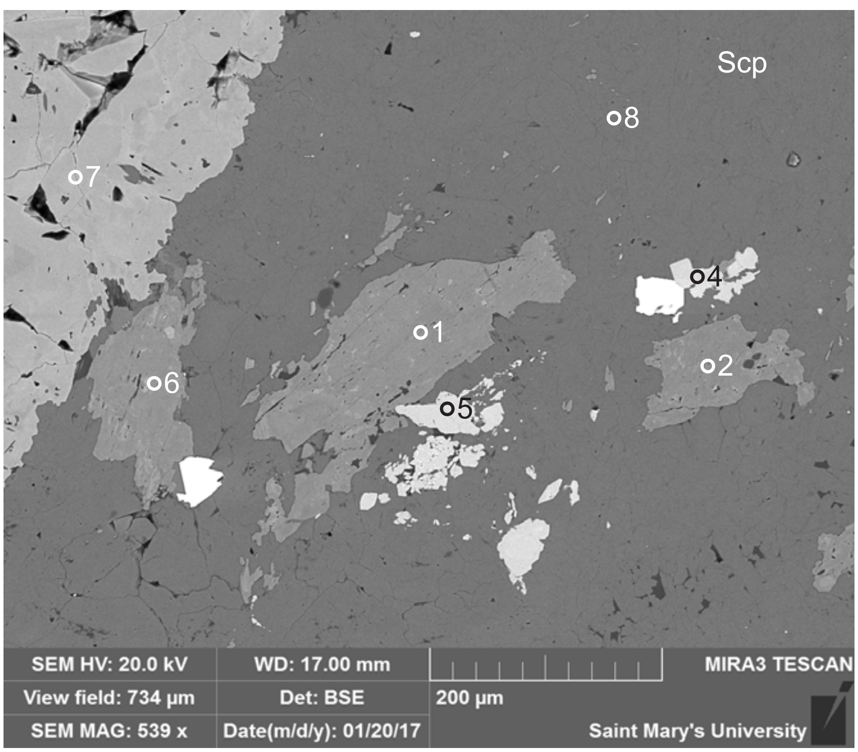
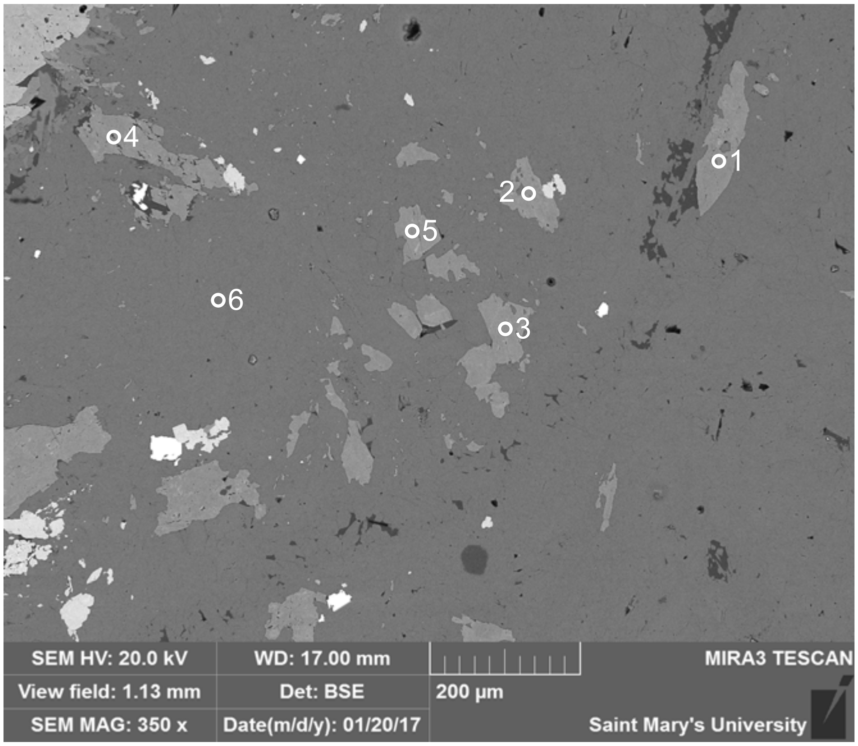



Figure 11-2.26: Sample 9958a (SEM). Contact between diorite and scapolite vein.




1:Actinolite
2:Actinolite
3:Goethite
4:Titanite
5:Titanite
6:Actinolite
7:Epidote
8:Scapolite

Figure 11-2.27: Sample 9958a site 15 (SEM). (Table 11-2.2). This site consists of relic actinolite (11-2,6) crystals within a scapolite (8) vein. Titanite (4-5) appears to postdate the amphiboles.




1:Actinolite
2:Actinolite
3:Actinolite
4:Hornblende
5:Actinolite
6:Scapolite

Figure 11-2.28: Sample 9958a site 16 (SEM). (Table 11-2.2). This site consists of relic actinolite (1-3,5), and hornblende (4) crystals within a scapolite (6) vein.

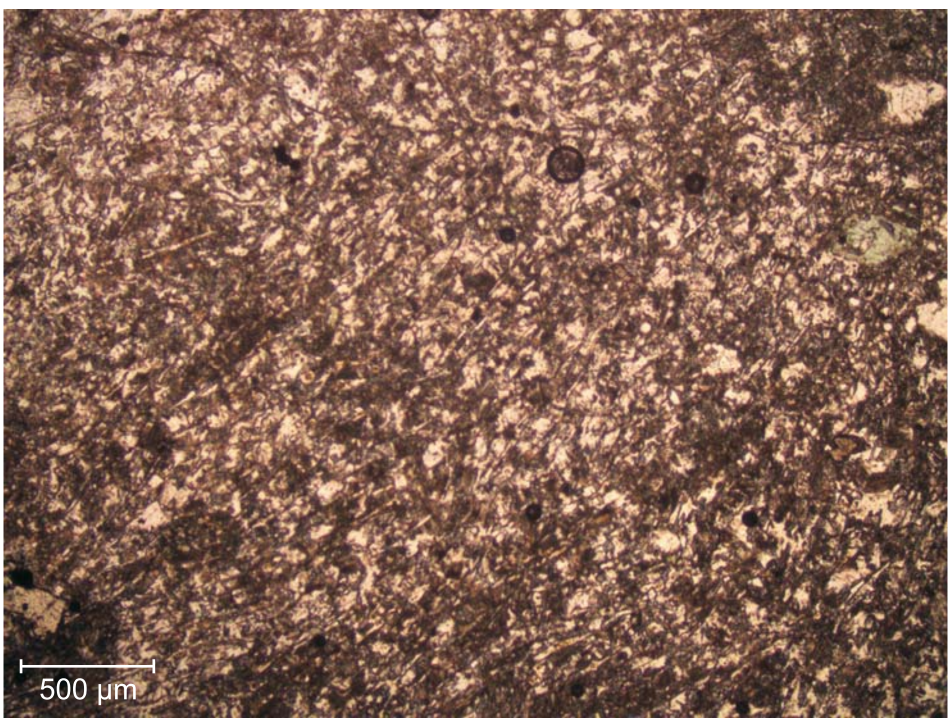



Figure 11-2.29: 4x ppl. Zoisite patch in diorite with scapolite veins.

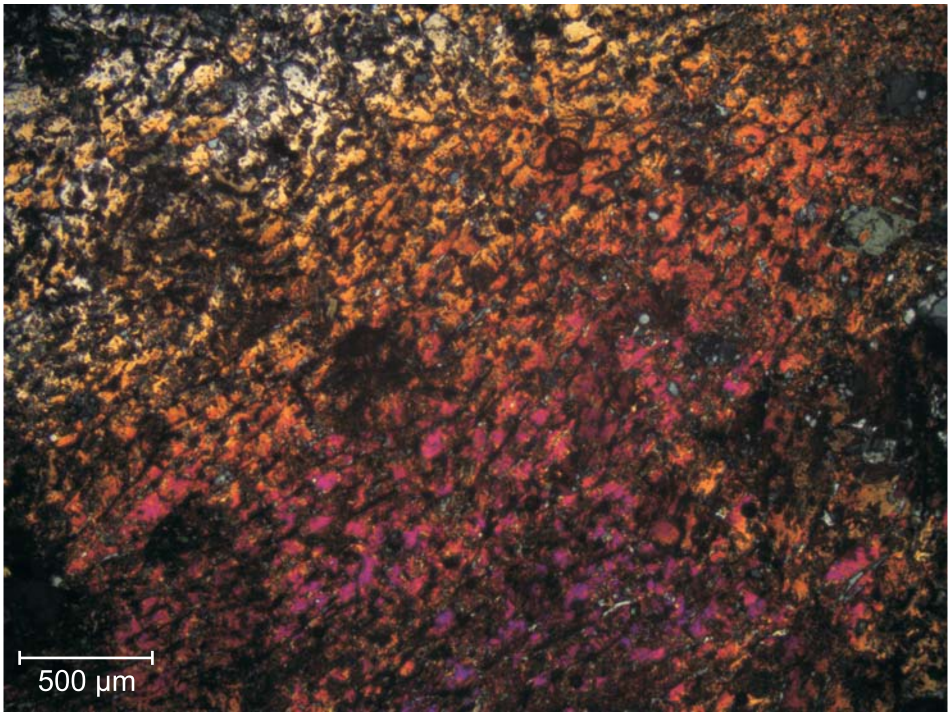



Figure 11-2.30: 4x XPL. The zoisite patch shows a fabric that trends NE-SW and it is limited only in the zoisite. This suggests that the zoisite patch is a xenolith probably from the granulite.

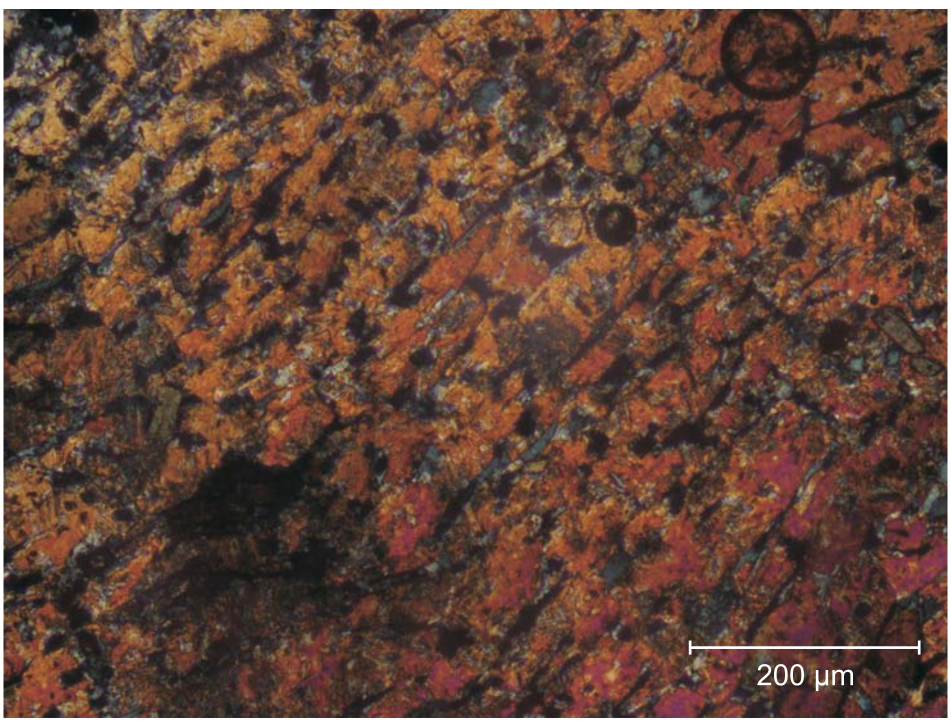



Figure 11-2.31: 10x XPL. Straight extinction seen in fabric direction.

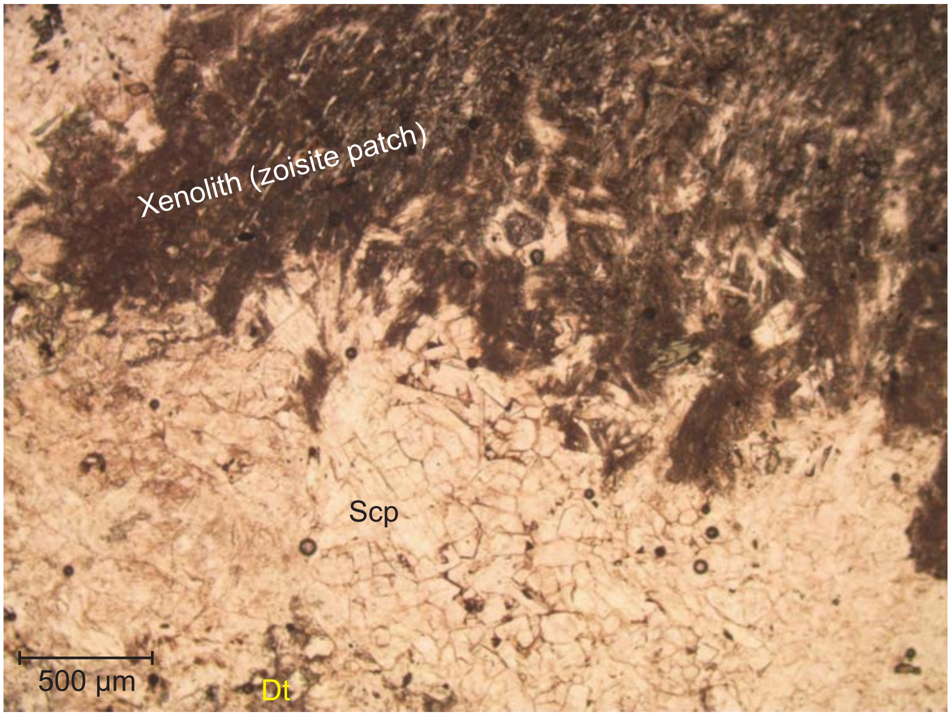


Figure 11-2.32: 4x PPL. Contact between the xenolith (zoisite patch) and scapolite patch.

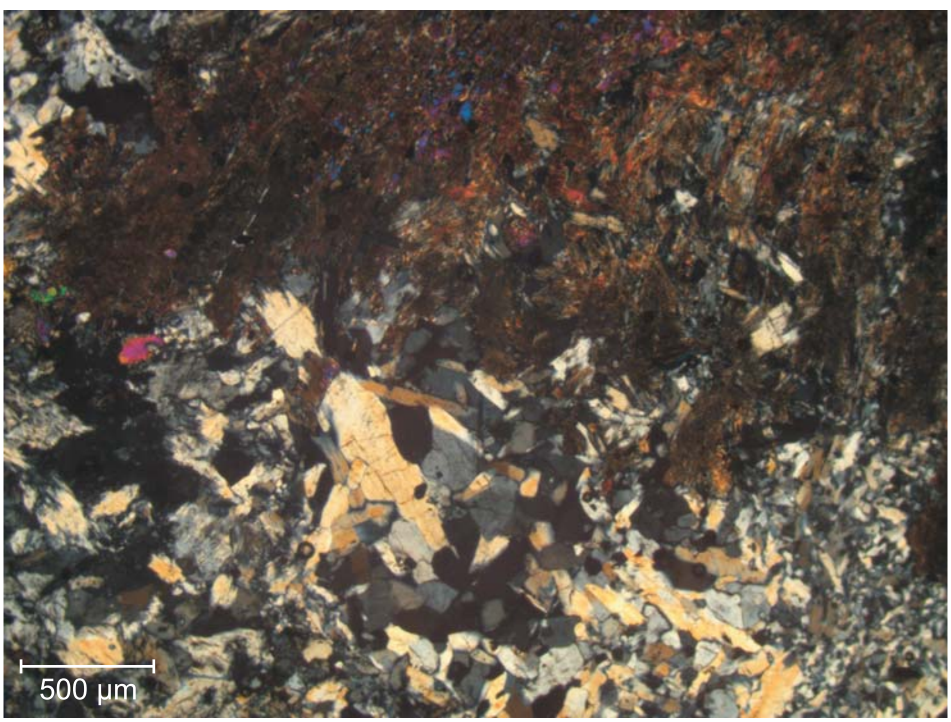


Figure 11-2.33: Same as Figure 4 ,but XPL.

Table 11-2.1: EDS analyses for sample 9958a.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | ZnO | BaO | WO3 | Total | Actual Total | Calculated Wt % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958a | 1 | 1 | Ttn | 33.14 | 36.42 | 1.73 | 0.80 | | 27.91 | | | | | | | | | | | 100 | 113 | |
| 9958a | 1 | 2 | Scp | 58.06 | | 21.25 | | | 5.74 | 10.48 | 0.64 | | | | 3.83 | | | | | 100 | 118 | |
| 9958a | 1 | 3 | Act | 55.72 | | 2.28 | 8.34 | 18.27 | 11.92 | 0.47 | | | | | | | | | | 97 | 113 | |
| 9958a | 1 | 4 | Act | 55.67 | | 2.70 | 9.12 | 17.44 | 11.68 | 0.40 | | | | | | | | | | 97 | 112 | |
| 9958a | 1 | 5 | Ep | 40.34 | | 25.04 | 8.98 | | 22.64 | | | | | | | | | | | 97 | 110 | |
| 9958a | 1 | 6 | Gth | 0.67 | | | 99.33 | | | | | | | | | | | | | 100 | 95 | 80 |
| 9958a | 1 | 7 | Kfs | 66.38 | | 17.82 | | | | | 15.80 | | | | | | | | | 100 | 115 | |
| 9958a | 1 | 8 | Ep | 39.55 | | 23.77 | 10.55 | | 22.54 | | | 0.59 | | | | | | | | 97 | 107 | |
| 9958a | 1 | 9 | Lm | 3.46 | | 0.91 | 91.45 | 1.05 | 1.20 | | | | 0.94 | | | | 1.00 | | | 100 | 91 | 76 |
| 9958a | 1 | 10 | Qz | 98.93 | | 0.71 | | | | 0.36 | | | | | | | | | | 100 | 120 | |
| 9958a | 1 | 11 | Ab | 69.43 | | 18.89 | | | | 11.68 | | | | | | | | | | 100 | 117 | |
| 9958a | 1 | 12 | Anl | 58.97 | | 20.17 | | | | 11.87 | | | | | | | | | | 91 | 105 | |
| 9958a | 1 | 13 | Act | 55.05 | | 2.80 | 8.62 | 17.87 | 11.92 | 0.50 | | | | | 0.23 | | | | | 97 | 113 | |
| 9958a | 1 | 14 | Scp | 57.99 | | 21.84 | | | 5.41 | 10.42 | 0.51 | | | | 3.82 | | | | | 100 | 119 | |
| 9958a | 1 | 15 | Kfs | 65.77 | | 18.80 | | | | | 15.44 | | | | | | | | | 100 | 116 | |
| 9958a | 1 | 16 | Ab + ? | 67.74 | | 19.29 | | | 0.79 | 10.79 | 1.40 | | | | | | | | | 100 | 115 | |
| 9958a | 2 | 1 | Ep | 39.99 | | 23.65 | 10.70 | | 22.66 | | | | | | | | | | | 97 | 110 | |
| 9958a | 2 | 2 | Scp | 57.61 | | 21.86 | | | 6.67 | 9.94 | 0.52 | | | | 3.39 | | | | | 100 | 114 | |
| 9958a | 2 | 3 | Anl | 59.88 | | 20.38 | | | | 10.74 | | | | | | | | | | 91 | 102 | |
| 9958a | 2 | 4 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 120 | |
| 9958a | 2 | 5 | Anl | 59.14 | | 20.23 | | | 0.23 | 11.40 | | | | | | | | | | 91 | 101 | |
| 9958a | 2 | 6 | Ap | | | | | | 48.71 | | | 44.17 | | 5.49 | 0.18 | | | | 1.46 | 100 | 120 | |
| 9958a | 2 | 7 | Scp | 57.37 | | 22.10 | | | 6.96 | 9.81 | 0.46 | | | | 3.31 | | | | | 100 | 115 | |
| 9958a | 2 | 8 | Anl | 59.51 | | 20.36 | | | | 11.13 | | | | | | | | | | 91 | 101 | |
| 9958a | 3 | 1 | Gth | 0.61 | | | 99.39 | | | | | | | | | | | | | 100 | 95 | 80 |
| 9958a | 3 | 2 | Act | 55.41 | 0.37 | 2.67 | 8.42 | 17.99 | 11.59 | 0.55 | | | | | | | | | | 97 | 111 | |
| 9958a | 3 | 3 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 120 | |
| 9958a | 3 | 4 | Kfs | 65.57 | | 17.99 | | | | | 15.51 | | | | | | | 0.92 | | 100 | 115 | |
| 9958a | 3 | 5 | Ap | 1.90 | | 0.29 | | | 48.19 | 0.86 | | 40.64 | 2.03 | 3.26 | 1.28 | | | | 1.53 | 100 | 117 | |
| 9958a | 3 | 6 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 115 | |
| 9958a | 3 | 7 | Scp | 57.19 | | 22.09 | | | 7.21 | 9.28 | 0.90 | | | | 3.34 | | | | | 100 | 114 | |
| 9958a | 3 | 8 | Scp | 57.73 | | 21.62 | | | 5.68 | 10.17 | 0.85 | | | | 3.95 | | | | | 100 | 119 | |
| 9958a | 3 | 9 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 124 | |

Table 11-2.1: EDS analyses for sample 9958a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | ZnO | BaO | WO3 | Total | Actual Total | Calculated Wt % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958a | 3 | 10 | Scp | 60.22 | | 30.76 | 1.36 | 4.25 | 0.67 | 1.09 | 1.34 | | | | 0.31 | | | | | 100 | 98 | |
| 9958a | 3 | 11 | Scp | 57.97 | | 22.94 | | 0.30 | 5.09 | 9.11 | 0.86 | | | | 3.73 | | | | | 100 | 116 | |
| 9958a | 4 | 1 | Lm | 0.59 | | | 99.41 | | | | | | | | | | | | | 100 | 91 | 76 |
| 9958a | 4 | 2 | Act | 54.65 | | 3.47 | 9.96 | 16.53 | 11.64 | 0.60 | | | | | 0.15 | | | | | 97 | 111 | |
| 9958a | 4 | 3 | Act | 53.80 | | 3.73 | 10.59 | 16.32 | 11.77 | 0.62 | 0.17 | | | | | | | | | 97 | 109 | |
| 9958a | 4 | 4 | Gth | 0.66 | | | 99.34 | | | | | | | | | | | | | 100 | 96 | 81 |
| 9958a | 4 | 5 | Scp | 57.85 | | 21.54 | | | 5.70 | 10.39 | 0.66 | | | | 3.86 | | | | | 100 | 118 | |
| 9958a | 4 | 6 | Scp | 58.01 | | 21.74 | | | 5.73 | 10.38 | 0.49 | | | | 3.65 | | | | | 100 | 113 | |
| 9958a | 4 | 7 | Ttn | 33.12 | 37.18 | 1.25 | 0.77 | | 27.68 | | | | | | | | | | | 100 | 112 | |
| 9958a | 5 | 1 | Act | 53.38 | 0.36 | 4.41 | 10.13 | 16.37 | 11.35 | 0.85 | | | | | 0.15 | | | | | 97 | 109 | |
| 9958a | 5 | 2 | Anl | 59.22 | | 20.04 | | | | 11.74 | | | | | | | | | | 91 | 102 | |
| 9958a | 5 | 3 | Scp | 56.99 | | 22.17 | | | 7.13 | 9.79 | 0.61 | | | | 3.29 | | | | | 100 | 114 | |
| 9958a | 5 | 4 | Scp | 57.63 | | 21.75 | | | 5.90 | 10.30 | 0.67 | | | | 3.75 | | | | | 100 | 114 | |
| 9958a | 5 | 5 | Scp | 57.48 | | 22.13 | | | 6.19 | 10.23 | 0.48 | | | | 3.50 | | | | | 100 | 113 | |
| 9958a | 6 | 1 | Ap | | | | | | 48.97 | | | 44.22 | | 4.79 | 0.57 | | | | 1.45 | 100 | 120 | |
| 9958a | 6 | 2 | Ep | 40.62 | | 23.44 | 10.77 | | 22.17 | | | | | | | | | | | 97 | 105 | |
| 9958a | 6 | 3 | Lm | | | | 99.65 | | 0.35 | | | | | | | | | | | 100 | 92 | 77 |
| 9958a | 6 | 4 | Ep | 40.21 | | 24.36 | 9.83 | | 22.61 | | | | | | | | | | | 97 | 106 | |
| 9958a | 6 | 5 | Scp | 61.21 | | 22.42 | 0.24 | | 2.81 | 11.76 | 0.22 | | | | 1.34 | | | | | 100 | 108 | |
| 9958a | 6 | 6 | Scp | 57.16 | | 22.03 | | | 6.11 | 10.25 | 0.70 | | | | 3.76 | | | | | 100 | 113 | |
| 9958a | 6 | 7 | Ep | 40.19 | | 23.43 | 11.05 | | 22.34 | | | | | | | | | | | 97 | 106 | |
| 9958a | 6 | 8 | Scp | 57.94 | | 21.70 | | | 6.57 | 9.92 | 0.51 | | | | 3.36 | | | | | 100 | 115 | |
| 9958a | 6 | 9 | Scp | 57.62 | | 21.63 | | | 5.89 | 10.61 | 0.53 | | | | 3.72 | | | | | 100 | 115 | |
| 9958a | 6 | 10 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 118 | |
| 9958a | 7 | 1 | Scp | 57.75 | | 21.71 | | | 6.68 | 9.91 | 0.52 | | | | 3.43 | | | | | 100 | 115 | |
| 9958a | 7 | 2 | Qz | 98.21 | | 0.76 | 0.30 | 0.33 | | 0.27 | 0.14 | | | | | | | | | 100 | 117 | |
| 9958a | 7 | 3 | Lm | | | | 99.51 | | 0.49 | | | | | | | | | | | 100 | 94 | 79 |
| 9958a | 7 | 4 | Ep | 40.14 | | 22.94 | 11.75 | | 22.17 | | | | | | | | | | | 97 | 108 | |
| 9958a | 7 | 5 | Act | 55.07 | | 2.45 | 10.49 | 16.78 | 11.46 | 0.59 | | | | | 0.15 | | | | | 97 | 110 | |
| 9958a | 7 | 6 | Scp | 57.00 | | 22.33 | | | 7.25 | 9.58 | 0.51 | | | | 3.33 | | | | | 100 | 113 | |
| 9958a | 7 | 7 | Scp | 62.19 | | 22.70 | | | 2.15 | 11.58 | 0.24 | | | | 1.15 | | | | | 100 | 103 | |
| 9958a | 7 | 8 | Anl + | 57.80 | | 20.94 | 0.37 | 0.59 | 0.37 | 10.35 | 0.43 | | | | 0.15 | | | | | 91 | 100 | |
| 9958a | 7 | 9 | Scp | 56.98 | | 22.23 | | | 5.92 | 10.51 | 0.54 | | | | 3.82 | | | | | 100 | 114 | |

Table 11-2.1: EDS analyses for sample 9958a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | ZnO | BaO | WO3 | Total | Actual Total | Calculated Wt % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958a | 7 | 10 | Scp | 57.27 | | 21.78 | | | 6.36 | 10.23 | 0.56 | | | | 3.80 | | | | | 100 | 114 | |
| 9958a | 8 | 1 | Ep | 40.27 | | 23.57 | 10.40 | | 22.76 | | | | | | | | | | | 97 | 105 | |
| 9958a | 8 | 2 | Py | 0.15 | | | 28.28 | | | | | | 71.57 | | | | | | | 100 | 233 | |
| 9958a | 8 | 3 | Scp | 56.47 | | 22.84 | | | 7.49 | 9.33 | 0.46 | | | | 3.41 | | | | | 100 | 116 | |
| 9958a | 8 | 4 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 119 | |
| 9958a | 8 | 5 | Scp | 57.35 | | 21.93 | | | 5.86 | 10.41 | 0.52 | | | | 3.93 | | | | | 100 | 117 | |
| 9958a | 8 | 6 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 118 | |
| 9958a | 8 | 7 | Scp | 58.24 | | 21.80 | | | 5.23 | 10.63 | 0.56 | | | | 3.55 | | | | | 100 | 115 | |
| 9958a | 9 | 1 | Lm | 0.64 | | | 99.36 | | | | | | | | | | | | | 100 | 94 | 79 |
| 9958a | 9 | 2 | Anl | 60.27 | | 20.23 | | | | 10.50 | | | | | | | | | | 91 | 101 | |
| 9958a | 9 | 3 | Scp | 56.88 | | 22.22 | | | 6.31 | 10.04 | 0.71 | | | | 3.83 | | | | | 100 | 117 | |
| 9958a | 9 | 4 | Scp | 57.22 | | 21.92 | | | 5.85 | 10.46 | 0.61 | | | | 3.95 | | | | | 100 | 117 | |
| 9958a | 9 | 5 | Kfs | 66.35 | | 17.26 | 0.36 | 0.83 | | | 15.21 | | | | | | | | | 100 | 112 | |
| 9958a | 9 | 6 | Ep | 39.86 | | 23.23 | 11.37 | | 22.54 | | | | | | | | | | | 97 | 107 | |
| 9958a | 9 | 7 | Scp | 57.05 | | 22.18 | | | 6.69 | 9.77 | 0.71 | | | | 3.60 | | | | | 100 | 117 | |
| 9958a | 9 | 8 | Scp | 56.96 | | 22.04 | | | 5.75 | 10.56 | 0.57 | | | | 4.12 | | | | | 100 | 116 | |
| 9958a | 10 | 1 | Ep | 40.02 | | 23.43 | 11.05 | | 22.50 | | | | | | | | | | | 97 | 109 | |
| 9958a | 10 | 2 | Ttn | 33.48 | 37.76 | | 0.97 | | 27.79 | | | | | | | | | | | 100 | 110 | |
| 9958a | 10 | 3 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 120 | |
| 9958a | 10 | 4 | Chl | 29.02 | | 19.43 | 14.84 | 21.72 | | | | | | | | | | | | 85 | 100 | |
| 9958a | 10 | 5 | Ttn | 32.62 | 37.60 | 1.09 | 0.93 | | 27.76 | | | | | | | | | | | 100 | 111 | |
| 9958a | 10 | 6 | Ep | 40.21 | | 24.29 | 10.15 | | 22.35 | | | | | | | | | | | 97 | 109 | |
| 9958a | 10 | 7 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 121 | |
| 9958a | 10 | 8 | Act | 55.45 | | 2.72 | 8.81 | 17.93 | 11.66 | 0.44 | | | | | | | | | | 97 | 112 | |
| 9958a | 10 | 9 | Chl | 28.82 | | 19.08 | 15.45 | 21.65 | | | | | | | | | | | | 85 | 98 | |
| 9958a | 10 | 10 | Ep | 40.15 | | 23.44 | 10.93 | | 22.48 | | | | | | | | | | | 97 | 109 | |
| 9958a | 10 | 11 | Qz | 99.77 | | | 0.23 | | | | | | | | | | | | | 100 | 118 | |
| 9958a | 10 | 12 | Act | 54.79 | | 3.01 | 9.77 | 16.76 | 11.85 | 0.31 | 0.22 | | | | 0.29 | | | | | 97 | 112 | |
| 9958a | 10 | 13 | Chl | 28.58 | | 19.74 | 15.17 | 21.51 | | | | | | | | | | | | 85 | 100 | |
| 9958a | 11 | 1 | Ttn | 32.65 | 36.78 | 1.19 | 0.72 | | 27.91 | | | | | | | 0.75 | | | | 100 | 111 | |
| 9958a | 11 | 2 | Ttn | 31.97 | 36.74 | 0.97 | 1.01 | | 27.63 | 0.91 | | | | | 0.77 | | | | | 100 | 111 | |
| 9958a | 11 | 3 | Gth | | | | 100.00 | | | | | | | | | | | | | 100 | 96 | 80 |
| 9958a | 11 | 4 | Ttn | 32.50 | 37.22 | 1.07 | 0.68 | | 27.86 | 0.28 | | | | | 0.38 | | | | | 100 | 113 | |

Table 11-2.1: EDS analyses for sample 9958a.

| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | V2O5 | ZnO | BaO | WO3 | Total | Actual Total | Calculated Wt % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958a | 11 | 5 | Scp | 57.58 | | 21.64 | | | 6.04 | 10.28 | 0.73 | | | | 3.72 | | | | | 100 | 117 | |
| 9958a | 11 | 6 | Scp | 57.66 | | 21.62 | | | 5.89 | 10.38 | 0.70 | | | | 3.75 | | | | | 100 | 119 | |
| 9958a | 12 | 1 | Scp | 57.93 | | 22.01 | | | 5.92 | 10.28 | 0.48 | | | | 3.38 | | | | | 100 | 115 | |
| 9958a | 12 | 2 | Scp | 57.91 | | 21.54 | | | 5.58 | 10.41 | 0.77 | | | | 3.80 | | | | | 100 | 117 | |
| 9958a | 12 | 3 | Act | 55.57 | 0.24 | 2.40 | 9.08 | 17.68 | 11.53 | 0.49 | | | | | | | | | | 97 | 112 | |
| 9958a | 12 | 4 | Scp | 57.69 | | 21.71 | | | 6.05 | 10.25 | 0.62 | | | | 3.69 | | | | | 100 | 116 | |
| 9958a | 13 | 1 | Anl | 59.01 | | 20.37 | | | | 11.61 | | | | | | | | | | 91 | 103 | |
| 9958a | 13 | 2 | Qz | 99.82 | | | | | 0.18 | | | | | | | | | | | 100 | 118 | |
| 9958a | 13 | 3 | Zo | 47.87 | | 24.93 | | | 26.26 | 0.51 | | | | | 0.43 | | | | | 100 | 108 | |
| 9958a | 13 | 4 | Ttn | 33.14 | 36.29 | 1.31 | 1.24 | | 28.02 | | | | | | | | | | | 100 | 110 | |
| 9958a | 13 | 5 | Scp | 58.23 | 0.27 | 1.97 | 7.77 | 19.21 | 12.11 | 0.44 | | | | | | | | | | 100 | 112 | |
| 9958a | 14 | 1 | Scp | 56.91 | | 22.37 | | | 7.44 | 9.35 | 0.72 | | | | 3.21 | | | | | 100 | 117 | |
| 9958a | 14 | 2 | Qz + Scp | 85.33 | | 8.62 | | | 0.56 | 5.18 | | | | | 0.31 | | | | | 100 | 120 | |
| 9958a | 14 | 3 | Scp | 57.16 | | 22.17 | | | 7.19 | 9.53 | 0.71 | | | | 3.24 | | | | | 100 | 116 | |
| 9958a | 14 | 4 | Qz | 100.00 | | | | | | | | | | | | | | | | 100 | 119 | |
| 9958a | 14 | 5 | Ap | 0.93 | | | | | 48.78 | 0.56 | 0.18 | 38.61 | 1.96 | 7.47 | | | | | 1.50 | 100 | 120 | |
| 9958a | 14 | 6 | Kfs | 66.07 | | 17.96 | | | | 0.43 | 15.54 | | | | | | | | | 100 | 114 | |
| 9958a | 14 | 7 | Zo | 48.48 | | 25.34 | | | 25.81 | 0.37 | | | | | | | | | | 100 | 107 | |
| 9958a | 14 | 8 | Lm | 0.73 | | | 99.27 | | | | | | | | | | | | | 100 | 93 | 78 |
| 9958a | 14 | 9 | Anl | 56.94 | | 21.47 | | | 0.65 | 11.64 | | | | | 0.31 | | | | | 91 | 103 | |
| 9958a | 14 | 10 | Ab | 67.85 | | 19.44 | | | 1.14 | 11.17 | | | | | 0.40 | | | | | 100 | 116 | |
| 9958a | 14 | 11 | Zo | 47.64 | | 25.17 | | | 27.19 | | | | | | | | | | | 100 | 110 | |
| 9958a | 14 | 12 | Zo | 47.88 | | 25.22 | | | 26.91 | | | | | | | | | | | 100 | 111 | |
| 9958a | 14 | 13 | Anl | 59.61 | | 20.11 | | | 0.18 | 11.09 | | | | | | | | | | 91 | 104 | |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Oxide total | | | | | | | | | | | | | | | | | |
| | | | | Mag = | >90% | | | | | | | Average quartz total = 119 | | | | | | | | | | |
| | | | | Hem = | 85-89% | | | | | | | | | | | | | | | | | |
| | | | | Gth = | 80-84% | | | | | | | Oxide total = (wt % oxide / Avg. Qz total) * 100 | | | | | | | | | | |
| | | | | Lm = | <80% | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Notes | | | | | | | | | | | | | | | | | |
| | | | | + = indicates other minerals present | | | | | | | | | | | | | | | | | | |

# Appendix 11-3: SEM-BSE images and EDS mineral analyses for sample 9958b.

**Sample 9958b**

**Host: Altered Diorite**

Magmatic minerals seen: Hornblende, K-feldspar, quartz, albite

Minor and alteration minerals: albite, apatite, chlorite, Fe-hydroxides, kaolinite, titanite, zircon

**Types of Alteration (probably from early to late):**

a) Hornblende → actinolite

b) Albite

**Types of Veins**

a) Scapolite + analcime

b) Quartz + epidote

**Notes:**

1. Analcime usually is found along scapolite grain boundaries or interstitially between scapolite grains (Fig. 11-3.7). It has also replaced K-feldspar (Fig. 11-3.11).

2. There is a difference in grain size for scapolite that is cut by quartz + epidote vein (Fig. 11-3.7). The size difference appears to be due to cataclastic deformation of the site.

3. There seems to be mineral brecciation along the contact between scapolite vein and epidotized host diorite (Fig. 11-3.3). The mineral textures from this figure suggest that the epidote veins postdate the scapolite + analcime veins and their intrusion was accompanied by brecciation.

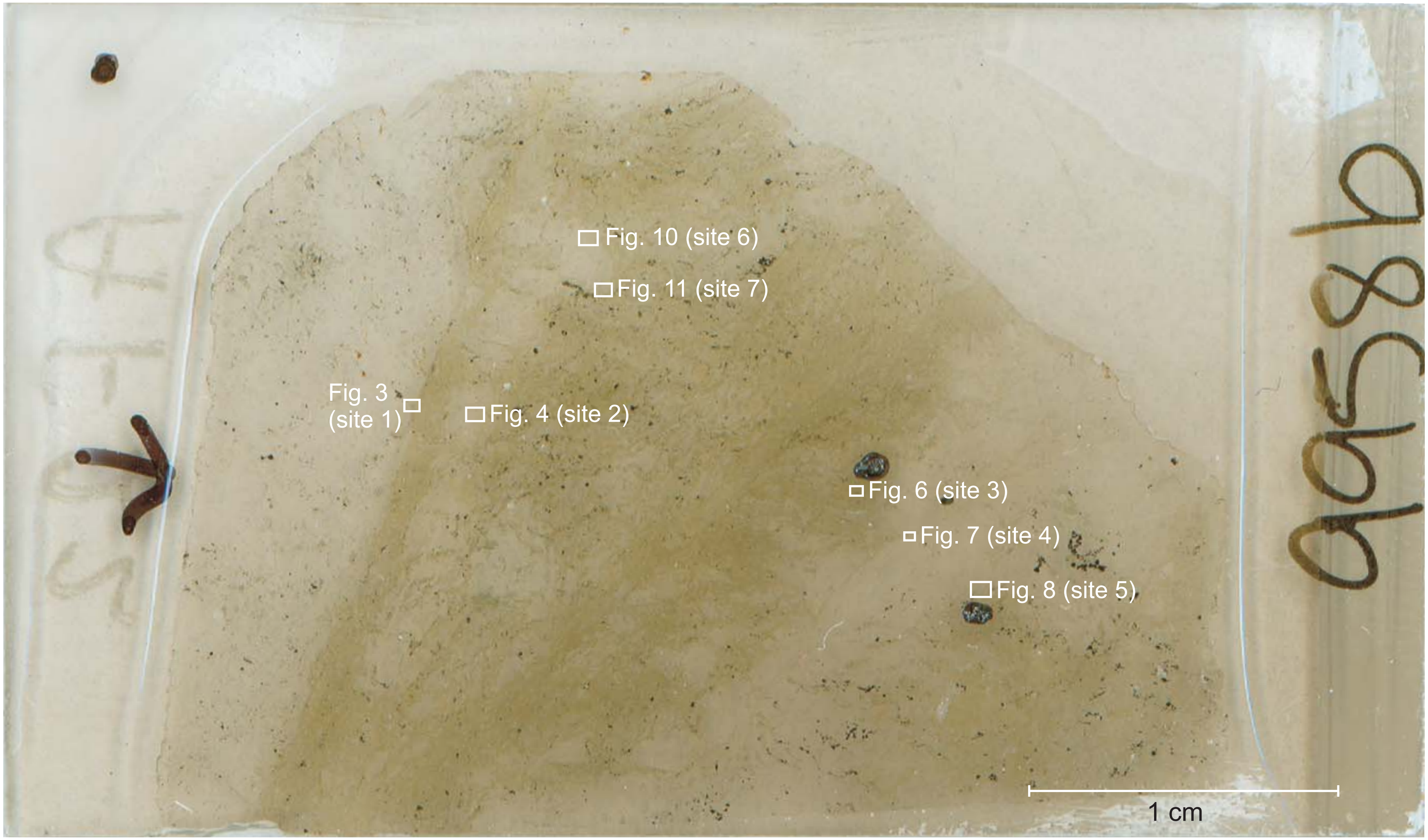



Figure 11-3.1: Scanned thin section of sample 9958b showing the location of analyzed site. This sample is a mafic rock (diorite) from a rockfall. This mafic rock is cut by scapolite veins and patches.

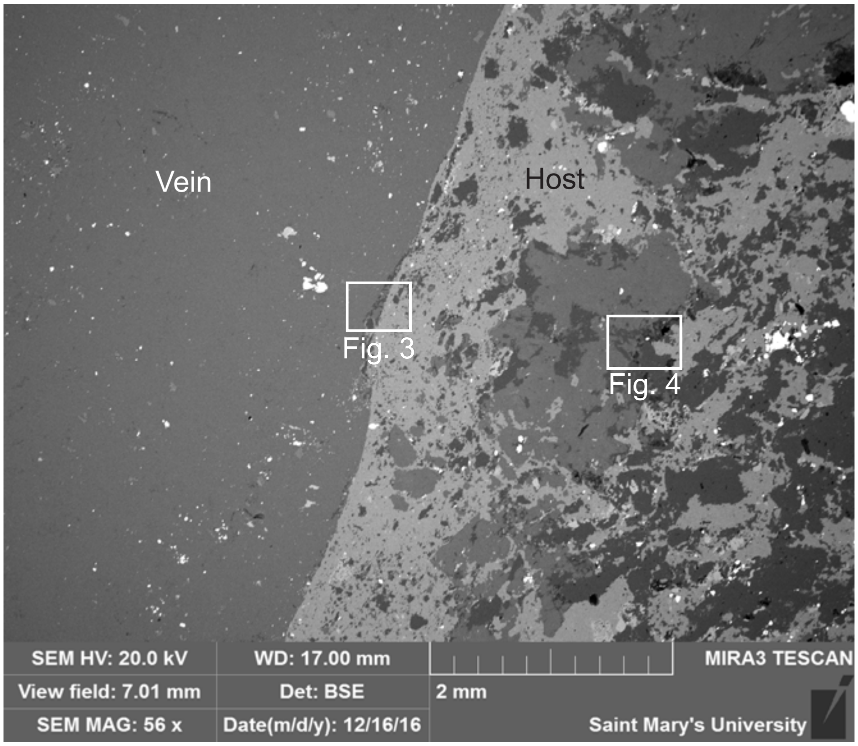



Figure 11-3.2: Sample 9958b (SEM).

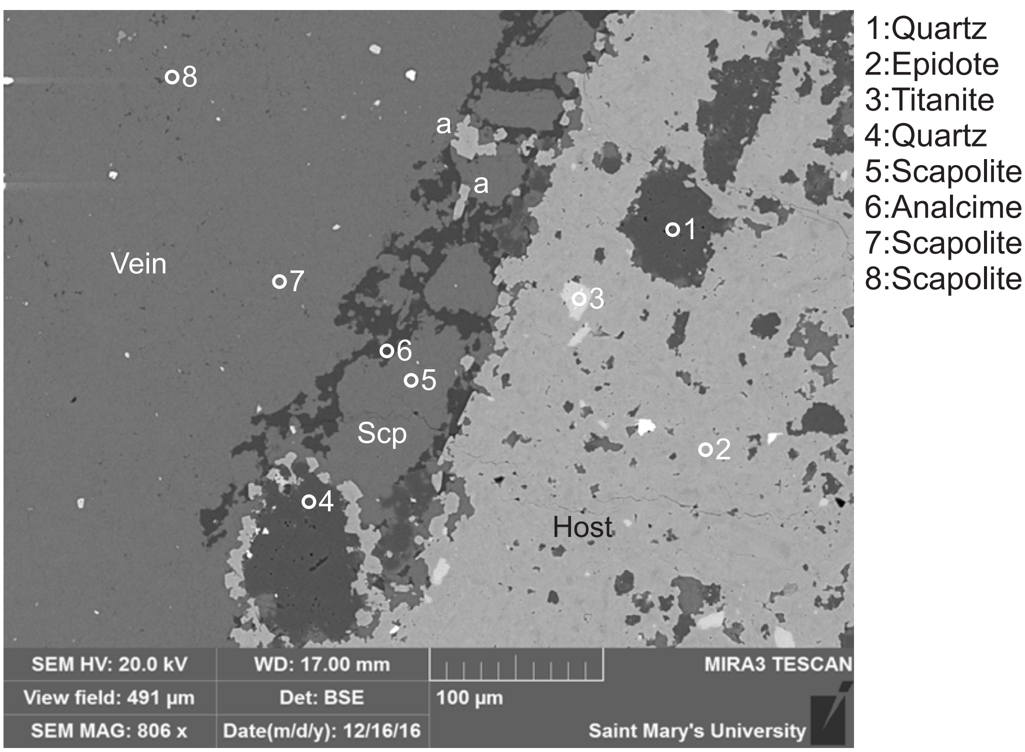



Figure 11-3.3: Sample 9958b site 1 (SEM). This site consists of a scapolite vein (7,8) cutting the host diorite that is epidotized (2). Quartz (4) appears to predate epidote. This quartz and brecciated scapolite (5) form a zone along the contact of the scapolite vein and the epidotized diorite. The scapolite fragments are mostly rimmed by analcime (6) and the quartz (4) by epidote, although some epidote grains also occur on the rims of the scapolite (position a). Titanite (3) postdates epidote and quartz due to cross-cutting them.

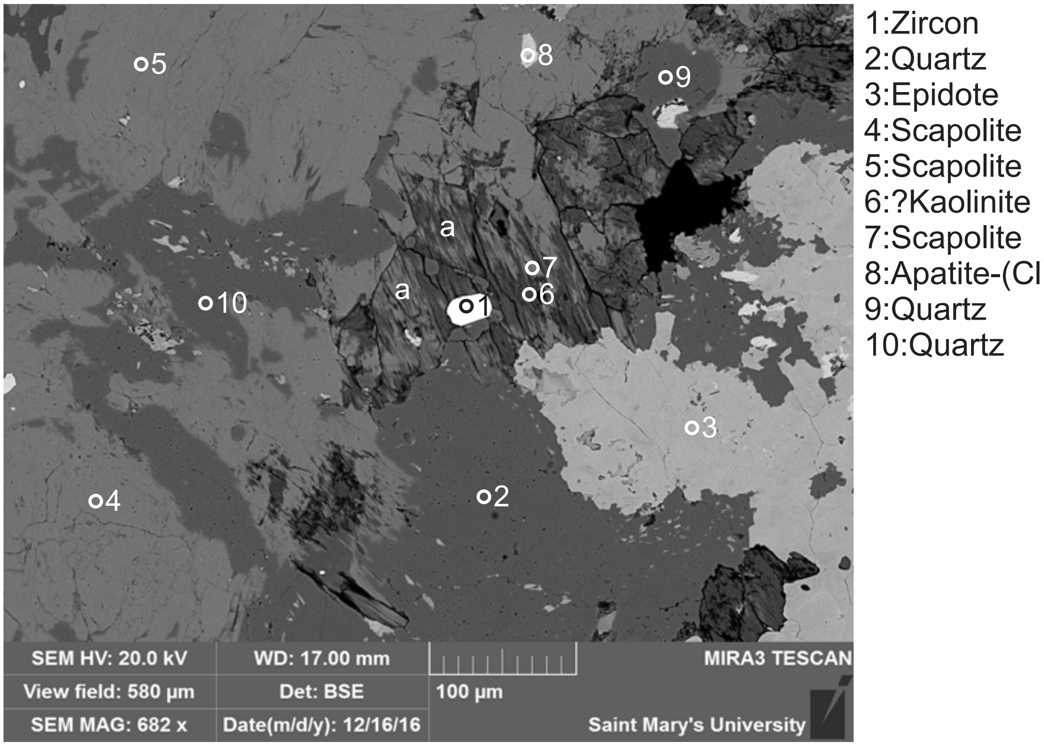



Figure 11-3.4: Sample 9958b site 2 (SEM). Quartz (2,9-10) appears to predate or co-precipitate with epidote (3). Scapolite (7) and analcime (6) appear to be replacing a relic amphibole crystal, judging from the crystal outline and cleavage of the precursor mineral (positions a) (see also Fig. 11-3.10).. Euhedral zircon (1) crystal appears to postdate scapolite and analcime.

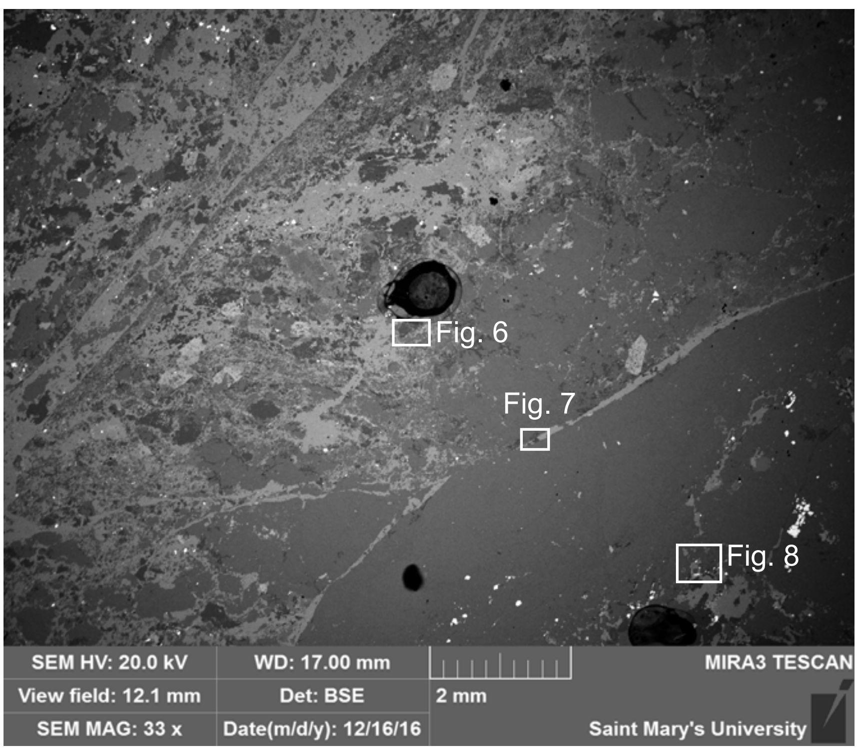



Figure 11-3.5: Sample 9958b (SEM).

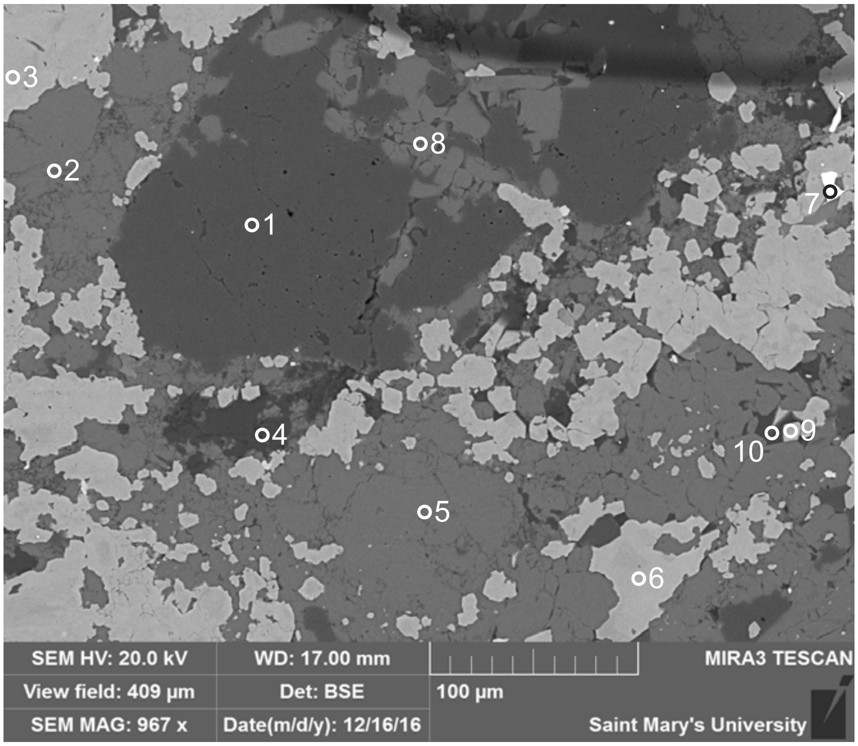



Figure 11-3.6: Sample 9958b site 3 (SEM). This site consists of quartz (1), epidote (3,6,9), scapolite (2,5,8,10), analcime (4), and limonite (7). Analcime occurs along scapolite grain boundaries or interstitially.

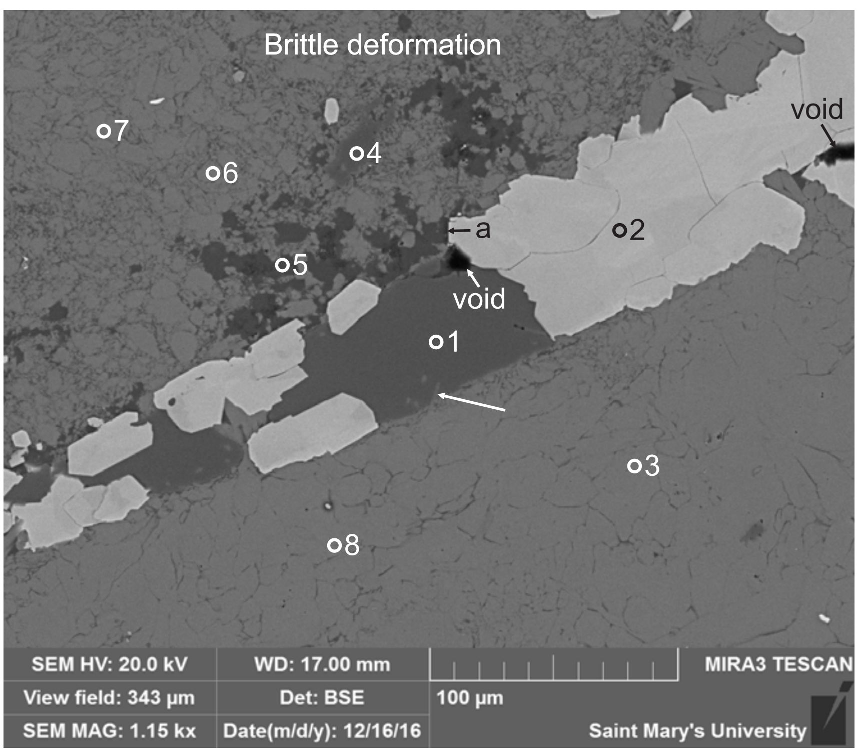
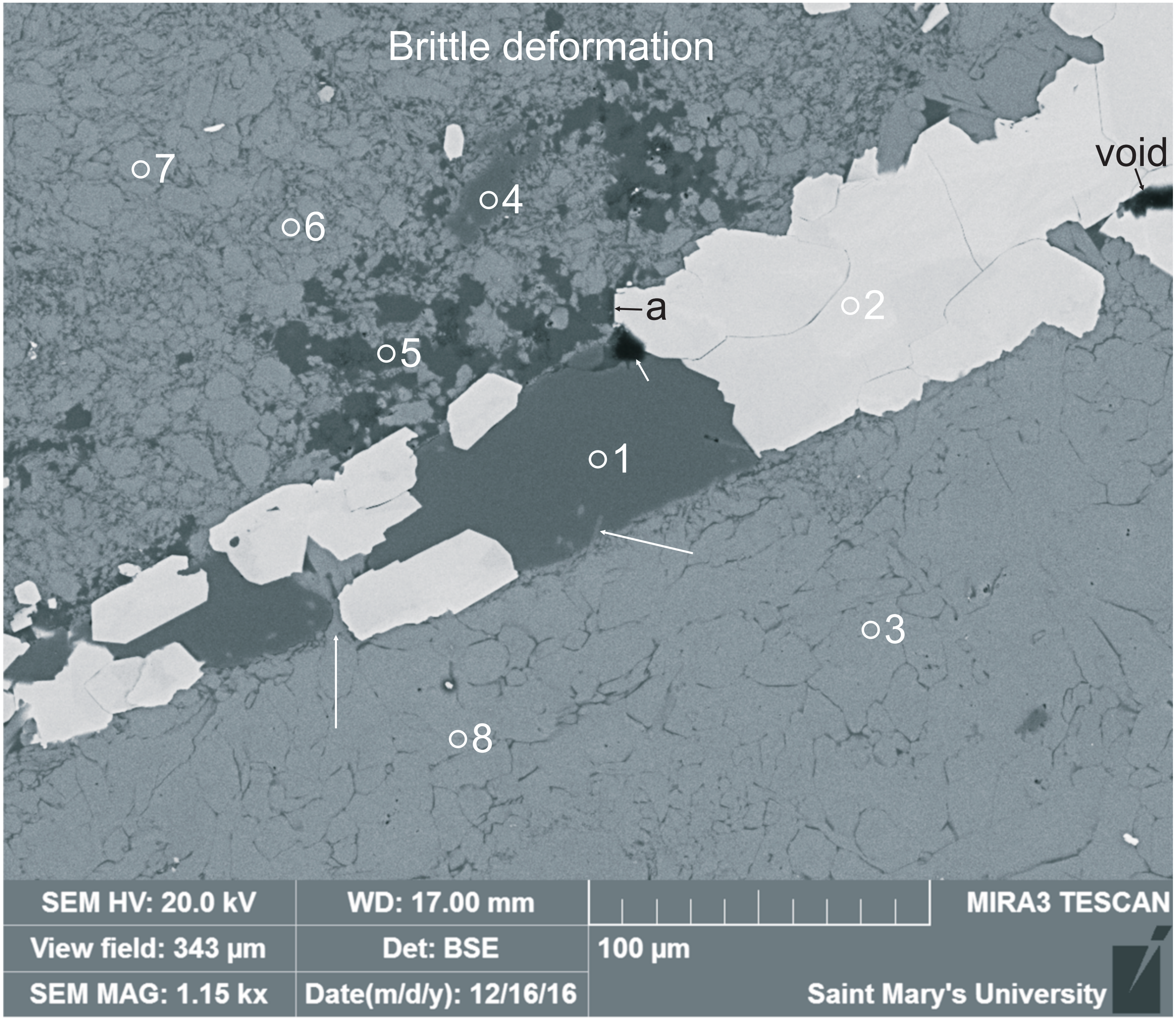



Figure 11-3.7: Sample 9958b site 4 (SEM). Cataclastic deformation of scapolite. Linear vein of quartz + epidote along fracture. Late mobility of some scapolite (arrows) cuts the vein. Analcime seems to predate vein (postion a).




1:Quartz
2:Epidote
3:Scapolite
4:Quartz
5:Analcime
6:Scapolite
7:Scapolite
8:Scapolite

Figure 11-3.7a: Sample 9958b site 4 (SEM). Cataclastic deformation of scapolite. Linear vein of quartz + epidote along fracture. Late mobility of some scapolite (arrows) cuts the vein. Analcime seems to predate vein (postion a).

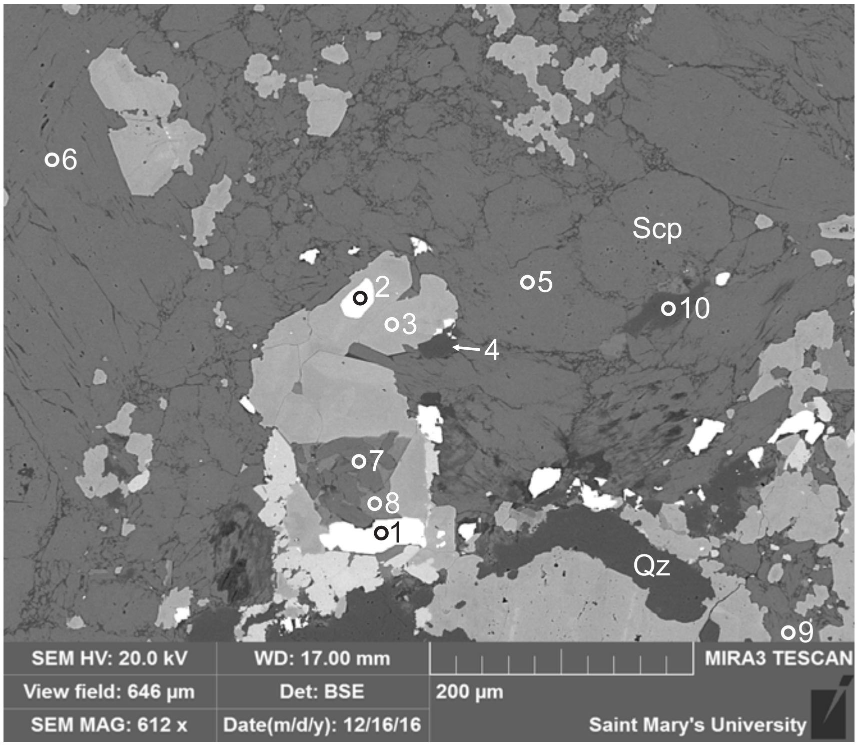



Figure 11-3.8: Sample 9958b site 5 (SEM). Scapolite (5-6,9) appears as large grains probably with analcime occurring along grain boundaries. Quartz (4) appears to be postdating or co-precipitating with epidote, and albite (10) appears to be invading scapolite and analcime. Fe-oxides/hydroxides are the latest minerals to form.

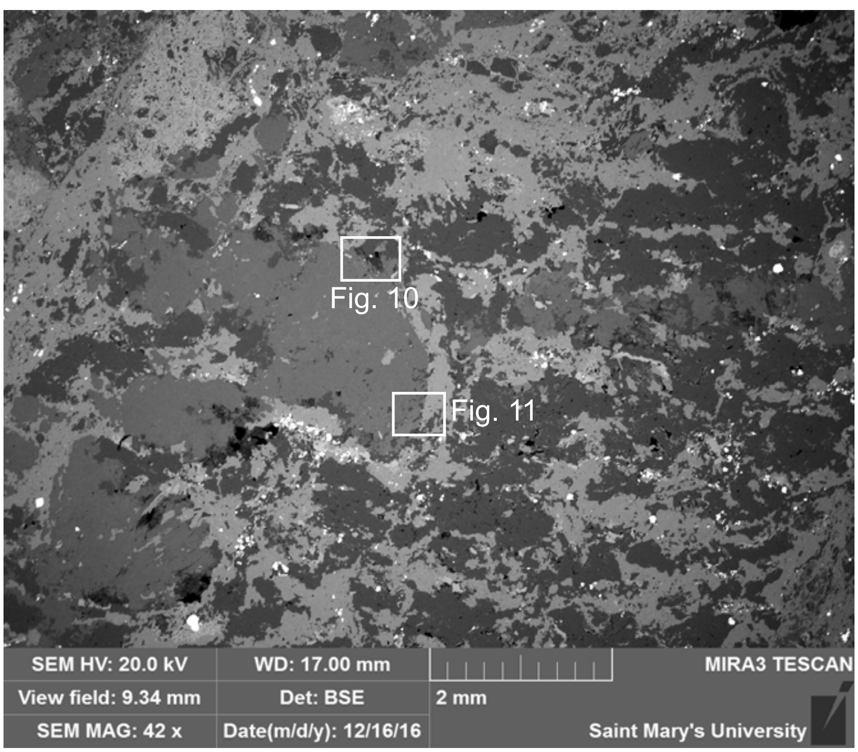
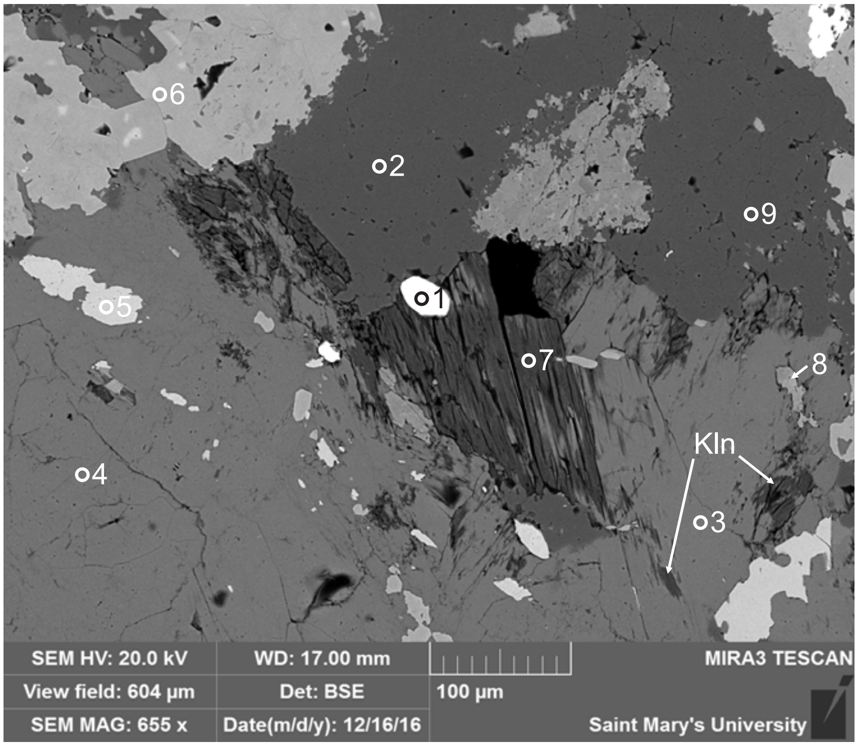
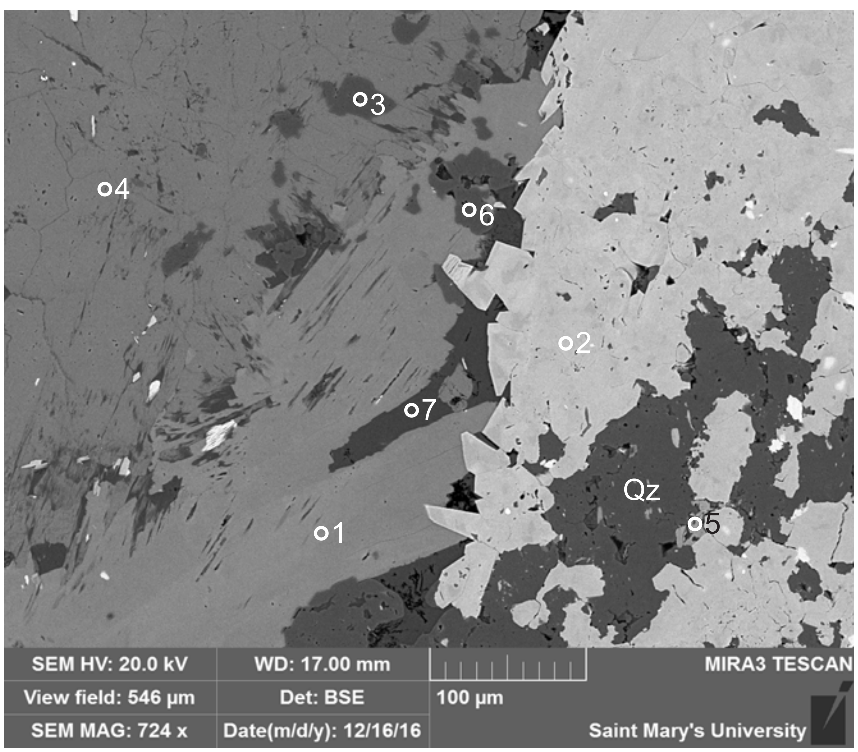



Figure 11-3.9: Sample 9958b (SEM).




1:Zircon
2:Quartz
3:Scapolite
4:Scapolite
5:Titanite
6:Epidote
7:Kaolinite
8:Hornblende
9:Quartz

Figure 11-3.10: Sample 9958b site 6 (SEM). Relic hornblende (8) occurs in scapolite (3-4) patch. Kaolinite (7) appears to be replacing scapolite. Quartz (2,9) appears to be predating epidote.




1:K-feldspar
2:Epidote
3:Quartz
4:Scapolite
5:Actinolite
6:Quartz
7:Analcime

Figure 11-3.11: Sample 9958b site 7 (SEM). This site consists of relic K-feldspar (1), that is being cross-cut by epidote (2). Scapolite and analcime appear to be replacing K-feldspar. Relic actinolite (5) appears to have been replaced by epidote. Epidote appears to be replacing or co-precipitating with quartz (6).

Table 11-3.1: EDS analyses of sample 9958b.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | Cl | ZrO2 | BaO | WO3 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958b | 1 | 1 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 121 | |
| 9958b | 1 | 2 | Ep | 40.99 | | 24.40 | 9.82 | | | 21.80 | | | | | | | | | 97 | 109 | |
| 9958b | 1 | 3 | Ttn | 33.11 | 36.16 | 1.99 | 0.85 | | | 27.90 | | | | | | | | | 100 | 112 | |
| 9958b | 1 | 4 | Qz | 99.47 | | | 0.32 | | | 0.21 | | | | | | | | | 100 | 121 | |
| 9958b | 1 | 5 | Scp | 57.43 | | 22.06 | | | | 6.12 | 10.24 | 0.52 | | | 3.63 | | | | 100 | 118 | |
| 9958b | 1 | 6 | Anl | 60.08 | | 20.34 | | | | | 10.58 | | | | | | | | 91 | 100 | |
| 9958b | 1 | 7 | Scp | 58.05 | | 22.04 | | | | 5.90 | 9.69 | 0.67 | | | 3.64 | | | | 100 | 116 | |
| 9958b | 1 | 8 | Scp | 57.65 | | 21.86 | | | | 5.90 | 10.47 | 0.56 | | | 3.56 | | | | 100 | 116 | |
| 9958b | 2 | 1 | Zrn | 31.43 | | | | | | | | | | | | 68.57 | | | 100 | 121 | |
| 9958b | 2 | 2 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 122 | |
| 9958b | 2 | 3 | Ep | 40.26 | | 23.67 | 10.49 | | | 22.58 | | | | | | | | | 97 | 111 | |
| 9958b | 2 | 4 | Scp | 57.18 | | 22.30 | | | | 6.78 | 9.82 | 0.60 | | | 3.32 | | | | 100 | 116 | |
| 9958b | 2 | 5 | Scp | 57.08 | | 22.06 | | | | 6.71 | 10.05 | 0.52 | | | 3.57 | | | | 100 | 115 | |
| 9958b | 2 | 6 | ?Kln | 63.39 | | 27.01 | 1.35 | | 4.75 | 1.60 | 0.59 | 1.11 | | | 0.19 | | | | 100 | 96 | |
| 9958b | 2 | 7 | Scp | 57.61 | | 21.76 | | | | 5.67 | 10.37 | 0.63 | | | 3.96 | | | | 100 | 118 | |
| 9958b | 2 | 8 | Ap-(Cl) | | | | | | | 47.67 | 1.36 | | 42.75 | 3.11 | 3.50 | | | 1.61 | 100 | 111 | |
| 9958b | 2 | 9 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 119 | |
| 9958b | 2 | 10 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 120 | |
| 9958b | 3 | 1 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 120 | |
| 9958b | 3 | 2 | Scp | 57.72 | | 21.74 | | | | 5.98 | 10.35 | 0.50 | | | 3.71 | | | | 100 | 116 | |
| 9958b | 3 | 3 | Ep | 39.55 | | 23.77 | 10.77 | | | 22.42 | | | 0.49 | | | | | | 97 | 108 | |
| 9958b | 3 | 4 | Anl | 59.45 | | 20.57 | 0.48 | | 1.36 | 0.33 | 8.82 | | | | | | | | 91 | 99 | |
| 9958b | 3 | 5 | Scp | 57.77 | | 22.16 | | | | 5.91 | 10.41 | 0.43 | | | 3.32 | | | | 100 | 117 | |
| 9958b | 3 | 6 | Ep | 40.03 | | 23.02 | 11.39 | | | 22.57 | | | | | | | | | 97 | 111 | |
| 9958b | 3 | 7 | Lm | | | | 99.38 | | | 0.62 | | | | | | | | | 100 | 95 | 79 |
| 9958b | 3 | 8 | Scp | 57.97 | | 21.83 | | | | 6.50 | 9.92 | 0.46 | | | 3.32 | | | | 100 | 116 | |
| 9958b | 3 | 9 | Ep | 39.92 | | 23.38 | 11.26 | | | 22.45 | | | | | | | | | 97 | 111 | |
| 9958b | 3 | 10 | Scp | 59.02 | | 22.01 | 2.58 | | | 6.15 | 10.25 | | | | | | | | 100 | 104 | |
| 9958b | 4 | 1 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 120 | |
| 9958b | 4 | 2 | Ep | 40.09 | | 23.67 | 10.80 | | | 22.45 | | | | | | | | | 97 | 108 | |
| 9958b | 4 | 3 | Scp | 57.57 | | 21.88 | | | | 6.25 | 10.03 | 0.66 | | | 3.61 | | | | 100 | 118 | |
| 9958b | 4 | 4 | Qz | 99.49 | | | | | | 0.18 | 0.34 | | | | | | | | 100 | 119 | |
| 9958b | 4 | 5 | Anl | 60.75 | | 20.12 | | | | | 10.13 | | | | | | | | 91 | 95 | |

# Table 11-3.1: EDS analyses of sample 9958b.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | Cl | ZrO2 | BaO | WO3 | Total | Actual Total | Calculated Wt% Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9958b | 4 | 6 | Scp | 57.64 | | 21.85 | | | | 5.92 | 10.22 | 0.60 | | | 3.77 | | | | 100 | 116 | |
| 9958b | 4 | 7 | Scp | 57.77 | | 21.74 | | | | 5.96 | 10.31 | 0.49 | | | 3.73 | | | | 100 | 116 | |
| 9958b | 4 | 8 | Scp | 57.63 | | 21.80 | | | | 6.04 | 10.17 | 0.66 | | | 3.69 | | | | 100 | 118 | |
| 9958b | 5 | 1 | Gth | 0.57 | | | 99.43 | | | | | | | | | | | | 100 | 98 | 81 |
| 9958b | 5 | 2 | Lm | | | | 99.59 | | | 0.41 | | | | | | | | | 100 | 95 | 79 |
| 9958b | 5 | 3 | Ep | 39.93 | | 23.28 | 11.23 | | | 22.55 | | | | | | | | | 97 | 110 | |
| 9958b | 5 | 4 | Qz | 99.75 | | | 0.25 | | | | | | | | | | | | 100 | 122 | |
| 9958b | 5 | 5 | Scp | 57.64 | | 21.49 | | | | 5.48 | 10.65 | 0.69 | | | 4.05 | | | | 100 | 120 | |
| 9958b | 5 | 6 | Scp | 57.14 | | 22.52 | | | | 6.92 | 9.74 | 0.45 | | | 3.23 | | | | 100 | 114 | |
| 9958b | 5 | 7 | Scp | 57.39 | | 21.73 | 0.39 | | | 6.73 | 9.92 | 0.50 | | | 3.34 | | | | 100 | 118 | |
| 9958b | 5 | 8 | Chl | 29.06 | | 18.21 | 18.62 | 0.23 | 18.89 | | | | | | | | | | 85 | 101 | |
| 9958b | 5 | 9 | Scp | 57.67 | | 21.47 | | | | 5.44 | 10.43 | 0.95 | | | 4.03 | | | | 100 | 122 | |
| 9958b | 5 | 10 | Ab | 69.38 | | 18.81 | | | | 0.20 | 11.60 | | | | | | | | 100 | 120 | |
| 9958b | 6 | 1 | Zrn | 31.33 | | | | | | | | | | | | 68.67 | | | 100 | 116 | |
| 9958b | 6 | 2 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 119 | |
| 9958b | 6 | 3 | Scp | 57.08 | | 21.59 | | | | 5.61 | 10.40 | 0.80 | | 0.46 | 4.06 | | | | 100 | 120 | |
| 9958b | 6 | 4 | Scp | 57.03 | | 22.30 | | | | 6.99 | 9.90 | 0.45 | | | 3.34 | | | | 100 | 116 | |
| 9958b | 6 | 5 | Ttn | 32.92 | 36.87 | 1.60 | 0.62 | | | 27.99 | | | | | | | | | 100 | 109 | |
| 9958b | 6 | 6 | Ep | 39.93 | | 23.74 | 10.67 | | | 22.66 | | | | | | | | | 97 | 107 | |
| 9958b | 6 | 7 | Kln | 60.94 | | 31.05 | 0.89 | | 4.11 | 1.15 | 0.71 | 0.96 | | | 0.20 | | | | 100 | 97 | |
| 9958b | 6 | 8 | Hb | 52.17 | | 5.79 | 11.79 | 0.25 | 14.26 | 11.82 | 0.67 | 0.25 | | | | | | | 97 | 108 | |
| 9958b | 6 | 9 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 119 | |
| 9958b | 7 | 1 | Kfs | 65.56 | | 17.88 | | | | | | 15.54 | | | | | 1.03 | | 100 | 118 | |
| 9958b | 7 | 2 | Ep | 40.19 | | 23.24 | 11.25 | | | 22.32 | | | | | | | | | 97 | 110 | |
| 9958b | 7 | 3 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 119 | |
| 9958b | 7 | 4 | Scp | 57.48 | | 21.85 | | | | 6.01 | 10.26 | 0.62 | | | 3.78 | | | | 100 | 116 | |
| 9958b | 7 | 5 | Act | 56.42 | | 2.05 | 8.90 | | 17.69 | 11.94 | | | | | | | | | 97 | 113 | |
| 9958b | 7 | 6 | Qz | 100.00 | | | | | | | | | | | | | | | 100 | 119 | |
| 9958b | 7 | 7 | Anl | 60.36 | | 20.19 | | | | | 10.45 | | | | | | | | 91 | 100 | |

Notes as in Table 11-3.1

# Appendix 11-4: SEM-BSE images and EDS mineral analyses for sample 9959.

**Sample 9959**

**Host: Altered Diorite**

Magmatic minerals seen: quartz, biotite

Accessory and alteration minerals: apatite, Fe-oxides/hydroxides, scapolite, titanite, chlorite.

**Types of Veins:**

a) Scapolite

**Notes:**

1. Scapolite appears to be partially replaced by a fine grained clay mineral (Fig. 11-4.9)

2. The host rock contains epidote + quartz, which is most likely postdates the magmatic minerals (see sample 9958a,b).

3. A clay mineral appears to follow along grain boundaries and irregular fractures in the scapolite vein (Fig. 11-4.5).

4) Scapolite postdates quartz + epidote due to cross-cutting them (Fig. 11-4.7).

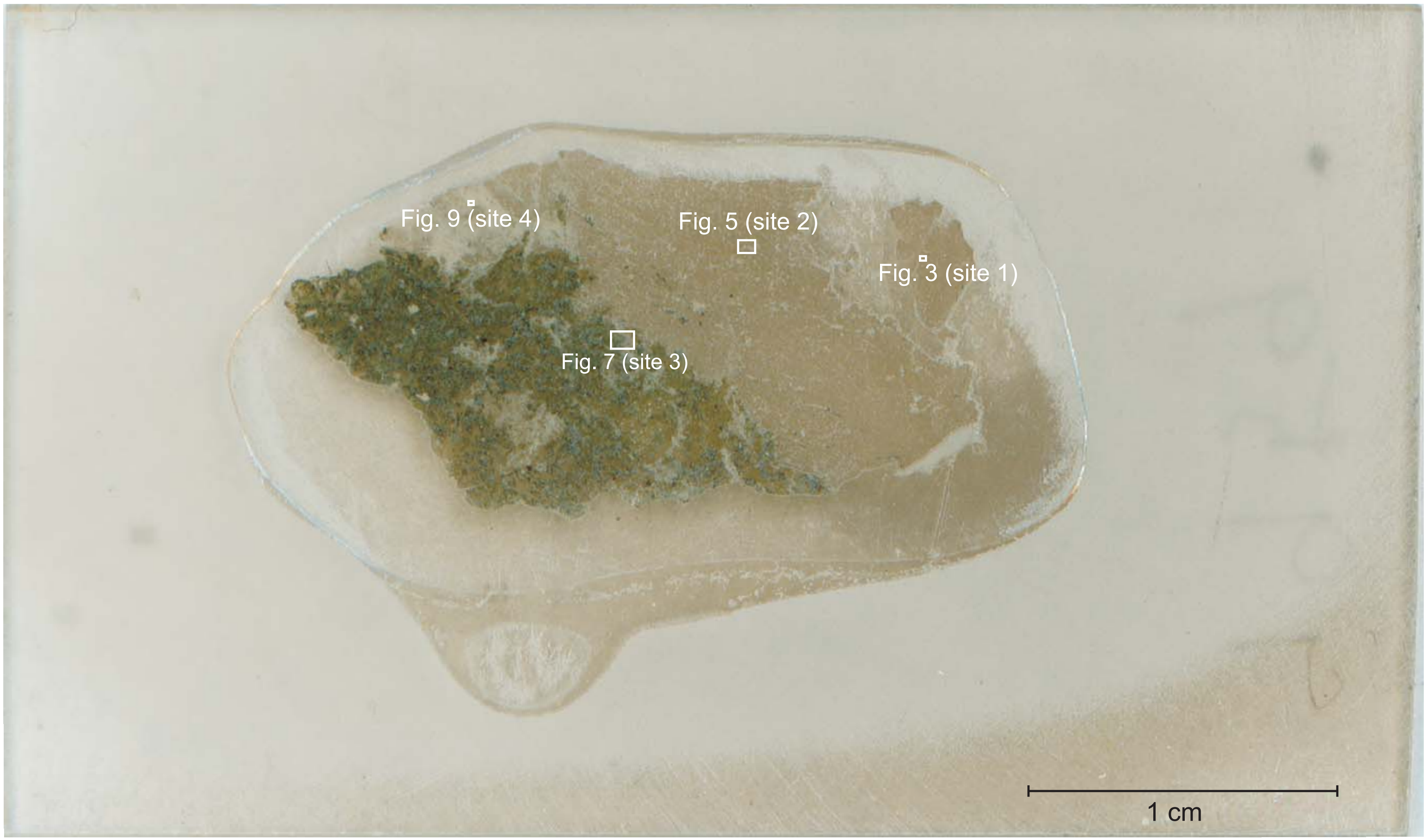



Figure 11-4.1: Scanned thin section of sample 9959 showing the location of analyzed sites. This sample is a mafic rock (diorite) and comes from a rockfall. It contains thin white veins. Some of these veins are deformed, some are planar.

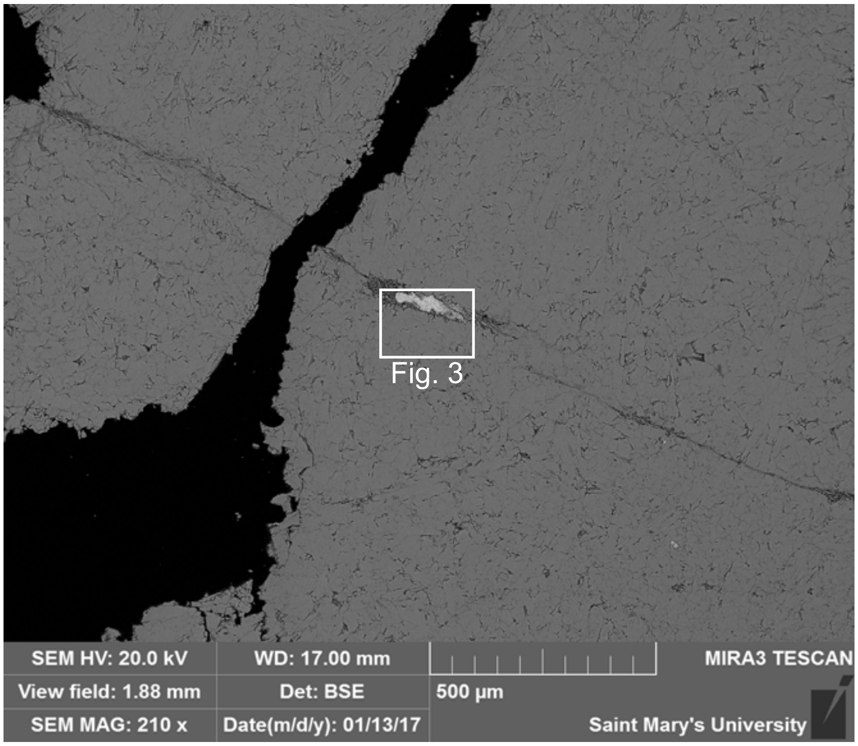
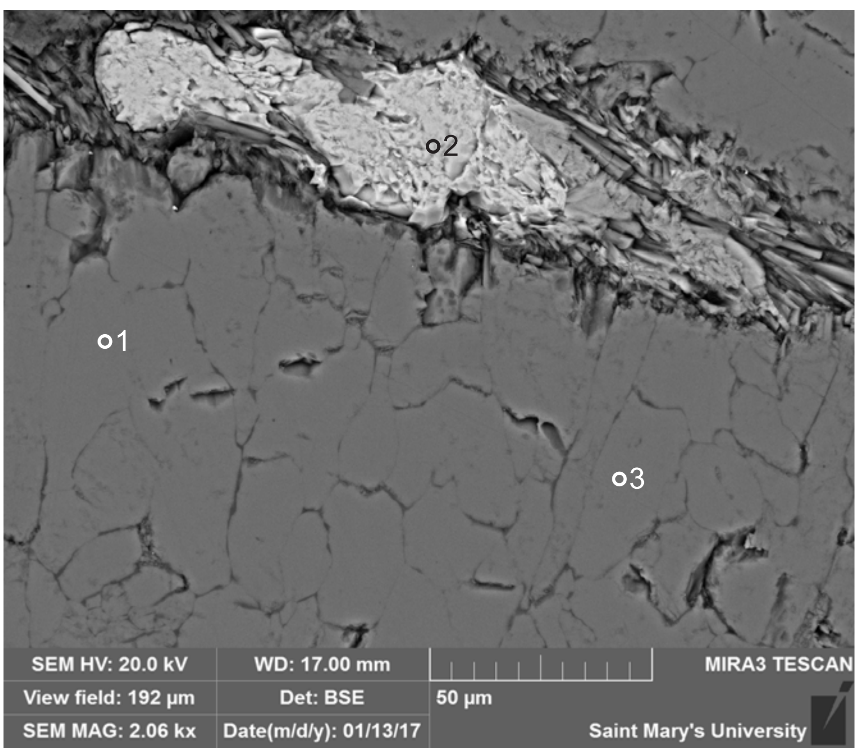



Figure 11-4.2: Sample 9959 (SEM).




1:Scapolite
2:Apatite
3:Scapolite

Figure 11-4.3: Sample 9959 site 1 (SEM). This site consists of scapolite (1,3) and apatite (2).

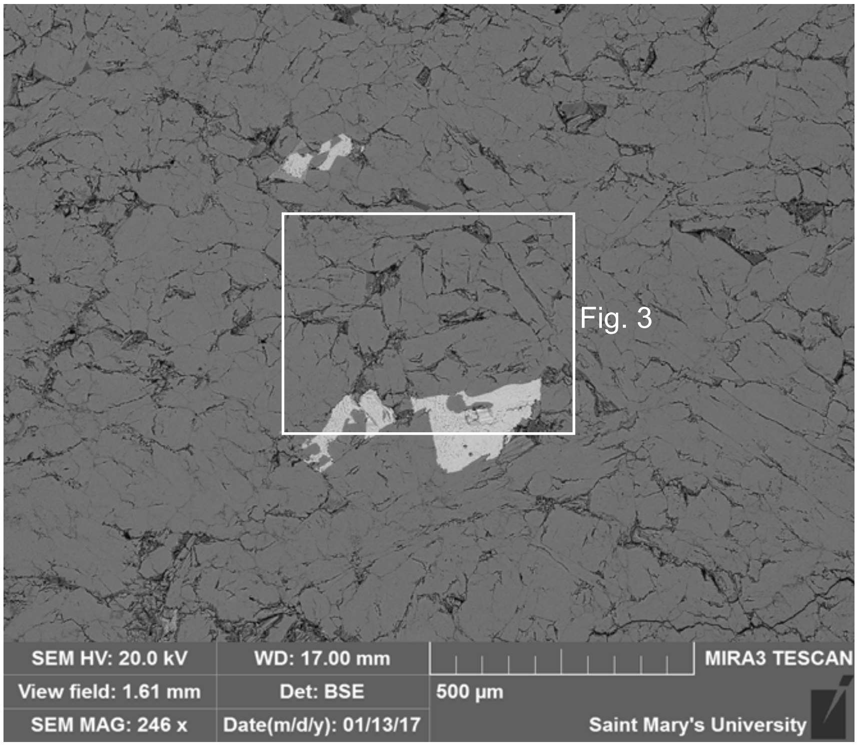
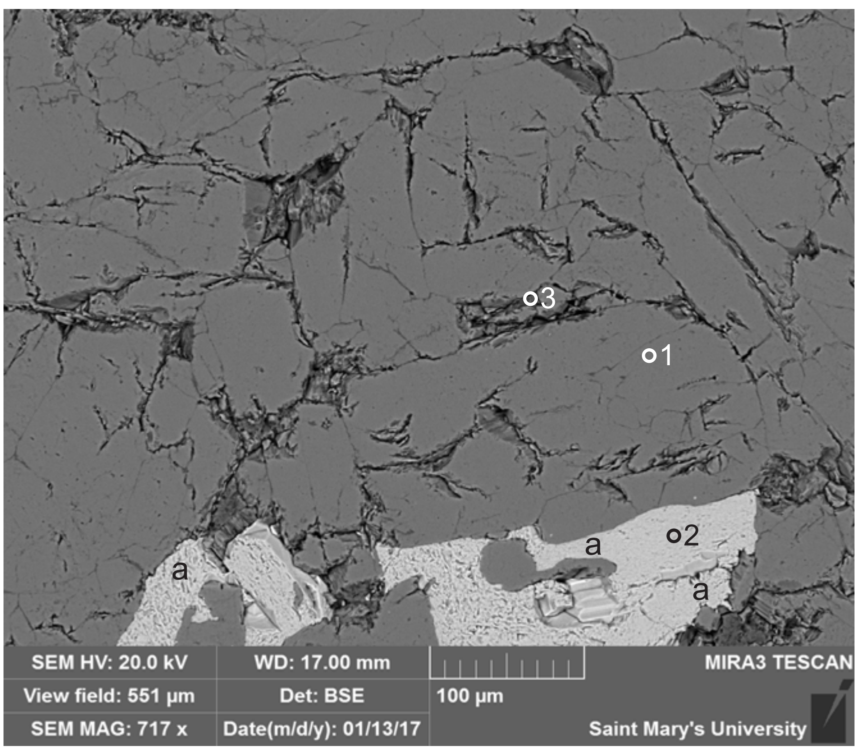



Figure 11-4.4: Sample 9959 (SEM).




1:Scapolite
2:Apatite
3:Clay

Figure 11-4.5: Sample 9959 site 2 (SEM). Apatite (2) appears to cut irregular fractures often along grain boundaries in the scapolite crystals mat (positions a).

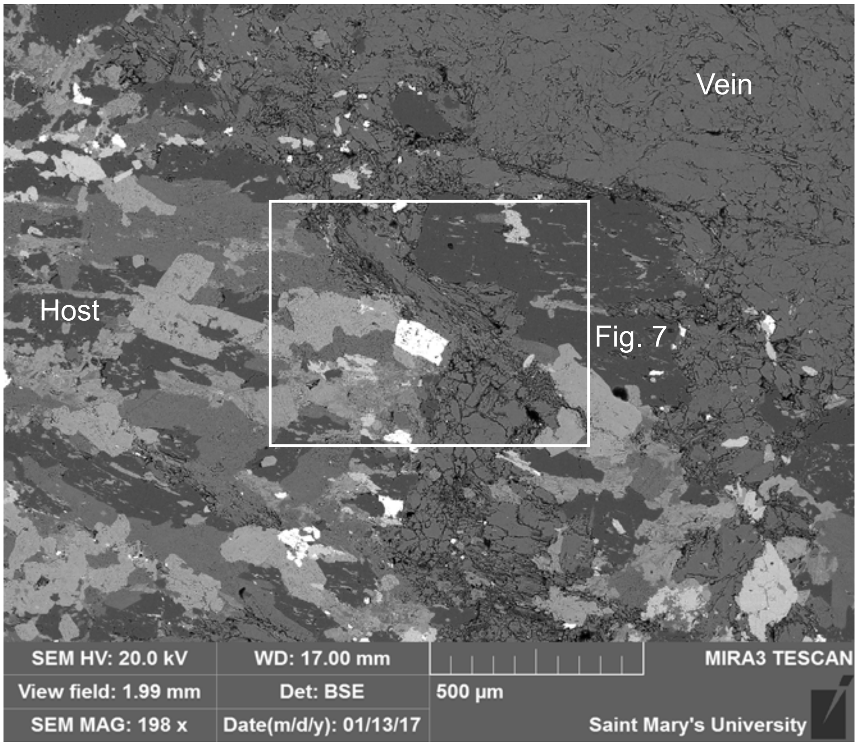
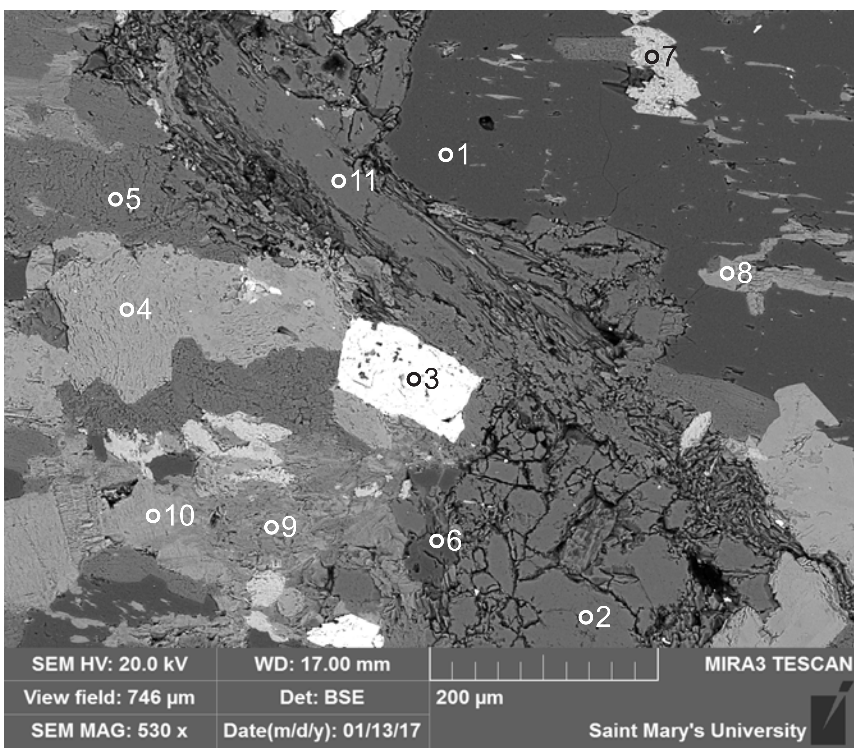



Figure 11-4.6: Sample 9959 (SEM).




1:Quartz
2:Scapolite
3:Goethite
4:Epidote
5:Chlorite
6:Quartz
7:Titanite
8:Biotite
9:Chlorite + Biotite
10:Biotite
11:Scapolite

Figure 11-4.7: Sample 9959 site 3 (SEM). This site consists of host diorite being invaded by scapolite (2,11). Fe-oxides/hydroxides (3) postdate scapolite due to cross-cutting the host and scapolite. Epidote (4) appears to postdate scapolite. Other minerals present include biotite (8,10), late titanite (7), quartz (1) and chlorite that seems to be replacing biotite (9).

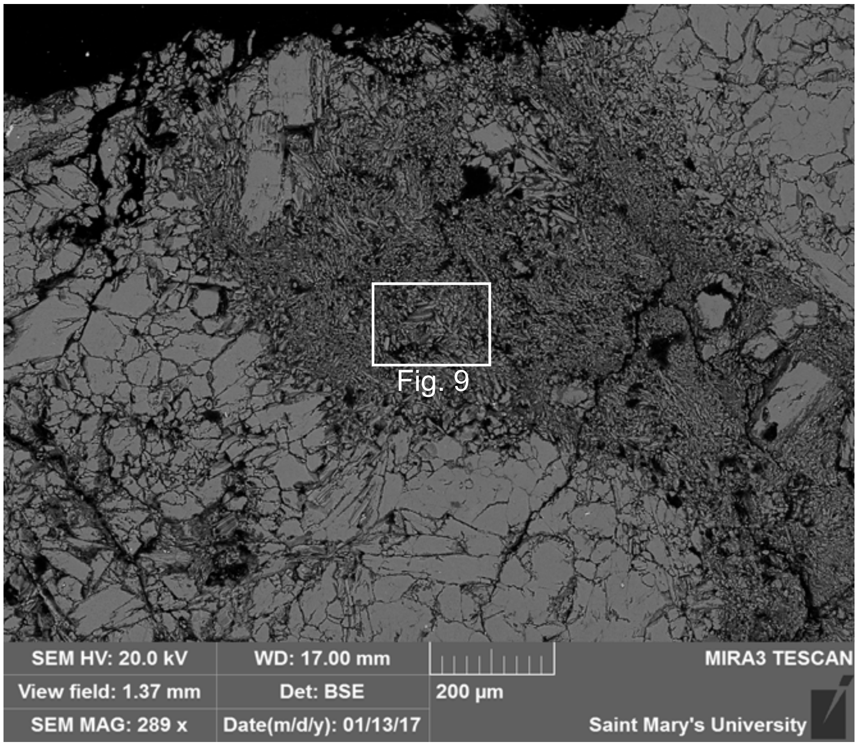
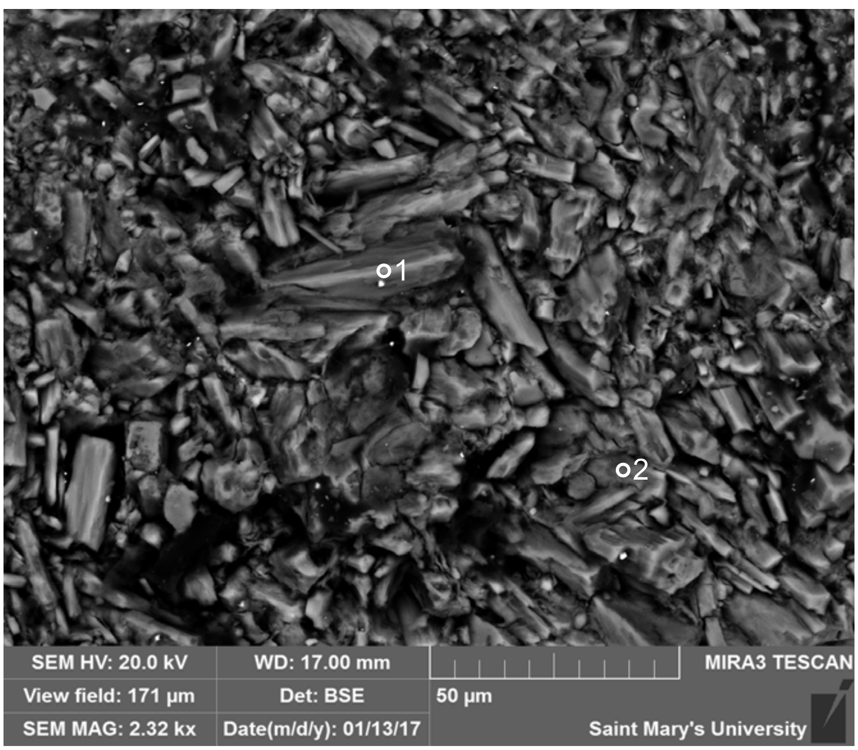



Figure 11-4.8: Sample 9959 (SEM).




1:Scapolite
2:Clay

Figure 11-4.9: Sample 9959 site 4 (SEM). This site consists of a patch of fine grained darker scapolite with a clay mineral.

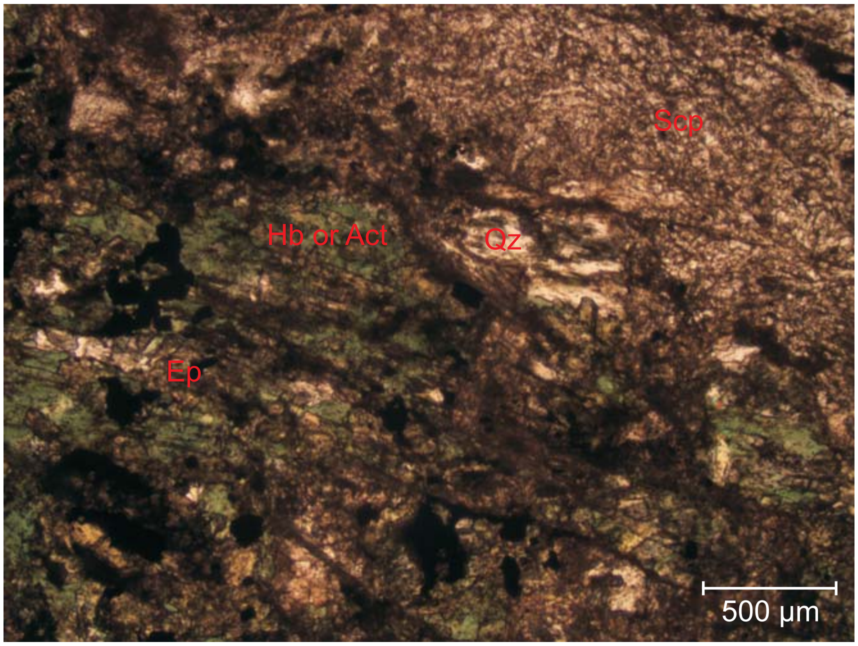


Figure 11-4.10: Microphotograph showing the contact between the scapolite vein and the diorite. 4x ppl.

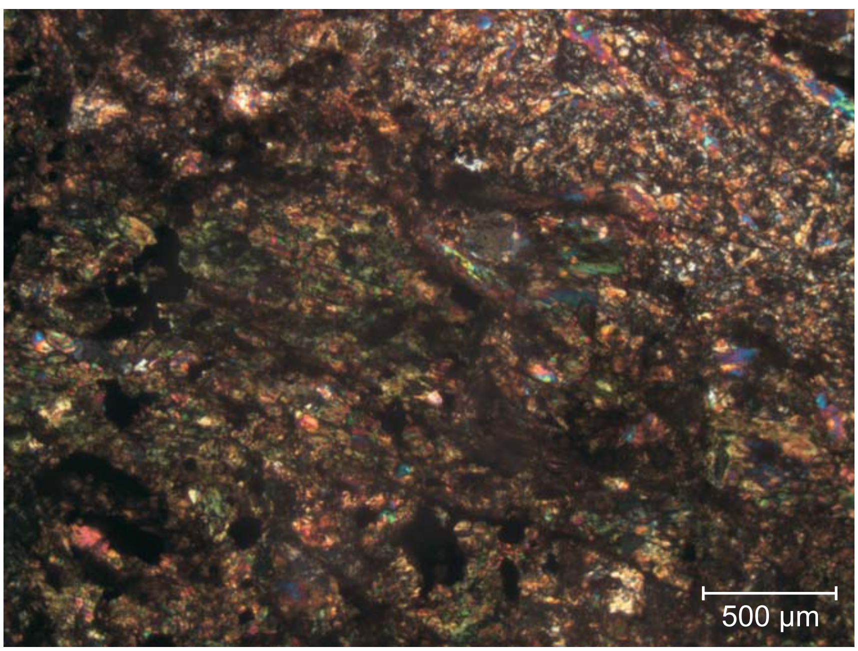


Figure 11-4.11: Same as Figure 11-4.10 but xpl.

Table 11-4.1: EDS analyses from sample 9959.



| Sample | Site | Position | Mineral | SiO2 | TiO2 | Al2O3 | FeO | MnO | MgO | CaO | Na2O | K2O | P2O5 | SO3 | F | Cl | WO3 | Total | Actual Total | Calculated Wt % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9959 | 1 | 1 | Scp | 57.30 | | 22.15 | | | | 6.84 | 9.57 | 0.62 | | | | 3.52 | | 100 | 114 | |
| 9959 | 1 | 2 | Ap | 0.72 | | | | | | 51.22 | 0.86 | | 35.54 | 3.82 | 7.83 | | | 100 | 112 | |
| 9959 | 1 | 3 | Scp | 57.54 | | 22.04 | | | | 6.59 | 9.44 | 0.87 | | | | 3.52 | | 100 | 115 | |
| 9959 | 2 | 1 | Scp | 57.95 | | 21.41 | | | | 5.32 | 10.51 | 0.75 | | | | 4.06 | | 100 | 119 | |
| 9959 | 2 | 2 | Ap | | | | | | | 49.08 | | | 44.37 | | 5.17 | 0.29 | 1.09 | 100 | 126 | |
| 9959 | 2 | 3 | Clay | 63.27 | | 25.65 | 0.81 | | 4.54 | 2.95 | 0.80 | 1.66 | | | | 0.32 | | 100 | 101 | |
| 9959 | 3 | 1 | Qz | 100.00 | | | | | | | | | | | | | | 100 | 117 | |
| 9959 | 3 | 2 | Scp | 57.68 | | 21.34 | | | | 5.86 | 10.39 | 0.53 | | | | 4.20 | | 100 | 115 | |
| 9959 | 3 | 3 | Gth | 0.54 | | | 99.46 | | | | | | | | | | | 100 | 95 | 80 |
| 9959 | 3 | 4 | Ep | 41.42 | | 24.67 | 10.90 | | | 23.01 | | | | | | | | 100 | 105 | |
| 9959 | 3 | 5 | Chl | 28.63 | | 19.69 | 15.19 | | 21.49 | | | | | | | | | 85 | 93 | |
| 9959 | 3 | 6 | Qz | 99.62 | | | 0.38 | | | | | | | | | | | 100 | 120 | |
| 9959 | 3 | 7 | Ttn | 32.76 | 36.58 | 1.80 | 0.74 | | | 28.12 | | | | | | | | 100 | 105 | |
| 9959 | 3 | 8 | Bt | 40.16 | 1.12 | 14.75 | 15.81 | | 14.81 | | | 8.42 | | | | 0.92 | | 96 | 107 | |
| 9959 | 3 | 9 | Chl + Bt | 35.94 | 0.35 | 19.38 | 22.71 | 0.30 | 19.91 | | | 1.43 | | | | | | 100 | 101 | |
| 9959 | 3 | 10 | Bt | 39.62 | 1.55 | 14.79 | 14.54 | | 15.60 | | | 9.16 | | | | 0.74 | | 96 | 108 | |
| 9959 | 3 | 11 | Scp | 57.74 | | 21.18 | | | | 5.60 | 10.46 | 0.50 | | 0.32 | | 4.20 | | 100 | 114 | |
| 9959 | 4 | 1 | Scp | 58.26 | | 21.40 | | | | 4.70 | 11.13 | 0.74 | | | | 3.76 | | 100 | 125 | |
| 9959 | 4 | 2 | Clay | 60.72 | | 24.08 | 0.33 | | 3.00 | 4.07 | 4.43 | 0.97 | | | | 2.39 | | 100 | 108 | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | Oxide total | | | | | | | | | | | | | | | | | |
| | | Mag = | >90% | | | | | | | Average quartz total = 118.5 | | | | | | | | | | |
| | | Hem = | 85-89% | | | | | | | | | | | | | | | | | |
| | | Gth = | 80-84% | | | | | | | Oxide total = (wt % oxide / Avg. Qz total) * 100 | | | | | | | | | | |
| | | Lm = | <80% | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | Notes | | | | | | | | | | | | | | | | | |
| | 1 | + = indicates other minerals present | | | | | | | | | | | | | | | | | | |