

CONTACT METAMORPHISM AND HYDROTHERMAL ALTERATIONS AROUND ANDESITE INTRUSION OF THE JARMUTA HILL, PIENINY (POLAND)

W. SZELIGA¹ and M. MICHALIK¹

¹ Institute of Geological Sciences, Jagiellonian University, ul. Oleandry 2a, 30–063 Kraków, Poland;

szeliga@geos.ing.uj.edu.pl; michalik@geos.ing.uj.edu.pl

Abstract. Contact zones developed around andesite intrusions of the Jarmuta hill (Pieniny Mts.) were studied. Sedimentary rocks were subjected to contact metamorphism under pyroxene-hornfelse facies conditions. It is possible that sanidinite facies conditions were developed temporarily within sedimentary rocks in the immediate vicinity of the intrusion. Contact zone (andesite and metamorphosed sedimentary rocks) was subsequently altered by hydrothermal solutions. Hydrothermal activity took place within broad range of temperature conditions. Chemical composition of solutions was changing during the decline of temperature.

Keywords: contact metamorphism, hydrothermal activity, andesites, Pieniny Mts.

Introduction

Tertiary andesites in the Pieniny Mts. in Poland occur in small intrusions form, sills and dykes. Contact metamorphism and hydrothermal activity related alterations of andesites and country rocks were investigated by many authors (e.g., Wojciechowski 1950, 1955; Birkenmajer 1956, 1986, 1996; Małoszewski 1956; Gajda 1958; Małkowski 1958; Banaś et al 1993; Sokołowska & Wojciechowski 1996; Pyrgies & Michalik 1998; Birkenmajer & Pécskay 1999, 2000). Andesites and hydrothermal veins connected with them were the object of ore prospection since 15th century (Wojciechowski 1955, Małkowski 1958).

Contact metamorphism, hydrothermal alterations and ore deposits formation related to Tertiary volcanics were broadly investigated in Slovakia (e.g., Štohl et al 1994; Kraus et al 1999; Lexa et al 1999).

Geologic settings

Several vein-like intrusions of andesite are present in the Jarmuta area (the Grajcarek stream valley near Szczawnica). Localization of intrusions based on geophysical methods was determined by Małoszewski (1956). Two lithological varieties of andesite can be distinguished here: amphibole andesite (the older variety) and pyroxene-amphibole andesite (the younger one)(Małkowski 1958).

Andesites of the Jarmuta area intruded various sedimentary rocks of the Grajcarek group (shales, marls, sandstones, tuffaceous intercalations) (Fig. 1). The intrusion age determined using K-Ar method corresponds to Sarmatian (Birkenmajer & Pécskay 2000).

Sampling

Samples were collected in two localities - in the Malinowa quarry (fresh and altered andesite) and in the old adit on the eastern slope of the Jarmuta hill. Samples from the adit (Fig. 2) represent altered andesites and sedimentary rocks (various mudstones and sandstones) cut by hydrothermal veins.

Methods

Optical microscopy both in transmitting and reflected light was applied. X-ray diffractometry (Philips X'Pert APD apparatus) was used for identification the rock components. Powdered preparations were investigated in Cu radiation monochromatized using graphite monochromator. Pelitic material was separated from several samples after carbonate dissolution in acetic buffer and Fe oxides removal after reduction by Na dithionite in Na bicarbonate and Na citrate solution. Infrared spectrometry (Bio-Rad FTS-135 type spectrometer) was used also. Samples were prepared as disc with KBr. Scanning electron microscopy (JEOL JSM 5410 microscope) with energy dispersive spectrometry (NORAN, Voyager 3100) was applied. Samples were coated with carbon film.

Results

Altered sedimentary rocks

In sedimentary rocks in the vicinity of intrusion two mineral zones are observed. Sanidine, diopside, wollastonite, pigeonite and cristobalite zone (Fig. 3) is present close to the contact. Determination of sanidine and cristobalite is XRD based. XRD patterns indicate that sanidine is usually accompanied by other, more ordered,

potassium feldspar phase. Wollastonite, diopside and garnet zone is more distant from the contact. Rocks situated more distant from the contact than previous, only recrystallization (increase of average grain-size in the rock) and Fe, Ti or Fe-Ti oxides can be seen. Fine-dispersed graphite is present in several samples. Sulphides are dispersed locally in altered rocks (pyrrhotite, chalcopyrite, pyrite) of both zones. Secondary carbonates (calcite and siderite) and clay minerals (chlorite and kaolinite) can be observed in samples collected in a bigger distance from the contact

Most newly formed minerals mentioned above can be present both in altered mudstones and sandstones. Graphite is a secondary mineral present only in mudstones. Primary texture of sedimentary rocks are visible however, alterations are modified by alterations to various degree.

Contact alterations are observed macroscopically in the change of the colour of rocks and in modification of their mechanical properties (rocks are harder and splits into sharp-edged fragments) as it was pointed out by Birkenmajer (1956).

Alterations in andesite

Assemblage of newly formed minerals in altered andesite is relatively rich. Sanidine is present as anhedral grains. Potassium feldspar of adularia-like optical characteristics can also be observed. Diopside forms relatively big crystals enclosing older decomposed minerals, probably pyroxene phenocrysts. Wollastonite can be observed both as discrete grains and as complex intergrowths with feldspar and quartz (secondary quartz?).

Poikilitic biotite (Fig. 4) contains inclusions of quartz, apatite and rarely feldspar. Poikilitic biotite is characterized by relatively high content of chlorine. Apatite occurs commonly in rocks representing highest degree of alteration. Numerous apatite crystals are chlorine-rich. Fine-crystalline epidote is scarce in altered andesite. Secondary carbonate minerals (calcite and subordinately siderite) are present in andesite groundmass. Low amount of chlorite was determined in some samples using XRD.

Sulphide minerals were observed also (fig. 5, 6). Pyrrhotite is the most common among sulphides. It is often accompanied by chalcopyrite. Sphalerite and rarely electrum occurrence is related to chalcopyrite. Marcasite replaces pyrrhotite (fig. 7) and covellite replaces chalcopyrite (fig. 8). Pyrite and galena are present but

in a very small amount. In strongly altered rocks Fe hydroxides (for example goethite) are present.

Veins

Veins cut andesites and sedimentary rocks. High degree alteration of wall rocks around veins cause determination of the thickness of vein difficult. Type of alteration in wall rock near veins is similar to those described in the andesites.

Siderite is present in vein and dispersed within altered rocks. Sulphide minerals, secondary pyroxene and biotite similar to those described in altered andesite are present in vein and highly altered wall rocks around it. Growth of secondary clay minerals is widespread. Kaolinite often replaces biotite (Fig. 9). Coarse crystalline vermiculite (up to 7 mm in size) (Fig. 10) occurs in clusters in fine crystalline clayey matrix composed of kaolinite, chlorite, swelling mixed-layer minerals, and siderite.

Discussion

Neomorphic minerals and their assemblages

Two main secondary mineral assemblages were distinguished in altered rocks based on their inter-relationships and textures. The first one is related to contact metamorphism and conditions of low activity of fluids. The second assemblage contains minerals formed under hydrothermal conditions.

Contact metamorphism and low fluid activity conditions related to assemblage contains: sanidine, wollastonite, diopside, pigeonite, garnets, cristobalite and Fe, Ti oxides. Graphite is present in mudstones and was probably formed at the expense of primary organic matter. The assemblage represents minerals crystallized in various temperatures.

The second assemblage is related to hydrothermal alteration and comprises biotite and apatite with high content of chlorine, quartz, K-feldspars (adularia-type), carbonates, epidote, kaolinite, vermiculite, chlorite and swelling mixed-layer sheet silicates. Sulphides and oxides (pyrrhotite, pyrite, sphalerite, chalcopyrite, covellite, electrum, galena, marcasite and goethite) can also be included into hydrothermal conditions related assemblage.

Conditions of metamorphism and hydrothermal alterations

Determination of contact metamorphism and hydrothermal alteration conditions is difficult because equilibrium mineral assemblages were not attained in rocks, what is evidenced by their texture and mineral composition.

Presence of sanidine and wollastonite (\pm diopside) can suggest that sanidinite facies conditions were developed temporarily within sedimentary rocks in the immediate vicinity of the intrusion. Moreover sanidine can be found also in marginal zones of the andesite intrusion. The presence of sanidine can indicate rapid cooling from high temperature, but not necessarily from sanidinite facies conditions temperature. More volume of rock was subjected to pyroxene–hornfelse facies metamorphism conditions.

Hydrothermal alterations also took place in several stages. Biototization was probably connected with high temperature alteration in narrow zone near intrusion. Development of secondary biotite was earlier discussed by Gajda (1958). Secondary (poikilitic) biotite is usually rich in chlorine. It is possible that chlorine-rich apatite was formed in this stage. Formation of sulphides (pyrrhotite, chalcopyrite, electrum), quartz and scarce epidote and chlorite took place at lower temperature range. This stage can correspond to propylitization although mineral assemblage typical of propylitization is not fully developed here (scarcity of epidote and chlorite). Formation of carbonates (calcite and siderite) is related to the period of decreasing temperature. Widespread carbonatization was described earlier by Birkenmajer (1958).

In the hydrothermal vein and strongly altered wall rocks vermiculite, chlorite, swelling mixed-layer silicates, and kaolinite were formed probably under wide span of temperature conditions. Kaolinite (which replaces biotite) was formed at relatively low temperatures and at lowered pH.

Lowering of temperature and pH value influenced sulphides assemblage also. Pyrrhotite is partly replaced by marcasite and chalcopyrite by covellite. Formation of Fe hydroxides replacing sulphides and mafic silicates was related to low temperature oxidative conditions.

Conclusions

Sedimentary rocks around andesite intrusions of the Jarmuta hill area were subject to contact metamorphism under pyroxene-hornfelse facies conditions. It is possible that sanidinite facies conditions were developed temporarily within

sedimentary rocks in the immediate vicinity of the intrusion. Contact zone (both andesite and metamorphosed sedimentary rocks) was altered during hydrothermal solutions activity. Hydrothermal activity took place within broad range of temperature conditions. Chemical composition of solutions was changing during the decline of temperature.

References

- Banaś J., Nieć M., Salomon W., 1993. Bismuth tellurides from the Jarmuta hill (Pieniny Mts.) *Mineralogia Polonica*, 24, 33–40.
- Birkenmajer K., 1956. Badania geologiczne andezytów okolic Szczawnicy. *Przegląd Geologiczny*, No 2, 72-74.
- Birkenmajer K., 1986. Zarys ewolucji geologicznej Pienińskiego Pasa Skałkowego. *Przegląd Geologiczny*, 34, 293 – 303.
- Birkenmajer K., 1996. Miocenne intruzje andezytowe rejonu Pienin: ich formy geologiczne i rozmieszczenie w świetle badań geologicznych i magnetycznych, *Geologia*, AGH, 22, pp. 15 – 25.
- Birkenmajer K., Pécskay Z., 1999. K – Ar dating of the Miocene Andesite Intrusions, Pieniny Mts, West Carpathians, Poland, *Bull. Pol. Acad. Sci. Earth Sciences*, 47, 155 – 169.
- Birkenmajer K., Pécskay Z., 2000. K – Ar dating of the Miocene andesite intrusions, Pieniny Mts, West Carpathians, Poland: a supplement. *Studia Geologica Polonica*, 117, 7 – 25.
- Gajda E., 1958. Procesy hydrotermalne w andezytach okolic Pienin, *Prace Muzeum Ziemi*, 1, 57 – 76.
- Kraus I., Chernyshev I.V., Šucha V., Kovalenker V.A., Lebedev V.A., Šamajová E., 1999. Use of illite for K/Ar dating of hydrothermal precious and base metal mineralization in Central Slovak neogene volcanic rocks, *Geologica Carpathica*, 50, 353 – 364.
- Lexa J., Štohl J., Konečný V., 1999. The Banská Štiavnica ore district: relationship between metallogenetic processes and the geological evolution of a stratovolcano, *Mineralium Deposita*, 34, 693 – 654.
- Małkowski S., 1958. Przejawy wulkanizmu w dziejach geologicznych okolic Pienin, *Prace Muzeum Ziemi* 1, 105 – 113.
- Małuszewski S. 1956. Badania magnetyczne w Pieninach, *Przegląd Geologiczny* 2, 74 - 76.
- Pyrgies W., Michalik M., 1998. Contact effects of the pieniny andesites on the surrounding sedimentary rocks, w *Carpathian–Balkan Geological Association XVI Congress – Abstracts. Geological Society of Austria 1998*, pp. 502.
- Sokolowska G., Wojciechowski A., 1996. Złoto w andezytach Pienin, *Posiedzenia Naukowe PIG*, 52, 20 – 21.
- Štohl J., Lexa J., Kaličiak M., Bacsó Z., 1994. Metalogenéza žilníkových polymetalických mineralizácií v neovulkanitoch Západných Karpát, *Mineralia Slovaca*, 26, 75 – 117.
- Wojciechowski J., 1950. Złoto rodzime i minerały towarzyszące w żyłach kruszcowej pod Szczawnicą, *Acta Geol. Pol. T. I/2*, pp. 143 – 149.
- Wojciechowski J., 1955. O żyłach kruszcowych w okolicy Szczawnicy, *Biul. IG*, 101, 3 – 63.

Fig. 1. Geological sketch map of studied area. (After W. Ryłko 1991; simplified).

Fig. 2. Plan of the old adit on the eastern slope of the Jarmuta hill and sampling sites.

Fig. 3. Contact zone between andesite and mudstone. SEM.

Fig. 4. Poikilite biotite (Bt) with quartz (Qtz). SEM.

Fig. 5. Pyroxene and biotite partly replaced by sulphates. SEM.

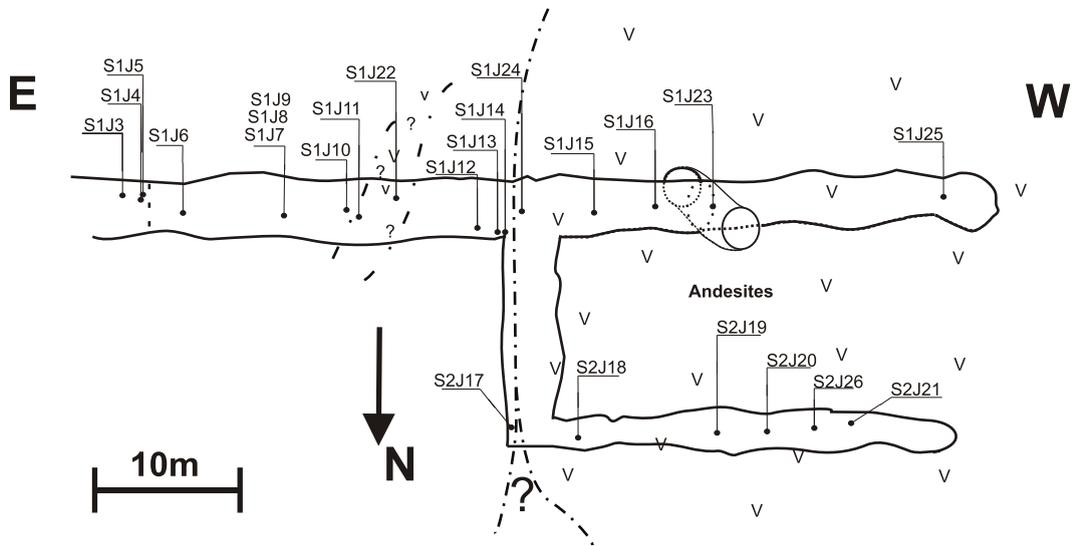
Fig. 6. Biotite replaced by Ti oxides and sulphides. SEM.

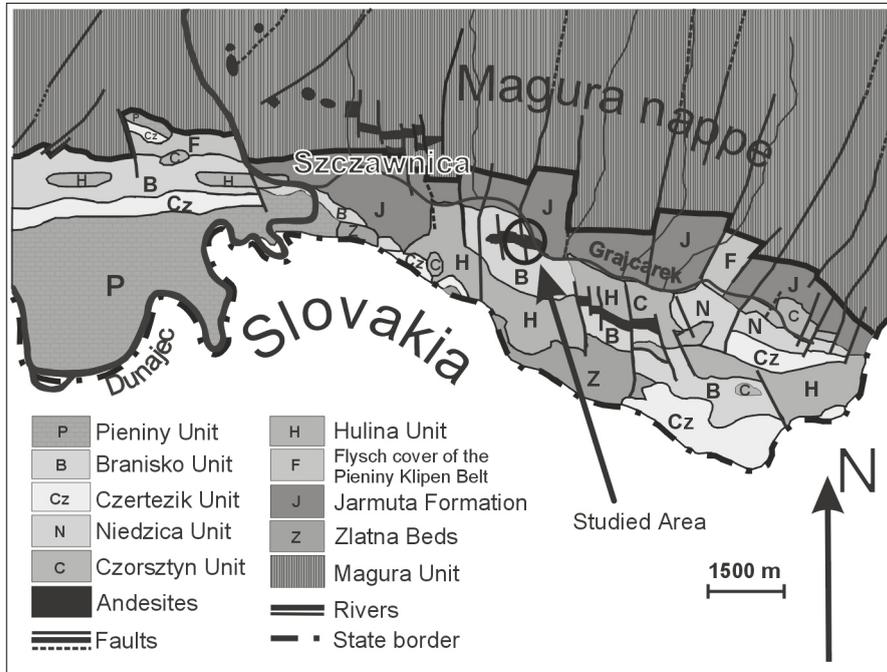
Fig. 7. Marcasite (Mrc) replaces pyrrhotite (Po). Optical microscope, reflected light.

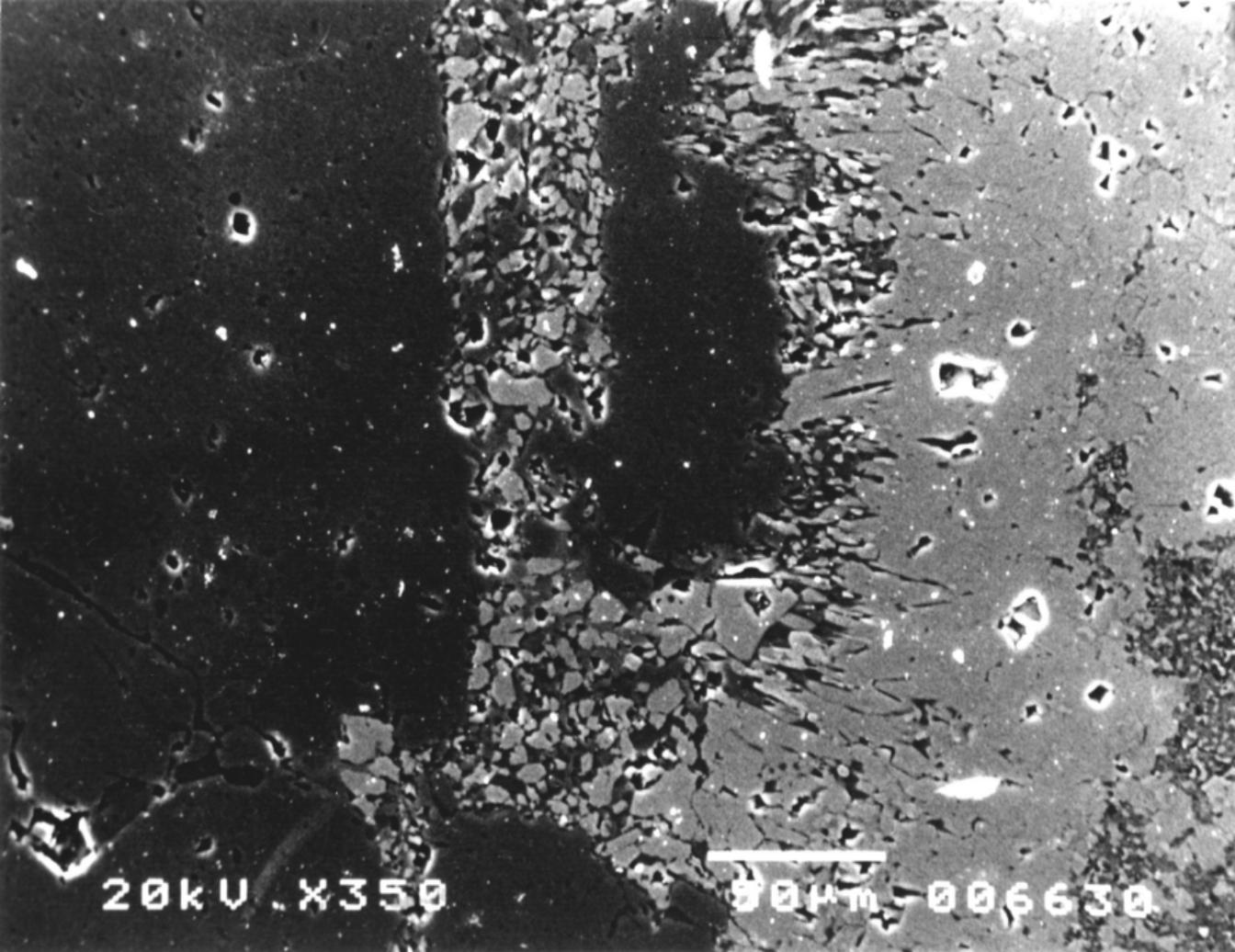
Fig. 8. Chalcopyrite (Ccp) changed by covellite (Cv). SEM.

Fig. 9. Fine grain of crystalline vermiculite. SEM.

Fig. 10. Biotite (Bt) replaced by kaolinite (Kln). SEM.







20kV X350

50µm-006630



Bt

Qtz

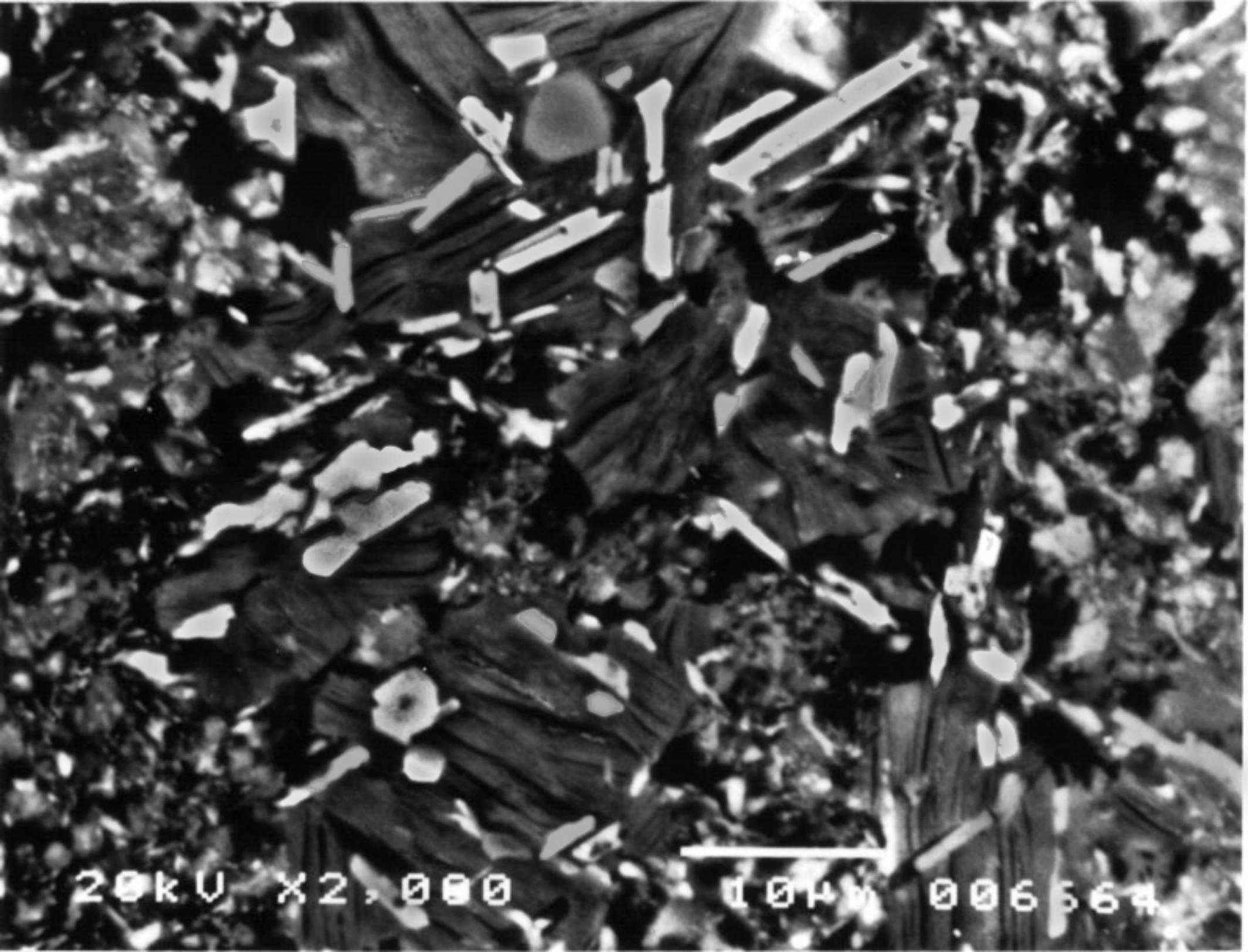
Bt

Qtz

20kV X350



50µm 006667



20kV X2,000

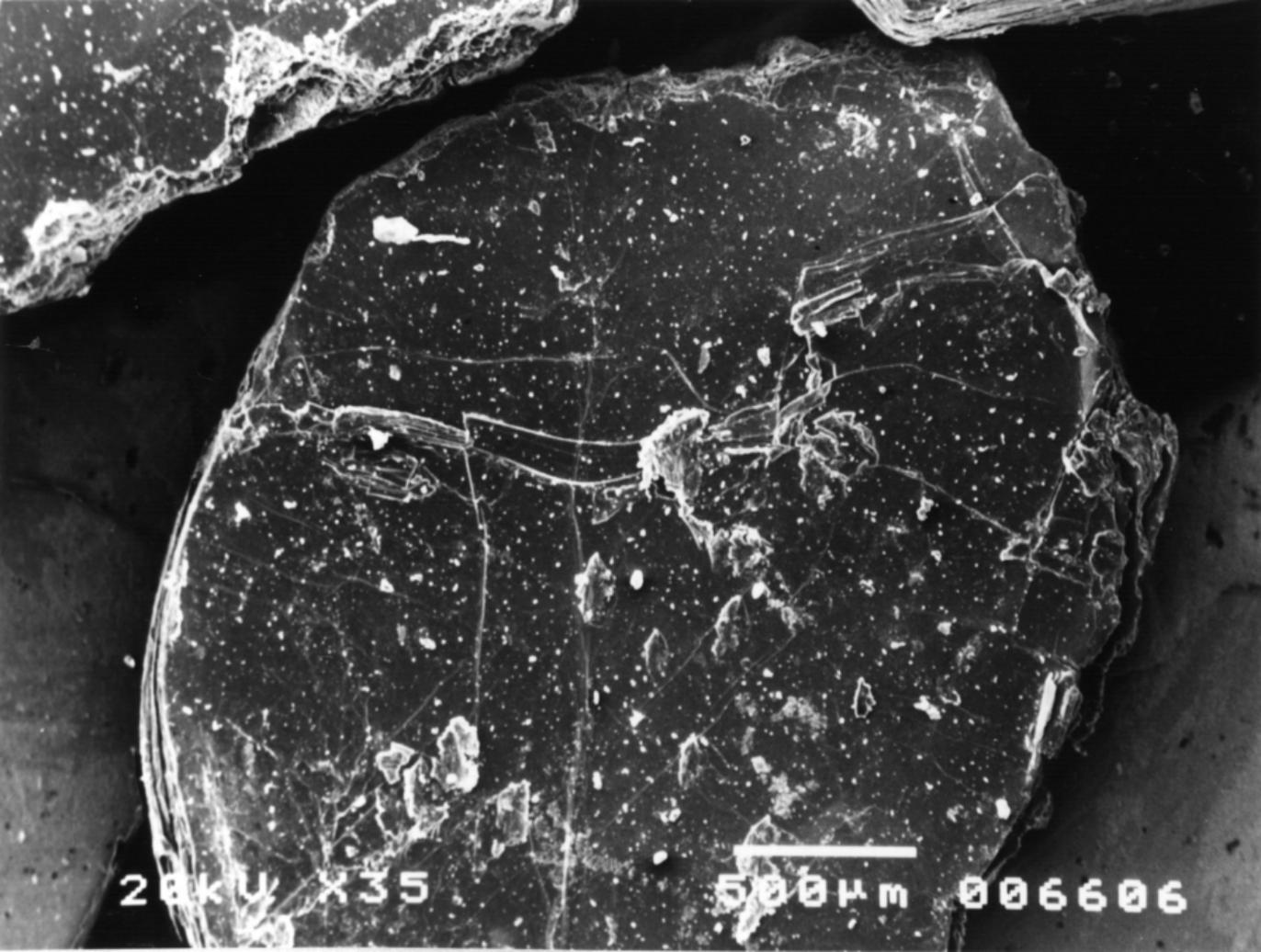


1040 006564



20KV X2,000

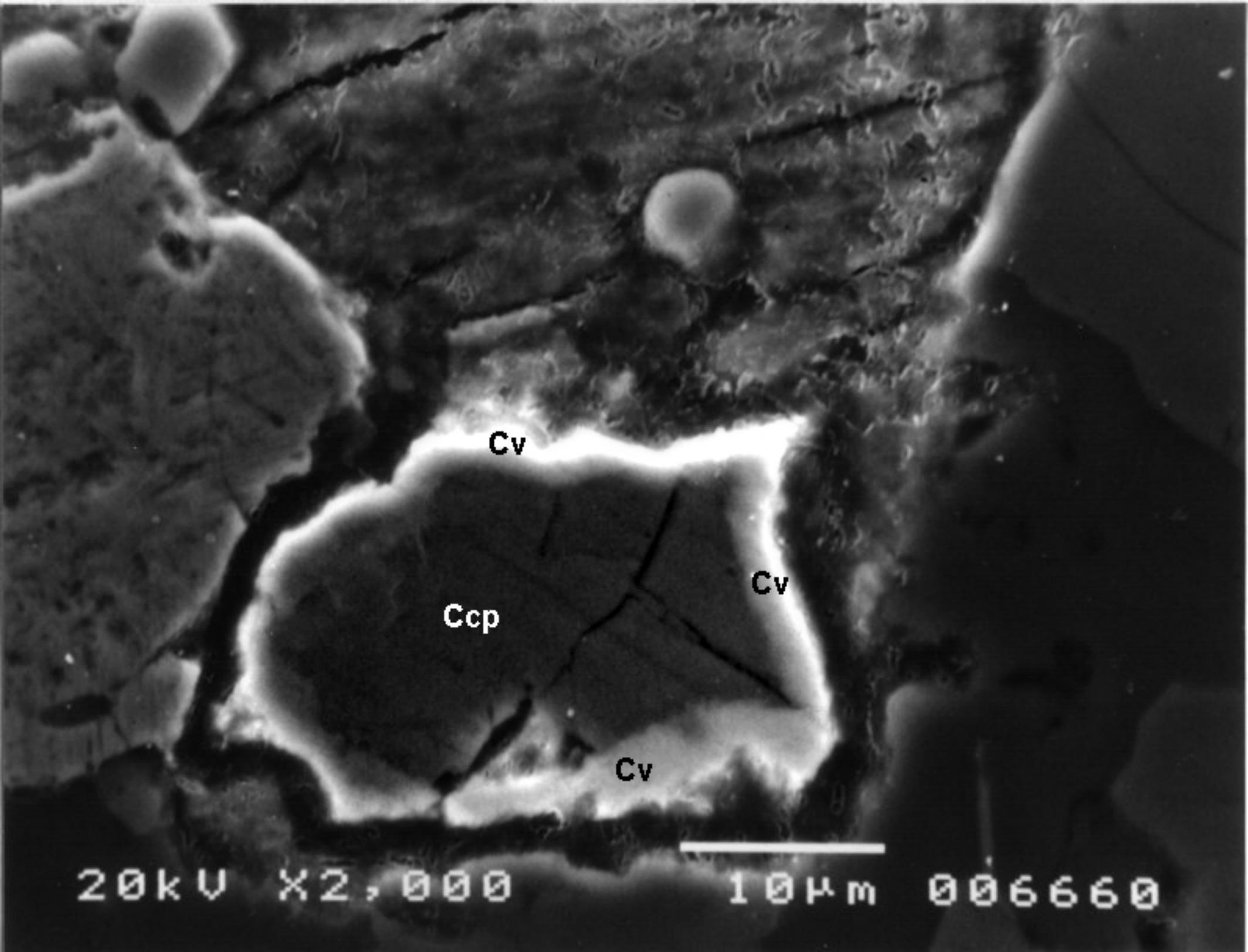
10µm 006721



20KV X35

500µm

006606



Cv

Ccp

Cv

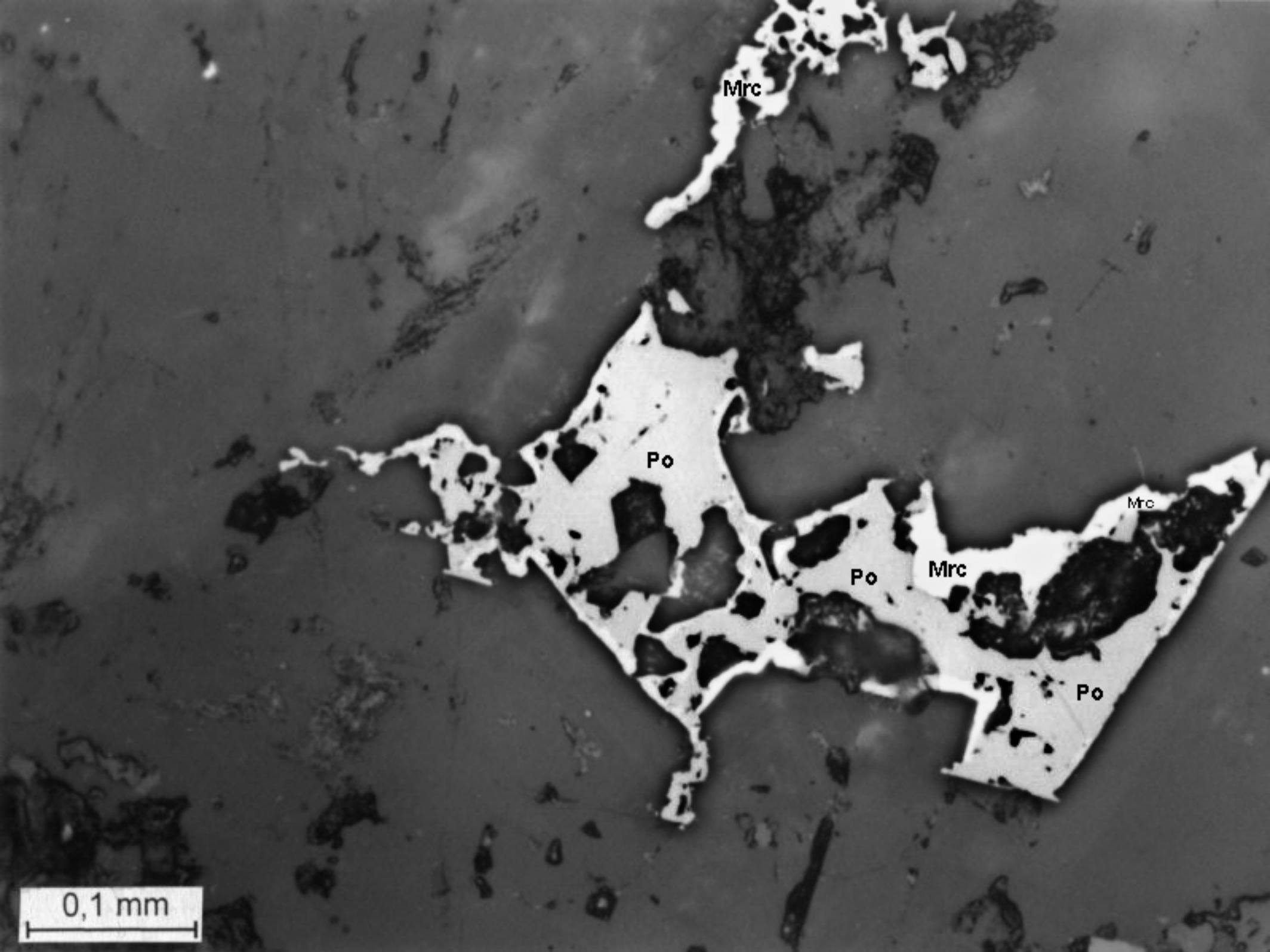
Cv



20kV X2,000

10µm

006660



Mrc

Po

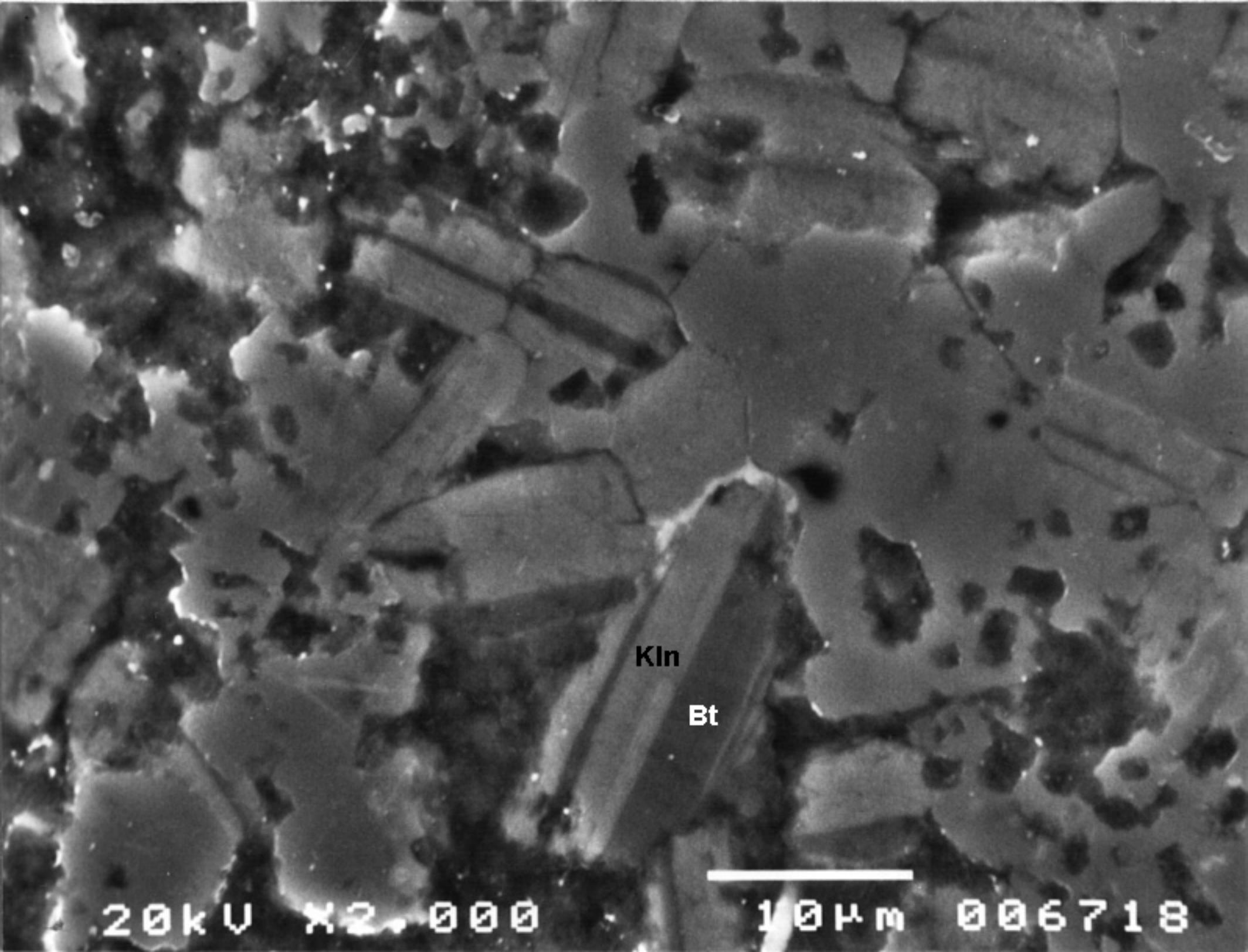
Mrc

Po

Mrc

Po

0,1 mm



Kln

Bt



20kV X2,000

10µm

006718