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Geochemistry and mineralogy of scheelite bearing and scheelite barren calc-silicates - Wietzen - Southern Bohemian Massif - Austria

verfasst von / submitted by

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Abstract:

A tungsten mineralization bound to calc-silicate rocks was investigated at an economically promising locality near the village of Wietzen, 20km W of Gföhl, Lower Austria. This Area is located in the Moldanubian zone (Bohemian Massif) of Austria. In particular, it pertains to the so called "Variegated Group", a metasedimentary geological unit which has experienced amphibolite to higher amphibolite facies metamorphism. Scheelite, the ore mineral is bound to a dark calc-silicate rocks which form intercalations in sillimanite gneisses. Hedenbergite, meionite-rich scapolite, quartz and calcite are the main rock-forming minerals in these rocks. In the samples that were analyzed, tungsten concentrations of up to 467 ppm were detected by X-ray fluorescence spectrometer. However, no additional elements that would be characteristic for an exoskarn formation could be found by geochemical analysis. The whole series of calc-silicate rocks could be traced for about 5km. To describe and understand the mineralization from Wietzen area specific sections of three drill cores (WOK2, WOK4 and WOK5) were mapped in detail. The phase content, bulk rock compositions and mineral chemistries were investigated by optical microscopy, X-ray fluorescence analysis (XRF), x-ray diffraction (XRD) and electron microprobe analysis (EPMA). The scheelite mineralization is disseminated in calc-silicate rocks and it is accompanied by minor pyrrhotite, pyrite und chalcopyrite. As reported by Beran et al. (1985), the scheelite mineralization is strata bound; however, exposure to intrusive rocks were not noticed. The field evidence could be easily adjusted and linked to a sedimentary origin, nevertheless the lack of relevant information and details regarding the geology of the region makes it difficult for this interpretation to be irrefutable.

Zusammenfassung:

Eine Wolframmineralisierung, die an Kalksilikatgestein gebunden ist, wurde an der wirtschaftlich vielversprechenden Lokalität Wietzen, 20km westlich von Gföhl, untersucht. Dieses Gebiet befindet sich im Moldanubikum (Böhmische Masse) in Österreich, geologisch gesehen in der sogenannten Bunten Serie. Dies ist eine metasedimentäre geologische Einheit, die eine amphibolit- bis höheren amphibolitfazielle Metamorphose erfahren hat. Das Mineral Scheelit ist an dunkle Kalksilikate gebunden und in Sillimanit-Gneisen eingelagert. Hedenbergit, meionitreicher Skapolit, Quarz und Calcit sind die wichtigsten gesteinsbildenden Minerale dieses Gesteins. In den gemessenen Proben konnten mittels Röntgenfluoreszenzanalyse Wolframgehalte von bis zu 467 ppm nachgewiesen werden. Weitere Elemente, wie sie für Exoskarnbildungen charakteristisch sind, konnten nicht nachgewiesen werden. Die Kalksilikat-Gesteine konnten insgesamt über eine Länge von etwa 5 km verfolgt werden. Zur Beschreibung und zum Verständnis der Mineralisierung im Gebiet von Wietzen wurden spzifische Abschnitte von drei Bohrkernen (WOK2, WOK4 und WOK5) detailliert kartiert. Die Phasenzusammensetzungen und Mineralchemismen wurden mit optischer Mikroskopie, Röntgenfluoreszenzanalyse (XRF), Röntgendiffraktometrie (XRD) und Elektronenstrahlmikrosonde (EMS) untersucht. Die Scheelit-Mineralisierung wird von geringen Gehalten an Pyrrhotit, Pyrit und Chalkopyrit begleitet. Wie von Beran et al. (1985) berichtet, ist die Scheelitmineralisierung schichtgebunden; ein Kontakt mit Intrusivgestein wurde jedoch nicht festgestellt. Die Feldbelege könnten mit einem sedimentären Ursprung in Verbindung gebracht werden, doch das Fehlen relevanter Informationen und Details zur Geologie der Region macht es schwierig, diese Interpretation eindeutig zu belegen.

Acknowledgments:

At this point I would like to thank Prof. Richard Göd, who gave me the opportunity to take on this interesting master's thesis and who always supported me with words and deeds on the way to completion. He gave me so much of his time just to make sure that I get the guide and support needed throughout the entire process. Another heartfelt thanks goes to Peter Nagl, who was not only a great lab guide but also a great editor for my master's project. He always had an open ear for questions and concerns of all kinds. I would also like to thank Prof. Rainer Abart for his support and advices during my bachelors and master's journey . A great thank to the Department of Lithosphere Research at the University of Vienna, especially Ilka Wünsche and Claudia Beybel, who helped me in the preparation of thin sections. Thanks to Franz Biedermann for his assistance in cutting the drill cores and also to Franz Kiraly for the analysis with the electron beam microprobe. Finally, a special thanks to the ministry of higher education at the sultanate of Oman for giving me the opportunity and the chance to pursue my studies at a prestigious university like the University of Vienna. I truly appreciate everyone who helped me throughout my bachelors and master's journey in Austria.

Contents:

Introduction:

This survey revealed numerous indications for scheelite occurrences in the Moravian and the Moldanubian zones, two major tectonic units of the Bohemian Massif. As scheelite bearing calc-silicates are known to occur in the Czech part of the Moldanubicum, equivalent lithologies in Austria nave been investigated as well (Jung, unpublished report from MINEREX company, Mineralexpolrationsgesellschaft, 1980).

The most promising scheelite mineralization was found in calc-silicate rocks around a small village (Wietzen) located in the Moldanubian part of the Bohemian Massif. The scheelite mineralization in the Wietzen area extends for ~ 5 km along strike.

The objective of this study is a mineralogical and geochemical characterization of the scheelite bearing calc-silicate rocks and of the accompanying rocks that appear in the Wietzen area. In addition, this study aims to identify the genesis of the calc-silicate rocks of the Variegated Group, especially in the Wietzen area, and the source of scheelite that occurs in dark calc-silicate rocks. This study is based on a detailed investigation of three drill cores. Emphasis was put on the mineralogy and geochemistry of the lithologies that are associated with the mineralization.

1. Geological setting:

1.1. Bohemian Massif:

The following summary is largely based on Fuchs and Matura, 1976, Linner, 1996, Petrakakis, 1997, Klötzli et al., 1999 and Matura, 2006. The area of interest belongs to the Bohemian Massif, representing the Variscan basement. SUESS, (1912) stated that the Bohemian Massif of the Waldviertel can be divided into the Variscan intruded South Bohemian Pluton in the W, the Moldanubian Gneiss Mountains and the Moravian. Today three major tectonic units are discerned in the Bohemian Massif: Moravicum, Moldanubicum, and Bavariacum. All of which have internal roof stacking napps. The Austrian, southernmost part of the Bohemian Massif is largely dominated by the Moldanubian Zone, which itself is composed of three major tectonic units including, from the textonically deeper to the tectonically higher units or from W to E. The "Monotonous Series" („ Ostrong Unit"), the „ Variegated Group " („Drosendorf Unit") and Gföhl Unit (Gföhler gneiss + accompanying rocks). These units generally strike NNE-SSW and mostly dip towards E *(Fig. 1).*

The textonically deepest „Monotonous Series" is predominantly composed of cordierite bearing paragneisses, which have been intruded by large amounts of granites during the Variscan orogeny forming the South Bohemian Pluton. The P-T conditions of the metamorphic peak within the paragneisses were determined at 720°C and 4,4kb (Linner, 1996). The Ostrong Unit is overlain tectonically by the granitic to granodioritic Dobra gneiss and, primarily associated with this, the Variegated Group. Where the Dobra gneiss is missing, the Variegated Group is in direct contact with the Monotone Serie. The two complexes are separated from the Monotonous Series by the so-called "granulite lamella", which Fuchs & Scharbert, (1979) interpret as a tectonic displacement path.

The Variegated Group is characterized by orthogneisses, quarzites, partially graphite bearing paragneisses, amphibolites and in particular by extended marbles and calc silicate rocks. The latter are of particular interest in the context of the scheelite mineralization studied here. Metamorphic P-T conditions of 700°- 800°C and 7-9kb were reported by Klötzli et al., 1999, however, Petrakakis (1997) refers to higher pressures of 8 to 11kb.

The tectonically highest „Gföhl Unit“ is mainly composed of the name giving Gföhl-orthogneiss and of granulites. The Gföhl Unit experienced the same metamorphic conditions as the Variegated Group (Petrakakis, 1997). The base of the Gföhl unit is characterized by the noticeable horizon of the Rehberg amphibolite. This occurs in close alternation with orthogneisses and in the adjacent of serpentinites. The Gföhl Gneiss itself is a metagranite with partly migmatic habitus. This unit is followed by chemically similar, fine-grained granulites. The accompanying rocks of the Gföhl gneiss include kyanite-bearing paragneisses, various amphibolites, garnet pyroxenites, diorite gneisses, metagabbros and syenite gneisses. The area known as the "mica schist zone" creates a boundary with the Moravian.

A more detailed overview on the lithologies and the lithostratigraphy of the series mentioned is given by Petrakakis,1997. The Monotonous series and the Gföhl unit are of secondary relevance in the given context as the area under investigation pertains to the Variegated Group. *Figure. 1* shows that the series grading in the Moldanubian is not uniform as it has been described. However, the Moldanubicum tectonic concepts give rise to controversy until today (Fuchs & Matura, 1980; Tollmann, 1982; Thiele, 1984).

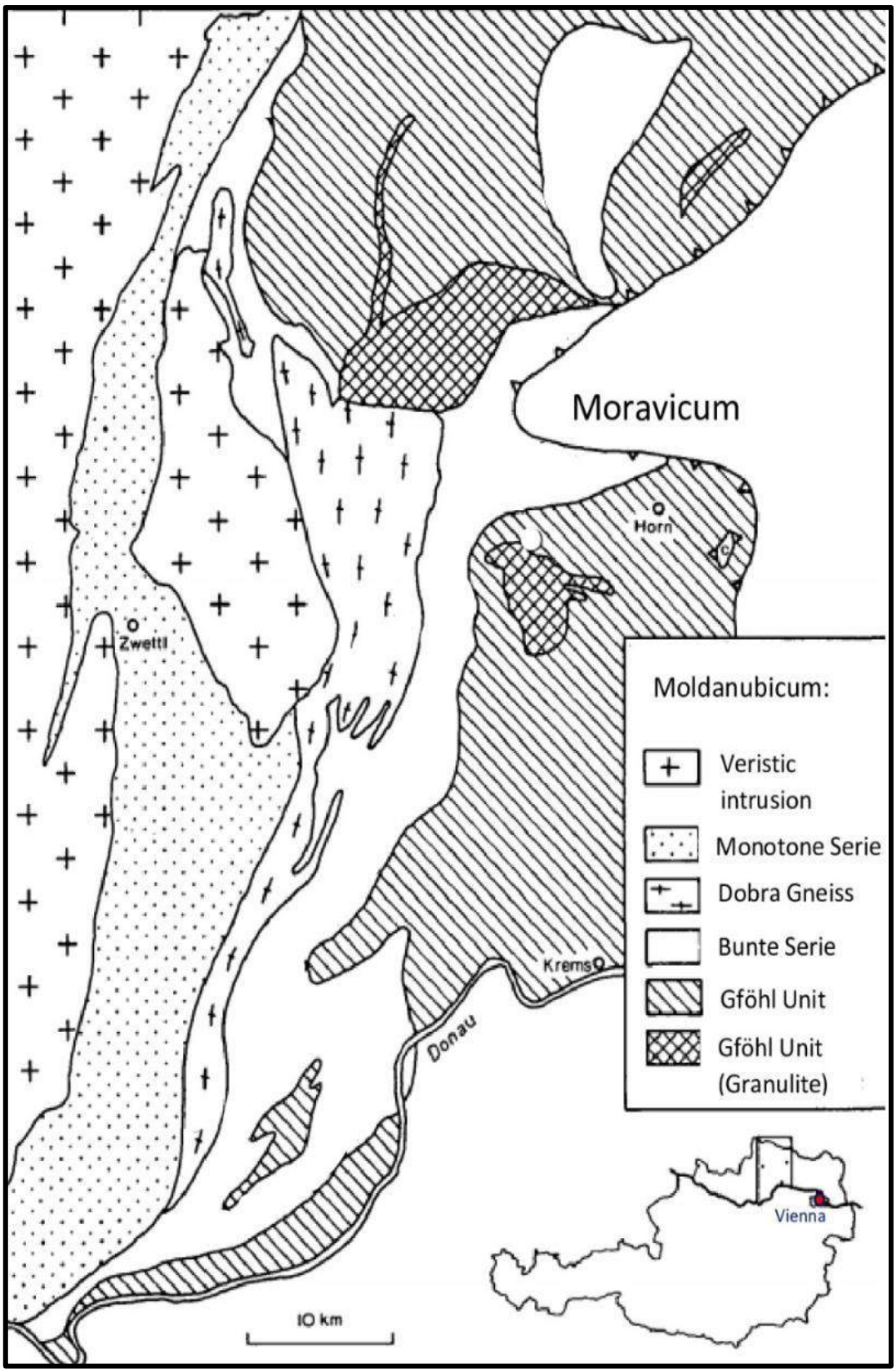


Figure 1:The geological and tectonic structure of the Waldviertel in Lower Austria According to Fuchs & Scharbert (1979).

1.2. Geology of the Variegated Group:

The scheelite-bearing rocks pertain to the Variegated Group or "Bunte Serie". In Austria, the Variegated group can be followed over ~ 80km and has a general SSW- NNE strike (Beran et al.,1985). Corresponding series can be found in Bavaria (Stettner 1975, 1980) and in the Czech Republic (Svoboda, 1966). As the name Variegated Group (Bunte Serie) tells, this rock assemblage is diverse in composition. This series generally consists of sillimanite- and locally graphite-bearing paragneisses, arkose gneisses, quartzites, marbles, calc-silicate rocks and amphibolite. This demonstrates an originally marine-sedimentary series with intercalations of basic magmatic rocks, which were transformed to amphibolite and higher amphibolite facies rocks during metamorphism. According to Fuchs & Matura (1980), the Variegated group is derived from an epicontinental sedimentary sequence.

The Variegated Group is closely associated with the Dobra-Gneiss, which is normally considered to be at least in part an orthogneiss. The field relations indicate that the Variegated Group was deposited upon the Dobra-Gneiss or in other words, it's deposited upon its predecessor. This is inferred-e.g., from the concordant, sharp but non-tectonic contact between the Variegated Group and the Dobra-Gneiss, the occurrence of arkose gneisses (possible derivatives of the predecessor of today's Dobra-Gneiss) and quartzites mainly in the lower strata of the paragneisses of the Variegated Group. As stated by Exner (1953) "the infrequent diffuse transitions between the Dobra-Gneis and Variegated Group is the consequence of a common metamorphic overprint. Authors debated about the sedimentary age of the Variegated Group, with some claiming it to be latest Archean to Early Proterozoic (e.g., Svoboda, 1966, p 17; Chaloupsk, 1978), while others link it to Silurian on the basis of lithological analogies with sediments of the Praha depression (e.g., Waldmann, 1951; Thiele, 1984).

1.3.The investigated area :

The Geological map of the examined area, Wietzen, is presented in *(Fig.2 and Fig. 3B).* The tungsten mineralization is associated with dark calc-silicate rocks. They form an approximately 5 km long, SSW-NNE striking intercalation in sillimanite-bearing paragneisses. Moreover, there are multiple calc-silicate layers, and these layers can reach ~ 20 m in thickness (Göd, 1981).

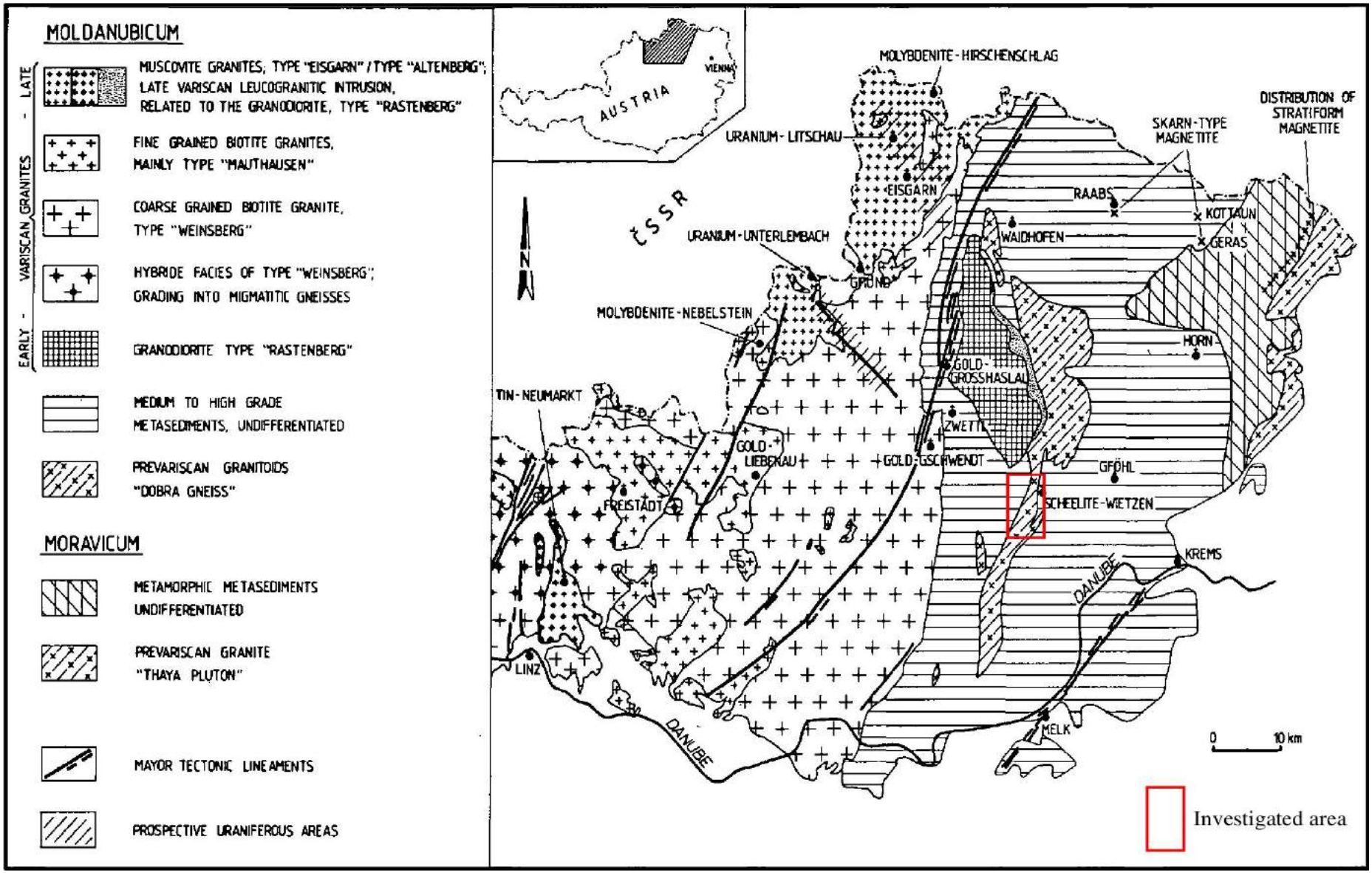


Figure 2:Geographic position of Wietzen area in Southern Bohemian Massif. From Göd, (1989), geology after Fuchs & Matura, (1976).

1.4.The local lithologies around the examined area from previous works:

1.4.1.The calc-silicate rocks (CS):

Macroscopically, the calc-silicate rocks occur in two different varieties: A dark green coarse-grained one and a light green, fine-grained one, forming alternating layers. The different colors of the calc-silicate rocks are mainly attributed to the different proportions of clinopyroxene (hedenbergite-diopside solid solution), scapolite, plagioclase, quartz and carbonate. In comparison to other minerals, garnet appears relatively rarely in the calc-silicate rocks (Göd, 1981). According to Śtemprok, (1984), vesuvianite can also occur in the calcsilicate rocks of the Variegated Group. As stated by Göd, (1981), the paragenesis diopside-scapolite-wollastonite ±garnet could be perceived in calc-silicate from Wietzen area. The most common accessory mineral is titanite. The scheelite mineralization is bound to the dark green, relatively coarse-grained variety of the calc-silicate rocks.

1.4.2.The marbles:

Marbles are the most prominent rock type of the Variegated Group (Fuchs & Matura, 1976 ,1980), where they often form elongated strata up to several km, which are exposed in numerous quarries. As reported by Fuchs & Matura (1980) these marbles appear in different forms from white coarsely crystalline homogeneous and very pure marbles to fine to medium-grained silicate mineral-bearing marbles of light to dark grey color. The marbles of the Variegated group are developed striped or laminated. The lamination is sometimes due to an alternation of calcite and dolomite-rich layers. However, it can also result from varying contents of silicate phases. In such instances, the rock often acquires a light green color. Close intercalations of marble with calc-silicate rocks are particularly easy to recognize in weathered state. The fact that the marble layers recede with respect to the more erosion resistant calc-silicate rocks, results in a grooved surface which differentiate marbles from the light grey type calc-silicate. As stated by Högelsberger (1987), calcite is the dominant carbonate phase in marbles of the Variegated group, sometimes it may be associated with dolomite.

1.4.3.Amphibolite and paragneiss of the Variegated Group:

According to Fuchs & Matura (1980), amphibolite occurs either as homogeneous thick-banded or inhomogeneous banded types. In addition to the main minerals hornblende and plagioclase, locally biotite and garnet are also found in the amphibolites of the Variegated group. The amphibolites tend to accumulate in the hanging parts of the Variegated group. As reported by Högelsberger (1987), the amphibolites are connected with the paragneiss by interbedding in the meter range. The alternation of amphibolite and paragneiss is very common in outcrops within the Variegated group. Amphibolites and paragneiss form thick bands in many of the outcrops of this area. Intercalation zones also exists containing several different lithologies of the Variegated group, especially intercalations of calc-silicate rocks, amphibolites and paragneisses are frequently observed. In the majority of cases, these intercalations are not sharp and enriched with sulfide ores. Small granitoids, aplites and pegmatites, occur in zones higher up in the Variegated group, especially in association with marble, calc-silicate rocks or quartzite (Fuchs & Matura, 1980). They are probably products of local melting of the country rocks. Thus, the Variegated group is derived from an epicontinental sedimentary sequence with intercalations of basic volcanic rocks (Fuchs & Matura, 1980).

2. Methodology:

In this project, three drill cores from the Wietzen area were examined. A total of 36 running meters were inspected macroscopically, microscopically and chemically in detail. The macroscopic examination consists of core mapping and lithology logs. Besides the microscopic examination of thin-sections various laboratory methods including wavelength dispersive X-ray fluorescence analysis (WDXRF or XRF), X-ray powder diffraction (XRD) and electron probe micro analysis (EMPA) were used (*Table. 19*). The process started by cutting the drill cores as follows: meter 45 to meter 61 of drill core WOK2, meter 56 to meter 71 of drill core WOK4, and meter 11 to meter 17 of drill core WOK5. Each running meter was split into two halves, one of which was used as a retention sample, while the other half was further split into two equal parts by further cutting. The first quarter was used to produce thin sections, whereas the second quarter was prepared for XRF.

2.1. Section Preparation:

A total of 44 thin sections were prepared for polarized light microscopy (in transmitted light) in the thin section laboratory of the Department of Lithosphere Research, University of Vienna.

2.2.Sample Preparation for X-ray fluorescence analysis (XRF):

Preparation of Rock Powder: The rocks were fragmented with a hammer and crushed in stages with a jaw crusher. Then grinded to the finest powder (less than 10 micrometer) possible in an agate swing mill to avoid contaminates. Approximately 15 grams of sample powder were used for the whole X-ray-fluorescence analysis.

A porcelain crucible was prepared by firing at 1050 ° C for at least 3 hours and cooled to room temperature in a desiccator. The crucible loaded with about 15 grams of sample was then placed in an oven at 110° C. After cooling to room temperature in a desiccator, the weight of crucible and sample is measured again and the loss of drying was recorded. The crucible containing the sample (after loss of drying) was placed in a muffle furnace at 850° C (1050° C for samples with carbonate (e.g.: marbles, calc-silicate) for 3 hours. After taking the crucible out of the furnace, it is placed in a desiccator until it was cooled down to the room temperature and then weighted for determination of loss of ignition.

2.2.1.Fused bead preparation using EAGON 2 (for major elements' analysis):

Major elements Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P (usually present in amounts >0.1wt% of element oxide) were determined on calcined rock powder fused with lithium tetraborate/metaborate as flux to form a glass bead. Thirty-five fused beads were produced for major element analysis.

2.2.2.Pressed pellet preparation (for trace elements' analysis):

A total of forty powder tablets were prepared for XRF trace element analysis. Thirty five powder tablets were originally required for the trace element analysis, but for validation purposes five additional tablets were prepared. 10g of rock powder was mixed with 0.5 ml of polyvinyl alcohol as a binding agent, homogenized and then pressed with a hydraulic press at approx. 16 t/ cm^2 to form pressed powder pellets.

2.3. X-ray fluorescence analysis (XRF) method

The XRF analyses are performed on a sequential X-Ray spectrometer PHILIPS PW2404 using a super-sharp end-window tube with a Rh-anode and a programmable 4kW generator (60kV max., 125mA max.; iso-Watt-switching). The accompanying software used is PANalytical "SuperQ" vers. 5.1B(5.2822.3) and with the software options “ProTrace” (for trace element analysis) and “Omnian”. The methodology is explained in details in (Nagl & Mader, 2019).

Omnian is Panalytical's XRF software that is used widely in cases where samples are completely unknown or calibration standards for (specific) elements are not available. It provides complete qualitative analysis of all detectable elements and also (semi) quantitative chemical composition analysis. Nonetheless, this software comes with its drawbacks; the values obtained tend to be not as precise as they are in conventional multi-standard calibrations; results are given in weight percent with two significate decimals. For the present master's thesis Omnian software was used to determine Cl, F and SO_3 concentrations.

2.4. X-ray diffraction (XRD):

For X-ray diffraction, 7 texture-free specimens were prepared for semi-quantitative analysis. The powdered samples were carefully conveyed into the sample holder with sandpaper to prevent the layer silicates from settling. XRD analysis was performed using a PANalytical PW 2040/60 X'Pert Pro X-ray diffractometer, with Cu K-alpha radiation at 40 kV serving as the X-ray. Measurements were scanned at 2θ angle from 2° to 70° at a rate of 1° 2θ per minute. The methodology is described in detail in Allmann (1994).

2.5. Electron probe micro analysis (EMS):

Five samples (ALB1, ALB2, 2083M, 405M, and 407M) were selected for the determination of the mineral chemistry and thin sections of 40 µm thickness were coated with carbon. These samples were measured with the electron beam microprobe "Cameca SXFiveFE Field Emission Electron Probe Micro Analyzer" at the Department of Lithosphere Research at the University of Vienna using 15 kV acceleration voltage. The instrument is equipped with a field emission electron gun and five spectrometers for wavelength dispersive elemental analysis (WDX). As well as with a system for energy dispersive elemental analysis (EDX). Homogeneous mineral standards, well known in their composition, were used for standardization for quantitative analysis. In addition, matrix correction was done with the ZAF method. The methodology of EMS is described in detail in Goldstein (2012).

2.6.Explanation of abbreviations

Three cores were examined: WOK 2, WOK 4 and WOK 5. The abbreviation WOK indicates:

W = Wietzen area.

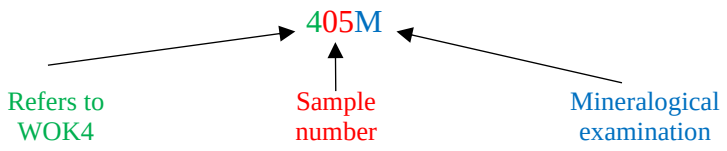
O = Obertage (Upper surface)

K = Kernbohrung (drill core)

Lfm = Laufender meter (running meter of the drill core).

- Three samples (ALB1, ALB2 and ALB3) were taken for mineralogical purposes from a specimen found next to the drilling location. Those samples were named ALB, based on the surname *(Albalushi)* of the author of this study.
- All thin section labels end's with (M), this letter indicates that these samples were used for *Mineralogical examination*. Sample labels ending with the letter (A) are considered to be used for *geochemical Analysis*.
- The abbreviation (CS) is used to indicate *calc-silicate.*
- The abbreviation *E* means that , the image was taken with parallel polarizers and *F* means that, the image was taken with crossed polarizers.

Example:



The following abbreviations have been used to refer to the mineral names :

Albite	Ab
Anorthite	An
Apatite	Ap
Biotite	Bt
Calcite	Cal
Chalcopyrite	Ccp
Chlorite	Chl
Clinopyroxene	Cpx
Clinozoisite	Czo
Dolomite	Dol
Feldspar	Fsp
Garnet	Grt
K feldspar	Kfs
Hornblende	Hbl
Opaque phase	Opq
Plagioclase	Pl
Pyrite	Py
Quartz	Qtz
Scpolite	Scp
Sphalerite	Sp
Titanite	Ttn
Vesuvianite	Ves
Wollastonite	Wo

3.Results:

3.1.Macroscopic description of the lithologies in the drill cores:

In this master thesis, three drill cores WOK2, WOK4 and WOK5 from Wietzen area of the Variegated Group were examined. Specific ranges were selected from these cores with emphasis on investigating the scheelite mineralization . (*Fig. 3A and Table 18 in the appendix).*

3.1.1. WOK2 (Fig. 3A):

The section from meter 45.00 to meter 61.00 (top to bottom) was mapped from WOK2.WOK2 consists of three lithologies: amphibolite, intercalations of calc-silicate and amphibolite, calc-silicate (carbonate and carbonate-free) and paragneiss. Generally, the calcsilicate in drill core WOK2 is highly weathered in comparison to the calc-silicate layers in the other drill cores and its approximately 8 m thick (drilled thickness). At the contact of the calc-silicate rocks and the paragneisses biotite and sulfidic minerals appear in addition to visibly secondary carbonate and quartz veins. Amphibolite is very common in the drill core. This lithology occurs at the hanging wall[1] of the drill core and it is often intercalated by calc-silicate rocks.

There are two intercalation areas in WOK2. The upper area is comprised of amphibolite intercalated by carbonate free dark calc-silicate, in which biotite and quartz can be distinguished. The lower a carbonate free light grey calc-silicate intercalates with amphibolite and is strongly weathered, however the sulfide ores are well identifiable. The inclusions of biotite-bearing amphibolite within this mineralized section (layer) are macroscopically difficult to separate . The paragneiss in WOK2 occurs only in the lower section of the drill core. Inclusions of quartz are discernible with naked eye. During the core cutting process it could be clearly noticed that the water from the cutting machine turned greyish black and had sulfurous odor. This can be taken as a clear indication that this paragneiss contains sulfide minerals and graphite.

[1] The term hanging wall does not reflect the true stratigraphic position of the geological setting , however it refers to the relative position of strata in drill cores.

3.1.2. WOK4 (Fig. 3A):

The section from meter 56.00 to meter 71.00 (top to bottom) was mapped from WOK4. WOK4 consists of four lithologies: carbonate bearing calc-silicate, marble, paragneiss and a thin layer of amphibolite, which is highly weathered. The dark calc-silicate is the dominant rock type and about three meters thick. A narrow layer of light grey calc-silicate rocks occur below the marble layer. The marbles are only present in WOK4 and they are strongly banded. The color of this marble is greenish grey, due to the presence of clinopyroxene in the marbles which are graphite-free.

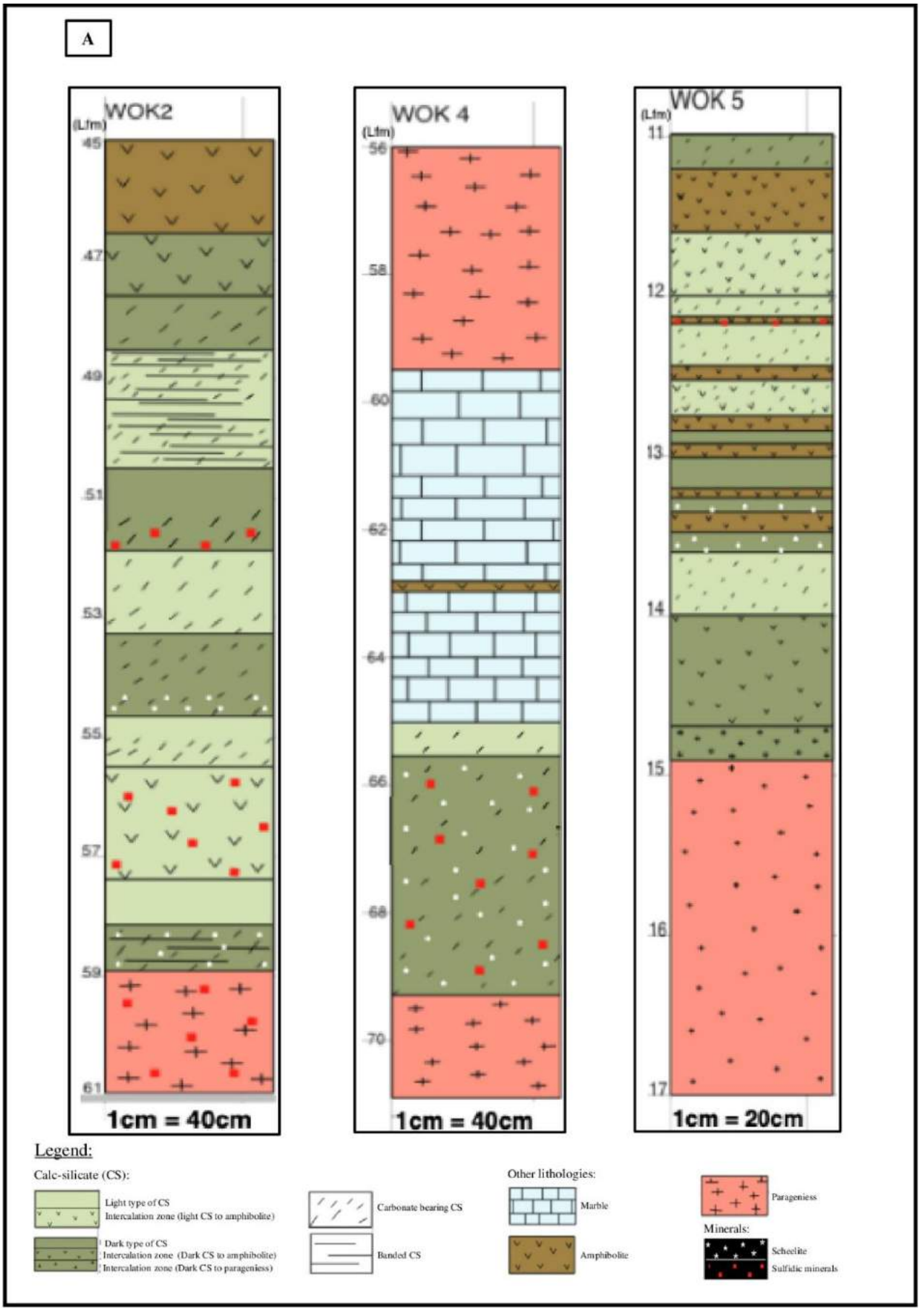
The HCl (Hydrochloric acid) test was used to differentiate between marbles and light grey calc-silicate. The surface of the marble created more foam than that of the light calc-silicates; which indicates a high percentage of carbonate. Close intercalations of marble with calc-silicate rocks could be easily identified in the weathered state. In the weathered state the marbles are strongly weathered in comparison to the calc-silicate rocks. In WOK4 the amphibole layer is very thin and occurs as an intercalation within calcite-dolomite marbles. The paragneiss in WOK4 is about 3,5 meter thick in the top section and 1.5 meter thick in the bottom section of the core. In the top section, the surface is very weathered, while in the bottom section the surface is very fresh and the quartz inclusions are very well discernable (0.5 - 2cm).

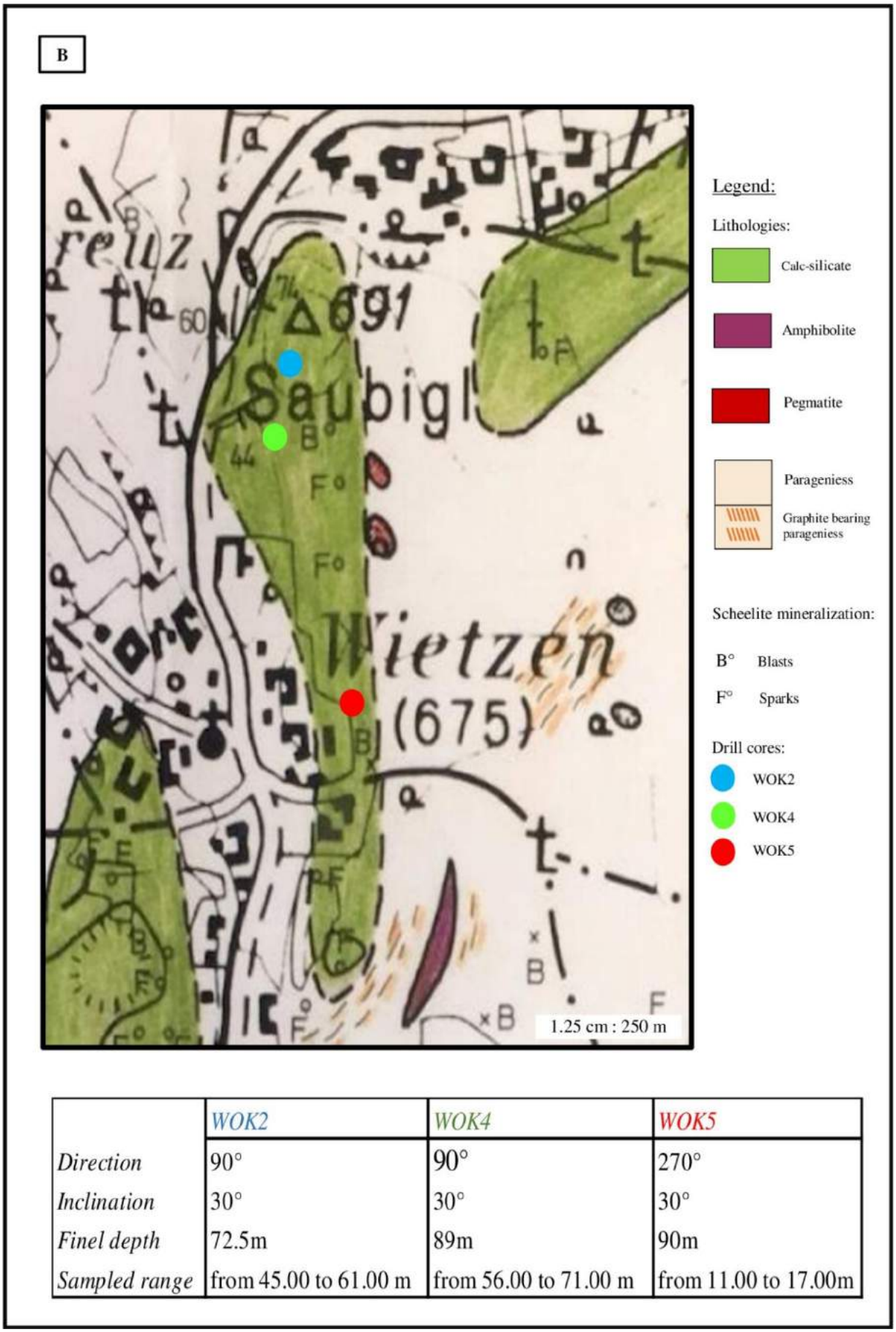
3.1.3. WOK5 (Fig. 3A):

The section from meter 11.00 to meter 17.00 (top to bottom) was mapped from WOK5.

WOK5 consists of four lithologies: calc-silicate (with carbonate and without carbonate), amphibolite, intercalations of calc-silicate with amphibolite, intercalations of calc-silicate with paragneiss and paragneiss. There is a strong and intimate alternation between calc-silicate and amphibolite in this core. The amphibolite is very frequent and homogeneous and biotite, plagioclase as well as sulfidic ores are recognizable with the unaided eye. There are three intercalation areas of amphibolite and calcsilicate. Two of which are intercalations of amphibolite and light grey carbonate-bearing calc silicate rocks, while the third layer is amphibolite associated with dark, carbonate free calc-silicate rocks. Biotite, quartz and plagioclase inclusions are noticeable in the intercalation areas of WOK5. The paragneiss layer appears in the bottom section of this drill core and it is three meters thick. The intercalation of carbonate barren calc-silicate rocks with paragneiss was observed in WOK5 only.

Macroscopically this area has a dark greenish-brown color, which is due to the high biotite and hornblende contents.





	WOK2	WOK4	WOK5
Direction	90°	90°	270°
Inclination	30°	30°	30°
Finel depth	72.5m	89m	90m
Sampled range	from 45.00 to 61.00 m	from 56.00 to 71.00 m	from 11.00 to 17.00m

Figure 3: A) The macroscopic description of the lithologies in drill cores. B) Local geology around Wietzen and position of the drill cores (Jung, MINEREX, 1982).

3.2.Scheelite mineralizations in the drill cores:

Using short-wavelength ultraviolet (SWUV) light, it was observed that all of the scheelite in the drill cores has a blue fluorescence, which emphasizes that the scheelite in Wietzen is molybdenum free. Scheelite is the only tungsten mineral that appears in all three drill cores from the Wietzen area. The scheelite mineralization is concentrated only in dark calc-silicate layers *(Fig. 3A)*. The scheelite grains are mm to tenths of mm sized. The most interesting mineralization in WOK2 occurs between meter 47.50 and 54.50 and between meter 58.20 and 58.90. There the scheelite appears in the form of very fine to coarse grained sparkles *(Fig. 4)*. The mineralization in this drill core is not associated with sulfide ores.

In WOK4 this mineralization is concentrated in the range of meter 66.70 to 69.30, which is not only fine-grained but also coarse. The distribution of scheelite within the dark calc-silicate is strongly disseminated *(Fig. 5)*. In this drill core the mineralization is associated with sulfidic ores and scapolite. This mineralization is associated with xenomorphic sulfidic ores. Sulfide grains vary in size, but in the majority of cases their grains are coarser (approximately 1.5 – 2.5 mm) than the scheelite grains. The mineralization of scheelite in WOK5 is characterized by very fine-grains, which are more or less homogenously distributed. It occurs between meter 13.25 and13.35 and between meter 13.52 and 13.66. This mineralization is not associated with sulfide ores, but it is adjacent to amphibolite layers. The scheelite-bearing calc-silicate layers are approximately 10 cm thick, however, the grains are concentrated in this small area *(Fig. 6)*. Not only the fluorescence of scheelite could be seen in WOK5, but also a yellow fluorescence of wollastonite and an orange fluorescence of scapolite are present in this core.

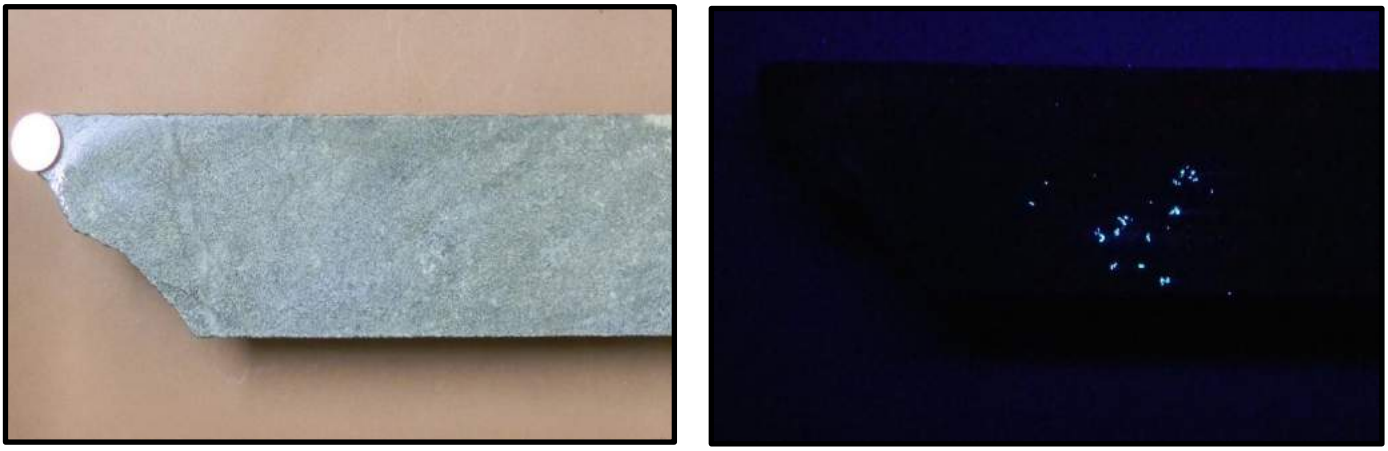


Figure 3: Sample [217] from WOK2 (range: meter 58.20 to meter 58.90), the mineralization is concentrated only in the right area of the sample. The grains are coarse and it is an indication of late formation of scheelite. The scale is the diameter of one cent coin (16.25 mm).

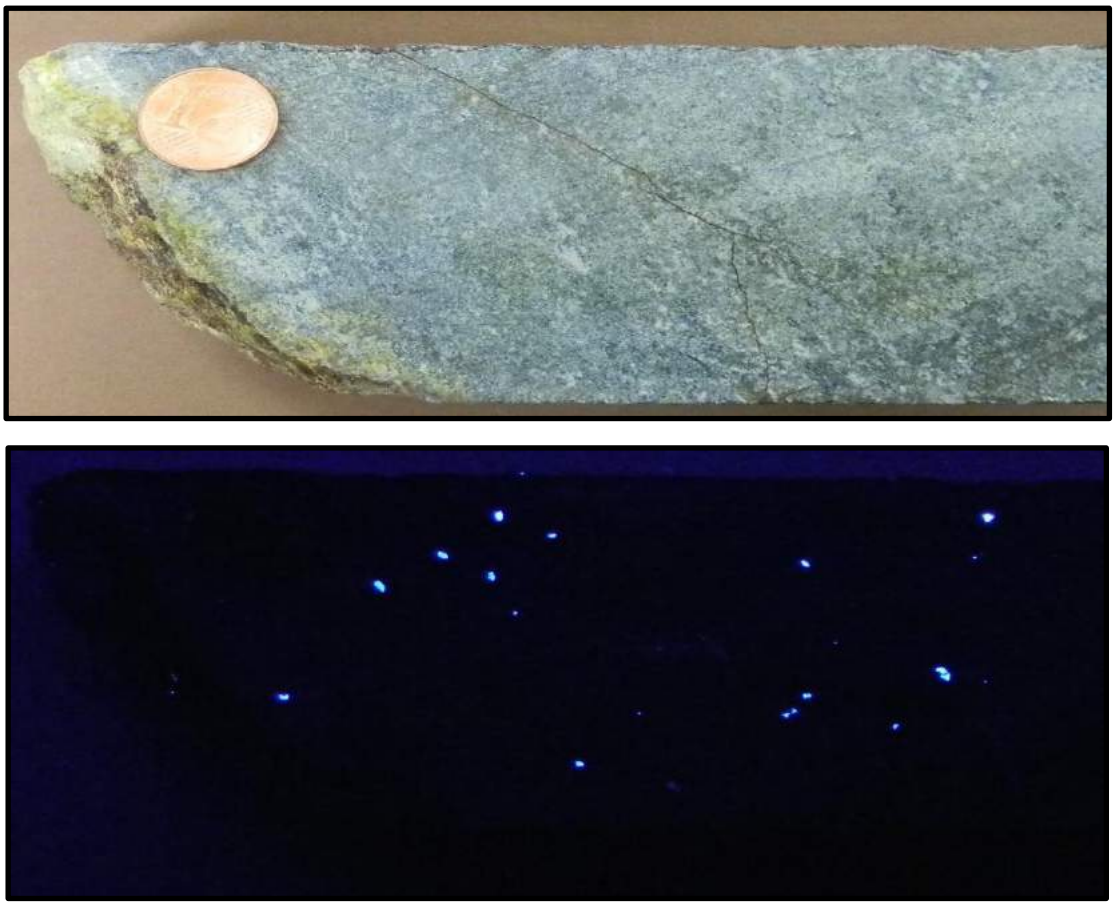
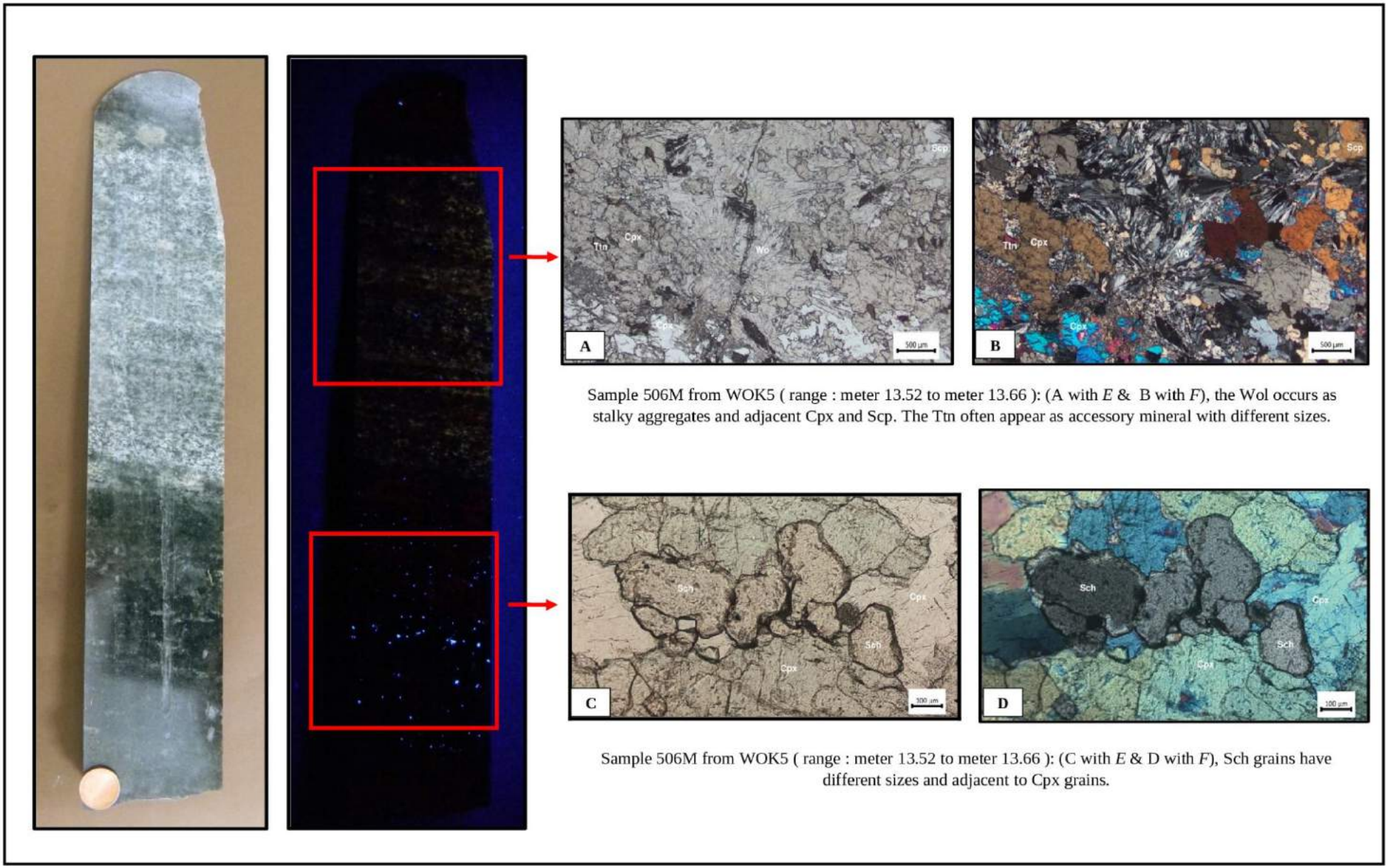


Figure 4: Sample [406] from WOK4 (range: meter 67.60 to meter 68.50), The scheelite grains are irregularly distributed in dark calc-silicate layer. (scale : coin diameter (16.25mm)).



Sample 506M from WOK5 (range : meter 13.52 to meter 13.66): (A with *E* & B with *F*), the Wol occurs as stalky aggregates and adjacent Cpx and Scp. The Ttn often appear as accessory mineral with different sizes.

Sample 506M from WOK5 (range : meter 13.52 to meter 13.66): (C with *E* & D with *F*), Sch grains have different sizes and adjacent to Cpx grains.

Figure 5: sample [506] was taken from WOK5, contact area between the wollastonite rich area and the scheelite rich area (range: meter 13.52 to meter 14.00). The upper area is wollastonite rich, it is observed that the yellow fluorescence of wollastonite is underlines emphasizes. The mineralization of wollastonite in this layer is homogeneous. In the lower area the scheelite grains are tightly associated to each other and their size varies.

4. Laboratory methods:

4.1.Thin sections results:

A total of 44 thin sections were prepared and examined under the microscope to understand the lithology of the drill cores (*Table. 1*). The aim was to estimate the modal composition of the calc-silicate rocks, marbles, amphibolite, intercalation zone (calc-silicate with amphibolite), paragneiss and intercalation zone (calc-silicate with paragneiss) from the Variegated Group. The results of the thin sections investigation are summarized in *Fig. 15 and Table. 20).*

Light type (CS)	Dark type (CS)	Marbel	Intercalation between CS and amphibolite
507M	501M	401M	504M
201M	512M	402M	508M
2011M	**5051M**	403M	509M
202M	**506M**	Amphibolite	212M
2091M	210M	502M	213M
204M	2092M	503M	214M
205M	203M	5052M	215M
206M	207M	Paragneiss	Intercalation between CS and paragneiss
2083M	2081M	511M	510M
211M	**2082M**	218M	
216M	**217M**		
404M	**405M**		
ALB3M	**406M**		
	407M		Total = 44 Thin sections
	408M		Thin sections with scheelite

Table 1: Thin sections from Wietzen area.

After examining the samples taken from the drill cores, the following results were observed:

4.1.1.The calc-silicate:

The dark type:

The dark type of the calc-silicate rock is of special importance, because it bears the tungsten mineralization. After examining 15 thin-sections under the microscope and supported by of X-ray diffractometry method for some samples, clinopyroxene, scapolite, and quartz were found to be the three most abundant minerals in the dark type calc-silicate rock.

Besides this paragenesis, plagioclase might sometimes be present in the dark type calc-silicate rock as well. The paragenesis clinopyroxene, scapolite, quartz and ± plagioclase forms at least 85 vol.% of the rocks. Their grain size varies from 0.5mm to 3.5mm. Their modal volume ratio varies widely in the thin sections, however, clinopyroxene is always the most abundant mineral which forms up to three-fourths of the rock volume.

XRD analysis and microprobe examination showed that the hedenbergite (Fe-rich clinopyroxene) is the dominating type of clinopyroxene in the dark type calc-silicate *(Diagram 1).* However, diopside appears also in this type of calc- silicate. It's hard to differentiate between hedenbergite and diopside under the microscope due to the complete solid solution formation between the two end members. Thus, powder diffraction and electron beam microprobe methods have been used on some samples. The diopside grains are colorless to slightly greenish; whereas, hedenbergite grains are brownish-green with hardly noticeable pleochroism. Optically the grains are homogenous without zoning. The clinopyroxene grains are xenomorphic to hyp-idiomorphic, and they occur in the sizes between 0.5mm and 3.5 mmm *(Fig. 7, 8 and 9).* The surfaces exhibit a significant cleavage and cleavage angles are occasionally recognizable, especially in large grains. In dark calc-silicate the scapolite often occurs as the main constituent next to clinopyroxene. This mineral appears as xenomorphic, but in rare cases it can be found as hyp-idiomorphic. The grain size varies from less than 0.5mm to 1.5mm and visually the scapolite is colorless. In addition, no twinning has been observed in this mineral and some grains are fractured. The scapolite resembles the plagioclase in parallel polarized light as the plagioclase are mostly twinned and extinguish obliquely. The scapolite has more intense and spotty interference color in comparison to plagioclase. Thus, it could be caused by the chemistry as it varies within a single grain *(Fig.7).* The scapolite is often adjacent to quartz and plagioclase, and it has

inclusions of quartz, apatite, potassium feldspar and titanite. Quartz with grain sizes of up to 2mm are not common in the dark type of calc-silicate, they usually occur in much smaller grains. As a rule, the optical extinction of quartz under crossed polarization is wavy or patchy. The paragenesis (clinopyroxene-scapolite-quartz-plagioclase) occurs in considerably variable amounts in different thin sections, some of which are virtually free of plagioclase. The plagioclase shows frequent twinning according to the albite law and sometimes weak zoning. Two types of dark calc- silicates exist, carbonate bearing and carbonate barren. The calcite occurs in two morphologies in carbonates bearing calc-silicates, either as primary grains in the matrix, or as secondary veins *(Fig. 9).* In the majority of cases, calcite grains are xenomorphic and smaller than 0.5mm.

Opaque minerals are common, forming up to 5% of the area in some thin sections ([407M] and [408M]). The opaque minerals appear particular in WOK4 dark type calc-silicate thin section samples. As an accessory mineral brown titanite appears with a tendency to be idiomorphic. It occurs as inclusions in clinopyroxene and also as individual grains. Irregularly distributed, small-rounded grains of apatite are typical accessory minerals in clinopyroxene and scapolite *(Fig. 7).* Small green chlorite grains often occur along the grain boundaries in clinopyroxene. The garnet appears in this type of calc-silicate, but is always classified as minor phase *(Fig. 8).* Scheelite is the only tungsten mineral that appears in thin sections of the dark calc-silicate rock. The borders against clinopyroxene and scapolite are irregular, but the mineral shows a tendency to be idiomorphic against quartz. The mineral is colorless and has high relief, high birefringence and is often homogeneous *(Fig. 6 and 10).* Scheelite is frequently associated with opaque minerals *(Fig. 9).* Clinozoisite occurs with typical elongated aggregates (columnar aggregates) in drill cores samples as an accessory mineral in [207M], however, in WOK4 it is sometimes a minor component of thin sections ([407M] and [408M]) *(Fig. 9).* This mineral was easy to identify because of the anomalous bright Prussian blue interference colors. The shape of the mineral is xenomorphic with an average grain size of less than 0.5mm. Vesuvianite was observed in one thin section of calcite-bearing dark calc-silicate rock [2081M] as accessory mineral and the grains tend to be hyp-idiomorphic. Wollastonite occurs only in [506M] thin section *(Fig. 6).* This mineral is the main component of this sample alongside clinopyroxene that forms stalky to radiating aggregates. Micas are completely missing in the dark calc-silicate rock.

Dark calc-silicate from WOK2:

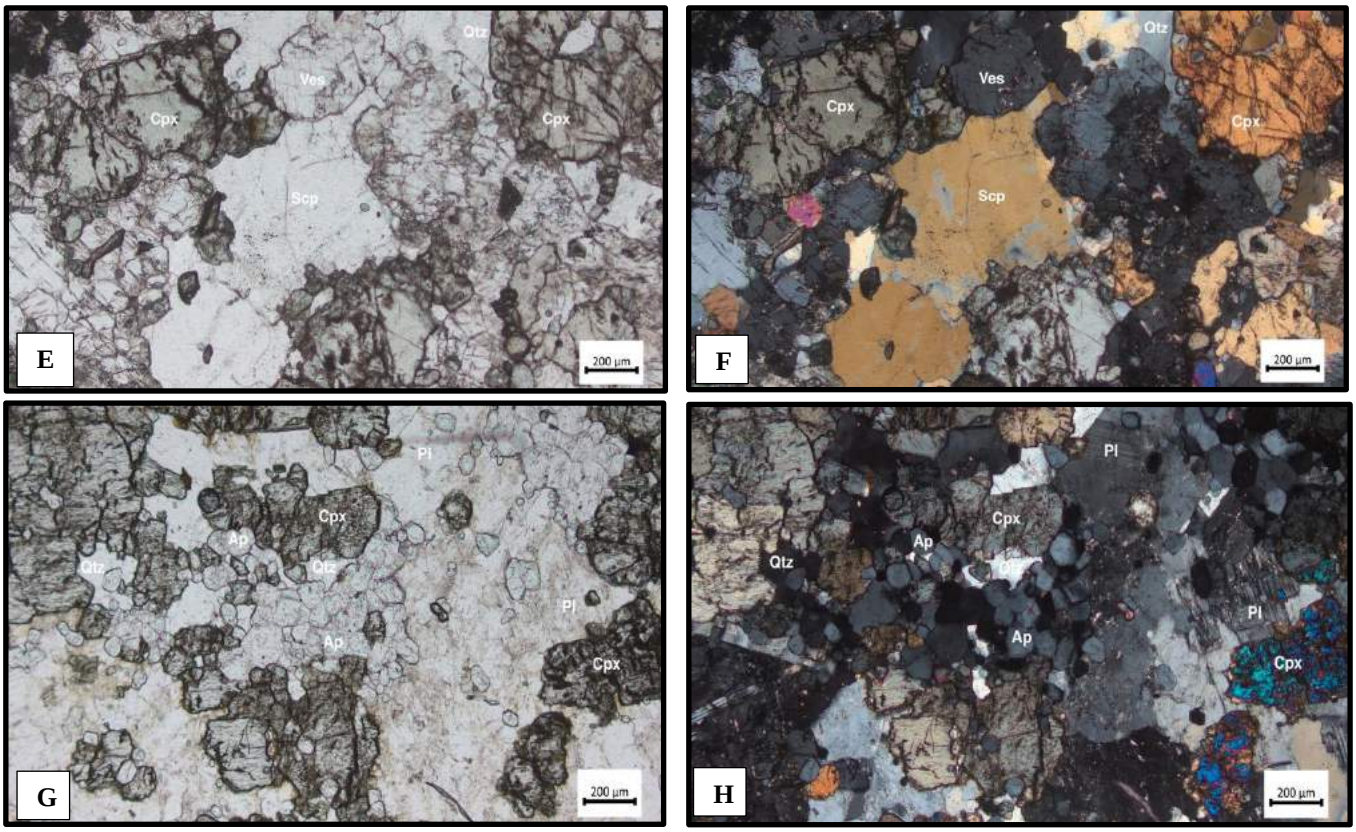


*Figure 6: Sample 2081M (range: meter 53.7 to meter 54.00), (*E *with E and* F *with F): The Cpx and Scp grains appear in this section with different sizes (mostly) larger than 0.5mm. The Cpx with interference colors (dark orange, pink and gray), the Scp have dull surface with (E) and patchy interference colors with (F) and the vesuvianite have dark gray tones as interference colors. Sample 2092M (range: meter 50.60 to meter 51.00), (G with E and H with F): the apatite networks is very dominant in this sample and is often noticed that the apatite grains occur in different sizes.*

ALB3:

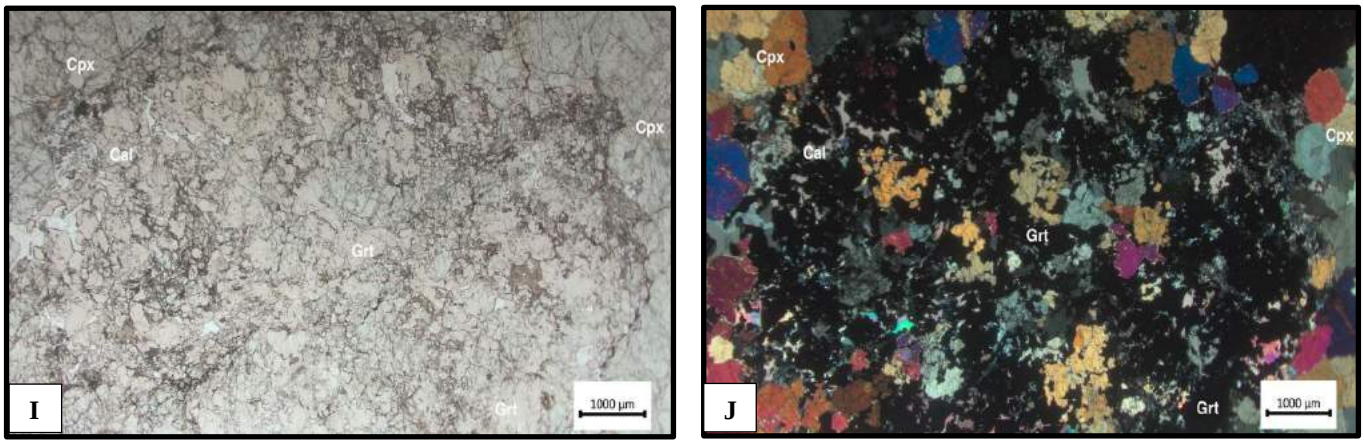


Figure 7: Sample ALB3 from specimen (I with E and J with F): The Grt is adjacent to the Cpx grains. This Grt grain is strongly fractured and deformed into deformed into small grains. The Cal grains in this section are always xenomorphic and very small.

Dark calc-silicate from WOK4:

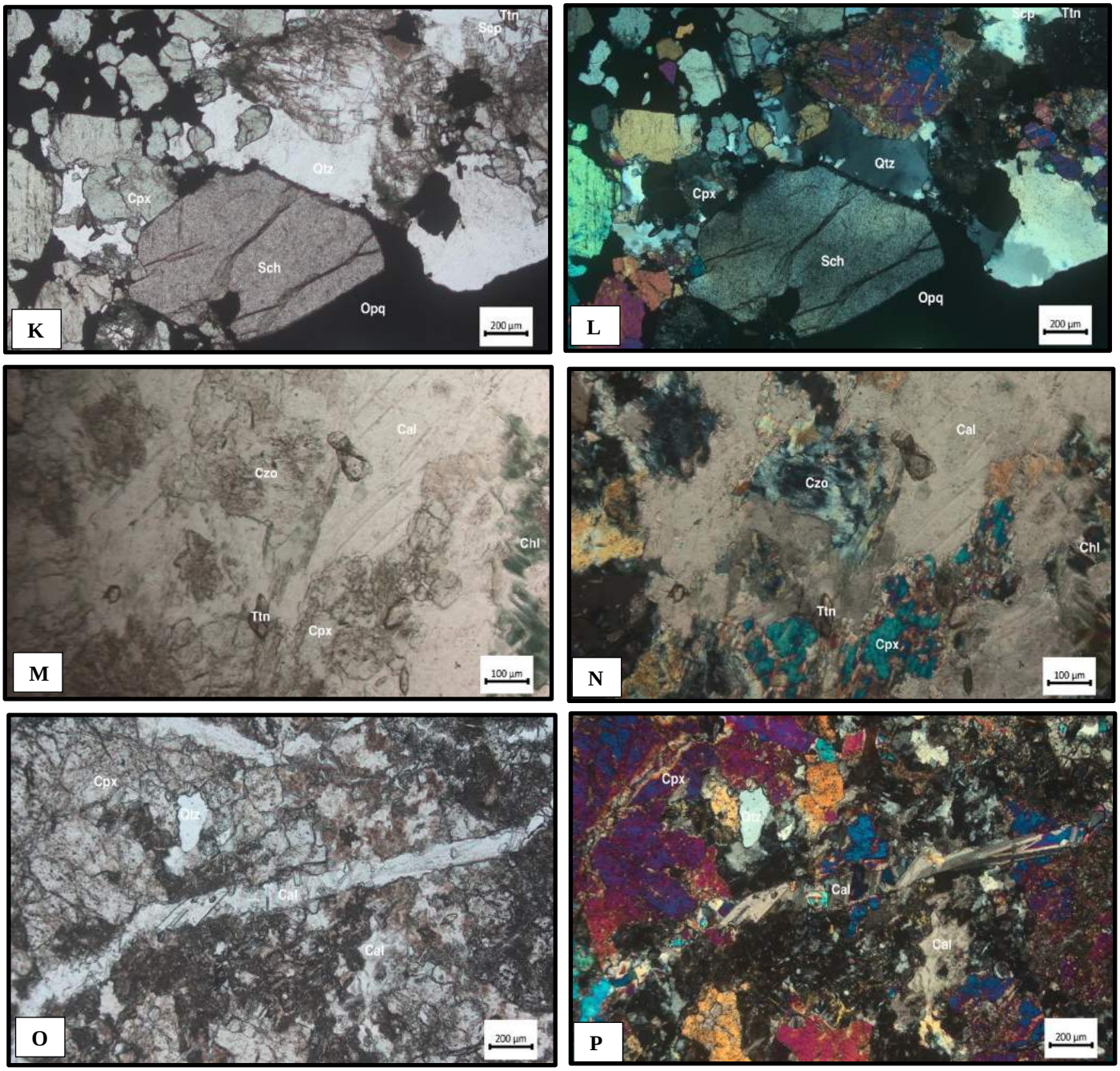


Figure 8: Sample 405M (range :meter 66.70 to meter 67.40), (K with E and L with F): The Sch grains in this section are always idiomorphic and adjacent to the Cpx, Scp, Qtz and Opq. With (E) Sch is colorless but cloudy and almost all Cpx surrounding Sch have light greenish pleochroism. With (F) the Sch is grayish brown.

Sample 406M (range :meter 67.60 to meter 68.00) (M with E and N with F) : This sample contains Czo as minor component . The primary Cal is common in matrix and larger than 0.3mm in [406M]. The images (O with E and P with F) are from the same section and Cal secondary vein is noticeable in both of O & P

Dark calc-silicate from WOK5:

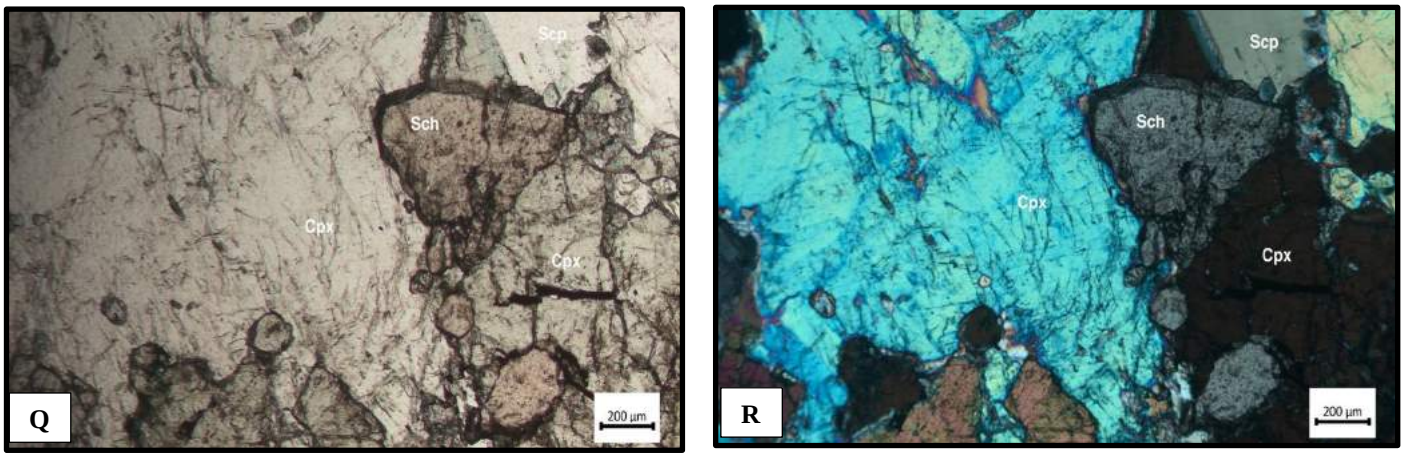


Figure 9: Sample 5051M (range: meter 13.25 to meter 13.35), (Q with E and r with F): Sch grains have different sizes and adjacent to Cpx grains

The light type calc silicate rock

Based on the examination of 13 thin sections of the light type calc-silicate rock, it has been noticed that Scheelite was not a component of this type as opposed to the dark type calc-silicate rock. Apart from the difference stated above, the mineralogical composition of the light type calc-silicate rocks is quite similar to that of the dark type. The mineralogical composition is mainly characterized by the predominance of clinopyroxene, scapolite, plagioclase and quartz. Some thin sections of the light type calc-silicate consist essentially of pyroxene scapolite minerals. In this type of rocks, the clinopyroxenes are hyp-idiomorph to xenomorphic, and they are not zoned. As observed from the samples of the light type calc-silicate rocks, both types of clinopyroxene are present, diopside (Mg- rich clinopyroxene) and hedenbergite (Fe-rich clinopyroxene). However, the magnesium-rich clinopyroxenes are more prominent in this type of calc-silicate *(Diagram.1).*

Optically, the scapolite in the light type calc-silicate looks similar to the dark type calc-silicate, however, often it can be noticed that the scapolite grains in the light type are larger than those in the dark type. The paragenesis clinopyroxene, scapolite, and plagioclase is dominates in some thin sections. Plagioclase, quartz and inclusions of potassium feldspar in plagioclase were found in many samples of the light type calc-silicate rocks. However, it should be recognized, that all of these minerals occur in very different amounts in the various thin sections, some of which are practically free of plagioclase and potassium feldspar. Plagioclase often shows twinning according to the albite law and some zoning and in some thin sections, they are very blurry and sericitized. The grains occur with different sizes (less than 0.5mm to 1mm) and in most cases they are xenomorphic and adjacent to quartz *(Fig.11).* Quartz was found in relatively large quantities in comparison to the dark type of calc-silicate rocks. The quartz is xenomorphic and can occur either as main or minor component, as an accessory mineral or in veins. The potassium feldspars occurs as an accessory mineral in some samples ([202M], [205M] and [2083M]). Similarly to what is found in the dark type calc-silicate rocks several accessory minerals were identified in the thin sections such as idiomorphic brown titanite which is often in associated with pyroxene, xenomorphic opaque minerals, small round grains of apatite, and green chlorite.

Almost all thin sections of the light calc-silicate rocks, except for sample [216M], contain calcite, either as primary xenomorphic small grains or secondary veins. The garnets are often

accessory minerals and only in [ALB3] they occur as a minor phase. Its beige colored high relief grains are strongly decomposed and often adjacent with clinopyroxenes. The mineral clinozoisite occurs with typical stalky/columnar aggregates as an accessory mineral in the light calc-silicate *(Fig. 11).* There was no trace of both wollastonite and vesuvianite in the light type calc-silicate rock.

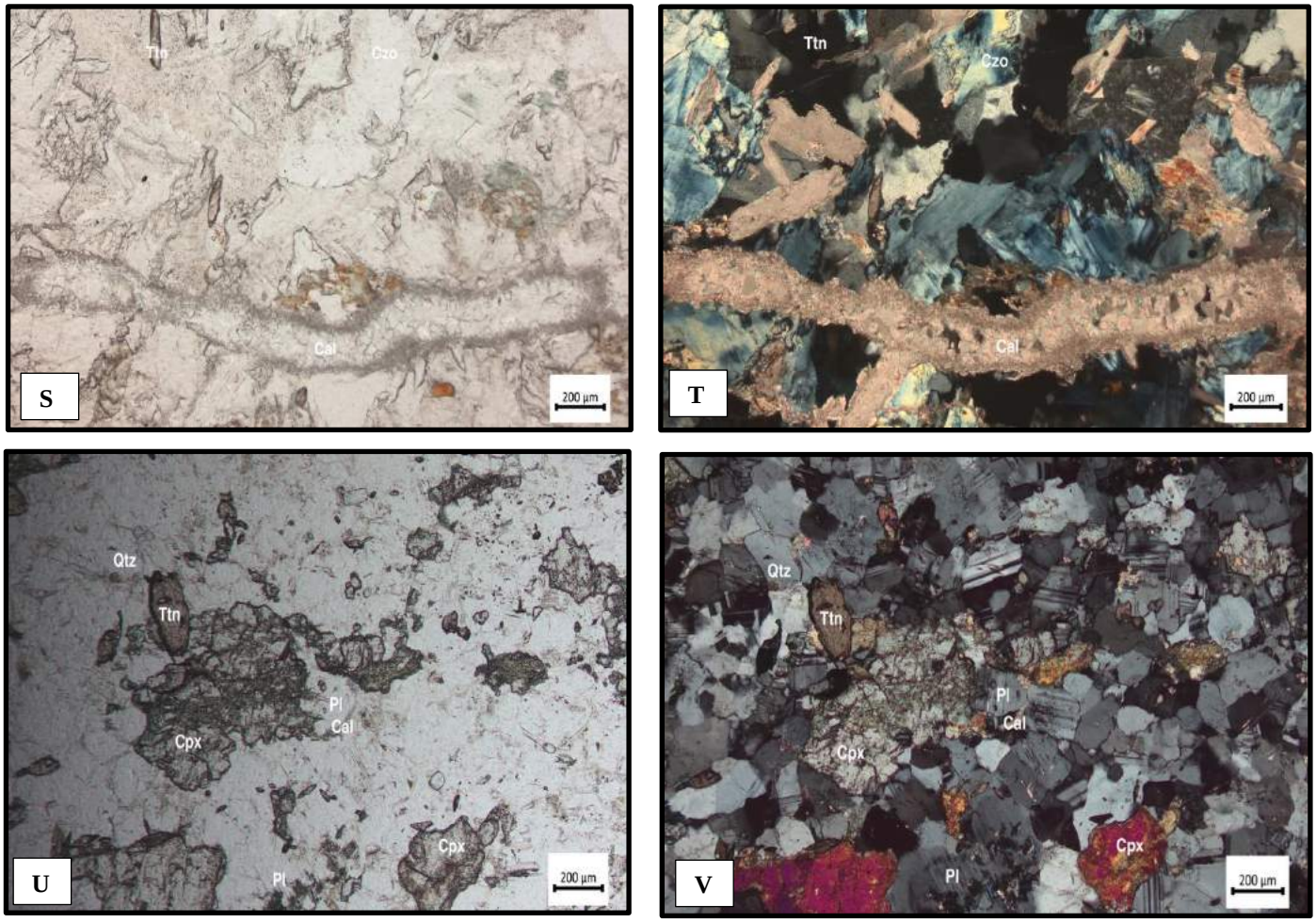


Figure 10: Sample 404M (range : meter 65.00 to meter 65.30), (S with E and T with F) : The Cal occurs in this image as primary xenomorphic grains and secondary vein.

Sample 507M (range: meter13.66 to meter 14.00), (U with E and V with F): the paragenesis Cpx, Qtz, Pl is often observed in Light CS. The surface of Cpx is always with cleavage cracks and the grains have a high relief.

4.1.2. The marbles:

Marbles can be defined as metamorphic rocks, which are formed by transformation (metamorphosis) of limestone. Marbles in their nature are homogeneous white rocks because of their high content of calcite and/or dolomite. In other words, a pure marble consists to 95% of calcite and/or dolomite. After examination of three thin sections of marble layers in WOK4, it was concluded that the marbles are petrographically more complex than pure marble. Macroscopically, the marbles have slightly greenish color. Microscopically, it was found that the color is caused by minor clinopyroxene content. The paragenesis calcite, clinopyroxene was observed in all marbles *(Fig. 12).*

However, only in thin-section [401M] the weathering phenomena on the surfaces of the mineral grains could be observed. Microscopically, calcite could be detected as the main constituent of the marble thin sections of WOK4. However, with the help of XRD it was observed that the marbles consist mainly of colorless calcites with little dolomite content. The grains are often xenomorphic, rarely hyp-idiomorphic and their size varies from 0.1 mm to 1 mm. The cleavages are very distinct almost in all grains, especially in the unweathered area of the thin sections. Clinopyroxenes occur in marbles as a minor phase forming ± 10% of the total thin section. In marbles the clinopyroxene grains are small xenomorphic and sometimes exhibit a round shape. In unweathered areas the clinopyroxenes have an intense interference color under crossed polarization in comparison to those in weathered areas. Often titanite appears as inclusions in clinopyroxenes. However, small grains of quartz and potassium feldspar occur as accessory minerals and are always xenomorphic with small grains. Scapolite, vesuvianite, garnet, wollastonite and opaque minerals were not detected in samples of the marbles of WOK4.

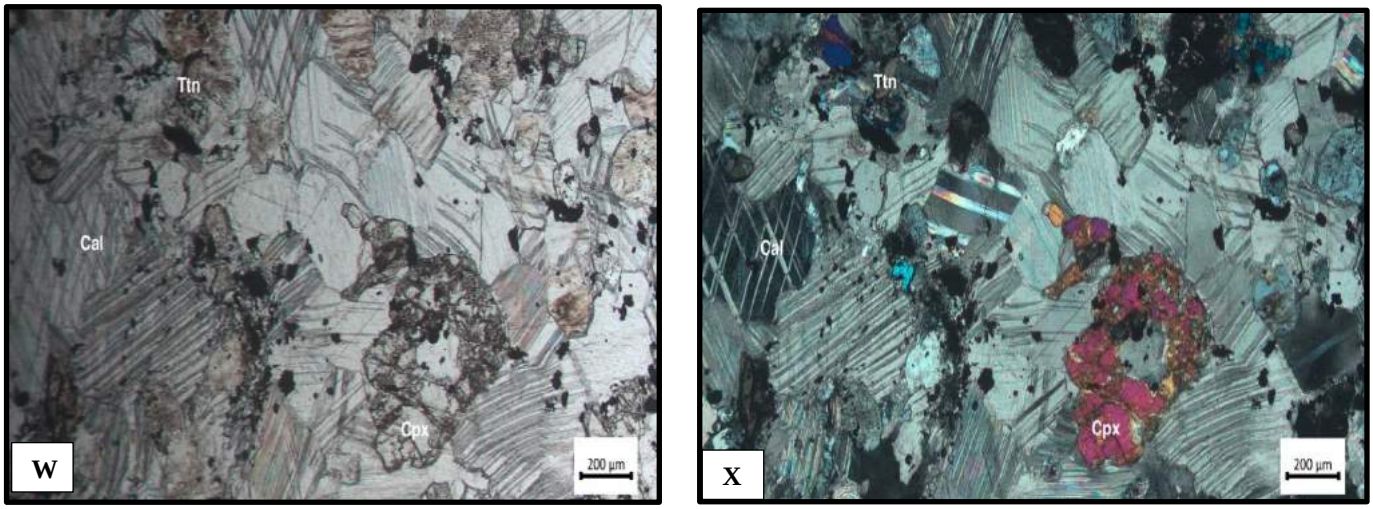


Figure 11: Sample 403M (range: meter 63.60 to meter 63.80) (W with E and X with F) : the typical paragenesis (Cal and Cpx) of marbles. The Cpx grains in marbles are smaller than those in the calc-silicate.

4.1.3. The amphibolite:

Three thin sections of amphibolite from WOK 5 were examined under the microscope. The paragenesis hornblende, plagioclase and biotite was always observed in the samples and formed the main phases of the sections *(Fig. 13).* The mineral hornblende is very easy to identify because of its distinctive absorption color and pleochroism. The absorption color of the hornblende varies from light green to olive green depending on the orientation and cut position of the mineral grain. The cleavages show the typical amphibole cleavage angle within larger grains, but in most cases the mineral grains are very small, smaller than 1mm and cleavage is hard to discern. The hornblende grains are always xenomorphic and, in most cases, have slender prismatic shape. The simple twinning effect is also observable and in most cases this mineral occurs next to biotite. The mineral biotite is very common and almost always smaller than 1mm. The crystals are xenomorphic and with clear to strong pleochroism. The color of this pleochroism varies between light brown, reddish brown and dark brown. Titanite and chlorite are the typical inclusion minerals in biotite and hornblende. Some biotite grains contain pleochroic halos.

The colorless plagioclase with low relief is xenomorphic and the mineral grains are smaller than 1.5mm. Twinning of plagioclase is always observed in the thin sections. However, the zoning of plagioclase is very weak and the surface of the mineral is always free of cleavage cracks. Quartz is a minor phase in the amphibolites of the WOK5 drill core. Quartz often occurs

next to plagioclase and forms xenomorphic grains. The mineral grains are always smaller than 1mm. Titanites and chlorites occur more often than apatite and opaque minerals as inclusion minerals in amphibolite of WOK5.

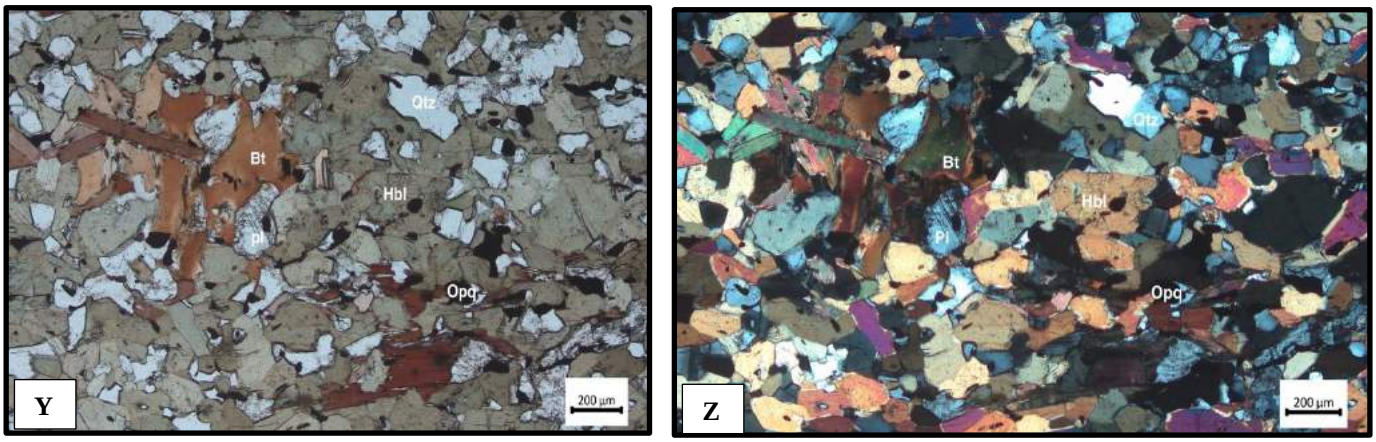


Figure 12: Sample 502M from WOK5 (range: meter 11.25 to meter 11.65), (Y with E and Z with F) : In all amphibolite sections the paragenesis (Hbl, Bt, Pl) is observed and the Qtz occurs in these sections as well.

4.1.4.The paragneiss:

In the paragenesis biotite, quartz and plagioclase are the dominating minerals in the [511M] and [218M] sections *(Fig. 14).* Biotite is xenomorphic with a typical brown pleochroism depending on the orientation of the grain and often with pleochroic halos. Greenish chlorite is often noticeable next to biotite especially in thin section [511M] as accessory mineral. Quartz is xenomorphic, irregularly distributed in thin sections and often adjacent to feldspars. Feldspars are minor phases in both sections, similarly garnet is a minor phase in [511M] and opaque minerals are minor phases in [218M]. The feldspars are either xenomorphic plagioclase with polysynthetic twinning or rarely alkali feldspar. Garnet grains are hyp-idiomorphic and are about 1-1.5mm in size. In [218M] the opaque minerals are irregularly distributed throughout the thin sections. Accessory primary calcite veins and secondary chlorite occur in section [218M]. A thin section of *intercalation between carbonate free calc-silicate and paragneiss* from the section between meter 17.75 and 15.00 was examined under the microscope. The first observation was that both lithologies in sample [510M] are slightly mixed. The main phases of the thin section are quartz, biotite and hornblende. The minor phases are plagioclase and clinopyroxene. Titanite often occurs as an inclusion mineral in

clinopyroxene. A strongly deformed xenomorphic garnet grain was noticed at the edge of the section.

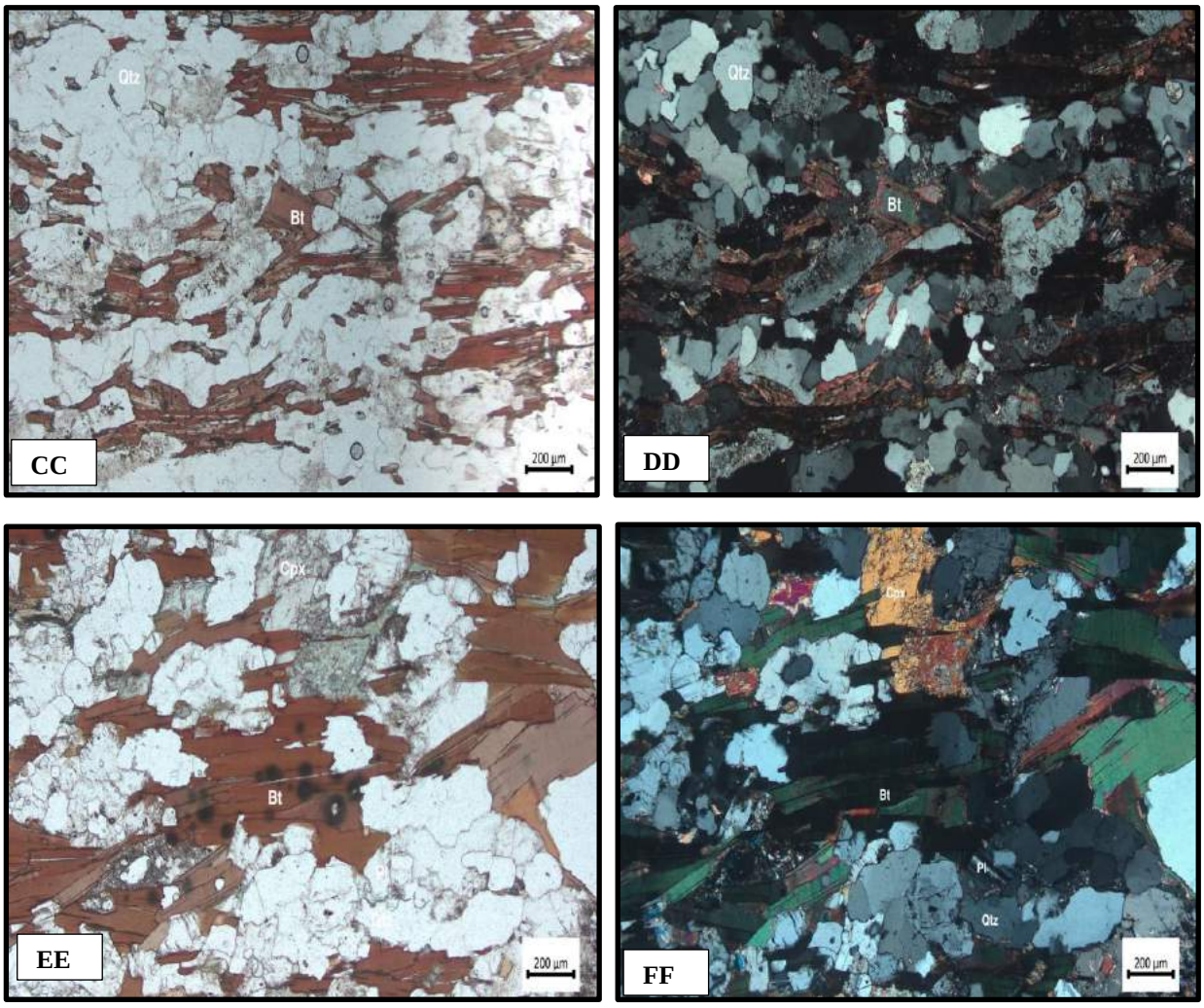


Figure 14: Paragneiss: Sample218M from WOK2 (range: meter 59.70 to meter 60.00), (CC with E and DD with F). Sample 510M from WOK5 (range: meter14.72 to meter 15.00) is intercalation between calc-silicate and paragneiss , (EE with E and FF with F). In [510] the Bt often occur with pleochroic halos and adjacent to Cpx

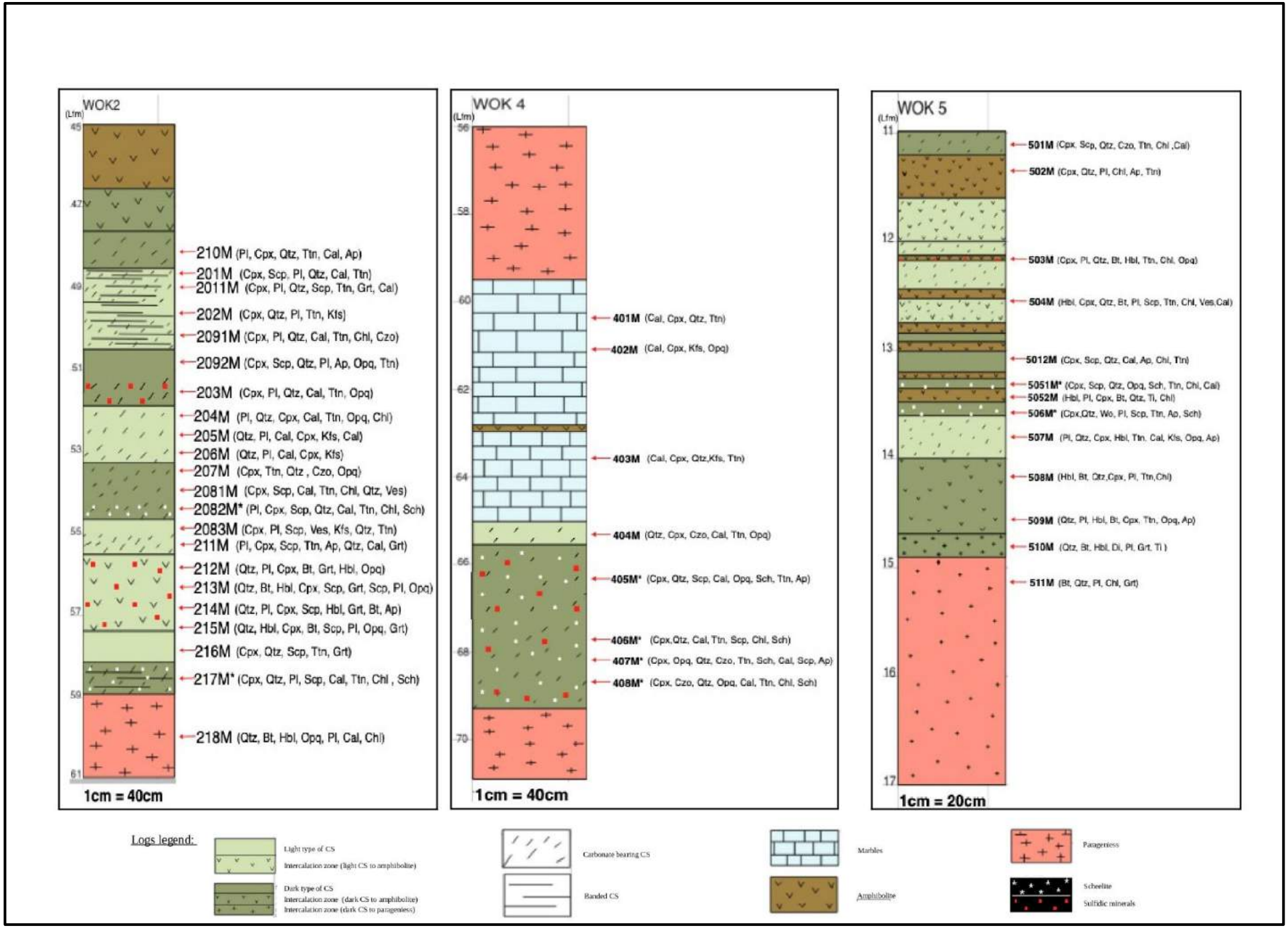


Figure 15: The microscopic composition of each thin section which is taken from drill cores.

4.1.5.Summary of macroscopic and microscopic observations:

* In all the samples of the dark calc-silicate rocks examined, the characteristic paragenesis is clinopyroxene (mainly the hedenbergite member), scapolite, and quartz; the only exception is sample [207M], which does not contain scapolite. In many cases, the dark calc-silicate rocks contain plagioclase either as a major or minor phase, e.g. (from WOK5: 506M, from WOK2: 210M, 203M, 2082M and 217M).

* In all the examined samples of the light calc-silicate, the characteristic paragenesis consists of clinopyroxene (mainly of diopside), scapolite and plagioclase, with the exception of samples [216M] and [404M]. However, dark and light variants of the calc-silicate are primarily distinguished by the different clinopyroxene species, where the diopside content is higher in the light variants of calc-silicate rock.

* Two types of calc-silicate rocks can be identified on the basis of carbonate content, the first is carbonate-bearing and the second is carbonate-free. Calcite occurs in two morphologies in the carbonate bearing calc-silicate rocks, either as primary grains in the matrix or as secondary veins.

*Garnet is present in dark [ALB1, ALB2 and ALB3] and light [211M] calc- silicates, but it is always a minor phase.

* Small bands of wollastonite were observed only in one scheelite bearing calc-silicate sample [506M] together with scapolite. Vesuvianite was detected in two samples ([2081M] and [2083M]).

* Among the accessory minerals mostly idiomorphic titanite, green chlorite, roundish apatite and alkali feldspars dominate.

* The marble in WOK4 is approximately 4 m thick, The footwall of the marbles exhibits a gradational transition to light calc-silicate rock.

* In WOK5, the scheelite-bearing samples [5051M] and [506M] are adjacent to the amphibolite lithology. Scheelite is frequently associated with the sulfides : pyrrhotite, pyrite and chalcopyrite. In WOK4, the thickness[2] of scheelite bearing strata is 3.5m.

[2] The thickness refers to the thickness of the drill core, and does not indicate the true thickness.

4.2. X-ray fluorescence analysis (Bulk chemistry) :

The individual analyses with rock standards are presented in the Appendix (*Table. 21 and 22).*

4.2.1.The calc-silicate:

The calc-silicate of the Wietzen area can be divided, both macroscopically and microscopically, into two types, which is emphasized by their confirmed geochemistry *(Table.5).*

Interpretation of *(Table. 2, 3 and 5)*:

- As shown in the results the SiO_2 content in both types of calc-silicate rocks is within the same range (between 46 wt% and 54 wt%). The average content ranges (51.60 wt% in light type and 49.58 wt% in the dark type) (*Table.5).*
- An important observation is that the Fe_2O_3 content in the dark calc-silicate is higher than in light calc-silicate.
- The Fe_2O_3 content in the light calc-silicate rock ranges from 5.36 wt% to 8.28 wt% and in the dark type from 8.48 wt% to 18.93 wt% in samples of WOKs. The average Fe_2O_3 contents are 7.16 wt% in light type and 11.54 wt% in the dark type.
- The CaO content in the dark type is higher than in the light type. The CaO content in the light calc-silicate rock ranges from 14.58 wt% to 19.42 wt% and in the dark type from 14.85 wt% to 22.88 wt% in samples of WOKs. The average CaO content is 17.32 wt% in light type and 18.79 wt% in the dark type.
- The Al_2O_3 and Na_2O content in light calc-silicates is higher than in the dark variant. the Al_2O_3 content in the light calc-silicate rocks ranges from 10.80 wt% to 14.89 wt% and in the dark type it ranges between 7.98 wt% and 11.11wt%. The Na_2O content in the light calc-silicate rocks ranges from 0.73 wt% to 3.48 wt% and in dark type it is between 0.41 wt% and 2.31 wt%.
- The content of other elements do not show any significant differences between the two types of calc-silicate rocks.
- The most important difference between both types of calc-silicate rocks is that the W concentration in dark type is significantly higher than in the light type. The average content of all dark calc-silicate samples is 156 ppm and in the light type it is only 7 ppm.

- The concentration of elements Cu, Ni and Zn are higher in the dark calc-silicate rocks than in the light ones.
- The elements Cr, Nb and Pb are about equally concentrated in both types of calc silicate rocks.
- The concentration of elements (Ba, Ce, La, Sr, V, Y and Zr) is bit higher in light calc-silicate rocks than in dark ones.

Sample	***512A***	***5051A***	***506A***	***210A***	***2092A***	***203A***	***207A***	***2081A***	***2082A***	***217A***	***405A***	***406A***	***407A***	***408A***
SiO2	48.92	48.54	50.44	47.95	52.65	51.48	51.14	52.21	50.74	54	46.16	45.97	46.04	47.84
TiO2	0.65	0.45	0.58	0.55	0.57	0.5	0.58	0.58	0.65	0.6	0.48	0.53	0.62	0.67
Al2O3	11.05	7.98	9.63	9.86	10.27	8.24	10.64	10.02	11.01	10.78	8.4	10.14	9.83	11.11
Fe2O3	10.8	15.48	9.73	8.48	9.18	9.16	8.87	9.32	8.99	10.17	18.93	12.5	17.69	12.32
MnO	0.46	0.54	0.42	0.57	0.37	0.29	0.49	0.52	0.58	0.47	0.47	0.44	0.41	0.38
MgO	3.44	2.92	2.67	3.87	4.08	3.55	3.51	3.75	4.33	3.1	2.18	2.3	2.68	2.82
CaO	19.8	20.04	22.88	22.19	16.43	15.79	19.38	19.13	19.17	17.66	17.06	19.86	14.85	18.75
Na2O	2.04	1.45	1.53	0.76	2.31	1.71	0.98	1.47	1.88	1.53	0.92	0.41	0.45	0.45
K2O	0.29	0.21	0.19	0.71	0.3	0.84	0.54	0.42	0.43	0.16	0.56	0.4	0.5	0.52
P2O5	0.12	0.17	0.12	0.24	0.4	0.59	0.09	0.08	0.18	0.1	0.07	0.08	0.1	0.09
Lol	0.19	0.00	0.36	3.90	2.02	6.15	2.28	1.18	0.96	0.30	2.47	5.24	3.98	2.68
Total	97.76	97.78	98.55	99.08	98.58	98.30	96.16	98.68	98.92	98.87	97.70	97.87	97.15	97.63
Ba	62	41	55	409	96	303	546	616	304	84	88	47	126	115
Ce	67	40	64	42	79	65	58	63	69	64	69	69	74	59
Cr	49	43	47	45	47	48	46	46	54	50	57	47	88	73
Cu	15	69	9	9	13	61	9	10	9	8	307	75	307	84
La	30	21	37	19	40	36	39	24	38	35	37	33	28	33
Nb	11	10	10	9	10	11	10	10	11	11	9	9	10	11
Ni	24	37	27	22	41	40	27	23	33	31	57	15	53	32
Pb	10	7	12	13	4	4	8	7	7	5	13	19	19	13
Sr	261	181	321	310	454	447	249	312	317	365	187	196	190	251
V	64	60	59	62	75	74	59	54	69	63	53	54	76	63
W	12	467	449	28	55	32	41	35	107	353	260	119	151	75
Y	29	23	22	29	29	32	22	20	29	26	19	19	24	21
Zn	146	155	132	198	93	69	169	170	164	160	120	135	126	108
Zr	156	107	150	122	133	119	140	133	150	141	139	145	143	176

Table 2: Composition of the dark type calc-silicate rocks in the area studied.
Major constituents in weight % and trace elements in ppm.

Sample	*507A*	*2091A*	*2083A*	*211A*	*404A*
SiO2	53.97	50.43	50.28	54.10	49.20
TiO2	0.90	0.64	0.67	0.72	0.79
Al2O3	14.89	10.80	11.00	11.34	13.56
Fe2O3	6.75	8.23	8.28	7.17	5.36
MnO	0.25	0.45	0.62	0.43	0.41
MgO	2.73	4.24	5.12	4.26	0.68
CaO	14.51	18.08	19.42	15.32	19.28
Na2O	3.48	2.07	1.77	2.55	0.73
K2O	0.66	0.40	0.41	0.93	0.68
P2O5	0.10	0.16	0.09	0.63	0.11
LOI	0.32	3.76	0.75	0.91	9.07
Total	98.56	99.26	98.41	98.36	99.87
Ba	419	209	194	289	120
Ce	85	68	69	105	88
Cr	65	46	55	64	59
Cu	9	20	9	19	8
La	46	29	36	64	51
Nb	17	11	11	12	13
Ni	26	27	25	23	15
Pb	8	16	7	7	14
Sr	498	582	335	339	302
V	69	61	70	84	70
W	7	8	7	9	4
Y	36	29	25	64	32
Zn	96	145	140	117	85
Zr	237	155	161	168	211

Table 3: Composition of the light type of calc-silicate rocks in the area studied.
Major constituents in weight % and trace elements in ppm.

4.2.2.Scheelite bearing samples:

Interpretation of *(Table 4)*:

- The Fe_2O_3 content in samples bearing scheelite ranges from 8.99 wt% to 18.93 wt%, with average 13.36 wt% *(Table. 5)*.
- The CaO content in scheelite bearing calc-silicate ranges from 14.58 wt% to 22.88 wt% with average 18.79 wt% .
- The average content of other main elements is about the same as for other dark calc-silicates, which do not contain scheelite.
- It is clear that the scheelite containing samples have high W concentration *(Table. 4 and 5)*. The average content is (272ppm). The sample [5051A] has the highest tungsten concentration (467ppm) of all samples and the sample 506A has the second highest content of tungsten (449ppm). Both samples are from WOK5 and both are form positions adjacent to the amphibolite lithology. The sample [217A] from WOK2 has tungsten concentration of (353ppm) and the sample [2082] has the second highest content of tungsten in WOK2 and is (107ppm). The dark calc-silicate layer in WOK4 also has high tungsten concentration and the concentration varies within this layer (e.g., sample [405A] has (260ppm) of tungsten while sample [408A] from the same layer has (75ppm).
- The average Cu (112ppm) and Ni (36ppm) concentrations in scheelite-bearing samples are also high, because the scheelite is frequently associated with sulfide ores.

Sample	*5051A*	*506A*	*2082A*	*217A*	*405A*	*406A*	*407A*
SiO2	48.54	50.44	50.74	54.00	46.16	45.97	46.04
TiO2	0.45	0.58	0.65	0.60	0.48	0.53	0.62
Al2O3	7.98	9.63	11.01	10.78	8.40	10.14	9.83
Fe2O3	15.48	9.73	8.99	10.17	18.93	12.50	17.69
MnO	0.54	0.42	0.58	0.47	0.47	0.44	0.41
MgO	2.92	2.67	4.33	3.10	2.18	2.30	2.68
CaO	20.04	22.88	19.17	17.66	17.06	19.86	14.85
Na2O	1.45	1.53	1.88	1.53	0.92	0.41	0.45
K2O	0.21	0.19	0.43	0.16	0.56	0.40	0.50
P2O5	0.17	0.12	0.18	0.10	0.07	0.08	0.10
Lol	0.00	0.36	0.96	0.30	2.47	5.24	3.98
Total	97.78	98.55	98.92	98.87	97.70	97.87	97.15
Ba	41	55	304	84	88	47	126
Ce	40	64	69	64	69	69	74
Cr	43	47	54	50	57	47	88
Cu	69	9	9	8	307	75	307
La	21	37	38	35	37	33	28
Nb	10	10	11	11	9	9	10
Ni	37	27	33	31	57	15	53
Pb	7	12	7	5	13	19	19
Sr	181	321	317	365	187	196	190
V	60	59	69	63	53	54	76
W	467	449	107	353	260	119	151
Y	23	22	29	26	19	19	24
Zn	155	132	164	160	120	135	126
Zr	107	150	150	141	139	145	143

Table 4: Composition of the scheelite bearing calc-silicate rocks in the area studied. Major constituents in weight % and trace elements in ppm.

	Minimum	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*
SiO2	49.20	54.10	51.60	45.97	54.00	49.58	45.97	54.00	48.84
TiO2	0.64	0.90	0.74	0.45	0.67	0.57	0.45	0.65	0.56
Al2O3	10.80	14.89	12.32	7.98	11.11	9.93	7.98	11.01	9.68
Fe2O3	5.36	8.28	7.16	8.48	18.93	11.54	8.99	18.93	13.36
MnO	0.25	0.62	0.43	0.29	0.58	0.46	0.41	0.58	0.48
MgO	0.68	5.12	3.41	2.18	4.33	3.23	2.18	4.33	2.88
CaO	14.51	19.42	17.32	14.85	22.88	18.79	14.85	22.88	18.79
Na2O	0.73	3.48	2.12	0.41	2.31	1.28	0.41	1.88	1.17
K2O	0.40	0.93	0.62	0.16	0.84	0.43	0.16	0.56	0.35
P2O5	0.09	0.63	0.22	0.07	0.59	0.17	0.07	0.18	0.12
LOI	0.32	9.07	2.96	0.00	6.15	2.27	0.00	5.24	1.90
Total	98.36	99.87	98.89	96.16	99.08	98.07	97.15	98.92	98.12
Ba	120	419	246	41	616	207	41	304	106
Ce	68	105	83	40	79	63	40	74	64
Cr	46	65	58	43	88	53	43	88	55
Cu	8	20	13	8	307	70	8	307	112
La	29	64	45	19	40	32	21	38	33
Nb	11	17	13	9	11	10	9	11	10
Ni	15	27	23	15	57	33	15	57	36
Pb	7	16	10	4	19	10	5	19	12
Sr	302	582	411	181	454	289	181	365	251
V	61	84	71	53	76	63	53	76	62
W	4	9	7	12	467	156	107	467	272
Y	25	64	37	19	32	25	19	29	23
Zn	85	145	117	69	198	139	120	164	142
Zr	155	237	186	107	176	140	107	150	139

Light calc-silicate	Dark calc-silicate	Scheelite bearing calc-silicate

Table 5: Minimum, maximum and average values of the calc-silicate rocks in the area studied. Major constituents in weight % and trace elements in ppm.

4.2.3. The marbles:

Interpretation of *(Table 6)*:

- Marbles occur only in WOK4 (*Table. 6*) displaying CaO content ranges 29.88 wt% to 40.18 wt%.
- The SiO_2 content in these marbles is significantly lower than in calc-silicate. The average SiO_2 content in the marbles is 23.80 wt%. For comparison, it is 51wt% in light calc silicate and 49.58wt%. in dark type calc-silicate An important remark after heating samples up to 1050° C is that the marbles experience a high loss on ignition compared to calc-silicate (which is clearly due to the CO_2-content).
- The W concentration in marbles WOK4 is lower than 1ppm. In sample [402A] Cr (110ppm), Cu (23ppm) and Ni (68ppm) are enriched, possibly because this marble is adjacent to an amphibolite layer.

Sample	***401A***	***402A***	***403A***	***Minimum***	***Maximum***	***Average***
SiO2	27.79	26.03	17.58	17.58	27.79	23.80
TiO2	0.53	0.36	0.22	0.22	0.53	0.37
Al2O3	7.55	5.86	3.75	3.75	7.55	5.72
Fe2O3	5.12	3.04	2.28	2.28	5.12	3.48
MnO	0.34	0.37	0.37	0.34	0.37	0.36
MgO	3.71	2.28	1.6	1.60	3.71	2.53
CaO	29.88	34.32	40.18	29.88	40.18	34.79
Na2O	1.24	1.09	0.73	0.73	1.24	1.02
K2O	1.32	1.29	0.81	0.81	1.32	1.14
P2O5	0.07	0.06	0.04	0.04	0.07	0.06
LOI	19.57	23.03	29.72	19.57	29.72	24.11
Total	97.12	97.73	97.28	97.12	97.73	97.38
Ba	214	205	143	143	214	187
Ce	26	20	23	20	26	23
Cr	110	33	17	17	110	53
Cu	23	9	9	9	23	14
La	17	20	11	11	20	16
Nb	6	6	3	3	6	5
Ni	68	14	6	6	68	29
Pb	8	9	8	8	9	8
Sr	442	505	555	442	555	501
V	73	32	16	16	73	40
W	1	1	1	1	1	1
Y	18	16	15	15	18	16
Zn	81	53	39	39	81	58
Zr	86	80	56	56	86	74

Table 6: Average composition of the marbles from WOK4. Major constituents in weight % and trace elements in ppm.

4.2.4. Intercalation zone of calc-silicate in amphibolite:

Interpretation of *(Table 7)*:

- The first observation is that the average content of SiO_2 in the intercalation domain is 57.95 wt%. This value is significantly higher than the average values in both calc-silicate types and marbles samples.
- The average value of the calcium oxide content is is 12.23 wt%, which is lower than all other average values of CaO in other lithologies.
- Sample [213A] and sample [214A] show significant high P_2O_5 content from 1.11 wt% to 1.34 wt%, however no further investigation has been done to study this phenomenon.
- It can be noticed that the samples and have higher P_2O_5 content as compared to the other samples.
- In the trace element analysis, it is observed that in sample [214A] from WOK2 the Cu content is 91ppm and in [215A] and the Cr concentration is 107ppm. The high average concentrations of these elements Cr (66ppm), Cu (46ppm) and Ni (31ppm) is due to the increased content of sulfide ores in these samples of the intercalations zones. These samples [213A, 214A and 215A] from the intercalation zone in WOK2 contained high V concentrations: 102, 102 and 132 ppm. Not only the element V is enriched in these samples, but also the element Zn, the concentration of which reaches up to 250ppm in this intercalation zone of WOK2.
- The W concentration in the intercalation areas ranges from 3 ppm to 13ppm.

Sample	*503A*	*504A*	*509A*	*212A*	*213A*	*214A*	*215A*	*216A*	*Minimum*	*Maximum*	*Average*
SiO2	50.06	53.86	57.35	57.51	53.10	56.17	54.28	81.20	50.06	81.20	57.94
TiO2	0.79	0.66	0.81	0.75	0.69	0.73	0.83	0.29	0.29	0.83	0.69
Al2O3	11.53	10.08	14.29	12.27	11.94	12.25	12.90	4.88	4.88	14.29	11.27
Fe2O3	9.02	9.13	5.57	6.15	8.78	9.12	10.16	3.24	3.24	10.16	7.65
MnO	0.49	0.43	0.22	0.33	0.46	0.40	0.36	0.16	0.16	0.49	0.36
MgO	4.88	3.80	2.79	3.44	4.27	3.94	4.88	1.74	1.74	4.88	3.72
CaO	17.81	17.66	12.45	11.49	13.34	10.02	8.85	6.18	6.18	17.81	12.23
Na2O	2.08	2.01	2.62	2.64	1.99	2.30	2.44	0.89	0.89	2.64	2.12
K2O	0.80	0.32	2.38	3.15	2.46	1.72	1.88	0.47	0.32	3.15	1.65
P2O5	0.30	0.15	0.09	1.11	1.34	0.71	0.39	0.21	0.09	1.34	0.54
Lol	0.66	0.65	0.34	1.80	0.68	0.98	1.35	1.08	0.34	1.80	0.94
Total	98.42	98.75	98.91	100.64	99.05	98.34	98.32	100.34	98.32	100.64	99.10
Ba	227	91	1195	688	823	353	364	123	91	1195	483
Ce	62	70	82	92	47	101	56	29	29	101	67
Cr	79	59	63	65	60	63	107	29	29	107	66
Cu	18	11	11	53	57	91	72	23	11	91	42
La	35	34	47	52	25	47	29	16	16	52	35
Nb	13	11	13	11	11	13	11	4	4	13	11
Ni	37	29	28	15	34	40	50	13	13	50	31
Pb	10	12	10	10	9	9	8	5	5	12	9
Sr	386	281	383	249	282	196	184	130	130	386	261
V	90	62	79	91	102	102	132	39	39	132	87
W	9	6	13	9	6	7	3	12	3	13	8
Y	29	26	31	56	51	81	24	16	16	81	39
Zn	131	123	55	122	211	239	250	56	55	250	148
Zr	161	150	191	168	153	154	158	61	61	191	150

Table 7: Average composition of the intercalation of calc-silicate to amphibolite. Major constituents in weight % and trace elements in ppm.

4.2.5. Omnian:

Sample	*F*	*SO3*	*Cl*
2011A	0.087	0.045	0.041
203A	0.082	0.93	0.017
207A	0.082	0.039	0.18
2081A	0.056	0.01	0.26
2082A	0.036	0.016	0.23
2083A	0.016	0.0082	0.16
2091A	0.1	0.17	0.029
2092A	0.1	0.072	0.016
2010A	0.068	0.019	0.086
211A	0.13	0.17	0.049
212A	0.16	0.88	0.031
213A	0.24	0.79	0.1
214A	0.19	1.1	0.1
215A	0.27	0.91	0.052
216A	0.1	0.32	0.051
217A	0.049	0.021	0.077
218A	0.17	2.1	0.032
401A	0.083	0.077	0.022
402A	n.d.	0.019	0.016
403A	n.d.	0.0071	0.022
404A	0.039	0.041	0.015
405A	0.13	2	0.068
407A	0.16	1.5	0.032
408A	0.11	0.63	0.031
406A	0.1	0.48	0.031
502A	0.19	0.32	0.048
503A	0.14	0.14	0.2
504A	0.072	0.085	0.38
5051A	0.13	0.052	0.023
506A	n.d.	0.035	0.24
507A	0.04	0.025	0.12
509A	0.046	0.029	0.03
511A	0.15	0.058	0.019
512A	0.085	0.068	0.52

Table 8: The F, Cl, and SO3 values in all samples from drill cores. Concentrations in [wt.% with 2significant decimals], (n.d. = not detected).

- *16 samples out of 34 display F contents > 0.1% (max =0.27%)*
- *7 samples out of 34 display SO_3 contents > 0.5% (max =2.1%)*
- *9 samples out of 34 display Cl contents > 0.1% (max =0.38%)*

Omnian was used for two main purposes : to support the assumption (Fuchs & Matura., 1980), about the origins of the Variegated Group and to estimate the sulfate content semi-quantitatively in samples from the Wietzen area.

- These elevated concentrations *(Table. 8)* pointe to the assumption, that calc-silicate might be derived from a former saline environment as assumed by Fuchs & Matura., (1980) in *discussion (page: 74).*
- All samples with increased content of these elements are italicized in the table 8.
- All the samples with high content of Cl are rich in the mineral scapolite and this mineral forms the main or second most abundant phase in thin sections of these samples. The increased content of Cl in scapolite in the ancient salinized calc-silicate is strong evidence that Fuchs & Matura (1980) are right.

4.2.6. X-ray diffraction:

This method was used as a complimentary method to the thin section's investigations and mainly to answer the question of whether the marbles in WOK4 are pure calcite marbles or if they contain other carbonates.

Two of the marbles powders were examined samples [402A] and [403A]. Sample [402A] contains the following minerals: calcite, clinopyroxene (augite), dolomite, anorthite and mica. The sample [403A] contains the following minerals: calcite, dolomite, clinopyroxene (hedenbergite), quartz and anorthite. It is confirmed that the marbles in WOK4 contain calcite and dolomite. Further investigations were not made on these calcite-dolomite marbles because it is not the subject of this master thesis.

4.3. Microprobe analysis:

For this method, five calc-silicate samples were examined for different purpose. In addition, from each sample more than one area was analyzed with microprobe for better understanding the chemical composition of minerals assemblage:

* The samples [ALB1 and ALB2] were taken from an outcrop in the Saubigel area *(Fig. 3B)*, not from drill cores. These samples are garnet bearing dark calc-silicate rocks. Clinopyroxene and garnets were analyzed from [ALB1] and clinopyroxene, garnet, feldspar and scheelite from [ALB2].

* Samples [405M and 407M] are dark calc-silicate rocks from WOK4. Clinopyroxenes, scapolite, feldspars, scheelites and opaque minerals were investigated in [405M]. In [407M] clinopyroxenes, scapolite and opaque minerals were analyzed.

* Sample [2083M] is a light grey calc-silicate rock from WOK2 and from this sample clinopyroxenes, scapolite and feldspars were analyzed.

4.3.1.Clinopyroxene:

From samples [ALB1, ALB2, 2083M, 405M and 407M], 64-point measurements for clinopyroxene grains were analyzed with the electron beam microprobe. Only 24 measurement points were selected (*Table 9)* and shown in photos:

Sample	2083M (Light type)	2083M	2083M	2083M	2083M	ALB2 (Dark type)	ALB2M	ALB2M	ALB2M	405M	405M	405M	405M	405M	405M	405M	407M	407M	407M	407M	407M	407M	407M
Area	2083M_Plg1	2083M_Plg1	2083M_Scap1	2083M_Scap2	2083M_Scap2	Alb2_Gt2_1	Alb2_Gt2_1	Alb2_Sch1_1	Alb2_Sch1_1	405M_Sch1_1	405M_Sch1_1	405M_Sch2_1	405M_Sch2_1	405M_Sch2_1	405M_Sch3_1	405M_Sch3_1	405M_Scp1	407M_Dip1_1	407M_Dip1_1	407M_Dip1_1	407M_Scp1	407M_Scp1	407M_Scp2	407M_Scp2
DataSet/Point	17 / 1 .	18 / 1 .	56 / 1 .	72 / 1 .	73 / 1 .	67 / 1 .	68 / 1 .	36 / 1 .	37 / 1 .	40 / 1 .	41 / 1 .	61 / 1 .	59 / 1 .	73 / 1 .	74 / 1 .	82 / 1 .	27 / 1 .	28 / 1 .	31 / 1 .	107 / 1 .	108 / 1 .	118 / 1 .	119 / 1 .
SiO2 [wt %]	51.353	51.756	51.276	51.044	50.940	48.566	48.727	47.765	48.072	49.462	48.949	48.849	49.280	48.883	49.372	49.312	50.790	50.498	50.555	49.561	49.410	49.410	49.513
TiO2	0.025	0.029	0.007	0.024	0.020	0.014	0.021	0.024	0.005	0.021	0.025	0.004	0.025	0.034	0.029	0.021	-0.001	-0.004	-0.012	0.021	0.014	0.011	0.025
Al2O3	0.384	0.447	0.359	0.502	0.387	0.295	0.305	0.296	0.265	0.336	0.286	0.272	0.276	0.358	0.262	0.259	0.153	0.153	0.010	0.234	0.251	0.290	0.213
Cr2O3	0.024	0.012	0.012	0.017	0.016	0.005	0.000	0.008	0.003	0.007	0.018	0.013	0.016	0.003	0.014	0.012	0.010	0.005	0.010	0.000	0.000	0.000	0.000
V2O3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FeO	14.579	12.435	14.244	13.701	14.637	26.369	25.669	26.697	26.192	23.464	24.263	25.421	22.879	24.402	23.340	23.232	17.502	19.647	18.170	23.118	23.325	23.735	23.245
MnO	1.364	1.055	1.382	1.585	1.391	0.867	0.482	1.268	0.844	0.793	0.947	0.871	0.725	0.767	0.830	0.840	1.109	0.988	1.262	0.810	0.805	0.788	0.822
ZnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NiO	-0.001	0.015	0.000	0.016	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MgO	8.318	9.773	8.644	8.689	8.176	1.076	1.551	0.245	0.876	3.048	2.302	1.615	3.518	2.517	3.080	3.032	6.524	5.177	5.982	3.115	3.084	2.773	3.304
CoO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	23.663	24.012	23.853	23.524	23.838	22.777	23.035	22.426	22.987	23.058	23.026	22.740	22.968	22.907	23.024	22.832	23.738	23.677	23.717	23.106	22.880	23.122	23.081
Li2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na2O	0.105	0.123	0.101	0.144	0.095	0.068	0.066	0.068	0.077	0.080	0.081	0.079	0.088	0.107	0.081	0.107	0.041	0.027	0.027	0.094	0.090	0.098	0.101
K2O	-0.004	0.005	-0.010	-0.007	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.004
Total	99.810	99.662	99.868	99.239	99.516	100.037	99.856	98.797	99.321	100.269	99.897	99.864	99.775	99.978	100.032	99.647	99.866	100.168	99.721	100.059	99.859	100.234	100.308
Si	1.992	1.988	1.983	1.984	1.983	1.985	1.987	1.989	1.981	1.987	1.984	1.992	1.983	1.977	1.988	1.993	1.996	1.998	1.998	1.993	1.993	1.989	1.985
Ti	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001
Cr	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.018	0.020	0.016	0.023	0.018	0.014	0.015	0.015	0.013	0.016	0.014	0.013	0.013	0.017	0.012	0.012	0.007	0.007	0.000	0.011	0.012	0.014	0.010
Fe3+	0.005	0.012	0.023	0.017	0.022	0.019	0.015	0.011	0.032	0.015	0.022	0.009	0.026	0.034	0.016	0.008	0.004	0.000	0.006	0.008	0.009	0.016	0.026
Fe2+	0.468	0.388	0.437	0.428	0.454	0.882	0.860	0.918	0.871	0.773	0.801	0.858	0.744	0.791	0.770	0.777	0.571	0.650	0.595	0.769	0.778	0.783	0.753
Mn	0.045	0.034	0.045	0.052	0.046	0.030	0.017	0.045	0.029	0.027	0.033	0.030	0.025	0.026	0.028	0.029	0.037	0.033	0.042	0.028	0.027	0.027	0.028
Ni	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.481	0.559	0.498	0.503	0.474	0.066	0.094	0.015	0.054	0.182	0.139	0.098	0.211	0.152	0.185	0.183	0.382	0.305	0.352	0.187	0.185	0.166	0.197
Ca	0.983	0.988	0.988	0.980	0.994	0.998	1.006	1.000	1.015	0.992	1.000	0.993	0.990	0.993	0.993	0.989	0.999	1.004	1.004	0.996	0.989	0.997	0.991
Na	0.008	0.009	0.008	0.011	0.007	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.007	0.008	0.006	0.008	0.003	0.002	0.002	0.007	0.007	0.008	0.008
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Enstatite (Mg-Cpx) [mol]	0.240	0.280	0.249	0.252	0.237	0.033	0.047	0.008	0.027	0.091	0.070	0.049	0.105	0.076	0.092	0.091	0.191	0.153	0.176	0.093	0.093	0.083	0.099
Ferrosalite (Fe-Cpx)	0.234	0.194	0.219	0.214	0.227	0.441	0.430	0.459	0.435	0.387	0.400	0.429	0.372	0.395	0.385	0.388	0.286	0.325	0.297	0.385	0.389	0.391	0.377
Wollastonite (Ca-Cpx)	0.488	0.488	0.486	0.482	0.489	0.492	0.497	0.495	0.501	0.490	0.494	0.493	0.489	0.488	0.491	0.491	0.498	0.501	0.502	0.495	0.491	0.493	0.491

Table 9: Composition of the clinopyroxene in both types of calc-silicate rocks. Oxides are given in wt%; cations per six oxygen atoms.

According to the microprobe analysis (*Table 10*) the chemical composition of the clinopyroxene varies in both types of calc-silicate *(Diagram.1).*

Sample	2083M (Light type)	2083M	2083M	2083M	2083M		407M(Darke type)	407M	407M	407M	407M	
Area	2083M_Plg1	2083M_Plg1	2083M_Scap1	2083M_Scap2	2083M_Scap2		407M_Dip1_1	407M_Dip1_1	407M_Scp1	407M_Scp1	407M_Scp2	
DataSet/Point	17 / 1 .	18 / 1 .	56 / 1 .	72 / 1 .	73 / 1 .	Avrage	27 / 1 .	28 / 1 .	107 / 1 .	108 / 1 .	118 / 1 .	Avrage
Na2O	0.11	0.12	0.10	0.14	0.10	0.11	0.04	0.03	0.09	0.09	0.10	0.07
SiO2	51.35	51.76	51.28	51.04	50.94	51.27	50.79	50.50	49.56	49.41	49.41	49.93
Al2O3	0.38	0.45	0.36	0.50	0.39	0.42	0.15	0.15	0.23	0.25	0.29	0.22
FeO	14.58	12.44	14.24	13.70	14.64	**13.92**	17.50	19.65	23.12	23.33	23.74	**21.47**
CaO	23.66	24.01	23.85	23.52	23.84	23.78	23.74	23.68	23.11	22.88	23.12	23.30
MgO	8.32	9.77	8.64	8.69	8.18	**8.72**	6.52	5.18	3.12	3.08	2.77	**4.13**
MnO	1.36	1.06	1.38	1.59	1.39	1.36	1.11	0.99	0.81	0.81	0.79	0.90
Cr2O3	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00		0.00
TiO2	0.03	0.03	0.01	0.02	0.02	0.02	0.00	0.00	0.02	0.01	0.01	0.01
K2O	0.00	0.01	-0.01	-0.01	0.01	0.00					0.01	0.01
NiO	0.00	0.02	0.00	0.02	0.01	0.01						
Total	99.81	99.66	99.87	99.24	99.52	99.62	99.87	100.17	100.05	99.84	100.22	100.03

Table 10: Comparison between the chemical composition of clinopyroxene in light CS [2083M] and dark CS [407M]. Results are given in wt%.

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- It is easy to notice that in the light calc-silicates (2083M) the clinopyroxene has a higher average content of MgO compared to the dark type.
- The MgO content in light type in this sample ranges from 8.81 wt% to 9.77 wt%, while the in [407M] varies from 2.77 wt% to 6.52 wt% maximum.

- There is also a significant difference in the FeO content in clinopyroxenes of both types of calc-silicates. The clinopyroxenes in light types contain significantly less FeO.
- compared to clinopyroxenes in the dark calc-silicates. The average FeO content in clinopyroxenes of the light calc-silicates in sample [2083M] is 13.92 wt% and in the dark type [407M] is 21.47 wt%. In general, the FeO content in clinopyroxenes of light calc-silicates can reach up to 14.57 wt%, while the clinopyroxenes in dark type show a significantly higher iron oxide content and can reach up to 26.36 wt% *(Table.11).*

	Minimum	***Maximum***	***Average***	***Minimum***	***Maximum***	***Average***
Na2O	0.10	0.14	0.11	0.03	0.11	0.08
SiO2	50.94	51.76	51.27	47.77	50.79	49.28
Al2O3	0.36	0.50	0.42	0.01	0.36	0.25
FeO	12.44	14.64	13.92	17.50	26.70	23.37
CaO	23.52	24.01	23.78	22.43	23.74	23.06
MgO	8.18	9.77	8.72	0.25	6.52	2.93
MnO	1.06	1.59	1.36	0.48	1.27	0.88
Cr2O3	0.01	0.02	0.02	0.00	0.02	0.01
TiO2	0.01	0.03	0.02	-0.01	0.03	0.02
K2O	-0.01	0.01	0.00	0.00	0.01	0.01
NiO	0.00	0.02	0.01	0.00	0.00	0.00

Table 11: Minimum, maximum and average values of the clinopyroxene from both types of calc-silicate. Results are given in wt%.

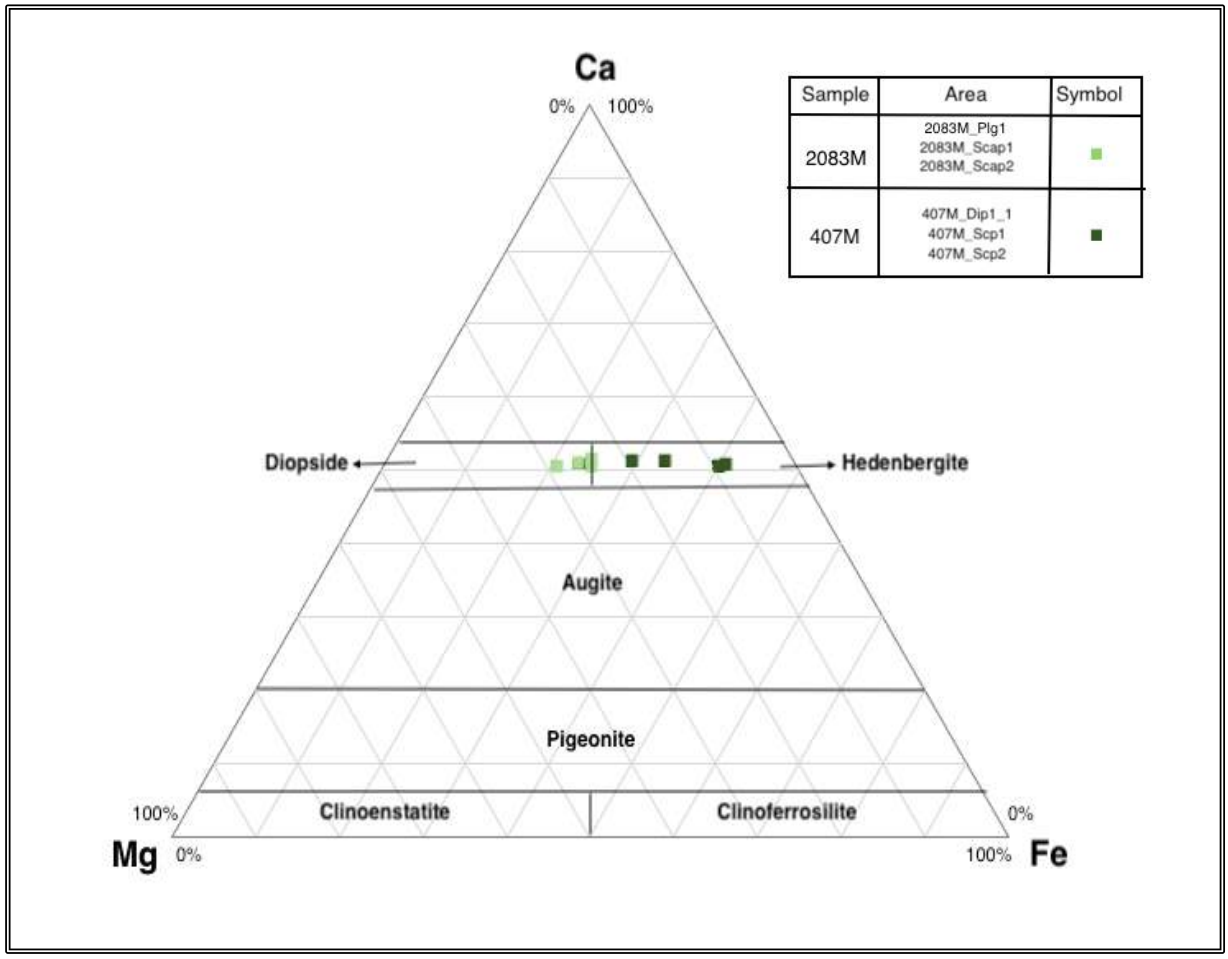

Diagram 1: The chemical composition (presented in mol %) of clinopyroxene in light calc-silicate[2083M] and dark calc-silicate [407M].

According to the classification Morimoto & Kitamura, (1983), the pyroxene in dark type of calc-silicate is a hedenbergite with an average composition of $Ca_{0.997}Mg_{0.175}Fe^{2+}_{0.775}Fe^{+3}_{0.015}Mn_{0.030}Na_{0.006}Si_{(1.989)2}Al_{0.012}O_6$ (*Table 9 &11 and Diagram 1*), with high Fe content, optically and chemically homogeneous and shows neither zoning nor twining. Microprobe analyses of the pyroxene in light calc-silicate in *table 9* shows , that this Mg-rich pyroxene is diopside with an average composition of $Ca_{0.987}Mg_{0.503}Fe^{+2}_{0.435}Fe^{+3}_{0.016}Mn_{0.044}Na_{0.009}Si_{(1.986)2}Al_{0.019}O_6$ as reported by Morimoto & Kitamura, (1983).

4.3.2.Scapolite:

According to microprobe analysis the chemical composition of the scapolite does not vary significantly in both type of calc-silicate. Fifteen measuring points of scapolite grains were displayed in images and in *table 12.*

The first remark is that the scapolite are same in both types of chemical composition. Surprisingly, within the same grain of the scapolite the chlorine content varies and in most cases the grains are strongly fractured. It appears that the scapolite grain was a large grain and during the metamorphism or a deformation event it was strongly broken into small xenomorphic grains (*Fig. 17*). The average Cl content in scapolite of both types of calc-silicate is about 0.5wt% and the Na_2O content is about 3.6wt % *(Table.13).* The highest Cl content in scapolite of all the measurement points *(Fig. 18*) is measurement point 116 and contains 1.110 wt%, whereas the measurement point 115 of the same area contains 0.329 wt% of Cl.

According to microprobe analysis (*Table 12*), the chemical composition of the scapolite does not varies strongly in Both type of calc-silicate. The average composition corresponds to the chemical formula : $Ca_{2.79}Na_{1.10}K_{0.08}Fe_{0.03}Mg_{0.00}Al_{4.89}Si_{7.10}O_{24}Cl_{0.14}(CO_3, OH,\ldots)_{0.86}$, (normalized to (Al+Fe+Si)=12). This considers that the mineral contains no analytical H_2O (and therefore no OH groups), so that the CO_2 content was calculated by the determined constituents. The chemical composition of scapolite is close to that of a solid solution between the end members $Na_4Al_3Si_9O_{24}Cl$ and $Ca_3NaAl_{15}Si_7O_{24}CO_3$, in accordance with the results of Evans et al. (1969).

Sample	*2083M (Light type)*	*2083M*	*2083M*	*2083M*	*2083M*	*405M (Dark type)*	*405M*	*405M*	*405M*	*405M*	*407M (Dark type)*	*407M*	*407M*	*407M*	*407M*
Area	*2083M_Scap1*	*2083M_Scap1*	*2083M_Scap1*	*2083M_Scap2*	*2083M_Scap2*	*405M_Sch2_1*	*405M_Sch2_1*	*405M_Sch2_1*	*405M_Scp1*	*405M_Scp1*	*407M_Scp1*	*407M_Scp1*	*407M_Scp2*	*407M_Scp2*	*407M_Scp2*
DataSet/Point	48 / 1 .	49 / 1 .	50 / 1 .	70 / 1 .	71 / 1 .	48 / 1 .	51 / 1 .	52 / 1 .	78 / 1 .	79 / 1 .	102 / 1 .	103 / 1 .	113 / 1 .	115 / 1 .	116 / 1 .
SiO2	46.022	46.383	45.976	46.779	48.26	47.702	46.798	46.075	46.581	47.935	45.816	46.009	47.918	46.419	49.335
Al2O3	27.885	27.613	27.694	27.631	27.027	27.051	27.27	27.712	27.778	26.897	27.663	27.717	26.94	27.915	26.563
FeO	0.103	0.091	0.082	0.061	0.143	0.166	0.282	0.19	0.297	0.213	0.226	0.507	0.733	0.533	0.454
MgO	0.018	0.014	0.027	0.019	0.02	0.004	0.003	0.026	0.006	0.015	0.005	0.015	0.004	0.004	0.003
CaO	17.93	17.724	17.545	17.284	16.107	16.464	17.457	18.296	17.603	15.836	18.363	18.011	16.283	18.151	15.111
Na2O	3.188	3.431	3.526	3.624	4.294	4.263	3.464	3.387	3.739	4.487	3.134	3.487	4.059	3.464	4.775
K2O	0.259	0.358	0.355	0.436	0.568	0.506	0.476	0.149	0.332	0.634	0.196	0.174	0.599	0.27	0.825
Cl	0.335	0.484	0.464	0.608	0.826	0.736	0.577	0.141	0.527	0.876	0.147	0.205	0.792	0.329	1.11
Total	95.405	95.614	95.205	95.834	96.419	96.156	95.75	95.835	96.336	96.017	95.403	95.92	96.536	96.756	97.066
Si	0.766	0.772	0.765	0.779	0.803	0.794	0.779	0.767	0.775	0.798	0.763	0.766	0.798	0.773	0.821
Al	0.547	0.542	0.543	0.542	0.53	0.531	0.535	0.544	0.545	0.528	0.543	0.544	0.529	0.548	0.521
Fe	0.001	0.001	0.001	0.001	0.002	0.002	0.004	0.003	0.004	0.003	0.003	0.007	0.01	0.007	0.006
Mg	0	0	0.001	0	0	0	0	0.001	0	0	0	0	0	0	0
Ca	0.32	0.316	0.313	0.308	0.287	0.294	0.311	0.326	0.314	0.282	0.327	0.321	0.29	0.324	0.269
Na	0.103	0.111	0.114	0.117	0.139	0.138	0.112	0.109	0.121	0.145	0.101	0.113	0.131	0.112	0.154
K	0.005	0.008	0.008	0.009	0.012	0.011	0.01	0.003	0.007	0.013	0.004	0.004	0.013	0.006	0.018
Cl	0.009	0.014	0.013	0.017	0.023	0.021	0.016	0.004	0.015	0.025	0.004	0.006	0.022	0.009	0.031
Total	1.743	1.75	1.745	1.756	1.774	1.769	1.751	1.753	1.766	1.77	1.741	1.754	1.77	1.769	1.79

Table 12: Average composition of Scapolite in two main types of calc-silicate rocks in the area studied. Oxides in wt%; cations per 16 oxygen atoms.

	Minimum	*Maximum*	*Average*
Na2O	3.13	4.78	3.75
SiO2	45.82	49.34	46.93
Al2O3	26.56	27.92	27.42
FeO	0.06	0.73	0.27
K2O	0.15	0.83	0.41
CaO	15.11	18.36	17.21
MgO	0.00	0.03	0.01
Cl	0.14	1.11	0.54
SO2	-0.01	0.05	0.01

Table 13:Minimum, maximum and average values of the scapolite from both types of calc-silicate. Results are given in wt%.

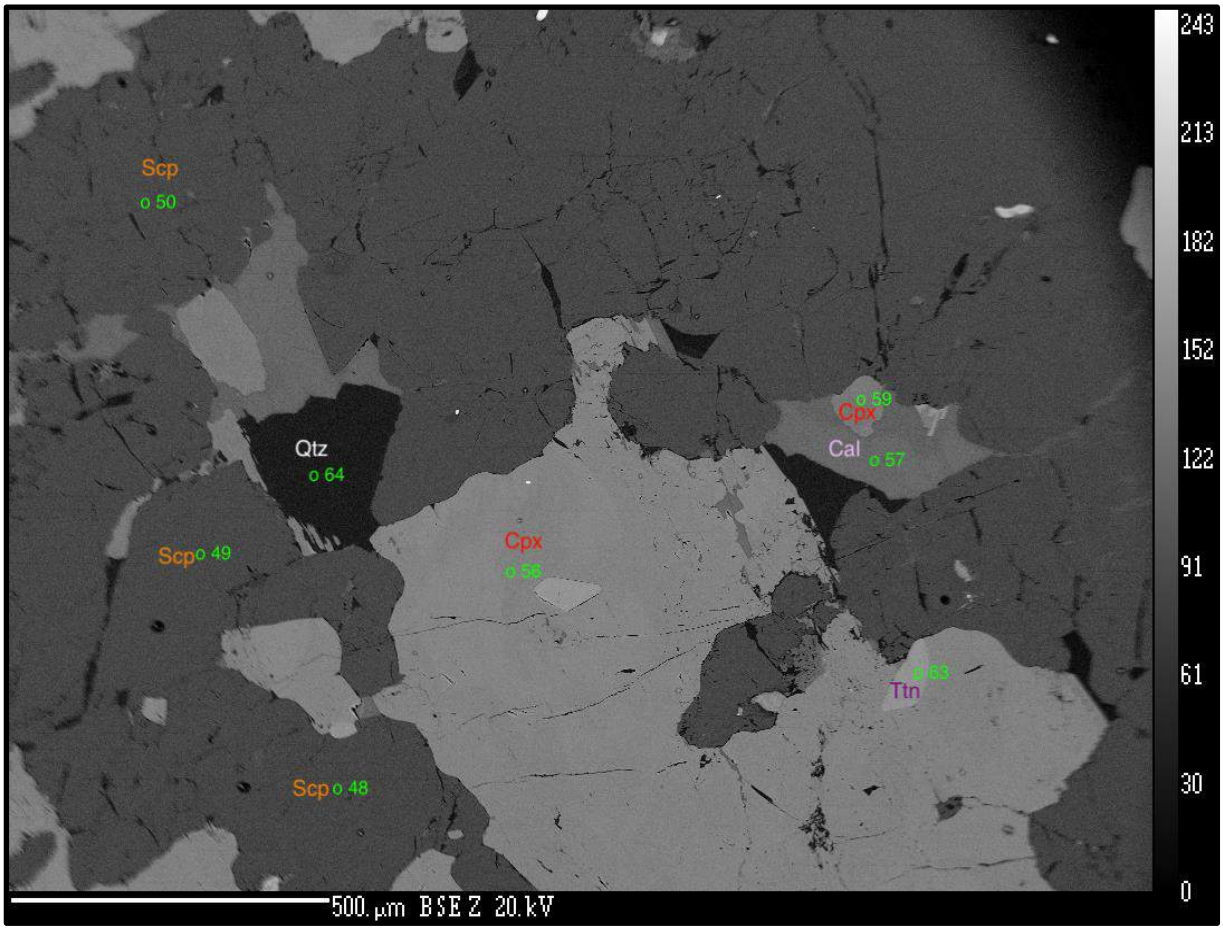

Figure 16: Sample 2083M from WOK2 (range: 54.50 – 55.00 m), Area 2083M_Scap1: The parageneses clinopyroxene and scapolite of light calc- silicates can be seen in this picture. The scapolite is large in size and contains small roundish zircon inclusions next to a large clinopyroxene (diopside) grain. The quartz, calcite and titanite inclusions are observed. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

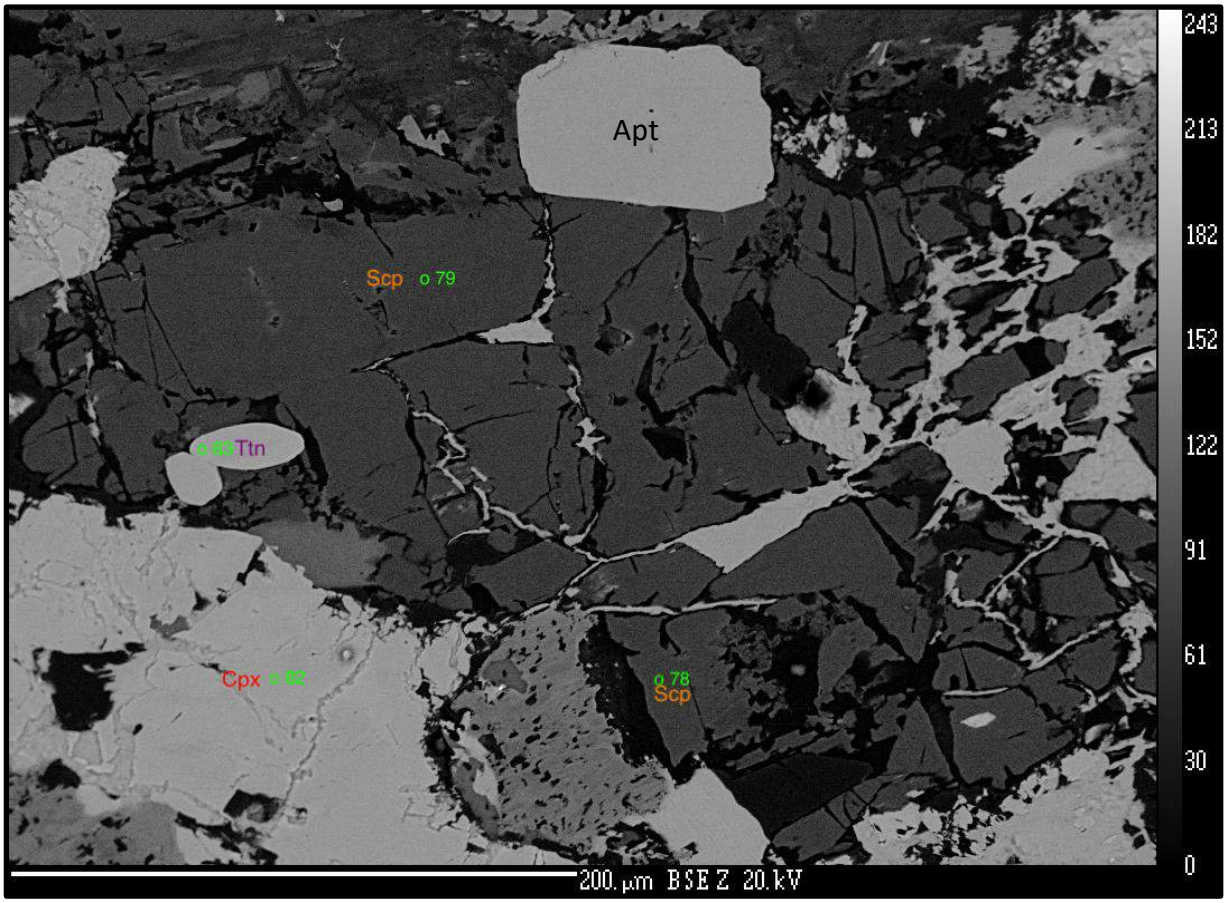

Figure 17: Sample 405M from WOK4 (range: 66.70 – 67.40 m), Area 405M_Scap1:The scapolite in dark calc-silicate are of appearance like those that occur in light calc-silicate. It is often observed that the scapolite contains inclusion minerals such as zircon (present in the previous image) and titanite and apatite (present in this image). Clinopyroxenes (hedenbergites) are adjacent to this strongly fractured scapolite. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

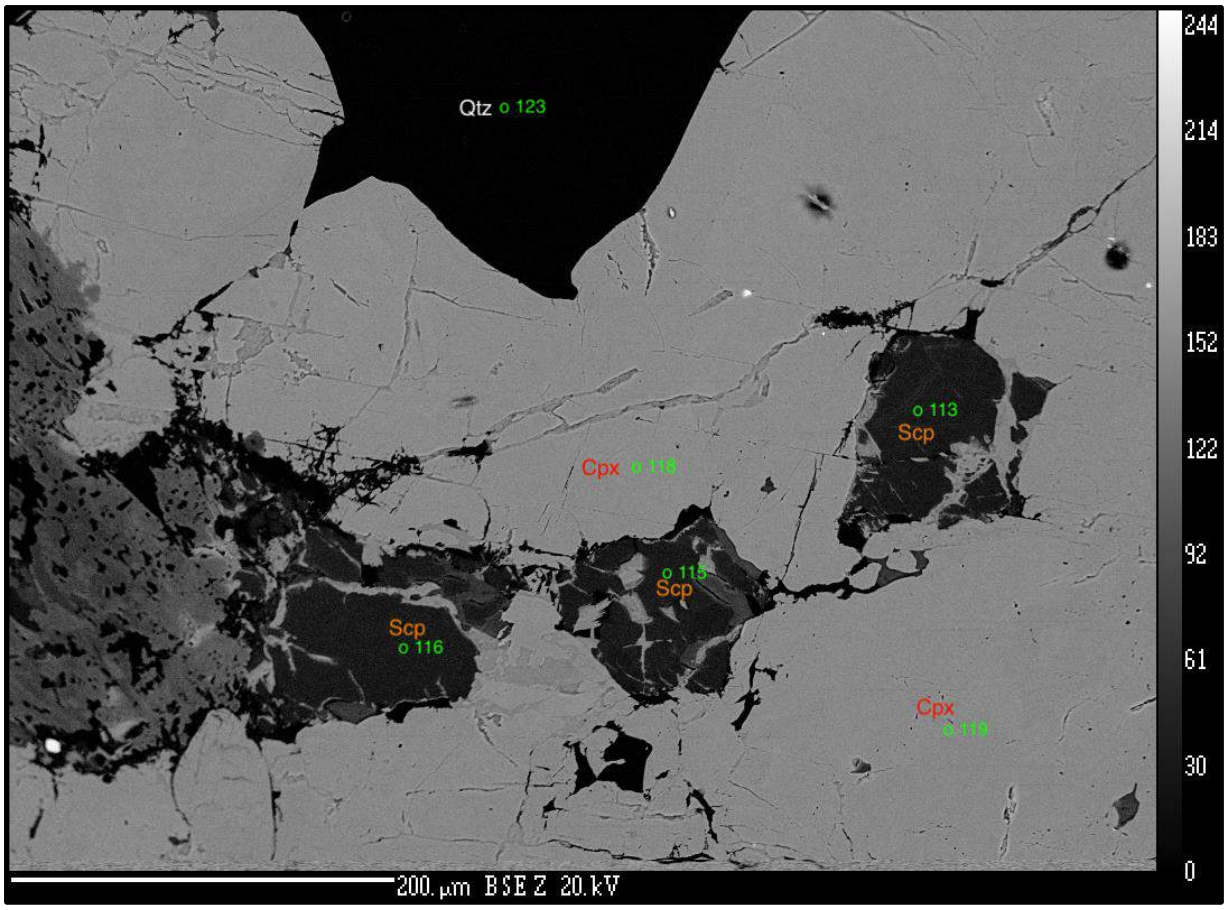

Figure 18: Sample 407M from WOK4 (range: 68.00 – 68.50 m), Area 407M_Scap2: The small scapolite grains are strongly deformed in the large clinopyroxene (hedenbergite) and it is in almost every scapolite grain that the chlorine content varies. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

4.3.3.Feldspar:

From samples [2083M, 405M and ALB2], 34 selected feldspar grains were analyzed by point measurements with EPMA. Eleven selected points from the dark type calc-silicate rock [ALB2 and 405M] and 16 points from sample [2083M] were plotted on the ternary feldspar diagram (*Diagram 2).*

Sample	*ALB2M*	*ALB2M*	*ALB2M*	*ALB2M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*	*2083M*
Area	Alb2_Gt1_1	Alb2_Gt2_1	Alb2_Gt2_1	Alb2_Gt2_1	2083M_Dip1	2083M_Dip1	2083M_Plg1	2083M_Plg1	2083M_Plg2	2083M_Plg3	2083M_Plg3	2083M_Plg3	2083M_Plg3	2083M_Plg3	2083M_Plg3
Point:	56 / 1 .	71 / 1 .	72 / 1 .	73 / 1 .	8 / 1 .	10 / 1 .	14 / 1 .	15 / 1 .	19 / 1 .	31 / 1 .	32 / 1 .	33 / 1 .	34 / 1 .	35 / 1 .	38 / 1 .
SiO2 [wt %]	64.541	47.656	61.89	66.303	54.793	56.265	51.717	57.249	52.695	52.096	50.896	52.772	51.118	52.366	52.867
Al2O3	18.55	33.154	24.151	19.379	28.132	27.407	30.614	26.872	29.666	30.696	31.492	30.073	31.151	30.29	29.685
CaO	0.03	16.044	5.208	2.549	10.615	9.359	13.23	8.727	12.333	12.929	13.808	12.187	13.532	12.573	12.208
Na2O	0.378	2.487	8.828	11.647	5.561	6.332	4.051	6.633	4.636	4.15	3.623	4.719	3.93	4.386	4.592
K2O	16.045	0.066	0.109	0.035	0.213	0.188	0.108	0.14	0.149	0.117	0.098	0.141	0.125	0.175	0.125
Total	99.544	99.407	100.186	99.913	99.314	99.551	99.72	99.621	99.479	99.988	99.917	99.892	99.856	99.79	99.477
Si	2.993	2.197	2.74	2.932	2.487	2.539	2.354	2.575	2.4	2.363	2.316	2.393	2.328	2.379	2.405
Al_IV	1.014	1.801	1.26	1.01	1.505	1.458	1.643	1.424	1.593	1.641	1.689	1.607	1.672	1.622	1.592
Ca	0.001	0.792	0.247	0.121	0.516	0.453	0.645	0.421	0.602	0.628	0.673	0.592	0.66	0.612	0.595
Na	0.034	0.222	0.758	0.999	0.489	0.554	0.358	0.578	0.409	0.365	0.32	0.415	0.347	0.386	0.405
K	0.949	0.004	0.006	0.002	0.012	0.011	0.006	0.008	0.009	0.007	0.006	0.008	0.007	0.01	0.007
Total	4.991	5.016	5.011	5.064	5.009	5.015	5.006	5.006	5.013	5.004	5.004	5.015	5.014	5.009	5.004
Orthoclase [mol %]	96.251	0.214	0.489	0.159	0.804	0.736	0.379	0.563	0.534	0.416	0.340	0.507	0.434	0.626	0.453
Anrothite	0.302	87.512	39.274	19.446	67.297	61.572	78.009	58.919	74.222	77.171	80.539	73.679	78.847	75.533	74.270
Albite	3.446	12.274	60.236	80.395	31.899	37.692	21.612	40.519	25.244	22.413	19.121	25.814	20.719	23.841	25.277

Table 14: The chemical composition of feldspars. Oxides are given in wt% ; cations per eight oxygen atoms.

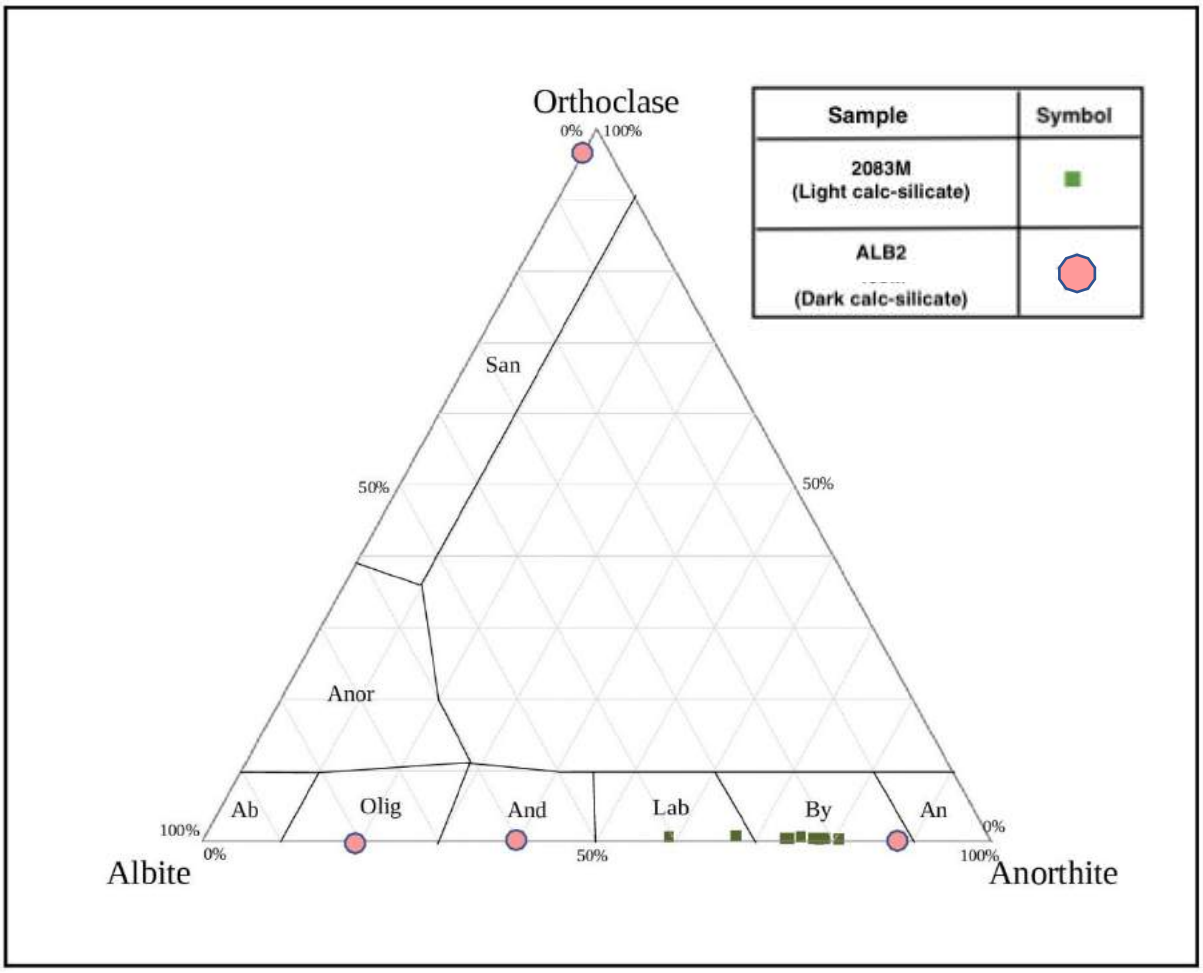

Diagram 2: Comparison between composition of feldspars in light CS [2083M] and dark CS [ALB2]. All values are presented in mol%.

Both samples have different feldspar compositions *(Table 14 and Diagram. 2).* In the dark calc-silicate measurement point (56/1) for orthoclase with chemical composition $K_{0.951}Na_{0.034}Ca_{0.001}Al_{1.016}Si_{(2.998)3}O_8$ (96.25 mol % Or)was detected, while in the light calc-silicates sample no K-fsp point was detected. An important observation that the alkali feldspar generally occur in this sample as an accessory mineral and segregated with plagioclase. In the diagram it is clear that the chemical composition of plagioclase in the dark type vary more than those in the light types. In the dark type one grain of oligoclase with chemical composition $Na_{0.986}K_{0.002}Ca_{0.119}Al_{0.997}Si_{(2.895)3}O_8$ (19.45 mol% An), one grain of andesine with chemical composition $Na_{0.756}K_{0.006}Ca_{0.246}Al_{1.258}Si_{(2.734)3}O_8$ (39.27 mol% An) and a grain of bytowite with chemical composition $Ca_{0.790}Na_{0.222}K_{0.0004}Al_{(1.795)2}Si_{(2.189)2}O_8$ (87.51 mol% An) were detected. In the light calc-silicate sample [2083M] ten grains of bytownite with average chemical composition $Ca_{0.436}Na_{0.565}K_{0.009}Al_{(1.438)2}Si_{(2.552)2}O_8$ with varied anorthite content between 73.68 mol% and 85.50 mol% were analyzed.

Two grains of Labradorite with 58.92 mol% An and 67.30 mol% An , with average chemical composition $Ca_{0.384}Na_{0.384}K_{0.008}Al_{(1.619)2}Si_{(2.374)2}O_8$ were also found. The significant difference in chemical composition of plagioclases in both types of calc-silicates, may indicate that the Wietzen area has experienced several deformation events.

4.3.4.Garnet:

A total of 32-point measurements were analyzed for Garnet grains from two different ranges in both samples [ALB1] and [ALB2]. Only two points from each range were plotted (*Table. 15*) in the ternary *diagram 3* to represent the chemical composition of garnets from the Saubigel Area.

Sample	*ALB1 (Dark type)*	*ALB1*	*ALB1*	*ALB1*	*ALB2 (Dark type)*	*ALB2*	*ALB2*	*ALB2*
Area	*ALB1_Gt1_1*	*ALB1_Gt1_1*	*ALB1_Gt2_1*	*ALB1_Gt2_1*	*ALB2_Gt1_1*	*ALB2_Gt1_1*	*ALB2_Gt2_1*	*ALB2_Gt2_1*
DataSet/Point	5 / 1 .	1 / 1 .	21 / 1 .	30 / 1 .	44 / 1 .	46 / 1 .	60 / 1 .	62 / 1 .
SiO2 [wt%]	39.153	38.488	37.606	37.684	38.778	38.293	38.857	38.856
TiO2	0.017	0.456	0.383	0.177	0.427	0.577	0.416	0.031
Cr2O3	-0.005	0.004	0.025	0.017	0.003	0.007	0.001	0.021
Al2O3	20.592	17.828	17.745	17.891	17.976	18.25	19.088	19.29
FeO	5.205	8.166	10.271	10.285	8.013	7.802	6.782	6.266
MnO	0.268	0.438	0.952	0.989	0.646	1.648	0.419	0.315
MgO	0.101	0.013	0.015	-0.003	-0.001	-0.003	0.032	-0.011
CaO	34.516	33.91	31.637	31.126	33.556	32.681	34.158	34.735
Total	99.847	99.303	98.634	98.166	99.398	99.255	99.753	99.503
Si	0.652	0.641	0.626	0.627	0.645	0.637	0.647	0.647
Ti	0.000	0.006	0.005	0.002	0.005	0.007	0.005	0.000
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.404	0.350	0.348	0.351	0.353	0.358	0.374	0.378
Fe	0.072	0.114	0.143	0.143	0.112	0.109	0.094	0.087
Mn	0.004	0.006	0.013	0.014	0.009	0.023	0.006	0.004
Mg	0.003	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Ca	0.615	0.605	0.564	0.555	0.598	0.583	0.609	0.619
Total	1.750	1.721	1.700	1.693	1.722	1.717	1.737	1.737
Almandine [mol%]	10.435	15.679	19.829	20.102	15.511	15.197	13.290	12.269
Grossular	88.660	83.425	78.258	77.951	83.226	81.563	85.767	87.145
Spessartine	0.544	0.852	1.861	1.958	1.266	3.251	0.832	0.625
Pyrope	0.361	0.045	0.052	-0.010	-0.003	-0.010	0.112	-0.038

Table 15:The chemical composition of garnets in dark calc-silicate. Oxides are given in wt%; cations per 12 oxygen atoms.

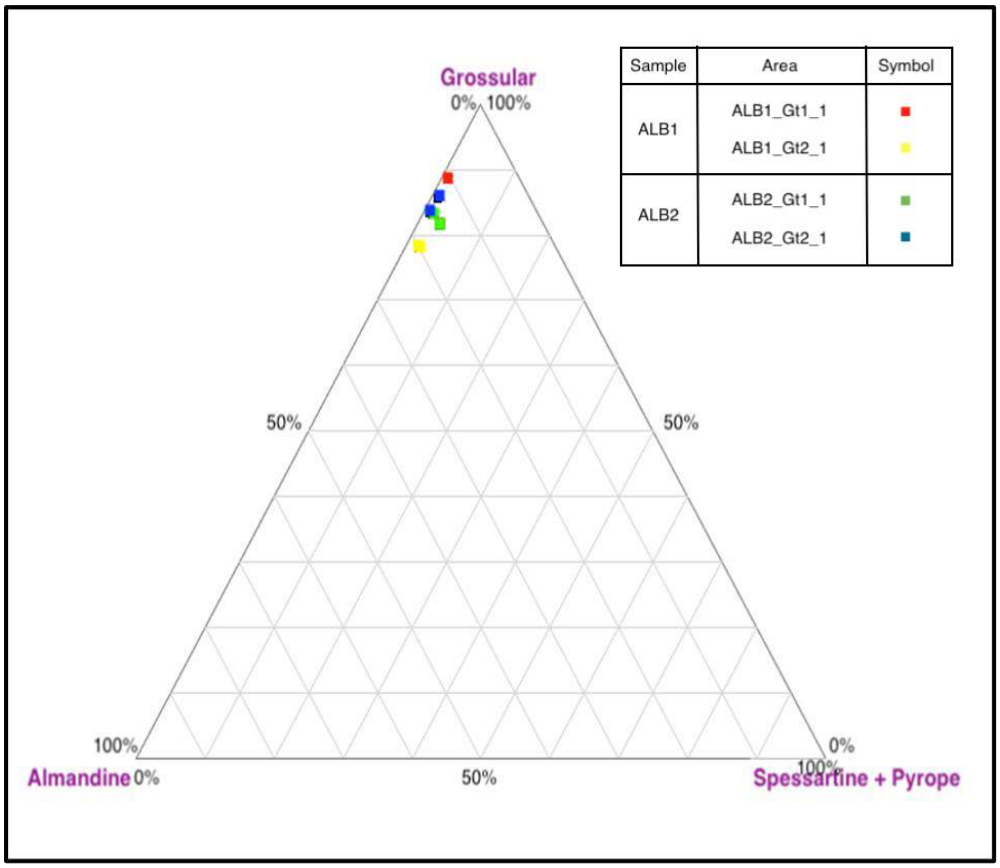

Diagram 3: The chemical composition of garnets in dark calc-silicate [ALB1 und ALB2]. All values are given in mol%.

From ALB1_Gt1_1 area, the two garnet grains consist of 88.66 and 83.42 mol% of Grossular, 10.43 and 15.68 mol% of Almandine. On the other hand, the garnet grains of the area ALB1_Gt2_1 have less grossular content in comparison to the first area, making 78.26 and 77.95 mol%, almandine content 19.83 and 20.10 mol%. In area ALB2_Gt1_1 the grossular content is between 83.23 and 82.56 mol% and the almandine content between 15.51 and 15.20 mol% in garnet grains. In ALB2_Gt2_1 almandine content is between 13.29 and 12.27 mol% and the grossular between 85.77 and 87.14 mol%.

According to table 15, the average chemical composition of Garnet grains in sample [ALB1] is $Ca_{(2.726)3}Fe_{0.343}^{+3}Fe_{0.209}^{+2}Mn_{0.044}Mg_{0.004}Cr_{0.001}Al_{(1.692)2}Si_{(2.967)3}O_{12}$ and in sample [ALB2] is $Ca_{(2.788)3}Fe_{0.301}^{+3}Fe_{0.164}^{+2}Mn_{0.050}Al_{(1.694)2}Si_{(2.981)3}O_{12}$ .The average content of eight garnet grains was calculated and the result shows that the garnet from Wietzen area consisted of 83.25 mol% Grossular, 15.29 mol% Almandine, 1.40 mol% Spessartine and 0.06 mol% pyrope.

4.3.5.Scheelite and opaque minerals:

In total 16 measuring points for scheelite grains were analyzed and in table 16 three measuring points of [ALB2] and four of [405M] of different areas were presented. As it is stated in the table, the scheelite of Wietzen area contains very little or no molybdenum. The average WO_3 content in scheelite from Wietzen is 80.871 wt% and the average CaO content is 19.572 wt% (*Table. 16 and Fig. 19, 20, 21 and 22*).

Sample	***Area***	***DataSet/Point***	***CaO***	***WO3***	***Total***
ALB2 (Dark type)	***ALB2_Sch1_1***	33 / 1 .	19.58	80.54	100.14
ALB2	***ALB2_Sch1_1***	34 / 1 .	19.58	80.42	99.99
ALB2	***ALB2_Sch1_1***	35 / 1 .	19.36	80.71	100.15
405M (Dark type)	***405M_Sch2_1***	42 / 1 .	19.61	81.09	100.66
405M	***405M_Sch2_1***	45 / 1 .	19.75	81.22	100.92
405M	***405M_Sch3_1***	63 / 1 .	19.51	81.12	100.58
405M	***405M_Sch3_1***	65 / 1 .	19.61	81.01	100.59
		Avrage	19.57	80.87	100.43

Table 16: The chemical composition of scheelite from Wietzen area. Results are given in wt%.

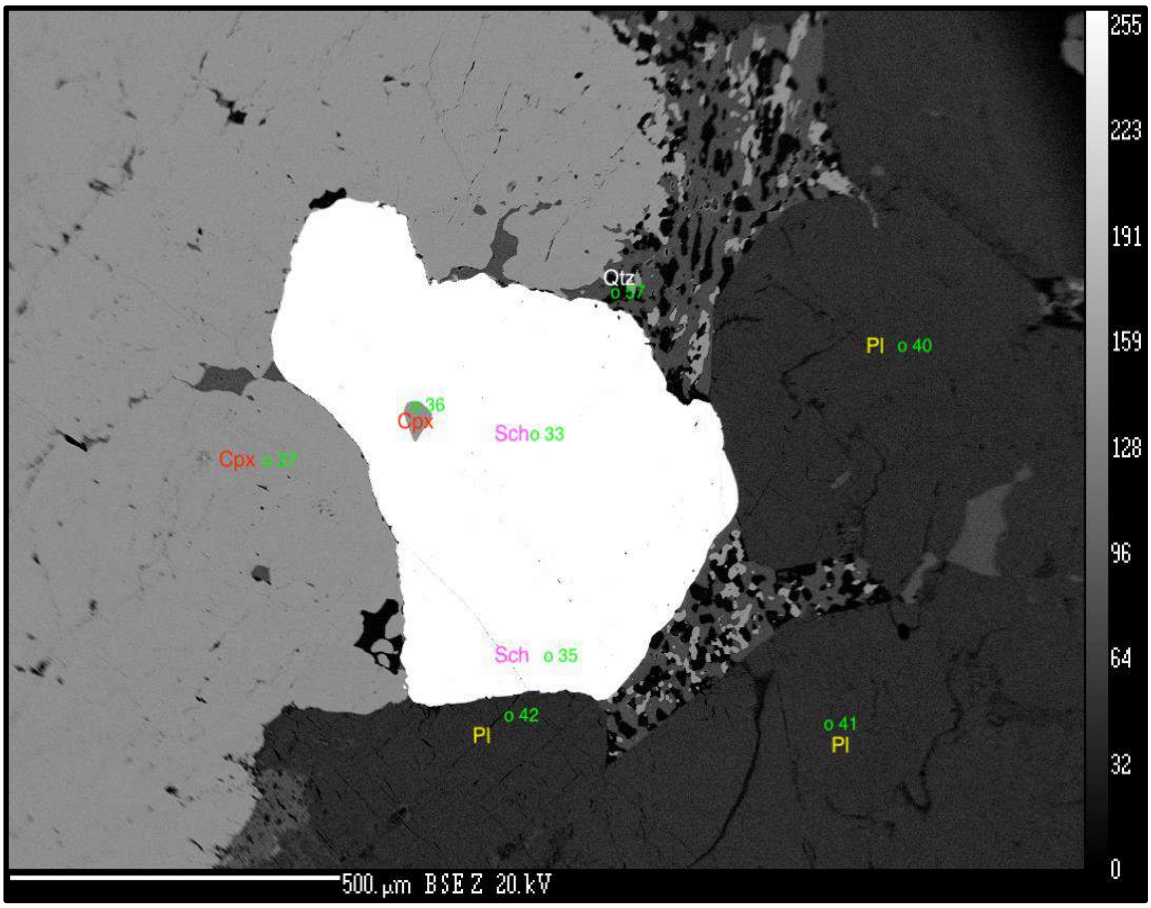

Figure 19: Sample from specimen ALB2, Area ALB2_Sch1_1: The scheelite is adjacent to clinopyroxene and plagioclase (bytownite), small xenomorphic quartz grains are adjacent to small xenomorphic clinopyroxene grains. Within this scheelite occur clinopyroxene (hedenbergite) as inclusion mineral. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

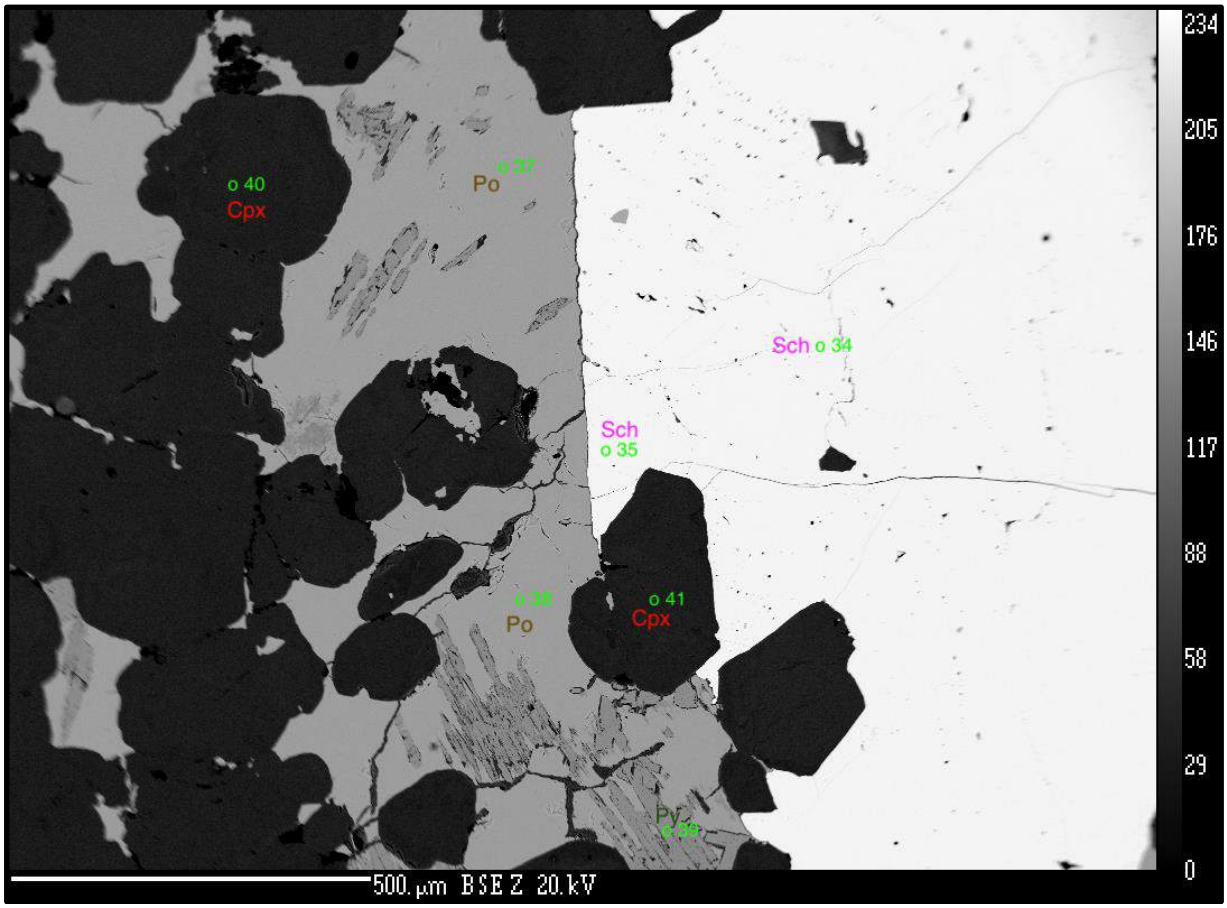

Figure 20: Sample 405M from WOK4 (range: 66.70- 67.40 m), Area 405M_Sch1_1: The scheelite grain is large, adjacent to a large pyrrhotite grain and hyp-idiomorphic clinopyroxene grains (hedenbergite). In pyrrhotite occur elongated aggregates of pyrites and within scheelite grain occur clinopyroxene as inclusion. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

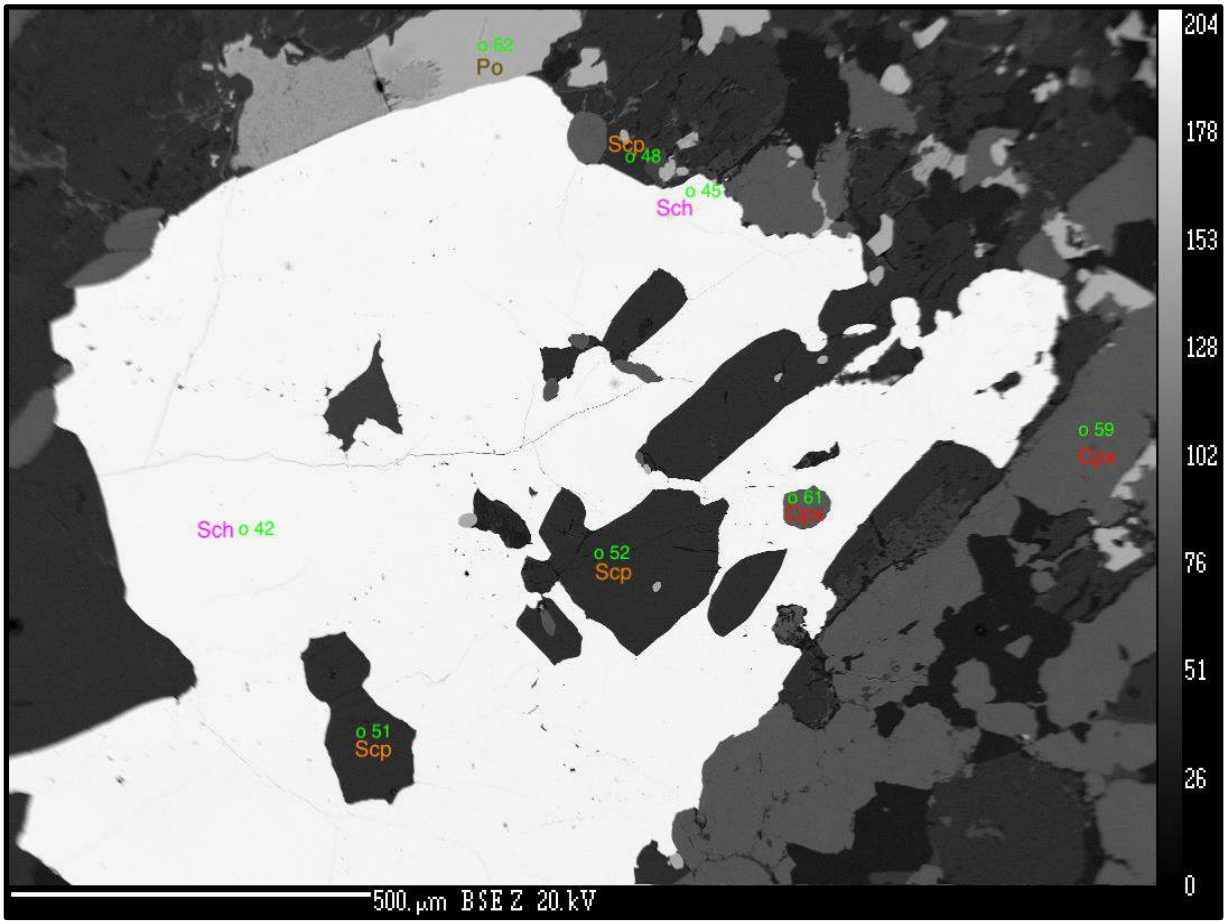

Figure 21: Sample 405M from WOK4 (range: 66.70- 67.40 m), Area 405M_Sch2_1: In this image hyp-idiomorphic scapolite grains and small clinopyroxene (hedenbergite) grains occur as inclusion minerals within scheelite grain. It is confirmed that the scheelite is younger than all other minerals. The sulfide mineral pyrrhotite is adjacent to the hyp-idiomorphic scheelite grain. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

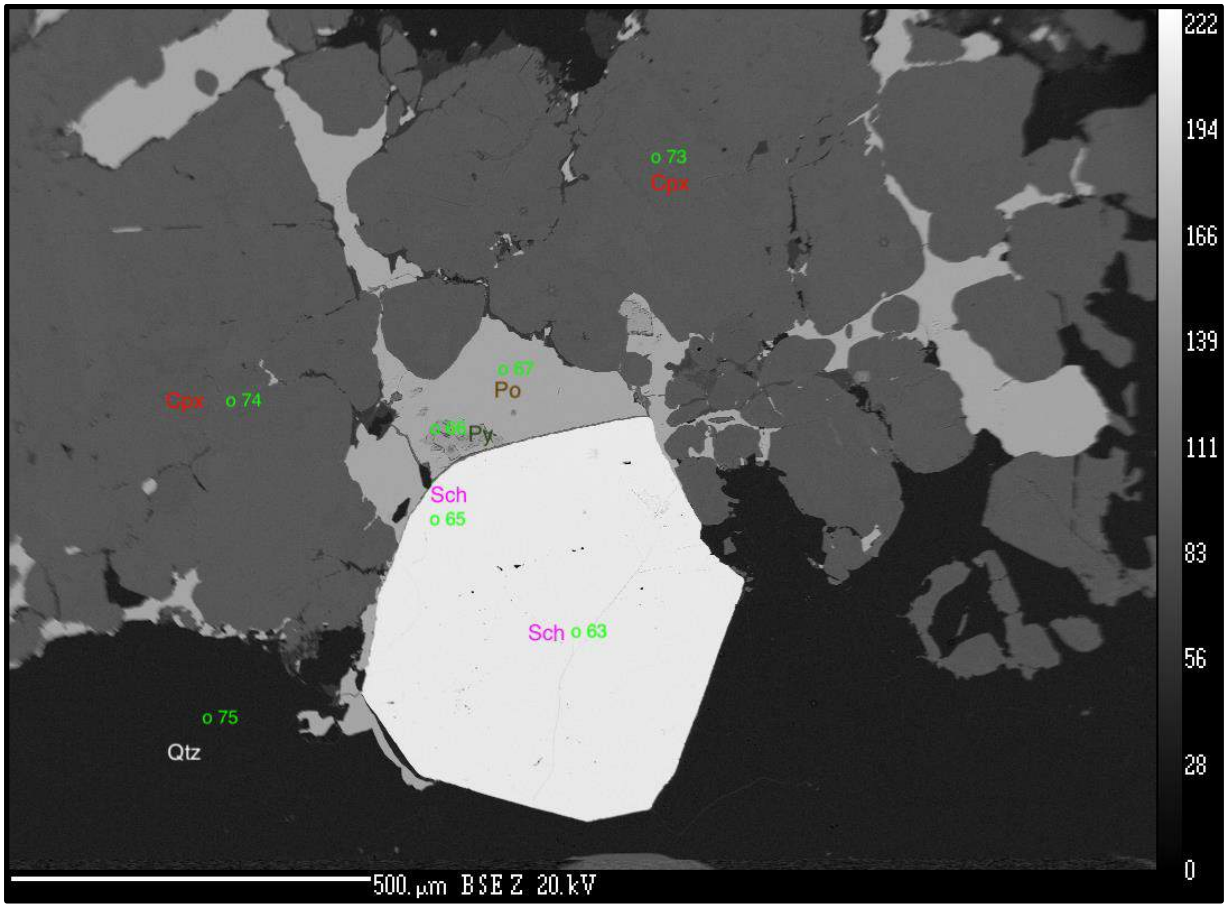

Figure 22: Sample 405M from WOK4 (range: 66.70- 67.40 m), Area 405M_Sch3_1: The clinopyroxene grains, quartz and pyrrhotite (with small pyrites aggregate) adjacent to a hyp-idiomorphic scheelite grain. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

Thirty-three measurement points were analyzed for opaque minerals. The opaque minerals occur as a major phase in [407M] and as a minor phase in [405M]. All opaque minerals are actually sulfides and only 14 selected points are shown in *table 17* and in the images. The dominant one is Pyrrhotite and accounts for about 50% of all the sulfides present in both samples , with chemical composition $Fe_{0.997}^{+3}Co_{0.001}Ni_{0.003}S_{1.982}$. Pyrites with average chemical composition ($Fe_{0.300}^{+3}Fe_{0.699}^{+2}Co_{0.001}Ni_{0.002}S_{1.150}$) and chalcopyrites with average chemical composition ($Fe_{0.001}^{+3}Fe_{0.501}^{+2}Cu_{0.499}S_{0.995}$) are equally present in both samples and make up 25% of the total sulfides. A small grain of sphalerite was detected in [407M] *(Fig. 23)* .

Sample	*Area*	*DataSet/Point*	*S*	*Fe*	*Co*	*Ni*	*Cu*	*Zn*	*Total*
405M (Dark type)	***405M_Sch1_1***	37 / 1 .	39.78	60.02	0.10	0.11	-0.08	0.00	99.93
405M	***405M_Sch1_1***	38 / 1 .	39.82	60.11	0.07	0.10	-0.09	0.01	100.02
405M	***405M_Sch1_1***	39 / 1 .	52.82	46.47	0.08	0.11	-0.06	0.00	99.42
405M	***405M_Sch2_1***	62 / 1 .	39.79	59.98	0.09	0.13	-0.07	-0.09	99.84
405M	***405M_Sch3_1***	66 / 1 .	53.21	46.89	0.11	0.11	-0.06	0.00	100.25
405M	***405M_Sch3_1***	67 / 1 .	39.70	60.25	0.09	0.08	-0.15	-0.01	99.96
407M (Dark type)	***407M_Op1_2***	14 / 1 .	53.70	46.64	-0.01	0.17	-0.04	-0.03	100.42
407M	***407M_Op1_2***	17 / 1 .	39.56	59.86	-0.01	0.14	-0.08	0.01	99.48
407M	***407M_Op1_2***	18 / 1 .	34.59	30.54	0.00	0.00	34.38	-0.04	99.48
407M	***407M_Op1_2***	19 / 1 .	34.67	30.65	0.00	0.00	34.41	-0.11	99.61
407M	***407M_Op1_2***	20 / 1 .	34.72	30.09	-0.01	0.01	34.50	-0.04	99.28
407M	***407M_Op1_2***	21 / 1 .	33.30	9.55	0.02	0.01	0.00	56.29	99.17
407M	***407M_Scp1***	110 / 1 .	39.72	60.25	0.05	0.05	-0.09	0.01	99.99
407M	***407M_Scp1***	111 / 1 .	39.64	60.09	0.07	0.07	-0.08	0.03	99.83

Table 17: The chemical composition of opaque minerals (sulfides). Results are given in wt%.

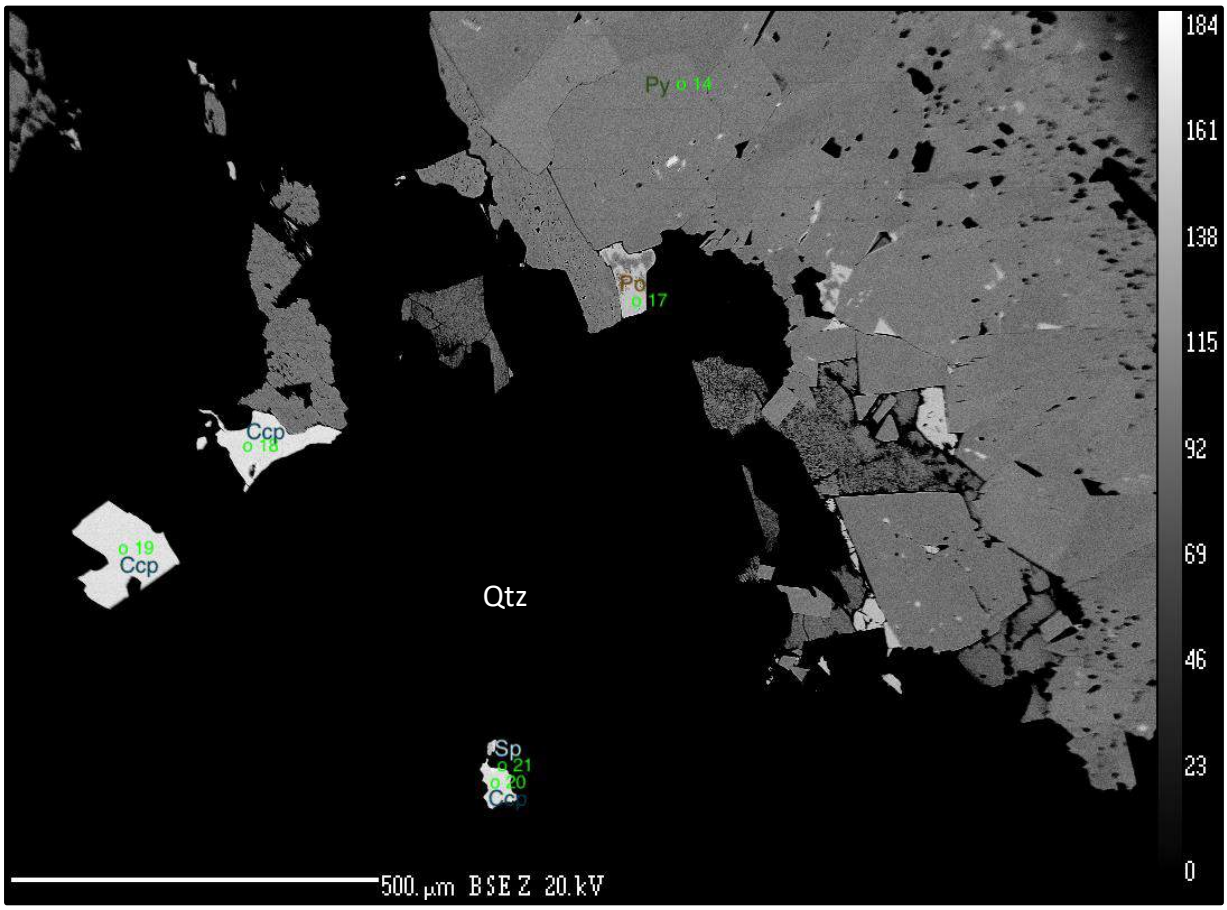

Figure 23: Sample 407M from WOK4 (range: 68.00 – 68.50 m), Area 407M_Op1_2: Four different sulfide ores occur in this image. Pyrite is the dominant sulfide mineral in this picture and a small pyrrhotite grain adjacent to this pyrit. Chalcopyrite, sphalerite and pyrrhotite occur as inclusion minerals in the quartz. Green labels represent the measurement points and the numbers of these labels correspond to those in the mineral chemistry Tables.

5.Discussion:

5.1. Scheelite mineralization in the Variegated group

According to Fuchs & Matura (1980), the Variegated Group is derived from an epicontinental sedimentary sequence. The high percentage of Cl and Na in scapolite mineral *(Table. 12)*, high content of F and SO3 in many samples *(Table. 8)*, and geochemical features indicate that the samples of the calc-silicate rocks and marbles taken from Wietzen area are partly of evaporitic origin and have come from primary saliniferous sediments. Calcite-rich marbles with the inclusions of dolomite in WOK4 from Variegated Group are probably products of (primary) dolomitization which is another sign that the origin of this rock goes back to the splash water area or salt pans. Thus, the former depositional area of the Variegated Group can be pictured as a coastal landscape with lagoons and salt lakes. According to Fuchs & Matura (1980), It might be possible that biogenic-rich marshes was the environment where today's graphitic shales were formed. Occasional basic eruptions led to the deposition of lavas and tuffs. These depositions later became amphibolite, whose chemistry corresponds to a continental tholeiite (Kuschnig, 1986).

As reported by Beran et al. (1985), stratabound scheelite mineralization in the Wietzen area occurs regional in the dark type calc-silicate rocks which are intercalations in a paragneiss series. This mineralization has an extraordinary occurrence and the calc-silicate rocks are very rich with scapolite. Drill cores show that the mineralization is disseminated in the dark calc-silicate rocks with several mineralized horizons with unknown lateral extensions. As mentioned by Beran et al. (1985), the scheelite mineralization in Wietzen area extend along strike for ~ 5 km. Near the mineralized area no acid intrusive rocks were found; however, the nearest Rastenberg Granodiorite crops out approximately 7 km NW of the Wietzen area. The Dobra-Gneiss cannot be postulated as the origin of tungsten intercalation in the calc-silicate rocks of the Variegated Group. Furthermore, occurrence of wollastonite in calc-silicate rocks as in sample [506M] *(Fig. 6)* is not definite proof for contact-metamorphism. According to Hapuarachchi,1968; Misch, I964; Mukherjee and Rege, 1973; Zaydan and Scharbert,1983 the wollastonite also has been observed in regional metamorphic paragenesis.

Many of the results point to the fact that the exoskarn formation could be a suitable interpretation for the investigated scheelite bearing calc-silicate. As reported by Newberry & Einaudi, (1981), exoskarn refers to those skarns that were formed by transformation of the adjacent rock (usually a limestone) outside the pluton. They can further be divided into proximal (near the pluton) and distal (far away from the pluton) skarns. According to Maucher,1965; Höll, 1975; Plimer, 1978, 1980, it seems that exoskarns in the examined area are a product of fluid infiltration over several hundred meters.

For example, the mineralogical composition and the massive grain texture of clinopyroxene (especially hedenbergite) in calc-silicate, the high Fe/Mg ratio in both the bulk analysis and the clinopyroxene microprobe analysis, and the presence of the hedenbergite in the scheelite bearing samples could be signs of a skarn deposit. Alongside with the previous genetic interpretation the following were also noticed:

(a) the absence of high concentration of any other elements that are typical for skarn deposits except tungsten;

(b) the mineralogical composition with very weak zoning of minerals that appear in scheelite bearing samples,

(c) the lack of chemical zoning within the single mineral grains, e.g., the plagioclase and the clinopyroxenes.

(d) As reported by Beran et al. (1985), both types of calc-silicate from Wietzen area correspond more to those sediments in comparison to that of acid intrusives.

As reported by Newberry & Einaudi, (1981), Meinert, (1992), ore enrichment can occur through various geologic processes and skarns[3]. Ore enrichments in skarns are typically generated by many factors such as temperature, pressure, fluid, host rock and geological position of the protolith. The most important feature is the mineralogical composition of the rock. Skarn mineralogy shows that the paragenesis pyroxene and garnet is dominant in calc-silicates, as in the Wietzen area (Newberry & Einaudi, Meinert, 1981, 1992).

[3] Skarn is a term that derives originally from central Sweden, where miners used it to refer to the coarse-grained calc-silicate gangue associated with iron ore. Since then the term has been extended to cover a diverse range of calc-silicate rocks which are rich in calcium, iron, magnesium, aluminum, and manganese, regardless of their association with minerals and ore of economic interest, and which were developed by the replacement of originally carbonate-rich rocks (Newberry & Einaudi, 1981).

Acoording to Meinert, (1992), this paragenesis is often repeated in different skarn ores. However, the chemical composition of the minerals in this paragenesis is the distinguishing characteristic for the particular ore enrichment. Normally tungsten skarns are associated with coarse-grained batholites (with pegmatites and aplite veins). These skarns are surrounded by high temperature metamorphic aureoles. The high temperature metamorphic aureoles typically in the tungsten skarn environment contain calc-silicates, calc-silicates hornfels and skarnoids composed of mixed contact-pelite series (Newberry & Einaudi; 1981, Newberry & Swanson; 1986; Kwak; 1987).

As reported by Newberry & Einaudi, (1981) the tungsten-bearing skarns are divided into two groups, the reduced and the oxidized type. The paragenesis hedenbergitic pyoxene, garnet (subcalcic garnet) is dominant in the reduced type. These parageneses often occur with deposition of early disseminated scheelite and its redeposition as coarse-grained or vein-controlled scheelite (with low or no molybdenum content) (Newberry, 1983). In reduced tungsten skarns sulfides such as pyrrhotite, chalcopyrite, sphalerite, molybdenite and hydrous minerals such as biotite, hornblende and epidote are found in large quantities. By contrast, in oxidized tungsten skarns andraditic garnets are more common than pyroxenes and scheelites have low molybdenum contents (Newberry, 1983). An example of the oxidized type is the Springer deposit in Nevada. In this deposit garnet is very abundant, and diopside pyroxenes, epidote and pyrites are more dominate than pyrrhotite. The subcalcic garnet is rarely found or sometimes even doesn't exist (Johanson & Keith, 1991).

Today the majority of the issues could be solved with the most postulation of a stratiform tungsten concentration in the calc-silicate rocks in the sedimentary Variegated Group with a subsequent metamorphism in higher amphibolite facies (or possibly several metamorphic events).According to all the observations and data that were mentioned in this master thesis, a hypothesis can suggest that the scheelite mineralization in the calc silicate rocks of the Wietzen area was caused by a fluid interaction with lithologies after metamorphism. During the metamorphism of saline sediments of the Variegated Group, the calc silicate and extraordinary marbles were formed. After this process, a tungsten rich fluid has come into contact with the lithologies of the Wietzen area especially with relatively porous calc-silicate rocks. This tungsten-rich fluid could have percolated though the iron-rich calc-silicate rocks (dark type) and deposited in the form of scheelite. This hypothesis may refer to term skarnoid or infiltration skarn (Newberry & Einaudi, 1981). Skarnoid is the result of metamorphism of impure

lithologies with some mass transfer by small-scale fluid movement. Fluid-controlled metasomatic skarn is generally coarser-grained (like most grains in dark calc-silicates from study area) (Newberry & Einaudid, 1981).

To support the assumption, that are mentioned above, these observations were pointed out on the hypothesis:

- An important observation is that most of the scheelites in cores were in the range of some mm. Scheelite veins were not observed and the grains in the drill core samples are mostly coarse and hyp-idiomorphic.
- In scheelite grains from [405M] and [ALB2] were observed inclusions of clinopyroxene, scapolite, however this is a hint that the scheelite in Wietzen are younger than the paragenesis clinopyroxene and scapolite *(Fig. 19, 20 and 21).*
- The paragenesis hedenbergite, garnet and scheelite is observed in ALB2 .
- All scheelite-bearing samples consist of hedenbergite as dominant clinopyroxene *(Diagram. 1).*
- The sulfide minerals are dominant in scheelite-bearing samples, especially pyrrhotite, pyrite and chalcopyrite *(Fig. 22).*
- The grossular and almandine components are predominant in garnet from Wietzen area and grains are strongly fragmented. Perhaps it's a sign of a deformation event (fluid movement in cala-silicate) after the metamorphism (*Fig. 8).*

Many areas all over the world are known for scheelite mineralization in calc-silicate rocks and some of them are of greater economic value, e.g. in the Pyrenees (Autran, 1980), Kings Island, Tasmania (e.g. Kwak and Tan, 1981) and occurrences in the Sierra Nevada of California (e.g. Newberry, 1982). However, the tungsten mineralization conditions that prevail in Wietzen are somewhat similar to the tungsten mineralization in Hindu Kush of Pakistan as described in Leake et al., (1989). Furthermore, in the case of Hindu kush, the strata bound scheelite mineralization occurs mainly in clinozoisite-bearing calc-silicate-quartzite strata. These layers occur within a sequence of mica schist and subordinate graphite phyllite, mica quartzite, tourmalinite and feldspar gneiss. The sequence is intruded by a minor leucogranite body, which was emplaced after the peak of metamorphism as a result of the later of two deformational phases, which are linked to continent-arc collisions. Scheelite crystallization occurred in the calc-silicate quartzites contemporaneously with clinozoisite before the emplacement of leucogranite and definitely has a metamorphic origin. As reported by Leake et al. (1989),

tungsten-rich brines, developed from fluid or hot springs within an extensional tectonic setting, probably were concentrated in the relatively porous calc-silicate-quartzite precursor during the diagenesis. Ensuing metamorphism recrystallized the tungsten as scheelite together with metamorphic silicate minerals, establishing a limited mobility of the element into veins.

In addition there is also another special stratabound scheelite occurrence in Australia (Broken Hill). According to Plimer, (1994), scheelite is present in regional calc-silicate rocks that are enriched with F and Zn, within a sequence of carbonaceous sulfide metapelite, tourmalinite, and amphibolite. This sequence overlies a felsic gneiss-metasedimentary sequence, which is interpreted as meta-evaporites. Scheelite distribution is not associated with Broken Hill syntectonic pegmatites or post-tectonic granitic rocks. However, the Scheelite in Broken Hill has experienced low remobilization through tectonism. The calc-silicate rocks have been interpreted as dolomitic limestone sediment which was part of a playa-lake sequence into which B-, W-, Zn-, and F-rich alkaline hot springs / fluid intruded.

These assumptions are still a matter of debate, which eventually be solved with additional investigations and studies of the outcrops not only of Wietzen area but the entire Variegated Group. Once the lack of evidence and relevant information is omitted, the origin of the Variegated Group and the appearance of scheelite mineralization in it could be discovered.

Conclusion:

The purpose of this study was to understand the mineralogical and geochemical properties of calc-silicate rocks, other lithologies and the scheelite mineralization in the Wietzen area. In addition, this study aimed to identify the origins of the calc-silicate of the Variegated Group. All in all, it can be concluded from this study that the scheelite mineralization is strata bound as reported by Baren (1985) and it is disseminated in dark type calc-silicate rocks. Furthermore, the lab results identified a metasedimentary origin of the rocks of the Variegated Group. However, further investigation is needed to clarify accurately the origins of tungsten mineralization in the Wietzen area.

References:

Allmann, R.: Röntgenpulverdiffraktometrie- Rechnergestützte Auswertung, Phasenanalyse und Strukturbestimmung. Verlag Sven von Loga / Springer (1994).

Autran, A.: Genése des skarns à tungstène dans les Pyrenées. In: Minėralisations liées aux granitoides, Z. Johan, Coord., Orléans: Mémoire B.R.G.M9.9, t91-319 (1980).

Beran, A., Göd, R., Götzinger, M. & Zemann, J.: A scheelite mineralization in calc- silicate rocks of the Moldanubikum (Bohemian Massif) in Austria. – Mineral. Deposita, 20, 16-22, Berlin - Heidelberg (1985).

Chaloupsky, J.: The precambrian tectogenesis in the Bohemian Massif. Geol. Rundsch. 67, 72-90 (1978).

Evans, B.W., Shaw, D.M., Haughton, D.R.: Scapolite stoichiometry. Contr. Miner. Petr. 24, 293-305 (1969).

Exner, Ch.: Über geologische Aufnahmen beim Bau der Kampkraftwerke (Südliche Böhmische Masse). Jb. Geol. B.A. (Wien) 96, 217-252 (1953).

Fuchs, G. & Matura, A.: Zur Geologie des Kristallins der südlichen Böhmischen Masse.- Jb. Geol. B.-A., 119, 1-43, Wien (1976).

Fuchs, G. & Matura, A.: Die Böhmische Masse in Österreich.- In: OBERHAUSER, R. (Red.): Der Geologische Aufbau Österreichs. - 121-143, Wien - New York (Springer) (1980).

Fuchs, G. & Scharbert, H. G.: Kleinere Granulitvorkommen im niederösterreichischen Moldanubikum und ihre Bedeutung für die Granulitgenese. - Verh. Geol. B.-A., 29-49, Wien (1979).

Goldstein, J.: Practical scanning electron microscopy: electron and ion microprobe analysis. Springer Science & Business Media (2012).

Göd, R.: A contribution to the Mineral Potential of the Southern Bohemian Massif, Austria. Arch. Lagerst.-forsch. Ostalpen, Bd. 11, 147 153, Geol. BA Wien (1989).

Göd, R.: Prospektion scheelitführender Kralksilikate im Moldanubikum Niederösterreichs. Fortschr. Miner. 59, Beih. 1, 53 (1981).

Hapuarachchi, D.J.A.C.: Cordierite and wollastonite-bearing rocks of south-western Ceylon. Geol. Mag. 105, 317-324 (1968).

Högelsberger. H.: Petrologie der Marmore und Kalksilikate der Bunte Serie (Niederösterreichisches Moldanubikum) – Diss. Univ. Wien (1987) .

Höll, R.: Die Scheelitlagerstätte Felbertal und der Vergleich mit anderen Scheelitvorkommen in den Ostalpen. Bayr. Akad. Wiss., Math.-naturw. KI., Abh. 157A u. B, 1-114, Anlagen (1975).

Johanson, V.Y & Keith, J.D.: Petrology and geochemistry of the Springer Scheelite skarn deposit, Mill City, Nevada, in Raines, G. L., Lisle, R. E., Schafer, R.W. and Wikinson, W.H., eds., Geology and Ore Deposits of the Great Basin: Geological Society of Nevada, Reno. V. 1. P. 553-578 (1991).

Jung, R.: Scheelitprospektion in der südlichen Böhmischen Masse. Unpublished field report,"Minerex"- Mineralexplorationsgesellschaft, archive of the mining authority; Vienna (1982).

Klötzli, U., Frank, W., Scharbert, S. and Thöni, M.: Evolution oft he SE Bohemian Massif Based on Geochronological Data-A Review; Jb.Geol.B,-A., Band 141, Heft 4, 377-394 (1999).

Kwak, T.A.P., Tan, T.H.: The geochemistry of zoning in skarn minerals at the King Island (Dolphin) Mine. Econ. Geol. 76, 468-497 (1981a).

Kwak, T.A.P.: W-Sn skarn deposits and related metamorphic skarns and granitoids: Developments in Economic Geology. No. 24, Elsevier, Amesterdam, 451p. (1987).

Leake, R.C., Fletcher, C.J.N., Haslam, H.W., Khan, B. and Shakirullah.: Origin and tectonic setting of stratabound tungsten mineralization within the Hindu Kush of Pakistan; Journal of the Geological Society, London, Vol. 146, pp. 1003-1016, (1989).

Linner, M.: Metamorphism and partial melting of paragneisses oft he Montonous Group, SE Moldanubikum (Austria); Mineralogy and Petrology 58, 215-234 (1996).

Matura, A.: Geologie der Österreichischen Bundesländer (Niederösterreich). Geol. BA. (Wien) 25 -35 (2006).

Maucher, A.: Die Antimon-Wolfram-Quecksilber-Formation und ihre Beziehungen zu Magmatismus und Geotektonik. Freiberger Forschung. C 186,173-188 (1965).

Meinert, L.D.: Skarn and skarn deposition. Pullman, Washington 99164-2812 USA, v.19-4 (1992).

Misch, P.: Stable association wollastonite-anorthite, and other calc-silicate assemblages in amphibolite-facies crystalline schists of Nanga Parbat, North west Himalayas. Contr. Miner. Petr. 10, 315-356 (1964).

Morimoto, N. & M. Kitamura, M.: Q-J diagram for classification of pyroxenes. Journal of the Japanese Association of Mineralogists, Petrologists and Economic Geologists, 78, 141 (in Japanese) (1983).

Mukherjee, A., Rege, S.M.: Stability of wollastonite in the granulite facies: some evidences from the Eastern Ghats, India. N. Jb.Miner., Abh. 118,23-42 (1973).

Nagl, P& Mader, D,: XRF and INAA for the geochemical analysis of rocks, presented on inhouse control samples (2019).

Newberry, R.J.: Tungsten-bearing skarns of the Sierra Nevada. I. The Pine Creek Mine, California. Econ. Geol. 77, 823-844 (1982).

Newberry, R.J.: The formation of subcalcic garnet in scheelie bearing skarns: Canadian Mineralogist, v.14, p. 57-81 (1983).

Newberry, R.J & Einaudi, M.T.: Tectonic and geochemical setting of tungsten skarn mineralization in the Cordillera: Arizona Geological Seciety, Digest, v.14. p.99-112 (1981).

Newberry,R.J & Swanson, S.E.: Scheelite skarn granitoids: An evalution of the roles of magmatic source and process: Ore Geology
Reviews, v.1, p. 57-81 (1986).

Petrakakis, K.: Evolution of Moldanubian rocks in Austria: review and sythesis; J. metamorphic Geol., 15, 203-222 (1997).

Plimer, I.A.: Proximal and distal strata-bound ore deposits. Mineral. Deposita 13, 345-353 (1978).

Plimer, I.A.: Exhalative Sn and W deposits associated with mafic volcanism as precursors to Sn and W deposits associated with granites. *Mineral*. Deposita 15, 275-289 (1980).

Plimer, I.A.: Strata-Bound Scheelite in Meta-evaporites, Broken Hill, Australia. Society of Economic Geologists, Inc. Economic Geology, v. 89, pp. 423-437, (1994).

Šemprok, M.: Scheelitovy skarn sev. od Hazlova u Chebu. Geol. Prûzkum, 26 (4): 119- 120; Praha (1984).

Stettner, G.: Zur geologisch- tektonischen Entwicklung des Oberpfälzer Grundgebirges. Aufbau des Fichtelgebirges. Aufschluß 31. 391- 403 (1975).

Stettner, G.: Zum geologischen Autbau des Fichtelgebirges. Aufschluß 31,391-403 (1980).

Suess, F.E.: Die moravischen Fenster und ihre Beziehung zum Grundgebirge des Hohen Gesenkes. Österreich. Akad. Wiss., math.-natw. Kl., Denkschrift, 88, 541-631 (1912).

Svoboda, J.: Regional Geology of Czechoslovakia. Part I. The Bohemian Massif. Prague: Geol. Surv. Czechoslovakia (1966)

Thiele, o.: Zum Deckenbau und Achsenplan des Moldanubikums der Südlichen Böhmischen Masse (Österreich). - Jb. Geol. B.-A., 126, 513-524, Wien (1984).

Tollman, A.: Großräumiger variszischer Deckenbau im Moldanubikum und neue Gedanken zum Variszikum Europas. - Geotekt. Forsch., 64, 1-91, Stuttgart (1982).

Waldmann, L.: Das auBeralpine Grundgebirge Osterreichs. In: Geologie von Osterreich, F.X. Schaffer, Ed., pp 10-104. Wien: Deuticke (1951).

Zaydan, A., Scharbert, H.G.: Petrologie und Geochemie moldanubischer metamorpher Serien im Raume Persenbeug (süd- westliches Waldviertel). Jb. Geol. B. A. (Wien) 126,181-199 (1983).

Laufender Meter Lfm	*WOK*	*Lithology*	*Type of calc-silicate (CS)*	*Sample*
11.00 - 11.25	5	Calc-silicate with carbonate	Dark type	501M
11.25 - 11.65	5	Amphibolite		502M
11.65 - 12.00	5	Intercalation zone (calc silicate carbonate to amphibolite)	Light type	_
12.00 - 12.25	5	Calc-silicate with carbonate	Light type	_
12.25 - 12.35	5	Amphibolite		503M
12.35 - 12.50	5	Calc-silicate with carbonate	Light type	_
12.50 - 12.55	5	Amphibolite		_
12.55 - 12.70	5	Intercalation of amphibolite to CS (with carbonate)	Dark type	504M
12.70 - 12.75	5	Amphibolite		_
12.75 - 12.85	5	Calc-silicate (carbonate free)	Dark type	_
12.85 - 13.00	5	Amphibolite		_
13.00 - 13.15	5	Calc-silicate (carbonate free)	Dark type	5012M
13.15 - 13.25	5	Amphibolite		_
13.25 - 13.35	5	Calc-silicate (carbonate free)	Dark type	5051M*
13.35 - 13.50	5	Amphibolite		5052M
13.50 - 13.66	5	Calc-silicate (carbonate free)	Dark type	506M*
13.66 - 14.00	5	Calc-silicate with carbonate	Light type	507M
14.00 - 14.75	5	Intercalation zone (calc silicate carbonate free to amphibolite)	Dark type	508M, 509M
14.72 - 15.00	5	Intercalation zone (calc silicate carbonate free to paragneiss)	Dark type	510M
15.00 - 17.00	5	Paragneiss		511M
45.00 - 46.75	2	Amphibolite		_
46.75 - 47.50	2	Intercalation zone (amphibolite to calc silicate carbonate free)	Dark type	_
47.50 - 48.75	2	Calc-silicate with carbonate	Dark type	210M
48.75 - 49.30	2	Calc-silicate with carbonate	Light type	201M, 2011M
49.30 - 48.40	2	Calc-silicate (carbonate free)	Light type	202M
50.20 - 50.60	2	Calc-silicate with carbonate	Light type	2091M
50.60 - 51.30	2	Calc-silicate (carbonate free)	Dark type	2092M
51.30 - 52.00	2	Calc-silicate with carbonate	Dark type	203M
52.00 - 53.45	2	Calc-silicate with carbonate	Light type	204M, 205M, 206M
53.45 - 54.50	2	Calc-silicate with carbonate	Dark type	207M, 2081M, 2082M*
54.50 - 55.00	2	Calc-silicate (carbonate free)	Light type	2083M*
55.00 - 55.50	2	Calc-silicate with carbonate	Light type	211M
55.50 - 57.50	2	Intercalation zone (calc silicate carbonate free to amphibolite)	Light type	212M, 213M, 214M, 215M
57.50 - 58.20	2	Calc-silicate (carbonate free)	Light type	216M
58.20 - 59.00	2	Calc-silicate with carbonate	Dark type	217M*
59.00 - 61.00	2	Paragneiss		218M
56.00 - 59.70	4	Paragneiss		_
57.70 - 62.90	4	Marble		401M, 402M
62.90 - 63.00	4	Amphibolite		_
63.00 - 65.00	4	Marble		403M
65.00 - 65.30	4	Calc-silicate with carbonate	Light type	404M
65.30 - 69.30	4	Calc-silicate with carbonate	Dark type	405M*, 406M*, 407M*, 408M*
69.30 - 71.00	4	Parageniss		_

Table 18:The macroscopic description of drill cores depending on running meters (Lfm) and lithology change. Note: (*) refers to scheelite bearing calc-silicate.

Nr.	Sample Nr.	Lithology	Analysis (XRF)	Mineralogy (Thin sections)	X-ray diffraction (XRD)	Electron beam microprobe (EMS)
1	501	calc-silicate with carbonate	_	*	_	_
2	502	Amphibolite	*	*	_	_
3	503	Amphibolite	*	*	_	_
4	504	Sharp intercalation of amphibolite to CS (with carbonate)	*	*	_	_
5	512	calc-silicate (carbonate free)	*	*	_	_
6	5051	calc-silicate (carbonate free)	*	*	_	_
7	5052	Amphibolite	_	*	_	_
8	506	calc-silicate (carbonate free)	*	*	_	_
9	507	calc-silicate with carbonate	*	*	_	_
10	508	Intercalation zone (calc silicate carbonate free to amphibolite)	_	*	_	_
11	509	Intercalation zone (calc silicate carbonate free to amphibolite)	*	*	_	_
12	510	Intercalation zone (calc silicate carbonate free to paragneiss)	_	*	_	_
13	511	Paragneiss	*	*	_	_
14	210	calc-silicate with carbonate	*	*	_	_
15	201	calc-silicate with carbonate	_	*	_	_
16	2011	calc-silicate with carbonate	_	*	_	_
17	202	calc-silicate (carbonate free)	_	*	_	_
18	2091	calc-silicate with carbonate	*	*	_	_
19	2092	calc-silicate with carbonate	*	*	_	_
20	203	calc-silicate (carbonate free)	*	*	_	_
21	204	calc-silicate with carbonate	_	*	_	_
22	205	calc-silicate with carbonate	_	*	_	_
23	206	calc-silicate with carbonate	_	*	_	_
24	207	calc-silicate with carbonate	*	*	_	_
25	2081	calc-silicate with carbonate	*	*	_	_
26	2082	calc-silicate with carbonate	*	*	_	_
27	2083	calc-silicate (carbonate free)	*	*	_	*
28	211	calc-silicate with carbonate	*	*	_	_
29	212	Intercalation zone (calc silicate carbonate free to amphibolite)	*	*	_	_
30	213	Intercalation zone (calc silicate carbonate free to amphibolite)	*	*	_	_
31	214	Intercalation zone (calc silicate carbonate free to amphibolite)	*	*	_	_
32	215	Intercalation zone (calc silicate carbonate free to amphibolite)	*	*	_	_
33	216	calc-silicate (carbonate free)	*	*	_	_
34	217	calc-silicate with carbonate	*	*	_	_
35	218	Paragneiss	*	*	_	_
36	401	Marble	*	*	_	_
37	402	Marble	*	*	*	_
38	403	Marble	*	*	*	_
39	404	calc-silicate with carbonate	*	*	_	_
40	405	calc-silicate (carbonate free)	*	*	_	*
41	406	calc-silicate with carbonate	*	*	_	_
42	407	calc-silicate with carbonate	*	*	_	*
43	408	calc-silicate with carbonate	*	*	_	_
44	ALB1	calc-silicate with carbonate	_		_	*
45	ALB2	calc-silicate with carbonate	_		_	*
46	ALB3	calc-silicate with carbonate	_	*	_	_

Note: all analysis samples ends with (A), and all thin sections and microprobe sections ends with (M).

Table 19: List of methods used for the investigated samples.

Nr.	WOK. Nr.	Sample Nr.	Laufender Meter Lfm	Lithology	Light/ Dark type	Analysis	W [ppm]	Mineralogy	Mineral components
1	5	501	11.00 - 11.25	calc-silicate with carbonate	Dark type	_	na	*	(Cpx, Scp, Qtz, Czo, Ttn, Chl ,Cal)
2	5	502	11.25 - 11.65	Amphibolite		*	4	*	(Cpx, Qtz, Pl, Chl, Ap, Ttn)
3	5	503	12.00 -12.50	Amphibolite		*	9	*	(Cpx, Pl, Qtz, Bt, Hbl, Ttn, Chl, Opq)
4	5	504	12.50 - 12.75	Sharp intercalation of amphibolite to CS (with carbonate)	Light type	*	6	*	(Hbl, Cpx, Qtz, Bt, Pl, Scp, Ttn, Chl, Ves, Cal)
5	5	512	13.00 - 13.15	calc-silicate (carbonate free)	Dark type	*	12	*	(Cpx, Scp, Qtz, Cal, Ap, Chl, Ttn)
6	5	5051	13.25 - 13.35	calc-silicate (carbonate free)	Dark type	*	467	*	(Cpx, Scp, Qtz, Opq, Sch, Ttn, Chl, Cal)
7	5	5052	13.35 - 13.50	Amphibolite		_	na	*	(Hbl, Pl, Cpx, Bt, Qtz, Ti, Chl)
8	5	506	13.52 - 13.66	calc-silicate (carbonate free)	Dark type	*	449	*	(Cpx, Qtz, Wo, Pl, Scp, Ttn, Ap, Sch)
9	5	507	13.66 - 14.00	calc-silicate with carbonate	Light type	*	7	*	(Pl, Qtz, Cpx, Hbl, Ttn, Cal, Kfs, Opq, Ap)
10	5	508	14.00 - 14.30	Intercalation zone (calc silicate carbonate free to amphibolite)	Dark type	_	na	*	(Hbl, Bt, Qtz, Cpx, Pl, Ttn, Chl)
11	5	509	14.30 - 14.72	Intercalation zone (calc silicate carbonate free to amphibolite)	Dark type	*	13	*	(Qtz, Pl, Hbl, Bt, Cpx, Ttn, Opq, Ap)
12	5	510	14.72 - 15.00	Intercalation zone (calc silicate carbonate free to paragneiss)	Dark type	_	na	*	(Qtz, Bt, Hbl, Cpx, Pl, Grt, Ti)
13	5	511	15.00 - 15.20	Paragneiss		*	6	*	(Bt, Qtz, Pl, Chl, Grt)
14	2	210	47.50 - 48.00	calc-silicate with carbonate	Dark type	*	28	*	(Pl, Cpx, Qtz, Ttn, Cal, Ap)
15	2	201	48.30- 48.40	calc-silicate with carbonate	Light type	_	na	*	(Cpx, Scp, Pl, Qtz, Cal, Ttn)
16	2	2011	48.40 - 48.60	calc-silicate with carbonate	Light type	_	na	*	(Cpx, Pl, Qtz, Scp, Ttn, Grt, Cal)
17	2	202	49.75 - 49.85	calc-silicate (carbonate free)	Light type	_	na	*	(Cpx, Qtz, Pl, Ttn, Kfs)
18	2	2091	50.20 - 50.60	calc-silicate with carbonate	Light type	*	8	*	(Cpx, Pl, Qtz, Cal, Ttn, Chl, Czo)
19	2	2092	50.60 - 51.00	calc-silicate with carbonate	Dark type	*	55	*	(Cpx, Scp, Qtz, Pl, Ap, Opq, Ttn)
20	2	203	51.30 - 52.00	calc-silicate (carbonate free)	Dark type	*	32	*	(Cpx, Pl, Qtz, Cal, Ttn, Opq)
21	2	204	52.00 - 52.20	calc-silicate with carbonate	Light type	_	na	*	(Pl, Qtz, Cpx, Cal, Ttn, Opq, Chl)
22	2	205	52.45 - 52.65	calc-silicate with carbonate	Light type	_	na	*	(Qtz, Pl, Cpx, Kfs, Cal)
23	2	206	53.00 - 53.45	calc-silicate with carbonate	Light type	_	na	*	(Qtz, Pl, Cal, Cpx, Kfs)
24	2	207	53.45 - 53.75	calc-silicate with carbonate	Dark type	*	41	*	(Cpx, Ttn, Qtz , Czo, Opq)
25	2	2081	53.75 - 54.00	calc-silicate with carbonate	Dark type	*	35	*	(Cpx, Scp, Cal, Ttn, Chl, Qtz, Ves)
26	2	2082	54.00 - 54.50	calc-silicate with carbonate	Dark type	*	107	*	(Pl, Cpx, Scp, Qtz, Cal, Ttn, Chl, Sch)
27	2	2083	54.50 - 55.00	calc-silicate (carbonate free)	Light type	*	7	*	(Cpx, Pl, Scp, Ves, Kfs, Qtz, Ttn)
28	2	211	55.00 - 55.50	calc-silicate with carbonate	Light type	*	9	*	(Pl, Cpx, Scp, Ttn, Ap, Qtz, Cal, Grt)
29	2	212	55.50 - 56.00	Intercalation zone (calc silicate carbonate free to amphibolite)	Light type	*	9	*	(Qtz, Pl, Cpx, Bt, Grt, Hbl, Opq)
30	2	213	56.00 - 56.50	Intercalation zone (calc silicate carbonate free to amphibolite)	Light type	*	6	*	(Qtz, Bt, Hbl, Cpx, Scp, Grt, Scp, Pl, Opq)
31	2	214	56.50 - 57.00	Intercalation zone (calc silicate carbonate free to amphibolite)	Light type	*	7	*	(Qtz, Pl, Cpx, Scp, Hbl, Grt, Bt, Ap)
32	2	215	57.00 - 57.50	Intercalation zone (calc silicate carbonate free to amphibolite)	Light type	*	3	*	(Qtz, Hbl, Cpx, Bt, Scp, Pl, Opq, Grt)
33	2	216	57.50 - 58.00	calc-silicate (carbonate free)	Light type	*	12	*	(Cpx, Qtz, Scp, Ttn, Grt)
34	2	217	58.20 - 58.90	calc-silicate with carbonate	Dark type	*	353	*	(Cpx, Qtz, Pl, Scp, Cal, Ttn, Chl , Sch)
35	2	218	59.70 - 60.00	Paragneiss		*	10	*	(Qtz, Bt, Hbl, Opq, Pl, Cal, Chl)
36	4	401	60.00 -60.50	Marble		*	1	*	(Cal, Cpx, Qtz, Ttn)
37	4	402	60.50 - 61.00	Marble		*	1	*	(Cal, Cpx, Kfs, Opq)
38	4	403	63.60 - 63.80	Marble		*	1	*	(Cal, Cpx, Qtz, Kfs ,Ttn)
39	4	404	65.00 - 65.30	calc-silicate with carbonate	Light type	*	4	*	(Qtz, Cpx, Czo, Cal, Ttn, Opq)
40	4	405	66.70 - 67.40	calc-silicate (carbonate free)	Dark type	*	260	*	(Cpx, Qtz, Scp, Cal, Opq, Sch, Ttn, Ap)
41	4	406	67.60 - 68.00	calc-silicate with carbonate	Dark type	*	119	*	(Cpx, Qtz, Cal, Ttn, Scp, Chl, Sch)
42	4	407	68.00 - 68.50	calc-silicate with carbonate	Dark type	*	151	*	(Cpx, Opq, Qtz, Czo, Ttn, Sch, Cal, Scp, Ap)
43	4	408	68.50 - 69.00	calc-silicate with carbonate	Dark type	*	75	*	(Cpx, Czo, Qtz, Opq, Cal, Ttn, Chl, Sch)
44		ALB3M		calc-silicate with carbonate	Light type	_	na	*	(Cpx, Scp, Grt, Qtz, Cal, Ttn)

Table 20: The mineralogical composition of each thin section from Wietzen area.

Nr.	WOK. Nr.	Sample Nr.	Laufender Meter Lfm	Lithology	Analysis	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI	Total
1	5	502A	11.25 - 11.65	Amphibolite	*	44.76	3.31	13.11	14.41	0.19	7.94	10.15	2.67	1.06	0.39	0.63	98.62
2	5	503A	12.00 -12.50	Amphibolite	*	50.06	0.79	11.53	9.02	0.49	4.88	17.81	2.08	0.80	0.30	0.66	98.42
3	5	504A	12.50 - 12.75	arp intercalation of amphibolite to CS (with carbonate)Amphibol	*	53.86	0.66	10.08	9.13	0.43	3.80	17.66	2.01	0.32	0.15	0.65	98.75
4	5	512A	13.00 - 13.15	calc-silicate (carbonate free)	*	48.92	0.65	11.05	10.80	0.46	3.44	19.80	2.04	0.29	0.12	0.19	97.76
5	5	5051A	13.25 - 13.35	calc-silicate (carbonate free)	*	48.54	0.45	7.98	15.48	0.54	2.92	20.04	1.45	0.21	0.17	0.00	97.78
6	5	506A	13.52 - 13.66	calc-silicate (carbonate free)	*	50.44	0.58	9.63	9.73	0.42	2.67	22.88	1.53	0.19	0.12	0.36	98.55
7	5	507A	13.66 - 14.00	calc-silicate with carbonate	*	53.97	0.90	14.89	6.75	0.25	2.73	14.51	3.48	0.66	0.10	0.32	98.56
8	5	509A	14.30 - 14.72	Intercalation zone (calc silicate carbonate free to amphibolite)	*	57.35	0.81	14.29	5.57	0.22	2.79	12.45	2.62	2.38	0.09	0.34	98.91
9	5	511A	15.00 - 15.20	Paragneiss	*	60.42	0.83	16.12	7.43	0.16	2.49	2.66	2.55	4.28	0.09	0.83	97.86
10	2	210A	47.50 - 48.00	calc-silicate with carbonate	*	47.95	0.55	9.86	8.48	0.57	3.87	22.19	0.76	0.71	0.24	3.90	99.08
11	2	2091A	50.20 - 50.60	calc-silicate with carbonate	*	50.43	0.64	10.80	8.23	0.45	4.24	18.08	2.07	0.40	0.16	3.76	99.26
12	2	2092A	50.60 - 51.00	calc-silicate with carbonate	*	52.65	0.57	10.27	9.18	0.37	4.08	16.43	2.31	0.30	0.40	2.02	98.58
13	2	203A	51.30 - 52.00	calc-silicate (carbonate free)	*	51.48	0.50	8.24	9.16	0.29	3.55	15.79	1.71	0.84	0.59	6.15	98.30
14	2	207A	53.45 - 53.75	calc-silicate with carbonate	*	51.14	0.58	10.64	8.87	0.49	3.51	19.38	0.98	0.54	0.09	2.28	98.50
15	2	2081A	53.75 - 54.00	calc-silicate with carbonate	*	52.21	0.58	10.02	9.32	0.52	3.75	19.13	1.47	0.42	0.08	1.18	98.68
16	2	2082A	54.00 - 54.50	calc-silicate with carbonate	*	50.74	0.65	11.01	8.99	0.58	4.33	19.17	1.88	0.43	0.18	0.96	98.92
17	2	2083A	54.50 - 55.00	calc-silicate (carbonate free)	*	50.28	0.67	11.00	8.28	0.62	5.12	19.42	1.77	0.41	0.09	0.75	98.41
18	2	211A	55.00 - 55.50	calc-silicate with carbonate	*	54.10	0.72	11.34	7.17	0.43	4.26	15.32	2.55	0.93	0.63	0.91	98.36
19	2	212A	55.50 - 56.00	Intercalation zone (calc silicate carbonate free to amphibolite)	*	57.51	0.75	12.27	6.15	0.33	3.44	11.49	2.64	3.15	1.11	1.80	100.64
20	2	213A	56.00 - 56.50	Intercalation zone (calc silicate carbonate free to amphibolite)	*	53.10	0.69	11.94	8.78	0.46	4.27	13.34	1.99	2.46	1.34	0.68	99.05
21	2	214A	56.50 - 57.00	Intercalation zone (calc silicate carbonate free to amphibolite)	*	56.17	0.73	12.25	9.12	0.40	3.94	10.02	2.30	1.72	0.71	0.98	98.34
22	2	215A	57.00 - 57.50	Intercalation zone (calc silicate carbonate free to amphibolite)	*	54.28	0.83	12.90	10.16	0.36	4.88	8.85	2.44	1.88	0.39	1.35	98.32
23	2	216A	57.50 - 58.00	calc-silicate (carbonate free)	*	81.20	0.29	4.88	3.24	0.16	1.74	6.18	0.89	0.47	0.21	1.08	100.34
24	2	217A	58.20 - 58.90	calc-silicate with carbonate	*	54.00	0.60	10.78	10.17	0.47	3.10	17.66	1.53	0.16	0.10	0.30	98.87
25	2	218A	59.70 - 60.00	Paragneiss	*	63.05	0.83	13.85	6.79	0.07	2.41	1.90	3.42	3.39	0.09	2.56	98.36
26	4	401A	60.00 -60.50	Marble	*	27.79	0.53	7.55	5.12	0.34	3.71	29.88	1.24	1.32	0.07	19.57	97.12
27	4	402A	60.50 - 61.00	Marble	*	26.03	0.36	5.86	3.04	0.37	2.28	34.32	1.09	1.29	0.06	23.03	97.73
28	4	403A	63.60 - 63.80	Marble	*	17.58	0.22	3.75	2.28	0.37	1.60	40.18	0.73	0.81	0.04	29.72	97.28
29	4	404A	65.00 - 65.30	calc-silicate with carbonate	*	49.20	0.79	13.56	5.36	0.41	0.68	19.28	0.73	0.68	0.11	9.07	99.87
30	4	405A	66.70 - 67.40	calc-silicate (carbonate free)	*	46.16	0.48	8.40	18.93	0.47	2.18	17.06	0.92	0.56	0.07	2.47	97.70
31	4	406A	67.60 - 68.00	calc-silicate with carbonate	*	45.97	0.53	10.14	12.50	0.44	2.30	19.86	0.41	0.40	0.08	5.24	97.87
32	4	407A	68.00 - 68.50	calc-silicate with carbonate	*	46.04	0.62	9.83	17.69	0.41	2.68	14.85	0.45	0.50	0.10	3.98	97.15
33	4	408A	68.50 - 69.00	calc-silicate with carbonate	*	47.84	0.67	11.11	12.32	0.38	2.82	18.75	0.45	0.52	0.09	2.68	97.63

Standards	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI	Total
SG-1A_FA	73.35	0.07	13.20	2.01	0.19	0.05	0.13	5.66	4.12	0.04	0.38	99.20
ref.	73.38	0.07	13.84	2.23	0.20	0.05	0.14	5.46	4.14	0.01	0.38	99.90
TDB-1_FA	51.03	2.36	13.29	13.80	0.19	5.76	9.72	2.43	0.92	0.24	0.22	99.96
ref.	50.22	2.30	13.61	14.88	0.20	5.90	9.60	2.20	0.89	0.23	0.22	100.25
BHVO-2_FA	50.38	2.73	13.20	11.71	0.16	7.24	11.35	2.39	0.54	0.28	0.04	100.02
ref.	49.93	2.73	13.51	12.31	0.17	7.23	11.41	2.22	0.52	0.27	0.04	100.34
JH-1_FA	49.02	0.67	5.58	9.71	0.18	16.77	14.94	0.83	0.54	0.12	1.82	100.18
ref.	48.00	0.66	5.57	10.23	0.19	16.81	14.92	0.71	0.52	0.10	1.82	99.53

Table 21: Major element analysis data with (XRF) in (oxid %) including rocks standards applied

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Nr.	WOK. Nr.	Sample Nr.	Laufender Meter Lfm	Lithology	Analysis	Ba	Ce	Cr	Cu	La	Nb	Ni	Pb	Sr	V	W	Y	Zn	Zr
1	5	502A	11.25 - 11.65	Amphibolite	*	247	72	163	41	41	34	130	7	162	291	4	26	189	223
2	5	503A	12.00 -12.50	Amphibolite	*	227	62	79	18	35	13	37	10	386	90	9	29	131	161
3	5	504A	12.50 - 12.75	Sharp intercalation of amphibolite to CS (with carbonate)Amphibolite	*	91	70	59	11	34	11	29	12	281	62	6	26	123	150
4	5	512A	13.00 - 13.15	calc-silicate (carbonate free)	*	62	67	49	15	30	11	24	10	261	64	12	29	146	156
5	5	5051A	13.25 - 13.35	calc-silicate (carbonate free)	*	41	40	43	69	21	10	37	7	181	60	467	23	155	107
6	5	506A	13.52 - 13.66	calc-silicate (carbonate free)	*	55	64	47	9	37	10	27	12	321	59	449	22	132	150
7	5	507A	13.66 - 14.00	calc-silicate with carbonate	*	419	85	65	9	46	17	26	8	498	69	7	36	96	237
8	5	509A	14.30 - 14.72	Intercalation zone (calc silicate carbonate free to amphibolite)	*	1195	82	63	11	47	13	28	10	383	79	13	31	55	191
9	5	511A	15.00 - 15.20	Paragneiss	*	661	52	76	37	23	14	41	16	121	113	6	27	99	164
10	2	210A	47.50 - 48.00	calc-silicate with carbonate	*	409	42	45	9	19	9	22	13	310	62	28	29	198	122
11	2	2091A	50.20 - 50.60	calc-silicate with carbonate	*	209	68	46	20	29	11	27	16	582	61	8	29	145	155
12	2	2092A	50.60 - 51.00	calc-silicate with carbonate	*	96	79	47	13	40	10	41	4	454	75	55	29	93	133
13	2	203A	51.30 - 52.00	calc-silicate (carbonate free)	*	303	65	48	61	36	11	40	4	447	74	32	32	69	119
14	2	207A	53.45 - 53.75	calc-silicate with carbonate	*	546	58	46	9	39	10	27	8	249	59	41	22	169	140
15	2	2081A	53.75 - 54.00	calc-silicate with carbonate	*	616	63	46	10	24	10	23	7	312	54	35	20	170	133
16	2	2082A	54.00 - 54.50	calc-silicate with carbonate	*	304	69	54	9	38	11	33	7	317	69	107	29	164	150
17	2	2083A	54.50 - 55.00	calc-silicate (carbonate free)	*	194	69	55	9	36	11	25	7	335	70	7	25	140	161
18	2	211A	55.00 - 55.50	calc-silicate with carbonate	*	289	105	64	19	64	12	23	7	339	84	9	64	117	168
19	2	212A	55.50 - 56.00	Intercalation zone (calc silicate carbonate free to amphibolite)	*	688	92	65	53	52	11	15	10	249	91	9	56	122	168
20	2	213A	56.00 - 56.50	Intercalation zone (calc silicate carbonate free to amphibolite)	*	823	47	60	57	25	11	34	9	282	102	6	51	211	153
21	2	214A	56.50 - 57.00	Intercalation zone (calc silicate carbonate free to amphibolite)	*	353	101	63	91	47	13	40	9	196	102	7	81	239	154
22	2	215A	57.00 - 57.50	Intercalation zone (calc silicate carbonate free to amphibolite)	*	364	56	107	72	29	11	50	8	184	132	3	24	250	158
23	2	216A	57.50 - 58.00	calc-silicate (carbonate free)	*	123	29	29	23	16	4	13	5	130	39	12	16	56	61
24	2	217A	58.20 - 58.90	calc-silicate with carbonate	*	84	64	50	8	35	11	31	5	365	63	353	26	160	141
25	2	218A	59.70 - 60.00	Paragneiss	*	780	84	79	123	43	14	27	29	223	112	10	36	56	176
26	4	401A	60.00 -60.50	Marble	*	214	26	110	23	17	6	68	8	442	73	<1	18	81	86
27	4	402A	60.50 - 61.00	Marble	*	205	20	33	9	20	6	14	9	505	32	<1	16	53	80
28	4	403A	63.60 - 63.80	Marble	*	143	23	17	9	11	3	6	8	555	16	<1	15	39	56
29	4	404A	65.00 - 65.30	calc-silicate with carbonate	*	120	88	59	8	51	13	15	14	302	70	4	32	85	211
30	4	405A	66.70 - 67.40	calc-silicate (carbonate free)	*	88	69	57	307	37	9	57	13	187	53	260	19	120	139
31	4	406A	67.60 - 68.00	calc-silicate with carbonate	*	47	69	47	75	33	9	15	19	196	54	119	19	135	145
32	4	407A	68.00 - 68.50	calc-silicate with carbonate	*	126	74	88	307	28	10	53	19	190	76	151	24	126	143
33	4	408A	68.50 - 69.00	calc-silicate with carbonate	*	115	59	73	84	33	11	32	13	251	63	75	21	108	176

Standards	Ba	Ce	Cr	Cu	La	Nb	Ni	Pb	Sr	V	W	Y	Zn	Zr
	299	80	6	16	45	42	2	33	111	21	8	73	26	168
	343	108	*5*	3	54	40	2	*31*	106	24	8	62	28	167
	916	41	29	63	20	5	15	9	822	93	<1	10	67	106
	1020	40	32	55	22	7	17	11	790	96	*0*	9	71	99
	578	123	131	62	69	74	137	4	1164	169	<1	24	148	310
	526	105	134	49	56	68	140	7	1100	167	*0*	22	150	277
	125	41	20	30	15	5	15	8	59	31	0	23	21	225
	143	48	20	19	21	6	17	8	58	33	1	22	20	214
	396	125	92	49	55	13	37	8	94	86	<1	30	56	106
	450	109	99	42	62	14	37	9	90	87	1	26	55	96
	129	28	30	34	13	5	16	13	922	33	<1	9	49	67
	120	25	32	23	15	7	18	18	913	36	1	9	52	62
	116	16	595	31	2	4	52	3	155	236	0	13	66	48
	106	18	*620*	9	8	4	*57*	3	*154*	*230*	1	14	*62*	48
	205	119	413	111	58	69	282	15	27	266	0	30	154	347
	180	98	410	97	45	64	276	14	26	245	1	27	142	318
	5	9	2169	25	<1	<1	2236	10	0	28	<1	0	45	<1
	1	*0*	2730	*10*	*0*	*1*	2380	*10*	0	31	*0*	*0*	*42*	*10*

Table 22: Trace element analysis data with (XRF) in (ppm) including rocks standard applied .

Sample	*Area*	*DataSet/Point*	*Na2O*	*SiO2*	*Al2O3*	*FeO*	*K2O*	*CaO*	*MgO*	*TiO2*	*MnO*	*Cr2O3*	*Total*
405M (Dark type)	*405M_Sch3_1*	75 / 1 .	-0.01	100.36	0.02	0.01		0.01	-0.01	0.01	0.00	0.00	100.40
405M (Dark type)	*405M_Scp1*	83 / 1 .	-0.02	30.68	4.53	0.55		28.65	0.00	32.78	0.08	0.13	97.39
407M (Dark type)	*407M_Scp2*	123 / 1 .	-0.01	100.97	-0.02	0.19	0.00	0.01	-0.01	0.01	-0.01		101.11
407M (Dark type)	*407M_Scp2*	109 / 1 .	0.01	100.80	0.01	0.01	-0.01	0.01	-0.01	-0.01	0.01		100.82
ALB2 (Dark type)	*Alb2_Sch1_1*	57 / 1 .	-0.01	100.35	0.00	0.14	0.00	0.31	0.00	0.00	0.02		96.69
ALB2 (Dark type)	*Alb2_Gt2_1*	69 / 1 .	0.01	30.28	5.27	0.93	29.28	29.28	0.01	0.06	30.83		100.79
2083M (Light type)	*2083M_Scap1*	57 / 1 .	-0.04	0.03	0.01	0.45	0.00	58.08	0.15				58.65
2083M (Light type)	*2083M_Scap1*	63 / 1 .	-0.01	30.30	2.67	0.56	0.00	28.58	0.02	35.77	0.09	0.02	97.97
2083M (Light type)	*2083M_Scap1*	64 / 1 .	0.00	100.29	-0.01	0.06	0.00	0.02	0.00	0.00			100.35
2083M (Light type)	*2083M_Scap2*	75 / 1 .	0.00	30.24	4.09	0.46	-0.01	28.34	0.04	33.72	0.12	0.04	97.07
2083M (Light type)	*2083M_Scap2*	76 / 1 .	0.02	30.36	3.57	0.48	0.01	28.50	0.01	34.44	0.14	0.01	97.53

Table 23: Microprobe data for Qtz and Ttn grains that are shown in images Resalts presented in wt%.