MINERALOGICAL AND PETROGRAPHIC STUDY OF COPPER DEPOSITS KIBUTU AND KAJUBA QUARRY'S (DEMOCRATIC REPUBLIC OF CONGO) AND SLAGS GENERATED AFTER SMELTING PROCESSES.

Studium mineralogiczno - petrograficzne złóż miedzi Kibutu i Kajuba (Demokratyczna Republika Konga) i odpadów powstających po ich przeróbce.

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Abstract:

Democratic Republic of Congo (DRC) is the second largest country in Africa, located in its central part, in the Congo basin. The word "congo" means *"hunter",* and comes from the Bakongo people. The capital of Congo is Kinshasa, situated in the north of the country, on the Congo River, with a population of more than 9 million people. Katanga, province in the southern part of the country, is most abundant in deposits, and the most important city is Lubumbashi, inhabited by 2 million people. The area covered by this research paper is located in this province, north and north-east of Lubumbashi. Studies conducted as part of this research paper were aimed at presenting comprehensive mineralogical and petrographic characteristics of copper deposits near Lubumbashi and slag produced in the process of raw materials recovery, as well as at analysing environmental aspects associated with, among others, extraction and refining of raw minerals. The paper was based on samples brought by Prof. Maciej Pawlikowski, PhD, Eng., collected during two visits to the Democratic Republic of Congo that took place in 2011.

The doctoral dissertation was completed by verifying the following theses:

- A wide range of different minerals is present in the area of Lubumashi due to the complicated genesis and composition of copper deposits.
- Mineralogical, petrographic, and geochemical recognition of ore and rocks will make it possible to refine them in a more efficient way.
- Phase composition of slag after remelting copper ore is varied.
- Determination of the phase composition of slag will be the basis for determining the optimal storage process minimizing negative environmental impacts.

- Mineralogical, petrographic, and geochemical recognition of slag will determine whether the content of copper remaining in waste is high enough to be recovered with profit.
- Mineralogical and geochemical studies will be the basis for the preparation of a simplified analysis of the state of the environment.

Achieving these assumptions required carrying out field research to collect samples for further studies, as well as numerous analyses. The following have been accomplished:

- Mineralogical and petrographic characterises of ore and rocks from three excavations located in the area of Lubumbashi.
- In situ geochemical measurements, made with DELTA Mining and Geochemistry Handheld XRF analyzer.
- Mineralogical, petrographic, and geochemical characteristics of slag from the process of copper ore remelting.
- The phase composition of slag from the process of copper ore remelting was identified,
- Associated minerals of copper ore were identified.
- Basic environmental analysis was made on the basis of mineralogical and geochemical research results, and information on the state of the environment and its changes.

Based on the analysis of literature, mineralogical and petrographic research of copper deposits in Kibutu, Kajuba, Renzo, and Lubumbashi area and slag generated in the process of their remelting, as well as the environmental analysis, we can draw the following conclusions:

- Deposits in Lubumbashi region consist of two parts.
- Subsurface deposits resulting from the oxidation of copper sulphides and reaction of by-products with carbonates - purely malachite deposits.
- Older deposits occur as dolomite sulphide mineralisation, with large variations of minerals: bornite, chalcopyrite, arsenopyrite, pyrite, and chalcocite.
- Copper ore from the subsurface (malachite) area can be remelted in furnaces, with the addition of haematite or magnetite.
- Copper present in the sulphide portion is not directly suitable for smelting process and should be enriched with flotation method, chemical method with acids, or other method.
- The copper content in the sulphide portion is up to 3%.
- Studies have shown that the covered deposits are small and are on the verge of profitability when it comes to extraction and processing.
- The phase composition of slag has been identified, the following have been distinguished:

-glass
-metal separation (copper, iron)
-silicate phases
-oxygen phases

- When analysing microscopic images, it was found that secondary formed crystallites, oxidized metals, and metallic ore residues are found in slag more often than glass.
- Glass in slag behaves differently, depending on the age of waste.
- Slag alloy is subject to cooling only in certain weather conditions, which are not conductive to rapid cooling in the region of Central Africa. The slower the cooling, the lower the amount of glass, but e.g. silicate phases are formed in larger amounts.
- Economically valuable elements, such as gold, silver, were not detected in the test samples.
- Debris containing metallic copper constitutes about 3% of the researched material, and it should be returned for remelting during the technological process. When applying additional technological processes, it seems possible to use copper slag for construction process (e.g. as a filler for concrete) and road construction (ballast used for paving roads).
- The following threats to the environment of the Democratic Republic of Congo have been identified: excessive deforestation, soil erosion, improperly stored mining and metallurgical waste, poaching, and water pollution.

Key words: copper deposits, Democratic Republic of Congo, copper slags

Streszczenie.

Demokratyczna Republika Konga (DRK) to drugie pod względem wielkości państwo Afryki, położone w jej środkowej części, w dorzeczu rzeki Kongo. Słowo 'kongo' oznacza '*myśliwy'* i pochodzi od ludu Bakongo. Stolicą kraju jest Kinszasa, położona na północy kraju nad rzeką Kongo, posiadająca ponad 9 milionów mieszkańców. Regionem najbardziej zasobnym w złoża jest leżąca na południu kraju prowincja Katanga, gdzie najważniejszym miastem jest 2 milionowe Lubumbashi. Obszar objęty badaniami niniejszej pracy znajduje się w tej prowincji na północ i północny- wschód od miasta Lubumbashi. Badania, które zostały przeprowadzone w ramach niniejszej pracy miały na celu przedstawienie kompleksowej charakterystyki mineralogicznej i petrograficznej złóż miedziowych okolic Lubumbashi oraz żużli powstających w procesie odzyskiwania surowca, a także przeanalizowanie aspektów środowiskowych związanych m.in. z wydobyciem oraz przeróbką surowców. Praca została oparta na próbkach przywiezionych przez prof. dr hab. inż. Macieja Pawlikowskiego zebranych podczas dwóch wyjazdów do Demokratycznej Republiki Konga w roku 2011.

Rozprawę doktorską zrealizowano poprzez weryfikację następujących tez:

- Skomplikowana geneza i budowa złóż miedzi okolic Lubumbashi predysponują występowanie w nich bogatej gamy zróżnicowanych minerałów.
- Rozpoznanie mineralogiczno - petrograficzne oraz geochemiczne rud oraz skał towarzyszących przyczyni się do umożliwienia poddania ich bardziej wydajnym procesom przeróbczym.
- Skład fazowy w żużlach po przetopie rudy miedziowej jest zróżnicowany.
- Określenie składu fazowego żużli będzie podstawą do określenia optymalnego procesu składowania zakładającego minimalizację negatywnego oddziaływania na środowisko.
- Rozpoznanie mineralogiczno – petrograficzne oraz geochemiczne żużli pozwoli stwierdzić czy zawartość miedzi pozostającej w odpadach jest na tyle wysoka, że opłacalne będzie jej odzyskiwanie.
- Badania mineralogiczne i geochemiczne będą podstawą sporządzenia uproszczonej analizy stanu środowiska.

Realizacja tak postawionych założeń wymagała przeprowadzenia badań terenowych w celu pobrania próbek do dalszych badań, a następnie licznych prac analitycznych. Wykonano:

- Charakterystykę mineralogiczno - petrograficzną próbek rud oraz skał towarzyszących z trzech wyrobisk w okolicach Lubumbashi.
- Pomiary geochemiczne in situ przy pomocy przenośnego analizatora DELTA Mining and Geochemistry Handheld XRF.
- Charakterystykę mineralogiczno – petrograficzną i geochemiczną żużli z procesu przetopu rudy miedziowej.
- Określono skład fazowy żużli z procesu przetopu rudy miedziowej,
- Zidentyfikowano minerały towarzyszące rudom miedzi w wymienionych lokalizacjach.
- Wykonano podstawową analizę środowiskową w oparciu o wyniki badań mineralogicznych i geochemicznych oraz informacji o stanie środowiska i jego zmianach.

Na podstawie przeprowadzonej analizy literatury, badań mineralogiczno- petrograficznych złóż miedziowych Kibutu, Kajuba i Renzo, okolic Lubumbashi oraz żużli powstających w procesie ich przetopu, a także sporządzenia analizy środowiskowej, można wyciągnąć następujące wnioski:

Złoża rejonu Lubumbashi są dwudzielne.

Przypowierzchniowe złoża powstały w wyniku utleniania siarczków miedzi i reakcji ich produktów utleniania z węglanami – jest to typ złoża czysto malachitowy.

Złoża starszego wieku występują jako siarczkowe okruszcowanie dolomitu, posiadają duże zróżnicowanie minerałów kruszcowych: bornit, chalkopiryt, piryt, arsenopiryt oraz chalkozyn.

Ruda miedzi ze strefy przypowierzchniowej (malachitowa) może być przetapiane tradycyjną metodą piecową z dodatkiem hematytu lub magnetytu.

Miedź występująca w siarczkowej części złoża nie nadaje się bezpośrednio do procesu hutniczego i powinna być wzbogacana metodą flotacji, chemiczną z użyciem kwasów lub inną.

Zawartość miedzi w strefie siarczkowej sięga 3%.

Badania wykazały, że złoża objęte badaniami są małe i ekonomiczne znajdują się na granicy opłacalności wydobycia i przeróbki.

Zidentyfikowano skład fazowy żużli , wyróżniono:

-szkliwo
-wytrącenia metali (miedź, żelazo)
-fazy krzemianowe
-fazy tlenowe

- Analizując obrazy mikroskopowe stwierdzono, że w żużlach częściej niż szkliwo występują wtórne wykształcone krystality, utlenione metale oraz metaliczne pozostałości rudy.
- Szkliwo w żużlach wykazuje zróżnicowany stopień zachowania, w zależności od wieku odpadów.
- Stop żużlowy podlega chłodzeniu wyłącznie w warunkach atmosferycznych, które w rejonie Afryki Środkowej nie sprzyjają szybkiemu schładzaniu. Im wolniejsze jest chłodzenie tym mniejsza jest ilość szkliwa, natomiast w większej ilości powstają, np. fazy krzemianowe.
- W badanych próbkach nie stwierdzono podwyższonych, istotnych pod względem ekonomicznym, ilości cenniejszych pierwiastków takich jak np. złoto, srebro. Niewielkie ilości srebra stwierdzono jedynie w pojedynczych żyłkach chalkozynowych.
- Okruchy odpadów zawierających miedź metaliczną stanowią w badanym materiale około 3%, powinny być zawracane w procesie technologicznym do ponownego przetopu. Po zastosowaniu dodatkowych procesów technologicznych wydaje się możliwym wykorzystanie żużli pomiedziowych do celów budowlanych (np. jako wypełniacz do niektórych betonów) oraz drogownictwa (podsypki do utwardzania dróg).
- Zidentyfikowano największe zagrożenia dla środowiska naturalnego DRK, którymi są: nadmierne wylesiane, erozja gleb, niepoprawnie składowane odpady górnicze i hutnicze, kłusownictwo oraz zanieczyszczenia wód.

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Introduction.

Democratic Republic of the Congo (DRK) is the second, in terms of a size African country, located in its middle part, in a basin of Congo river. A word ‘Congo’ means ‘a hunter’ and it comes from Bakongo nation (http://www.goafrica.gov.pl). A capital of the country is Kinshasa, located in the north part, over the Congo river, which owe more than 9 million of inhabitants. The most affluent in lodes region is Katanga Province, on the south part of the country, where the most important city is 2-milionth Lubumbashi. An area encompassed of this thesis’ research is located in this province, on the north and northeast from Lubumbashi city.

Democratic Republic of Congo is a country, unusually affluent in mineral resources, it is one of important exporter of: cobalt, diamonds, petroleum, gold and copper in the world. The main products which Democratic Republic of Congo exported in 2014 were natural resources: copper (share of 62% in all export), cobalt (19%, petroleum (9%) (https://www.eximcon-group.com).

It is a country strongly addicted from foreign export, but from 2011 to 2015, an economy of the Democratic Republic of Congo has been developing on the level of 7,5 percent yearly, which make it one of the fastest developing economies in the world (https://www.eximcon-group.com). Despite of huge loges’ resources and the possibility of distilling huge profits from it, DRK is disarranging of many wars, as well as neighboring countries and tribes, also with groups inside the country. Especially, a civil war, conducting in years 1998-2003, leaded to very poor political and economy situation of the country. Unfortunately, an unstable situation in the country in within previous decades, had an essential influence for a condition, a number and a quality of scientific research, conducting in this country. In May 1999, DRK’s government suppressed students’ protests by terror, who demanded of their laws and also destroyed university campuses (Turner, 2007; Reyntjens, 2009). From 1998 the second civil war has been continuing, which was called The Great African War, officially ended in 2003, when the Provisional Government of Democratic Republic of the Congo took over a dominion (Turner, 2007). But an unstable situation and military operations of battle groups didn’t stop. Over the period from 2008 to 2013 in DRK came to reprieve or limitation of work possibility and university’s operation, including among others an University in Lubumbashi (Turner, 2007). Because of continued anxieties in a region and escalating battles, it reached to mass escapes of civilian population. Additionally, in the economy destroyed and devastated of postwar chaos country, in 2014 an epidemic of Ebola virus was outbreak, with has weaken and eliminated civilian population. This country has a huge capability of economy development, but necessary is taking administrative operations, designed to political and economic situation' stability. Democratic Republic of Congo now is in difficult situation , but also hope giving for real improvement of situation.

According to International Monetary Fund data, an economy of Democratic Republic of Congo in 2014 was 97 management in the world with gross domestic product at amount of 32 milliards of dollars (so 17 times lesser economy that in Poland). A number of inhabitants in 2015 is estimated for 81 million (so 2 times more inhabitants than in Poland). A domestic product for one inhabitant in Democratic Republic of Congo is one of the lowest in the world and in 2014 it was barely 411 dollars for a year, so 1,13 $ daily (http://www.goafica.gov.pl). Until 63 percent of inhabitants live below so-called poverty threshold, and an unemployment in 2014 was 45 percent (http://www.goafrica.gov.pl).

It is estimated, although in 2019 the Democratic Republic of Congo may will reach growth of gross domestic product on a level of 7 percent yearly (growth of 40% within 5 years). There is a big chance for potential investors, but it also entails with a full risk. A conduction of a business in Democratic Republic of Congo, isn't passing off without obstacles. In a ranking of facility business' conducting, the country has a 184 position from 189 countries (http://goafrica.gov.pl). For individual categories: conduction of international trade – place 174 from 189, a difficulty with obtain an electricity – place 175 from 189, opening of business activity – place 172 from 189 countries (http://www.goafrica.gov.pl).

The dissertation was completed by verifying the following theses:

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·Mineralogical, petrographic, and geochemical recognition of ore and rocks will make it possible to refine them in a more efficient way.

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Achieving these assumptions required carrying out field research to collect samples for further studies, as well as numerous analyses. The following have been accomplished:

· Mineralogical and petrographic characterises of ore and rocks from three excavations located in the area of Lubumbashi.

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Methodology of research

During realization of thesis, field research within cooper lodes in Lubumbashi region, as well as laboratory tests were performed. In chapter mentioned below, details of performing labours were presenting, and research methods were characterized.

Field research of copper rocks' lodes in the neighbourhood of Lubumbashi city, at Katanga Providence, in Democratic Republic of Congo, were performed by post-doctoral professor and engineer Maciej Pawlikowski, on two rounds in 2011. Samples were charged from available lode's excavations, exactly from exploit excavations in Kibitu (10 samples), Kajuba (10 samples) and Renzo (3 samples).

Theoretically, the most optimal system of samples' charging will be the method of regular system sampling, from the biggest surface of studying area, with eventually samples' averaging from bigger squares. But, considering hard field conditions' and a problem with a transport of rock material from DRK, samples were charging by detecting, with a method of random samples' selection. The method of random samples' selection is quite often practising, especially when there is no possibility to make research on a high range. A benefit of this method is a random choice of points, independent from a subjective opinion of offtake's leader. A disadvantage is irregular area's covering, which in some situations, can conduct to no-detection of all possibly elements.

In a case of research conducting in situ with the help of DELTA Mining and Geochemistry Handheld XRF analyser, a method of samples' offtake along linear source was using. In this case, samples were charged along active activation's walls of quarries, analysed samples were studying at once and they weren't deliver to AGH. Places of next analysis were appointed at equal various sections, depending on the length of wall's excavation (the most often were distances close to 50 - 100 centimetres).

Samples allocating to further research, in the place of charging, were packed in string pouches and described in details with the consideration of their localization (also in the form of photographic documentation).

Additionally, samples of a slag/cinders (12 pieces) from alteration workshop, operating in the neighbourhood of three mentioned excavations were charged. Samples were charged, according to a rule describing above, from two localizations (slap heaps) with differential time of cinders' deposition (8 samples from a slap heap of a current preparation process and 4 samples from a slap heap with at least several years' deposition of waste material).

An amount of samples were limited, considering a need of transporting them to Poland by plane and limitations imposed from quarries' owners (Table 1).

During field research a rich photographic and audio-visual documentation was made. Additionally, already at a field, a part of geochemistry measurement was performing with the using of the DELTA x-ray portable analyser.

Polarized microscopy at transmitted light

Research with the using of polarized microscopy to transmitted light were made in order to recognition of mineral composition, structure and rocks' texture, also ascertain of potentially transforming presence, as well as in ore rocks and processing materials. Microscopy research and microphotographs of rocks at transmitted light were conducted by the use of polarized microscope of OLIMPUS BX-51 brand, additionally equipped with digital camera OLIMPUS DP-12, controlled by a computer from Analysis programme.

Microscopic cuts were used to research, which were uncovered and covered, with a preparation's thickness of 20 μm, polished on diamond polishing.

Polarized microscopy at reflected light

Research with the using of polarized microscopy to reflected light were made in order to identification of ore materials, performing in analysed rocks and their photographic documentation. To this aim, the Optiphot polarized microscope to reflected light of NIKON brand was used. It was equipped in computer system with an graphics card (frame grabber), which allowed to transform analogue images and the MultiSCAN 11a programme. Research were conducted in the Institute of Coalbed Geology and Mining at the Department of Geology, Geophysics and Environmental Protection by AGH.

Scanning electron microscopy with EDS micro-analyse

Research were conducted with by using of electron microscopy with an EDS adapter, they had a character of qualitative analyses, which completed previously mentioning analyses. They were used to morphology observations' of chosen minerals and cinders as well as making of micro-photographs. Research were made by:

- FEI Quanta electron microscope, attributed with an EDS spectrometry of EDAX brand, which is located in the Scanning Electron's Microscopy Laboratory of Geology, Geophysics and Environmental Protection Department at AGH. Research were conducted by MSc Adam Gawel and PhD engineer Piotr Bozecki.

To research microscopy cuts were used, polished on diamond polishing, with the preparation's thickness of 20 μm.

Geochemical analyses

Geochemical analyses were made by portable DELTA Mining and Geochemistry Handheld XRF Analyzer, of the USA production, with a voltage of 40kV. This method was used to geochemical analyses making of cooper lodes in excavations of Lubumbashi's neighbourhood. Samples with a cupriferous dolomite and metamorphic sericite slates were underlain. DELTA Mining and Geochemistry Handheld XRF Analyser allows to quantity determination of individual metals, detection of tendency and mineral disturbance in lode. An analyser exploits a X-ray fluorescent technology. Dedicated minerals from studying lodes were subjected of research for chemical element's composition. This method allows to fast analyse of samples, without necessity of their earlier preparation.

X-ray diffraction

X-ray analyses (XRD) were used to identify mineral component of chosen samples. This research were conducted with the help of the Philips APD X'Pert PW3020 X-ray diffractometer, which is located on Department of Geology, Geophysics and

Environmental Protection at Mining – Metallurgic Academy. X-ray research were made by Master Adam Gawel. To X-radiation emission a cupper lamp CuKa with wave's length of 1,5414Å. To analyse powder preparation were used, which were wiped in agate mortar, at aerial – dry condition (non-oriented). To mineral components' identification of testing samples, model data contained in the literature were used (Gawel, Muszynski, 1996).

Raman's spectroscopy

Research were made at room temperature, on natural surfaces of samples, with the using of DXR Raman Microscope Thermo Scientific spectrophotometer, collaborative with Olympus BX-40 light microscope (objectives 50x, 20x, 10x). A source of raising light was Spectra-Physics argon laser (delta=514.5 nm). A power of laser's beam ca. ~24mW and the time of raising were assorted to light character of testing samples. Research were conducted in Raman's Micro-spectroscopy Workplace of Phase, Structural and Textual Research Laboratory on WGGiOS Department at AGH. Research was made by Master engineer Beata Naglik.

Electron Microprobe

Research of Electron Microprobe designed to solid matter's research at micro-area, were conducted at Critical Chemical Elements' Laboratory by AGH-KGHM, where JEOL Super Probe Electron Microprobe is located. Research were made by Master engineer Adam Wlodek.

Kibutu's lode

Kibutu's lode is located in Katanga Province, at the south part of Democratic Republic of the Congo . Total province's surface is 496,877 square meters. It is inhabited by about 6 million people (statistical data from 2012, based on: World Gazetterr.com). The capital and province's biggest city as well as the second city as to the size in Democratic Republic of Congo is Lubumbashi (historic name: Elizabethville). The lode is located at NE from Lubumbashi.

Fig.1. A map of the Democratic Republic of Congo, in south part there is a Katanga Province (marked on red).

A mine occupies the area of about 2000 square meters. Three fundamental exploitation levels are observed here. East part of province is a mining region, where cooper, cobalt, zinc, radium, uranium and diamonds lodes are located (www.britannica.com). This region has not too variable morphology, which consists of distending plateau and small valleys as well as high grounds. Metalliferous layers cover with wasted aluminium of terra rossa type, which thickness come up to 20 meters in same places. A geological covered map (Shabad, 1956) points of metamorphic and mineralised slits from 500-650 million of years in this area. This slits are tectonic folded in the system of synclines and anticlines, which axles are approximate to NW-SE direction.

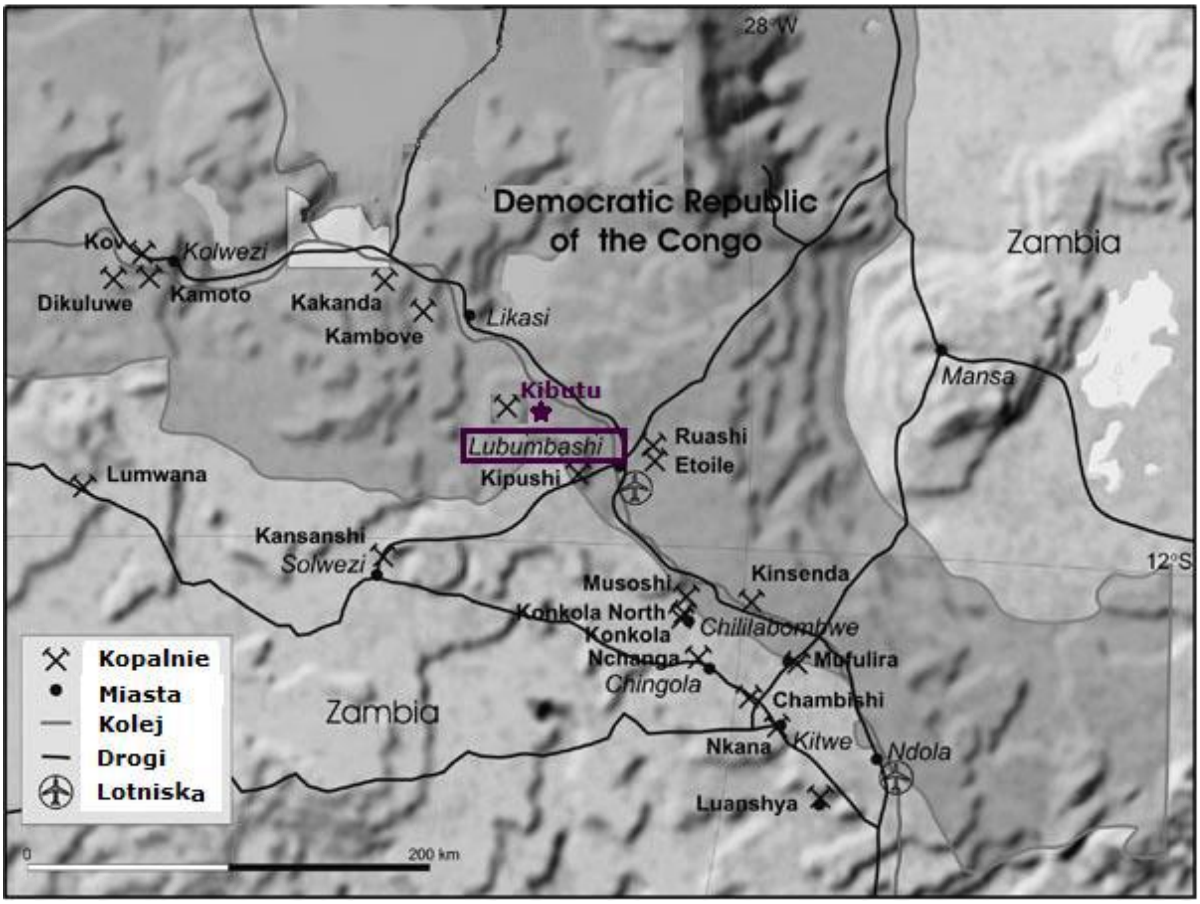

Fig.2. Localization of Kibutu's lode on the topographic map of Katanga Province (Korzekwa and Niedbal, 2008 - amended).

Tab.1. Statement of cupriferous formations, in which Kibutu, Kajuba and Renzo lodes are performing (the last two in next chapter) (Kadima and others, 2011).

Basic parameters of the lode

Lode is located in the central part of the narrow anticline, which axis in its region has a course EES – WWN. In the north direction it systematically changes its course and in the last resort it achieves N-S direction. Anticline's width amounts a few hundred meters. Its kernel determines Kafubu R3.4 (Table 5.1.), among others builds from cupriferous dolomite, which is a subject of exploitation. A mine is located within layers R3.4, R4.1, R4.2. A touch of R4.1 formation, occurring by both sides of anticline centrum is disturbing. From the south side, lodes of R4.2 and R4.1 layers partially reduced, disappearing beneath thick terra rosa layer. Within metallic dolomites, in central part of anticline, insert of silification rocks is observed. This rock, like neighbouring with it from both sides, cupriferous dolomites, is irregular mineralization (mainly in iron) by sericite– talc –haem slates, observing in D profile.

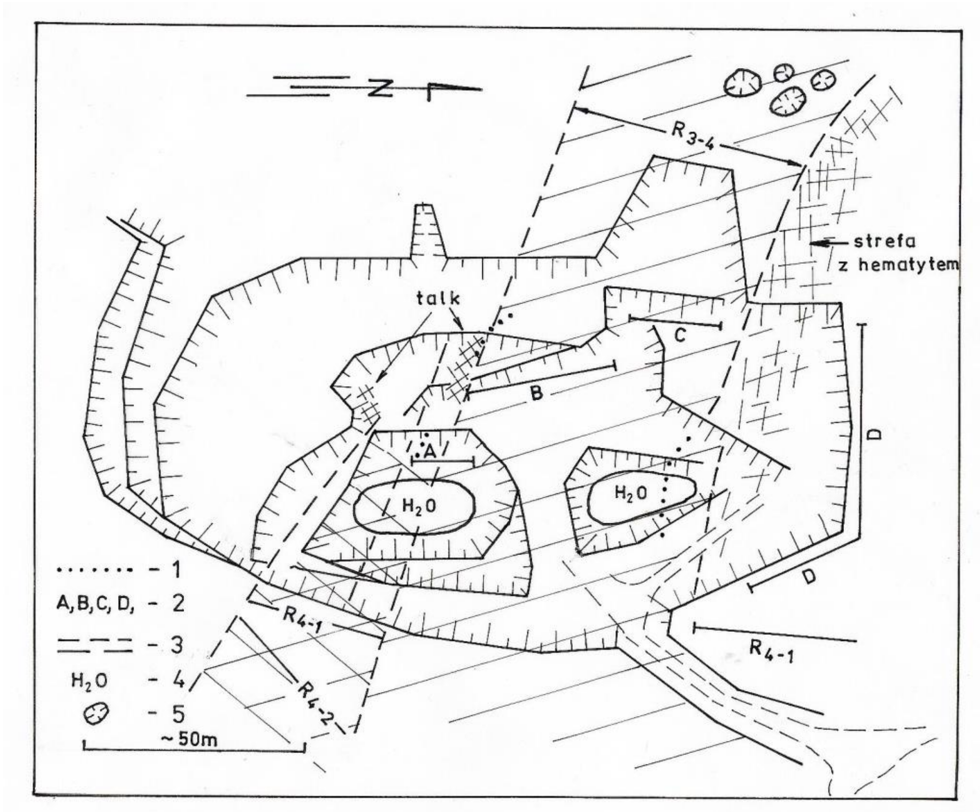

Fig.3. Draft of Kibutu's mine. 1 – Outreach zones of anticline's layers, 2 – studying geological profiles, 3 – ways of transportation, 4 – mine's lakes, 5 – 'wild' miners' fore-shafts, A,B,C,D – studying profiles.

Tab.1. Katanga Supergroup.

Group	Subgrup	Katanga system
Kundelungu		
Nguba		Monwezi Ng 1.2
		Likasi Ng 1.1
	Mwashya	

	Dipeta		
Roan	Mines	Kibutu (R4)	R 4.3
			R 4.2
			R 4.1
			R 3.4
			R 3.3
			R 3.2
		Komoya (R4)	R 3.1
			R 2.1

		Kafubu (R3) Kajuba (R2)	
	R.A.T. (R1)		R1

R3.4 cupriferous dolomite layer was dedicate by especial attention, which has been explored in B profile and R4.1 layer of sericite – talc slate with a hematite, which was analysing in D profile.

In research and mineralogical denominations were distinguish:

1-primordial sulphide mineralization by Cu and others minerals

2-secondary mineralization by copper minerals (mainly by malachite).

Fig.4. Photography of studying B profile in Kibutu lode (Photo: M. Pawlikowski).

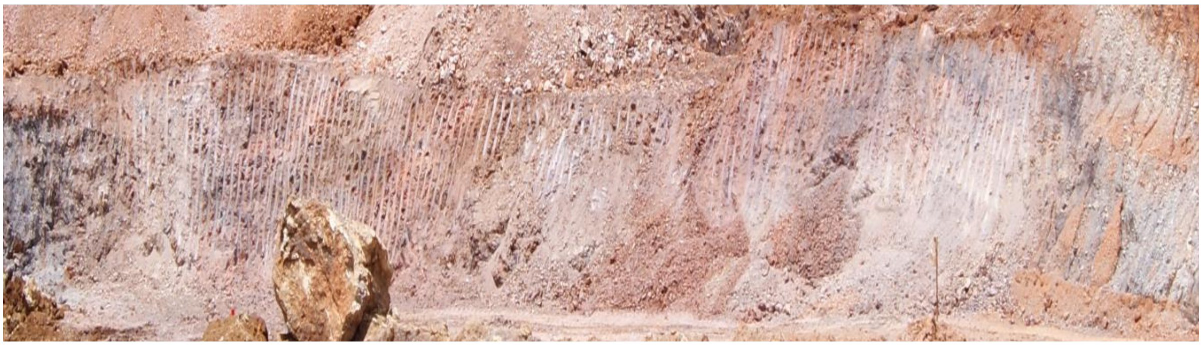

Fig.5. Photography of studying D profile in Kibutu lode (Photo: M. Pawlikowski).

It was performed series of diagrams illustrating content of particular chemical elements, which were applied on B (cupriferous dolomite) and D (sericite – talc – hematite slate) exposures' profiles, which will be presented in further part of thesis' chapter.

Tab.2. Content of copper, based on analyse of samples from boreholes in Kasonta region (Report Teal-mining, 2008).

Nr otworu	Głębokość w [m]	Zawartość miedzi w [%]
KASD 136	0	3,20
	25	4,80
	52	4,39
	133	1,47
KASD 134	0	2,73
	26,5	2,02
	46,80	1,92
	59,50	1,55
	65,50	1,97

Kibutu lode is located within metalliferous dolomites of R3.4 formation, forming in neo-Proterozoic .This is a lobe of medium copper resources. Copper ore is located in metalliferous dolomites, which comprises a kernel of a narrow anticline, collapses from SW, at the angle about 60-80 degrees. The lode has the SE-NW route in a place of actually functioning quarry, farther in west direction it turns at north. A width of metalliferous dolomites' sphere performing in it, provides a kernel of anticline within them – in the central part are occurring siliceous dolomites and other rocks with a lower mineralization than in R3.4 metalliferous dolomites' ambient layer. A depth of metalliferous dolomite's lode is probably big (but there is a lack of data from drilling in this place) and amounts at least several hundred meters.

Not-known is also horizontal range of lode as well as mineralization in the west and north – west direction, where lode is probably cutting by the tectonic fault. From a distance of about 20 kilometres on the west from Kibutu's lode, better testing (among other things by drilling system) was Kasonta lode (Report Teal-mining, 2008), which parameters is adducing in thesis for comparison with Kibutu lode. Points of holes were stationed every 400 meters, and in places of increasing mineralization every 100 meters (Report Teal-mining, 2008). Conducting holes allowed to ascertain a presence of two types of mineralization: oxygenate, mainly malachite and/or chrysotile and sulphate, where predominant role chalcocite was performed. They mainly performed in dolomite and in breccia (Report Teal-mining, 2008). A deployment of this forms is visible on geological intersection. Spheres regulated of mineralization are covered 50˚-60˚ for NE and demonstrate a variable thickness (Table 5.2.). The highest contents of copper amounted from 4,39 – 4,80%, they performed on the depth from 25 to 50 meters (Table 5.2.). In under discussion Kibutu's lode, in order to precise analyse, similar system of holes should be conduct also. However, only same interpretation of open profile's construction by field labour in mine, allowed to ascertain, that lode in Kibitu is also rich in ore of copper twofold way. So, it can be said about two types of copper mineralization within one lode

Mineralization of malachite type (B profile)

It is near surface part of lode, arisen as a result of copper sulphide's oxidation and reaction of its products' oxidation with carbonates. Lode, as well as mineralization is easy available and possible to exploitation, also by easy mining technics, which often is abuse by so-called 'wild' miners.

This type of mineralization represents only malachite. It concentrates in the form of nests and single crumbs of variable size, on the red waste's border of terra rossa type as well as in ore-mineralization of dolomite's roof. It is a raw material, the richest in copper, and its content in malachite reaches 56% Cu. In malachite's ore can performing numerous valuable admixtures, including rare metals, silver and others. This malachite is suitable direct to a melt by oven technique (with an addition of a magnetite) in order to receive copper stone, in other words so-called blister copper.

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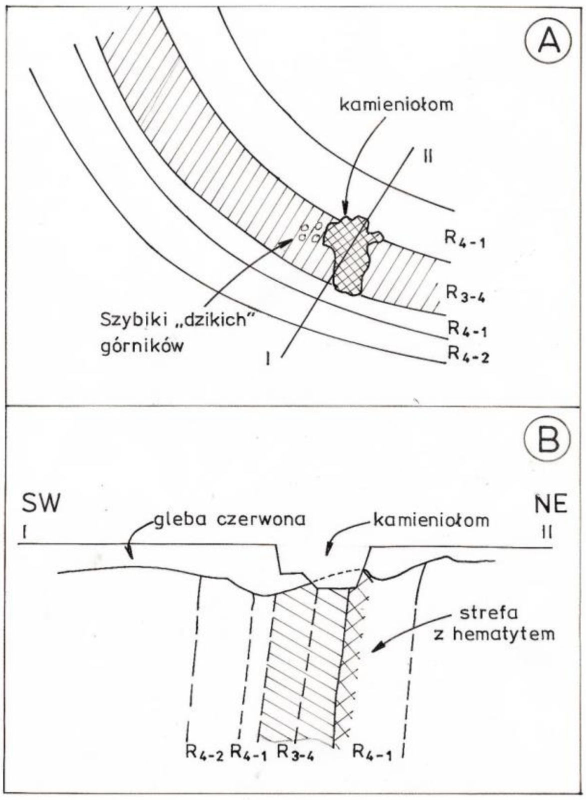


Fig.6. Localization of a mine in Kibutu towards to spatial anticline's arrangement. A – geological draft, B – geological intersection of quarry's area (mine).

Mineralization of mixing malachite – sulphide type (D profile)

This method of cupper's occurring relates with mineralization dolomite (formation R3.4), located under red waste of terra rossa type. Copper is performing here in the form of malachite's streaks of variable thickness (not too rich mineralization) and admixtures in other minerals. Research show, that approximate content of copper in mineralization dolomite is oscillate from 0,1% to a few percent, with an average content of about 1-2% Cu. So, it is less affluent part of Kibutu's lode, in relation to malachite sphere. Copper performing in this part of lode isn't directly suitable to a metallurgic process and it should be rich by flotation method, chemical with the use of acid or the other. Lower content of copper in mineralization dolomite however, don't disqualify this part of lode. Copper is harder available and relation with clean malachite, it requires additional processing before metallurgic process.

Mineralize dolomite is also precious part of load, especially that all range of other chemical materials accompanied with a copper.

A recapture of both copper as well as other chemical materials, requires bigger financial contribution before preparation to a heat in metallurgic process.

Lode's genesis

Slits marked as R4-2, R4-1, R3-4 are initial marine slits R4-2 (Kafubu's formation are slits with carbonate nature) (Kadima and others, 2011). R4-1 are sericite-talk slates with hematite (Kansuki formation) (Kadima and others, 2011). By contrast, R3-4 formation are mainly dolomites (Kadima and others, 2011). In brief way, it can be describes as follows: slits of formations mentioned above sink on the sea floor (Kadima and others, 2011). Next, they uplifted – they became a land, which in the wake of orogeny, became fold (Figure 5.12E) (Kadima and others, 2011). Further process of folding entailed with occurring processes of metamorphism and rocks' metasomatism as well as their mineralization with the bearing of Fe, Cu, Mn, Co and Rb dilutions (Figure 5.10F). After formatting of a very narrow and steep anticline, a process of rocks' erosion was starting, it lead to anticline's cutting (erosion), and next foundation of terra rossa slits (figure 5.12G) (Kadima and others, 2011).

Field geological profiles lead, that especially significant for exploitation, is contact of R4-1 and R3-4 formations, that is a contact of sericite – talc slates with a hematite in their roof, with a metallic dolomite – with R3-4 formation. This contact is variable in all lode's extension, and from SE-NW route it will be change moderately for N-S route with exploitation development. Tracing of it and exploitation's maintaining in this sphere, is the most essential with the point of economy's process alleviate of metallurgic process by malachite raw material.

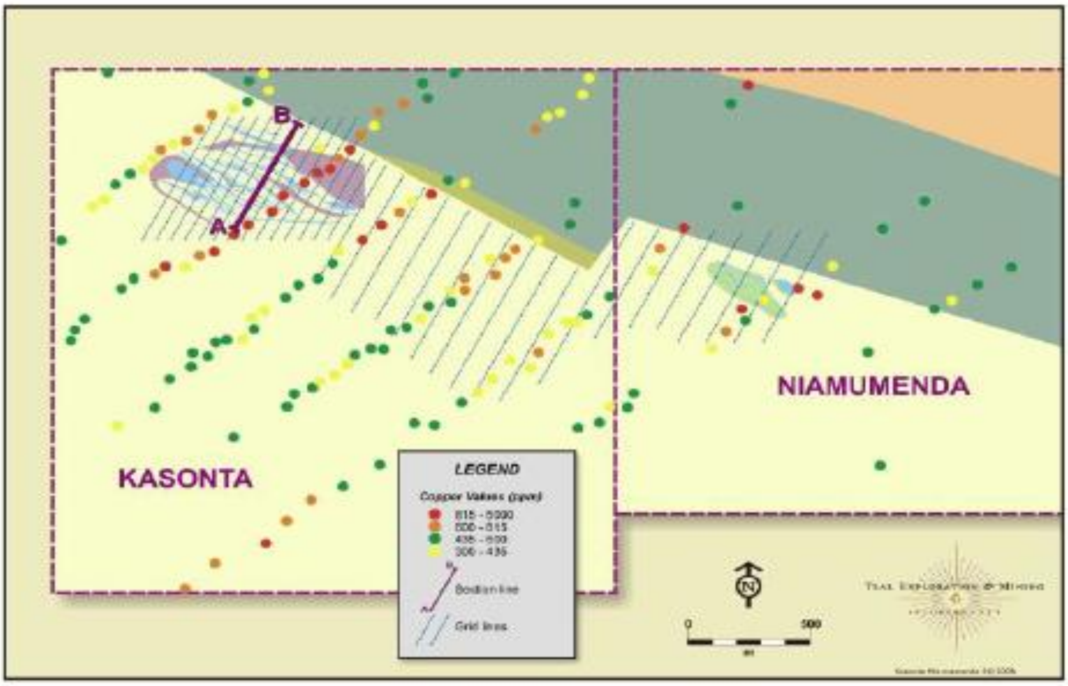


Fig.7. A schematic map of drillings in Kasonta lode region, with average content of copper. Red points – 815-5000 ppm Cu, orange – 600-815 ppm Cu, green – 435-600 ppm Cu, yellow – 300-435 ppm Cu. AB line – geological intersection (Fig.8) (Report Teal-mining).

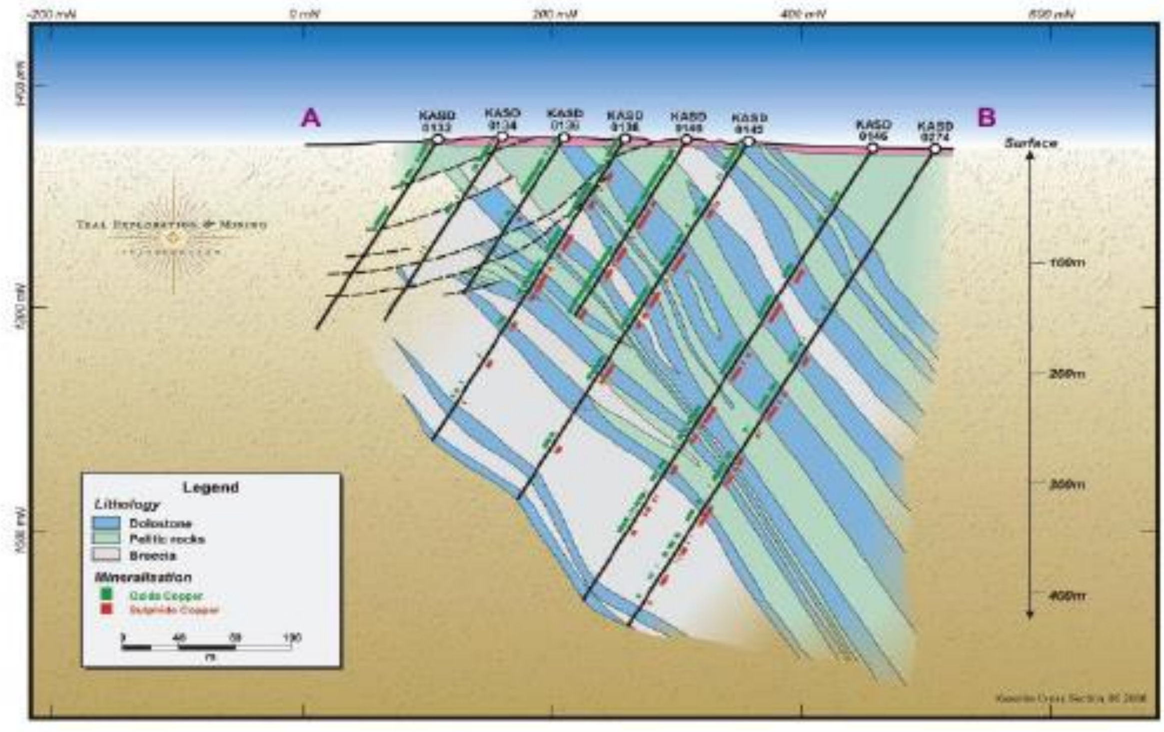


Fig.8. Schematic geological intersection of Kasonta lode. Green colour – a sphere of copper oxygenic lodes, red colour – a sphere of sulphide copper lodes (Report Teal-mining, 2008).

Mineralogical and petrography research

Next to a malachite in studying research were identify: bornite, chalcocite, chalcopyrite, azurite, pyrite, manganite, pyrolusite, siderite, sericite, hematite, goethite, quartz, opal, talc and chlorites.

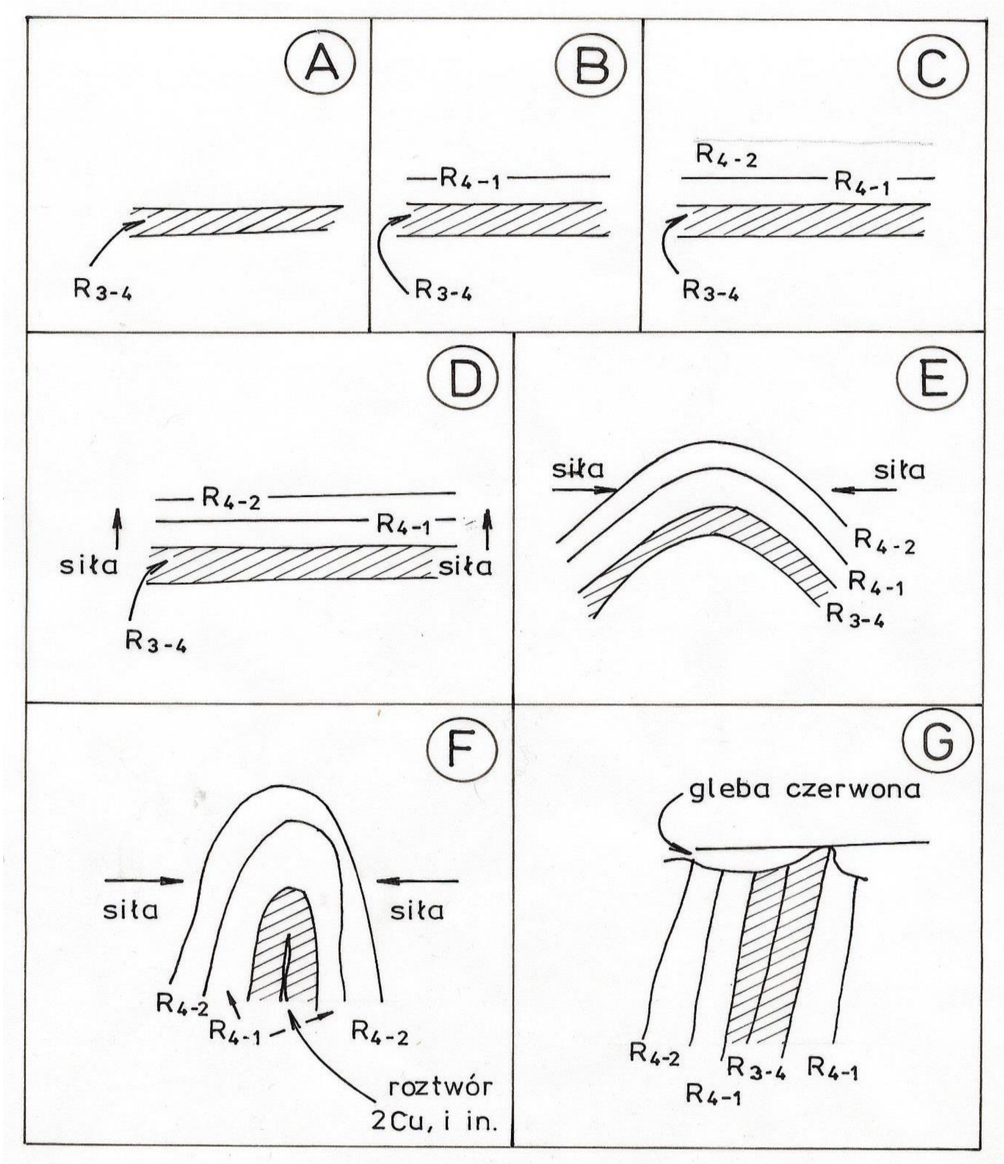


Fig.9 A-G phases of Kibutu lode formatting. Description in the text.

On the grounds of samples to research export's limitation, from Democratic Republic of Congo to Poland, introductory part of analyses had to be observed in the field conditions. To identification of minerals in lode used very often: macroscopic observation and appropriate amount of photographic documentation, additionally in situ chemical analyses with the using of DELTA X-ray analyser were performed. Samples, which were brought to The Department of Geology, Geophysics and Environmental Protection at AGH, were indexed, and next divided to use in the following research: polarized microscopy of transmitted and direct light, X-ray diffraction, scanning electron microscopy with EDS micro-analyse, Raman's spectrometry and electron microprobe.

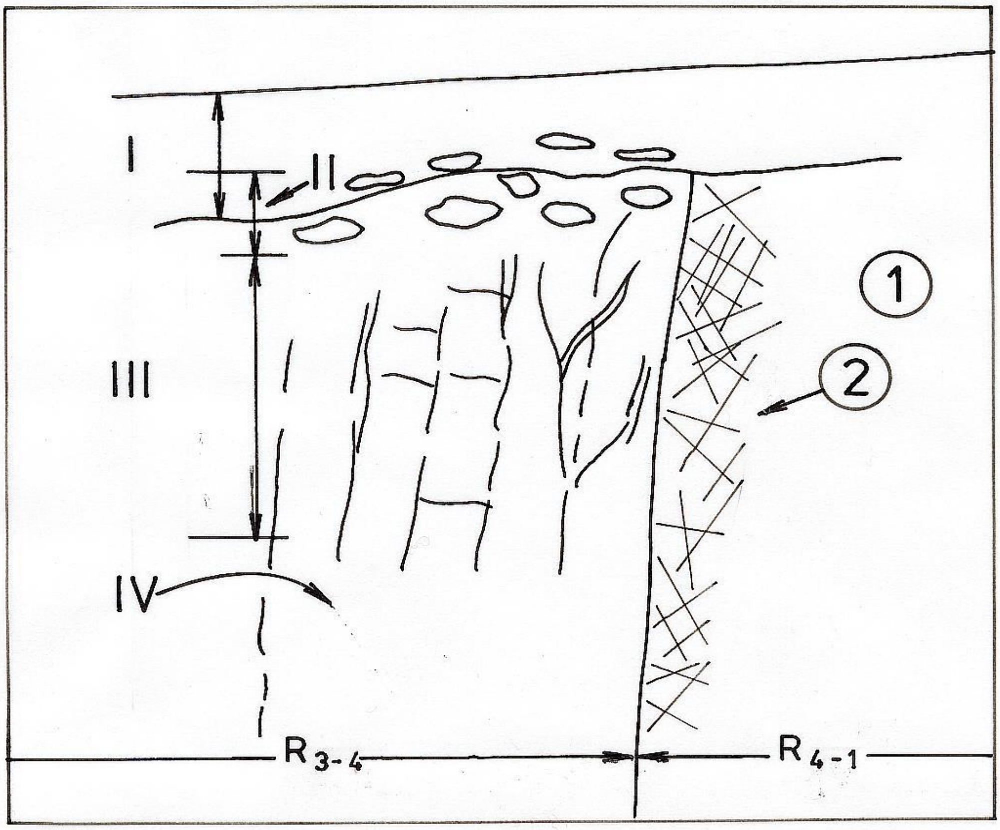


Fig.10. Actual geological situation of exploited wall (west) in Kibutu mine. Left part of the picture – R3-4 formation – metallic dolomite (cupriferous). I – terra rossa sphere with malachite concretions in sole, II – sphere of malachite's absorption in terra rossa sole and in metallic dolomite's roof (malachite lode), III – metallic dolomite with diffuse copper mineralization as well as with others minerals and chemical elements (D lode), IV – Deeper parts of metallic dolomite with copper sulphides and others. Right part of a picture – R4-1 formation: 1 – sericite-talc slates with a hematite, 2 – a sphere extended in a hematite and a molybdenite.

Macroscopy observation allowed to initial identification of most ore minerals. Malachite ($Cu_2CO_3(OH)_2$) in observing samples has a glassy polish, has conformation of needle-shaped crystals or kidney-shaped incrustations. It characterises of green colour and intensive green crevice as well as explicit cleavage. In small amounts, as accompanying mineral, a blue azurite ($Cu_3(CO_3)_2(OH)_2$) with silky polish and of blue crevice as well as chrysocolla – in other words hydrated silicate of copper ($(Cu; Al)_2H_2Si_2O_5(OH)_4 * nH_20$) have occurred.

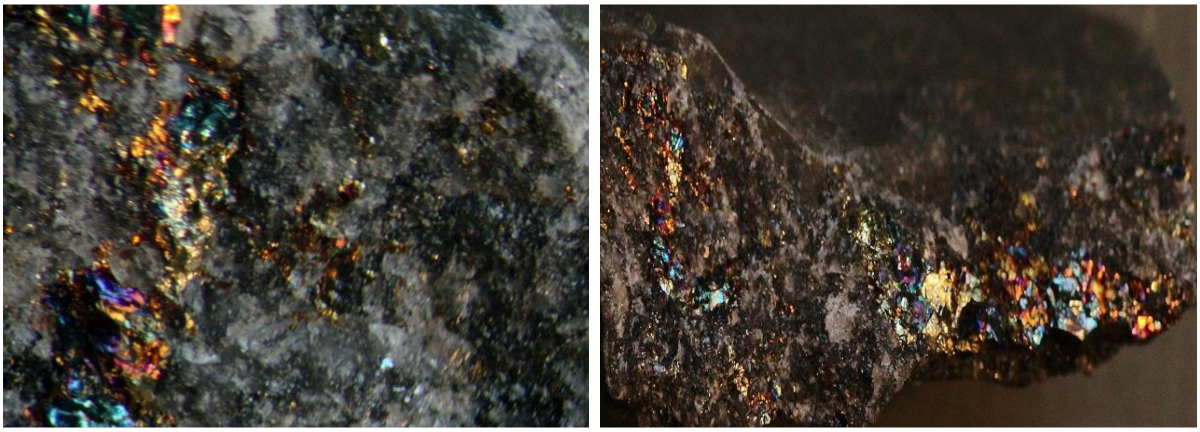


Fig.11. Primitive minerals in a dolomite. On the photos are: a bornite, a chalcocite. Digital microscope, zoom 15x.

Chalcopyrite ($CuFES_2$), characterizes of brass-gold colour and green-grey crevice, appeared quite often in the form of veins or grainy groups. A bornite (Cu_5FeS_4) has accompanied to it, which appeared in the form of finally lightly stale, because specimens were covered by coatings of cardinal-purple colour. In samples a covellite (CuS) has also appeared, which can be easy recognize by greasy and metallic polish as well as blue – black colour of crystals and crevice. In analysed specimens, a dark-grey chalcocite (Cu_2S) of glossy crevice and metallic polishing has also appeared.

Macroscopic observations allowed to identify a pyrite (FeS_2) also, which appeared in the form of isometric, tiny crystals of old-gold colour and black crevice, as well as a hematite (Fe_2O_3) in the form of speleothems and iron’s glance (specular haematite) (sometimes with infixes and/or malachite’s speleothem) with semi-metal and metallic polishing and cherry crevice.

To identify ore minerals appearing in lode, analyses with the use of polarized microscope in reflected light were made (Piestrzynski, 1992; Bolewski and Manecki, 1984).

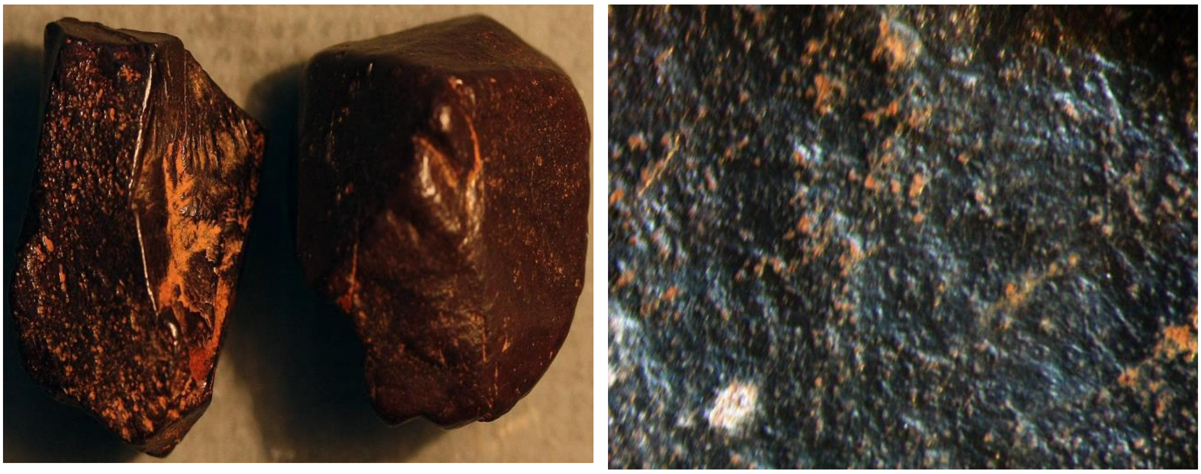
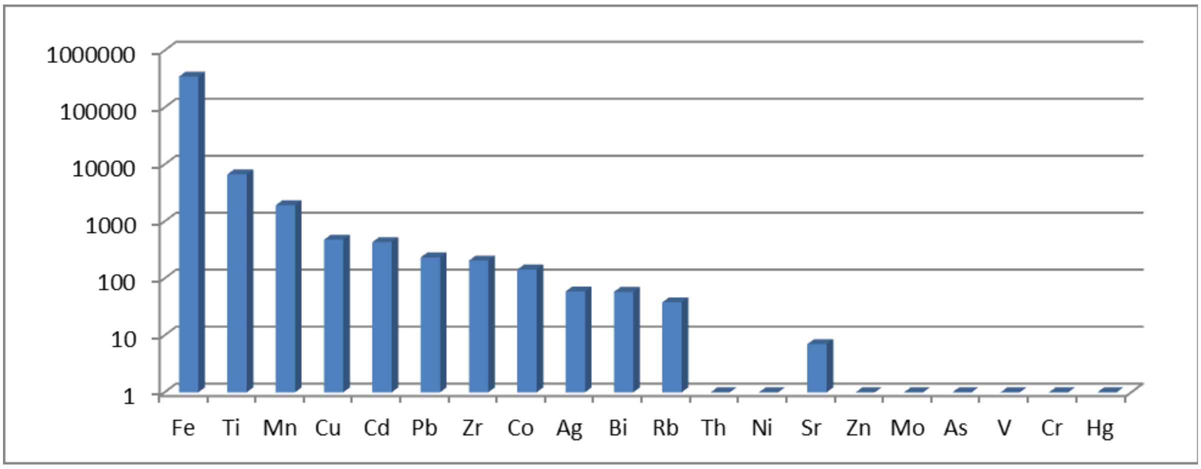


Fig.12. A hematite, occurring in D profile. Digital microscope, zoom 15x.

In analysed carbonate rocks' sample, mineralization of copper and iron was found. Copper mineralization in the form of malachite was identified by macroscopic identification, X-ray diffraction, electron microprobe and Raman's spectroscopy (results in further part of a chapter). Microscopy analyse in reflected light allowed to an identification of few forms of ore minerals' occurrence. Iron mineralization was represented among others by diffuse grains of pyrite and arsenic-pyrite, as well as hematite. Recognition of pyrite in reflected light is based on a colour, it is more yellow than a marcasite, but at once lighter and less yellow from a chalcopyrite, while arsenic-pyrite has creamy-pink colour and appears in grainy, stamen or stake form most often (Bolewski and Manecki, 1984). Individual pyrite and arsenic-pyrite grains in studying cuts have a size of a dozen or so micro-meters maximally, but in samples appear their 1-centimeter sets. Big crystals of chalcopyrite appear in form of intrusion or overgrow pyrite grains . Chalcopyrite was recognized by intensive yellow colour in reflected light, part of samples consisting chalcopyrite were studied while after preparations making, according to the literature (Piestrzynski, 1992), covered by brown-red coating, which also have confirmed identification of this ore mineral. As accompanying ore

Tab.3. Chemical's analyse results of a hematite ore from Kibutu lode (results in ppm) (logarithmic scale).



minerals, they appear with a high frequency of tennantite (in reflected light it has a characteristic grey-green colour, it is also more lighter than sphalerite (Bolewski and Manecki, 1984)) and sphalerite, which appear as a filling of free spaces in pyrite and/or chalcopyrite or in form of accompanying diffuse minerals. Samples with hematite mineralization were also studied. Samples were macroscopy identified as iron glance (haematite). In research, with the use of reflected light, it was observed that hematite appears in it in the form of elongated crystals sets. Mineralization is homogeneous in this case, it creates dense veins and alternating, as well as in research in reflected light, collocation of others minerals wasn't ascertain.

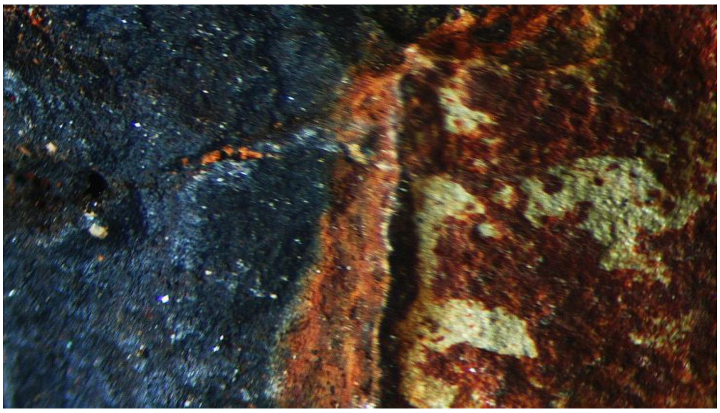


Fig.13. A black manganite with a pyrolusite (manganese's minerals) and brown minerals of an iron (oxides), a siderite (yellow). Digital microscope, zoom 15x.

In K4 sample (Figure 5.33), a quartz vein was identified, which crossing dolomite's background. In dolomite a bornite was identified, it appears as small crystals to a dozen or so micro-meters on sample's edges, also in the form of slightly vapid . Chalcocite and covellite appear seldom. This minerals are diffuse and rather create separate groups.

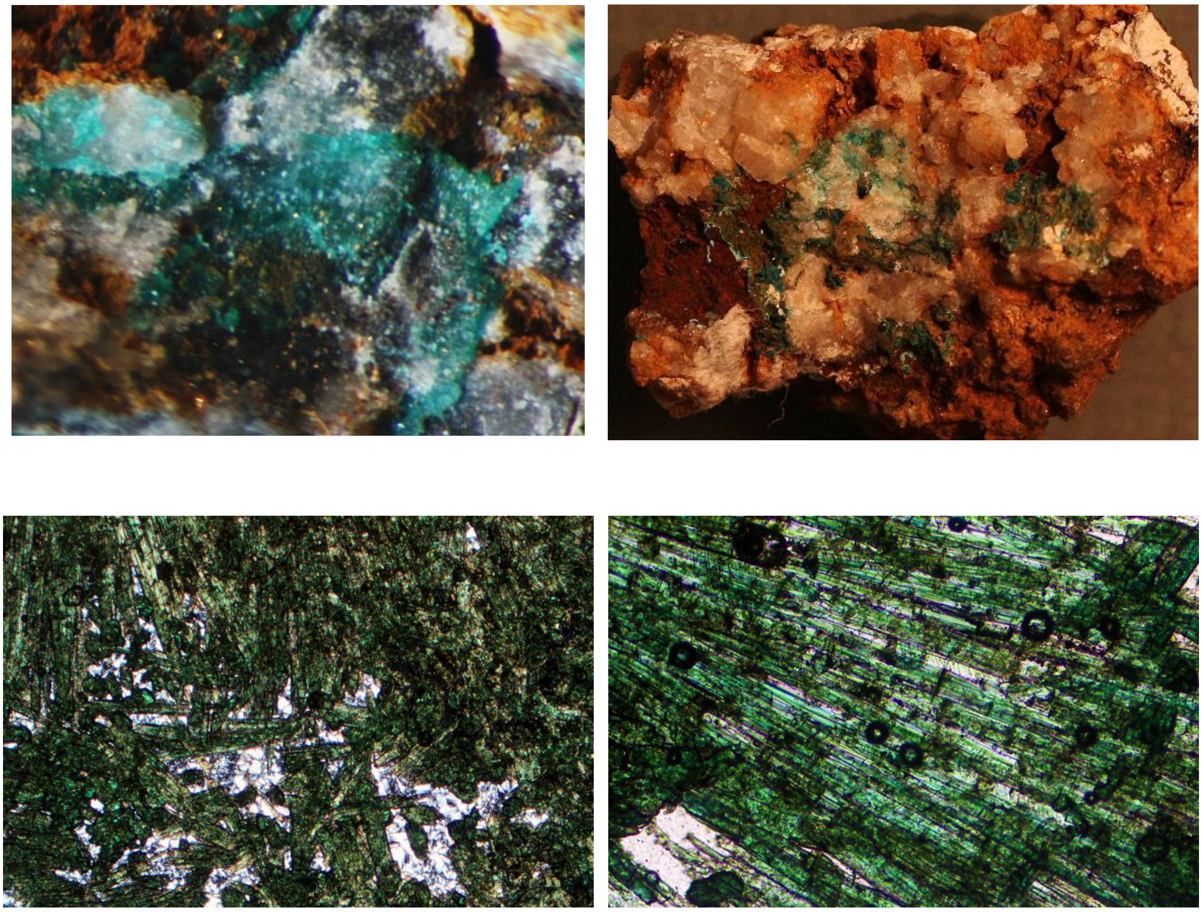


Fig.14. Mineralization of a dolomite by a malachite. Upper row – digital microscope, zoom 15x, lower row – polarised microscope, transmitted light, zoom 100x and 200x.

Younger than dolomite’s background is quartz vein, rich in big sets (to 1 centimetre) of chalcocite, often expanding with a bornite . Also single grains of bornite were identified, which secondarily (mainly in different types of cracks, pores or on the edges) were replaced by a covellite.

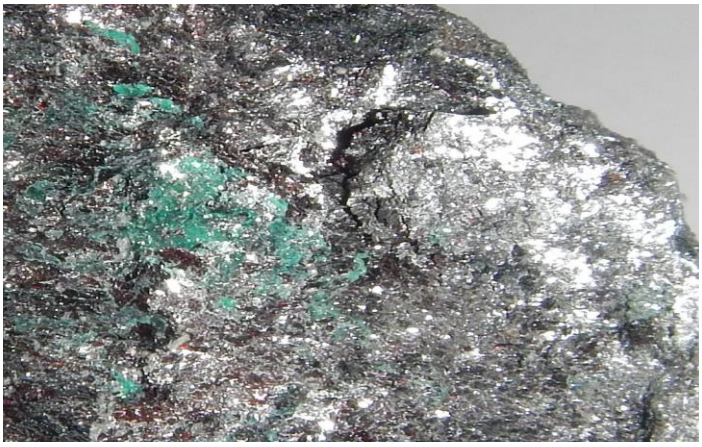


Fig.15. A hematite – an iron's glance from a sericite-talc-hematite slate with malachite's coating. Digital microscope, zoom 15x.

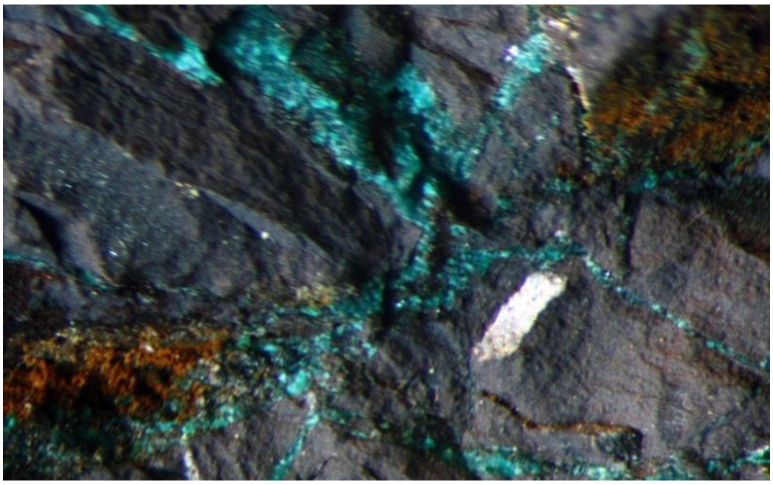
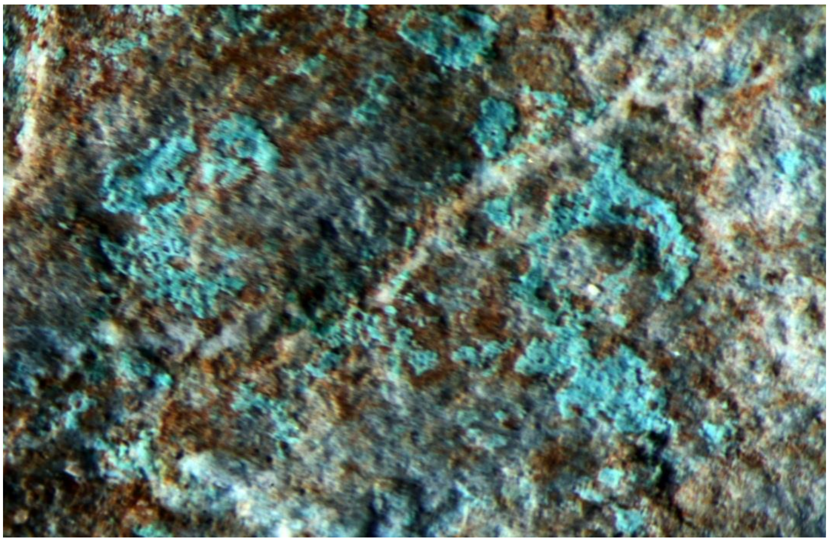


Fig.16. A hematite (metallic – grey) with a malachite (green) and with brown, oxidize iron's compounds. Digital microscope, zoom 20x.

In K6 sample appearing of background's two types were also confirmed: fine-crystalline carbonate and thick-crystalline carbonate with quartz grains. In both types of background copper mineralization appeared. In fine-crystalline carbonate, copper minerals also was small and created xenomorphic sets (to a dozen or so micro-meters). A bornite preponderated here, in less amounts a chalcocite appeared, and a covellite appeared occasionally.



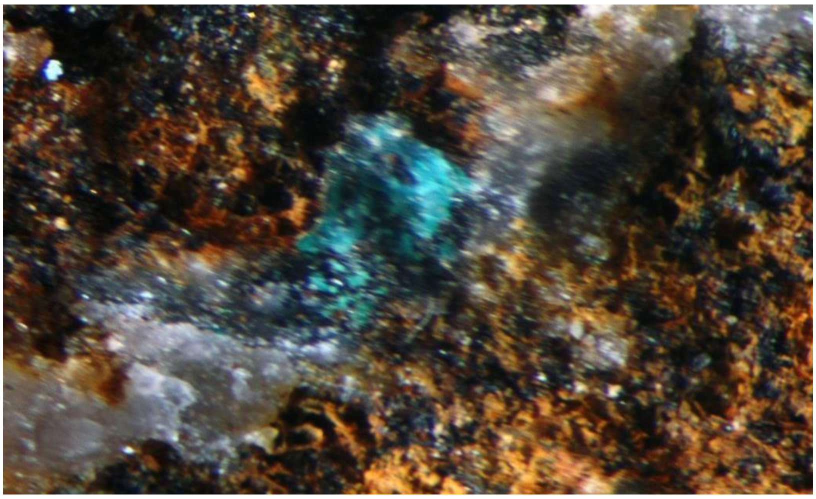


Fig.17. Pseudo-malachite and a manganite, occurring in siliceous parts of a dolomite. Digital microscope, zoom 20x.

In thick-crystalline carbonate bigger crystals appeared (size about 1 millimetre). Here, a basic ore material is a xenomorphic chalcopyrite, rarely with bornite's hypertrophies and a bornite (xenomorphic grains to several hundred of micro-meters at the most) sometimes overgrows with chalcocite (Figure 5.38). In sample it was also observed, that some bornite's grains started to be substitute by a covellite.

Fig.18. Bornite’s crystals from a metallic dolomite. Digital microscope, zoom 30x.

Fig.19. A cobaltite (black veins) in a dolomite. Digital microscope, zoom 30x.

Fig.20. A hematite from Kibutu lode. Digital microscope, zoom 10x.

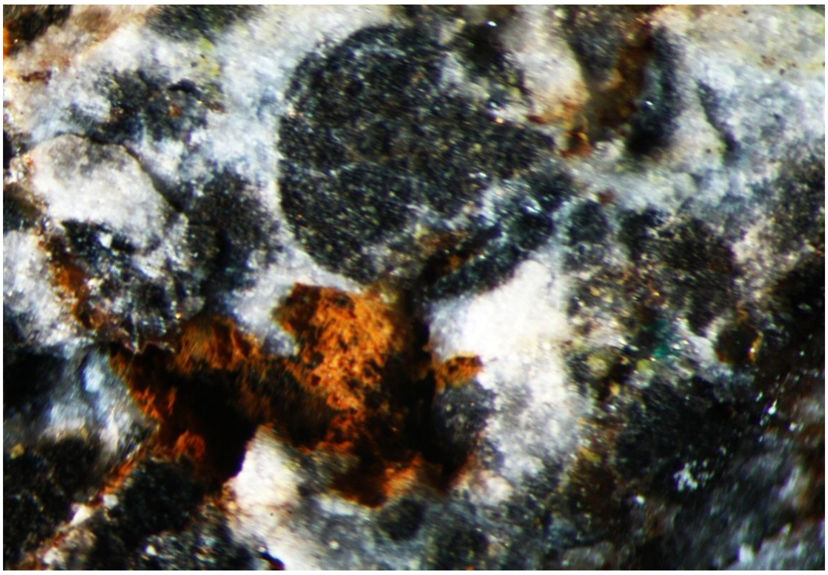


Fig.21. An oolitic siliceous metalliferous dolomite, mineralised with an iron and a copper. Digital microscope, zoom 16x.

Fig.22. A talc with a parallel system of blades. Digital microscope, zoom 12x.

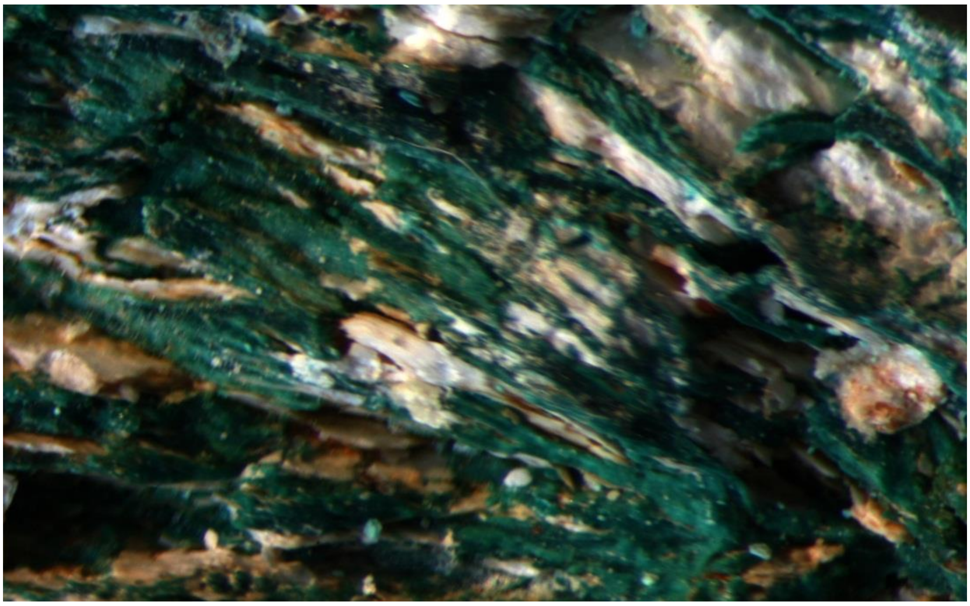


Fig.23. Light blades of talc, mineralised by a green malachite. Digital microscope, zoom 12x.

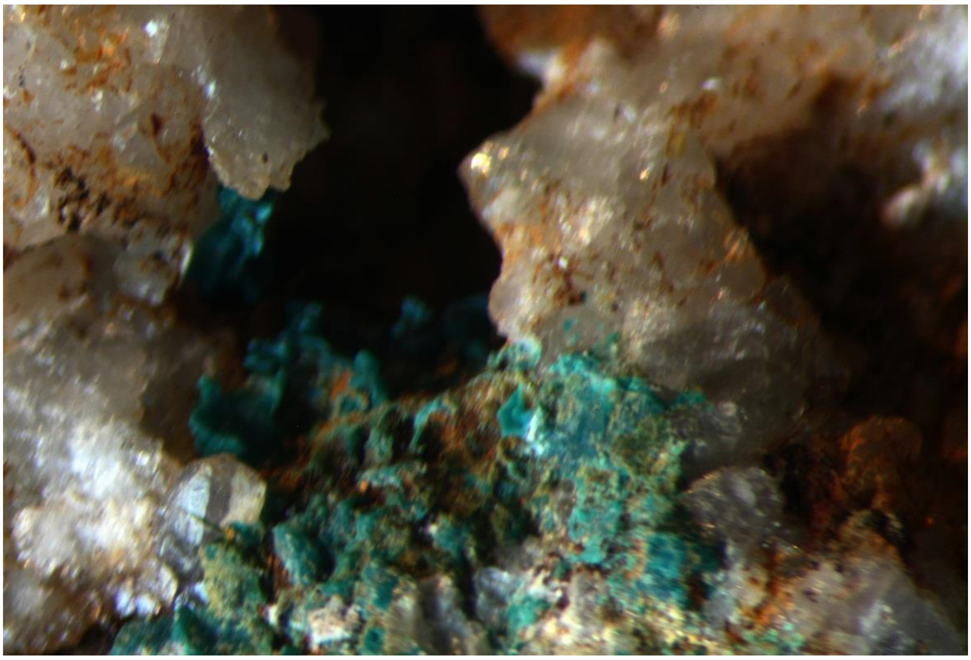


Fig.24. A chalcanthite in a R3-4 metallic dolomite, in a sphere of quartz occurring. Digital microscope, zoom 12x.

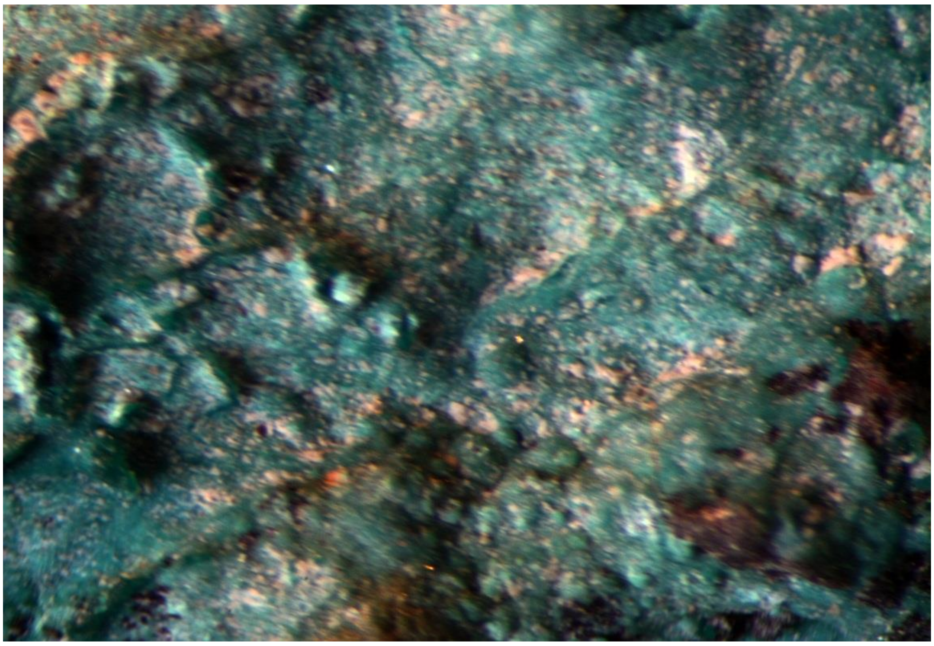


Fig.25. A malachite in speleothem form, from contractions occurring in red soils (terra rossa), above a metallic dolomite's roof. Digital microscope, zoom 10x.

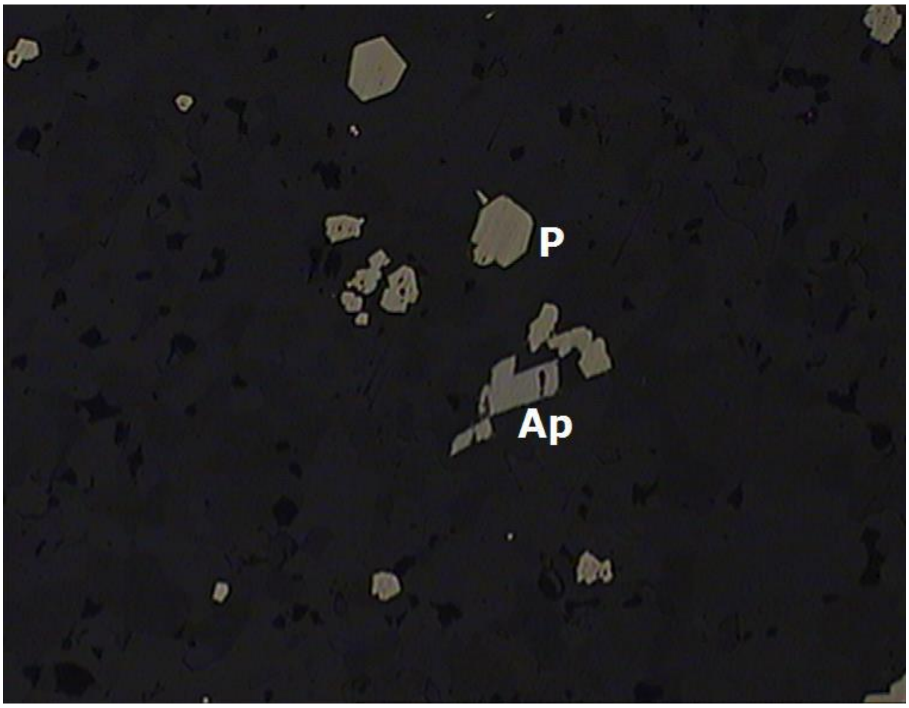


Fig.26. K2 sample. A diffuse pyrite (P) and an arsenopyrite (P) as well as a tennantite (T) and a sphalerite (Sf), occurring as fillings of a porous spaces. Zoom 600x.

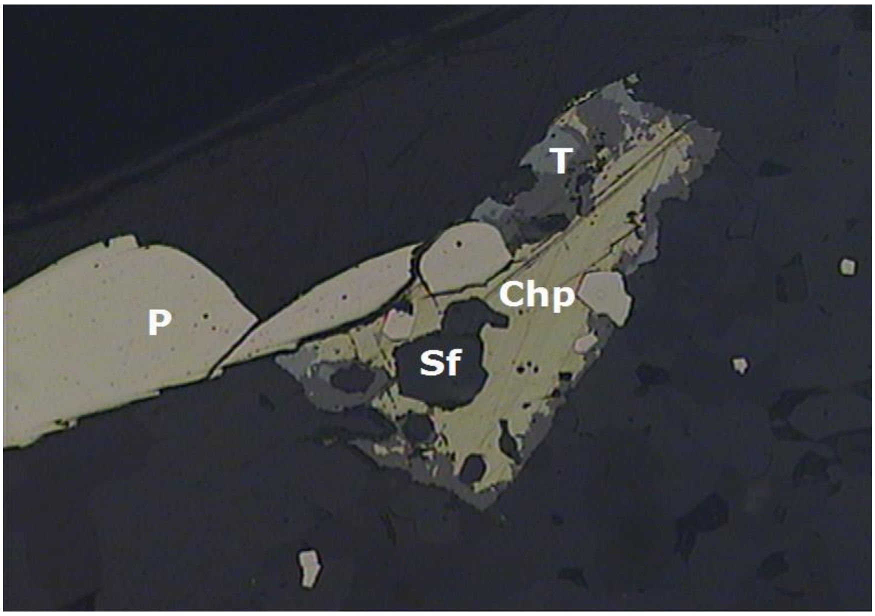


Fig.27. K2 sample. A diffuse pyrite (P),) a porous tennantite (T) and an accompanying sphalerite (Sf). Zoom 300x.

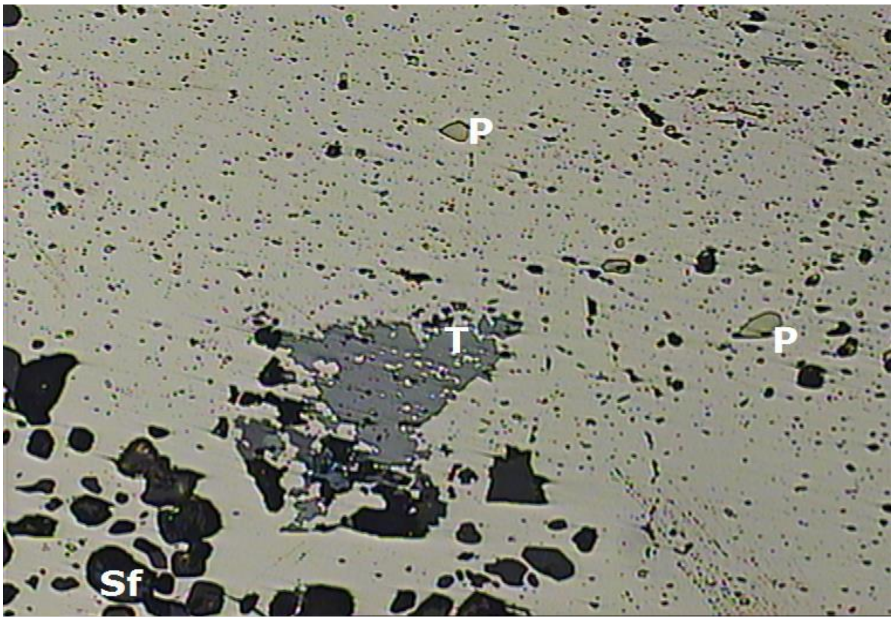


Fig.28. K2 sample. A diffuse pyrite (P),) a porous tennantite (T) and an accompanying sphalerite (Sf). Zoom 300x.

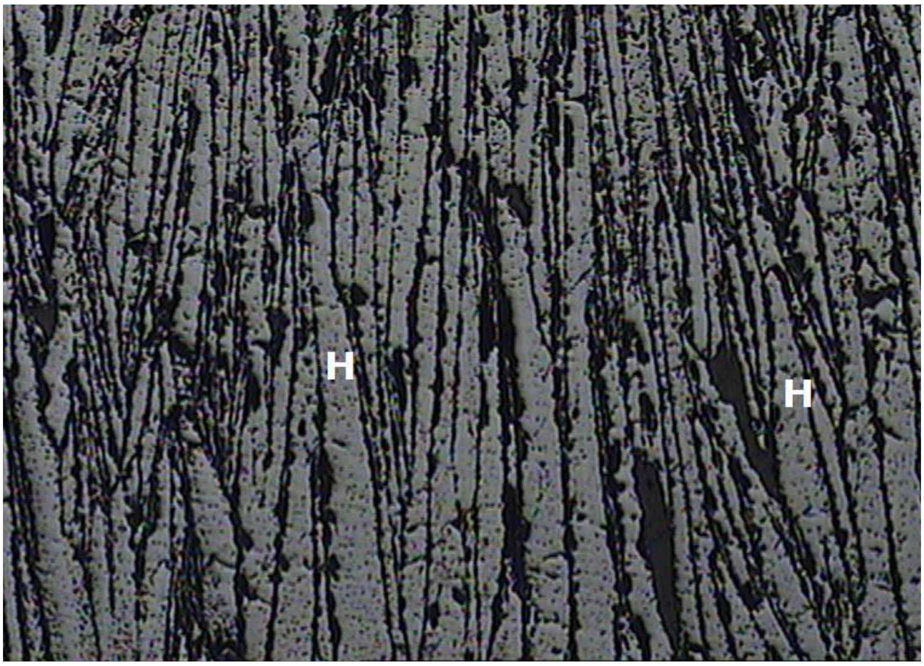


Fig.29. K5 sample. Elongate, needle-shaped crystals of a hematite (H). Zoom 150x.

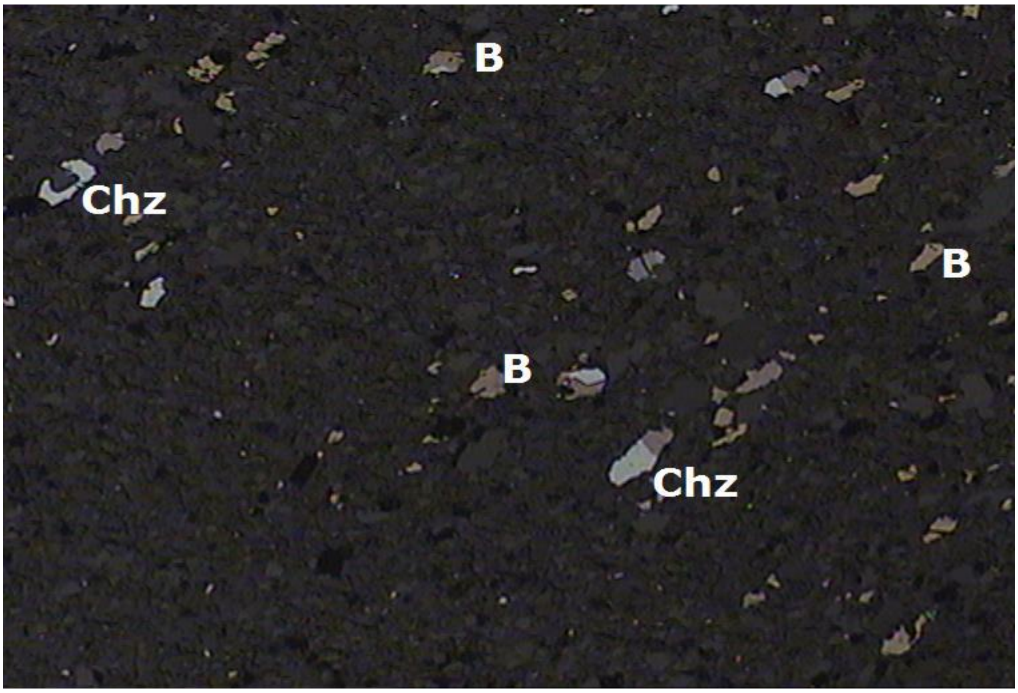


Fig.30. K4 sample. A chalcocite and a bornite diffusing in a dolomite. Zoom 300x.

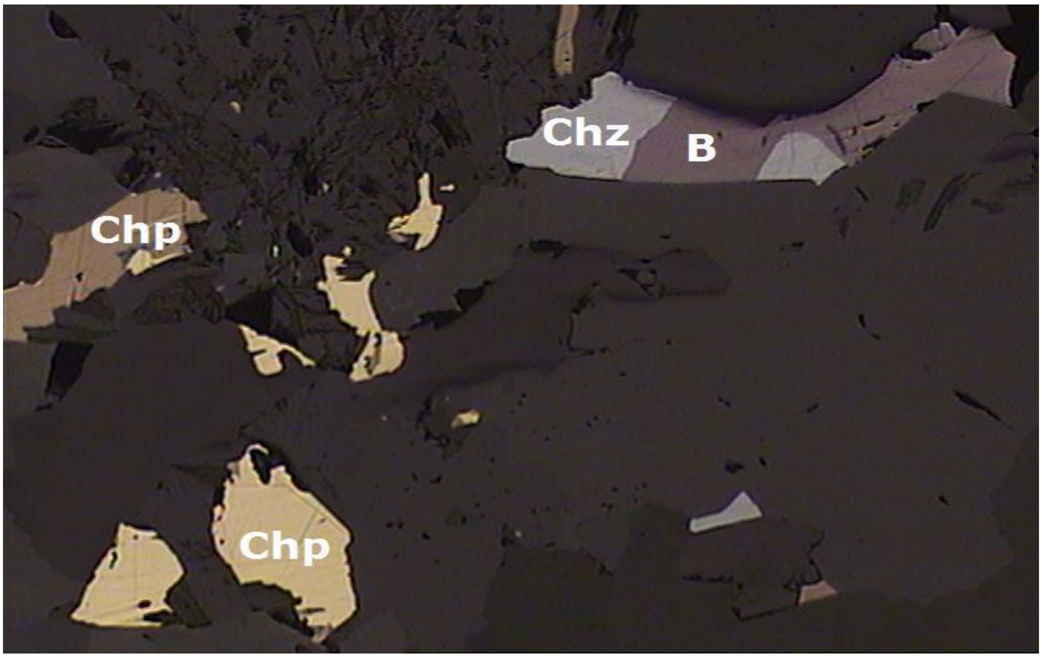


Fig.31. K4 sample. Crystals of a chalcopyrite and overgrowing crystals of a chalcocite and a bornite. Zoom 300x.

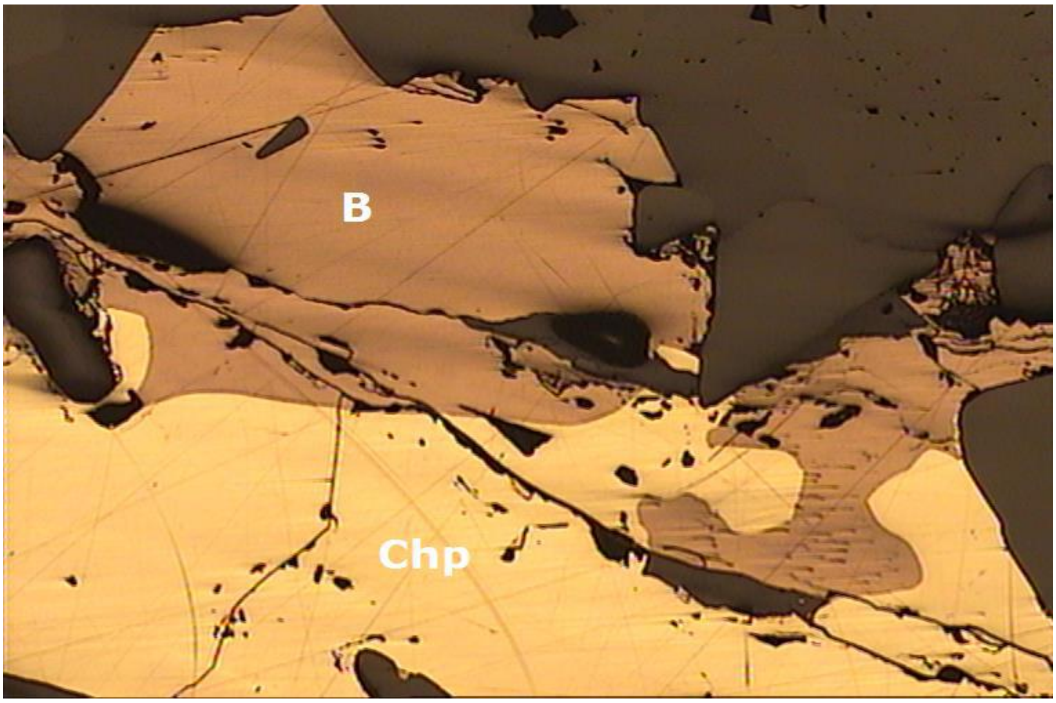


Fig.32. K4 sample. Overgrowing, big grains of a bornite (B) and a chalcopyrite (ChP). Zoom 150x.

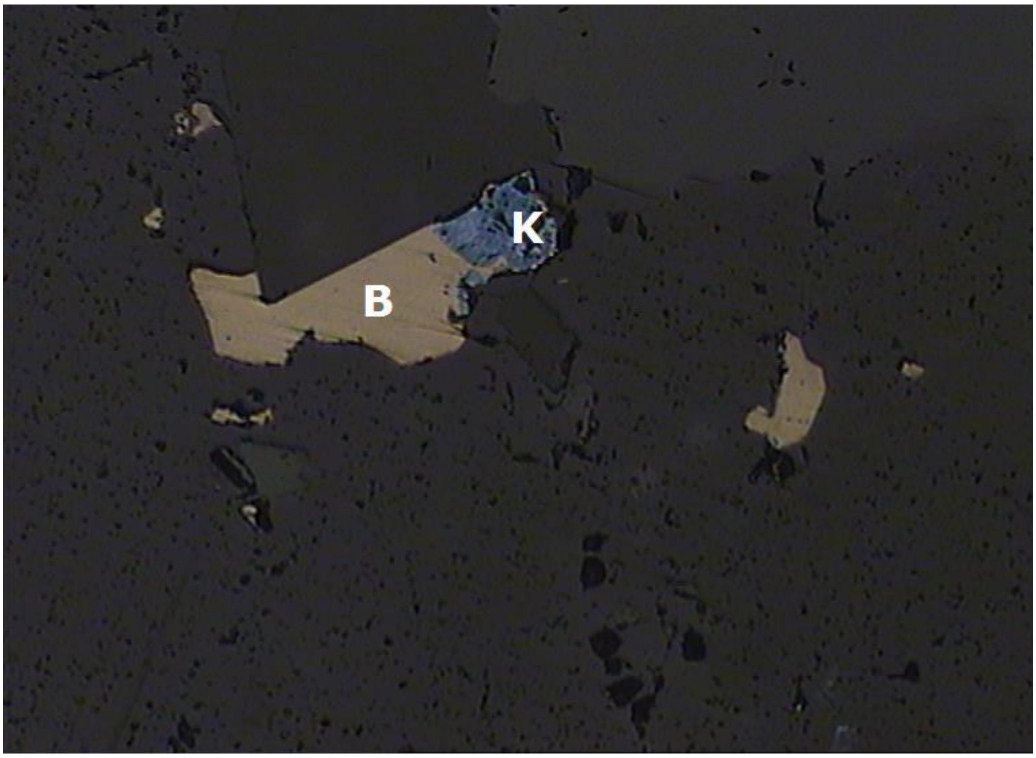


Fig.33. K4 sample. A bornite (B) replacing by a covellite (K). Zoom 300x.

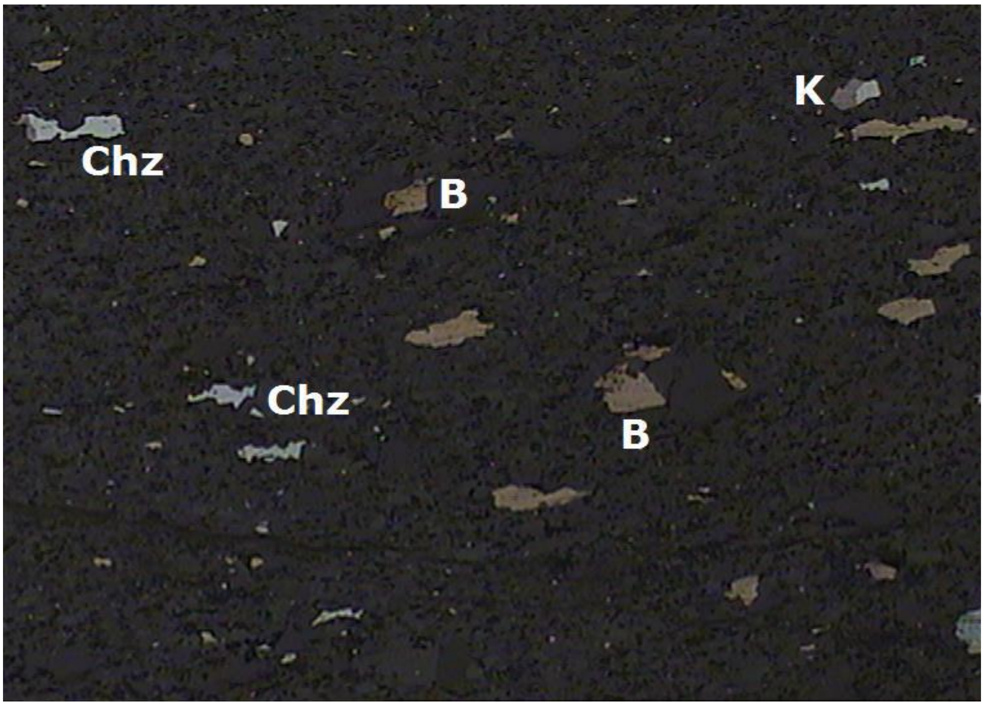


Fig.34. K6 sample. A diffusing mineralization of a bornite (B), a chalcocite (Chz) and a covelline (K). Zoom 300x.

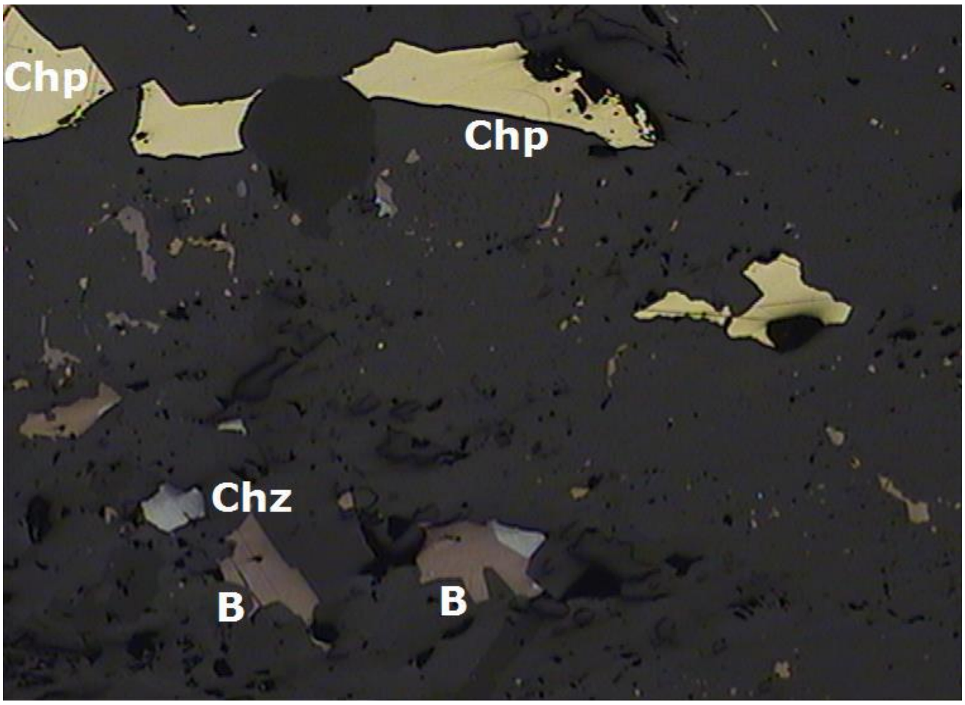


Fig.35. K6 sample. Mineralization by a chalcopyrite (Chp), a bornite (B) and a chalcocite (Chz). Zoom 150x.

In second place, X-ray analyses (XRD) were made to determinate structures of ore minerals. From implicated X-ray analyses, it results without any doubts, that samples of green copper ore is a clean, even model, malachite (Figure 5.39). On a diffractogram all characteristic strips for a malachite are visible, with the lengths: 2,78; 2,86; 3,69; 5,05 and 5,98 (Gawel and Muszynski, 1996).

Also a XRD analyse of hematite's sample was made, which contained only additions of a quartz.

At the same time, malachite's sample was studying by the method of Ramana's spectroscopy. A malachite has two, very strong, characteristic strips: 435 and 1495 cm-1 , they are very clearly signalised in an analysed sample. Other strips, typical for copper carbonate are: 215 cm-1 (in analysed sample – 222 cm-1), 269 cm-1 (in analysed sample – 270cm-1), 354 cm-1 (in analysed sample – 352 cm-1), 536 cm-1 (in analysed sample – 536 cm-1) (Mattei et al., 2008; Frost et al., 2002; Buzgar et al., 2009). According to strip's literature: 721 cm-1, 1100 cm-1 and 1368 cm-1 indicate about asymmetric deformations, occurring in CO3 group (Mattei et al., 2008; Frost et al., 2002; Buzgar et al., 2009). However, a strip in 3384-1 area, come directly from OH group (Mattei et al., 2008; Frost et al., 2002; Buzgar et al., 2009).

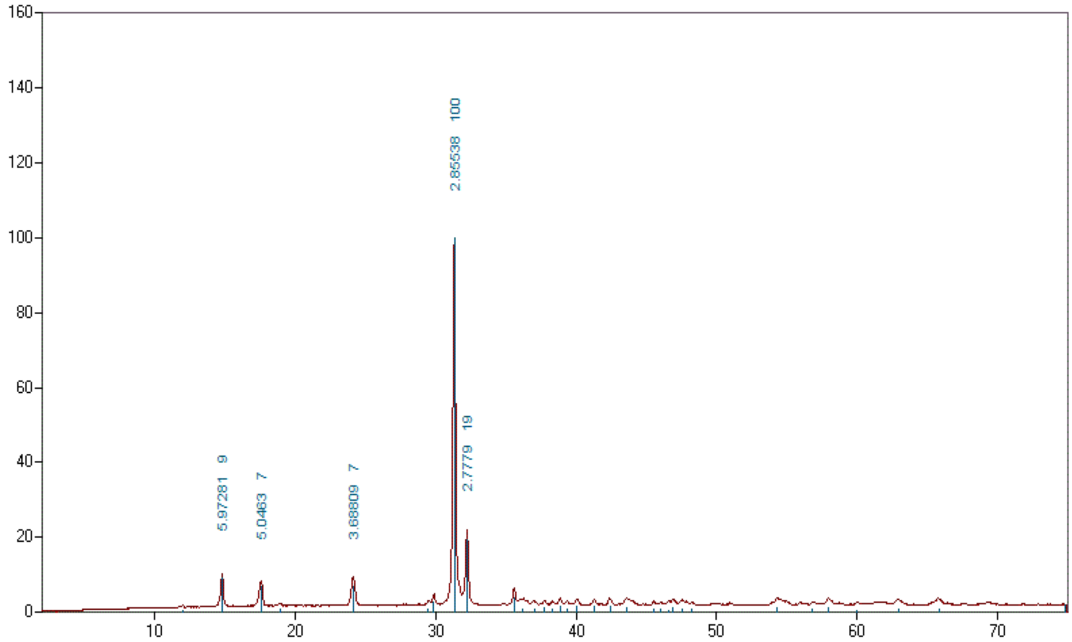


Fig.36. K7 sample. A diffractogram of a malachite's sample. All peaks with lengths characteristic for a malachite.

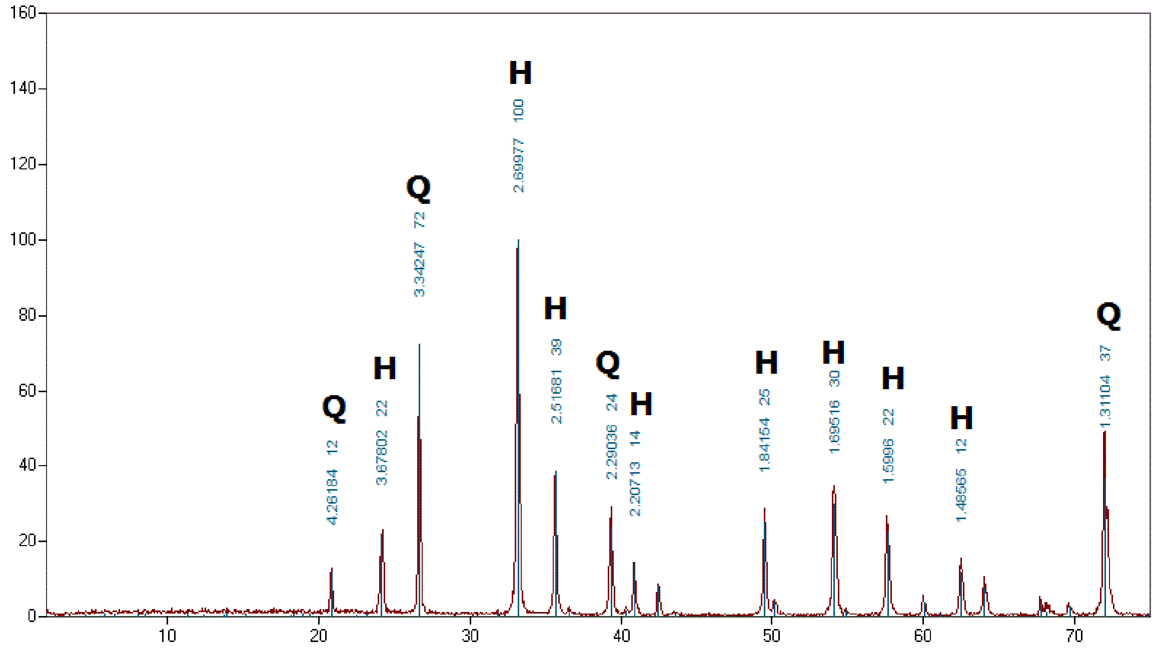


Fig.37. K10 sample. A diffractogram of a hematite's sample. H – a hematite, Q – a quartz.

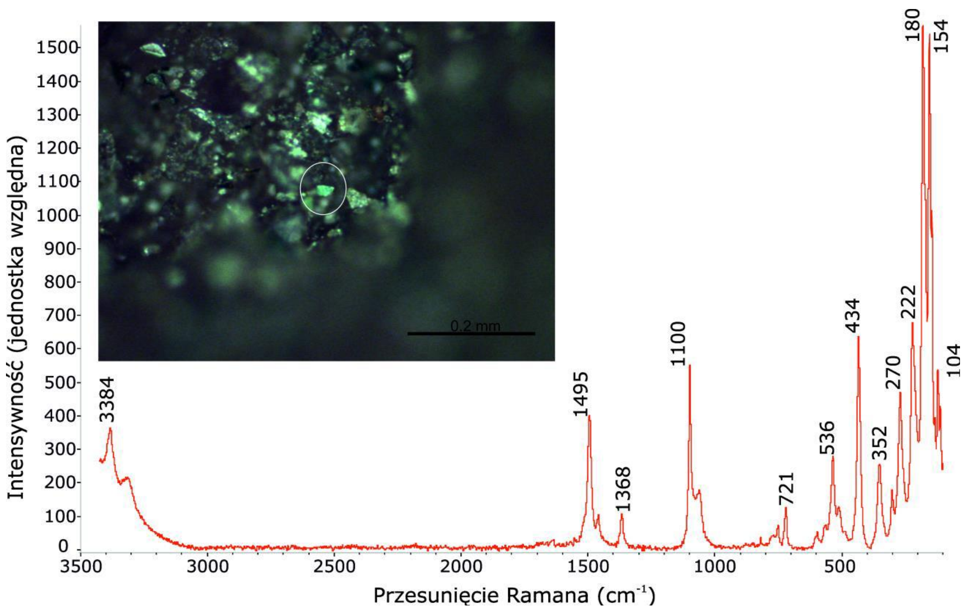


Fig.38. SK8 sample. Raman's spectrum with a micro-photography in reflection light of a malachite's sample.

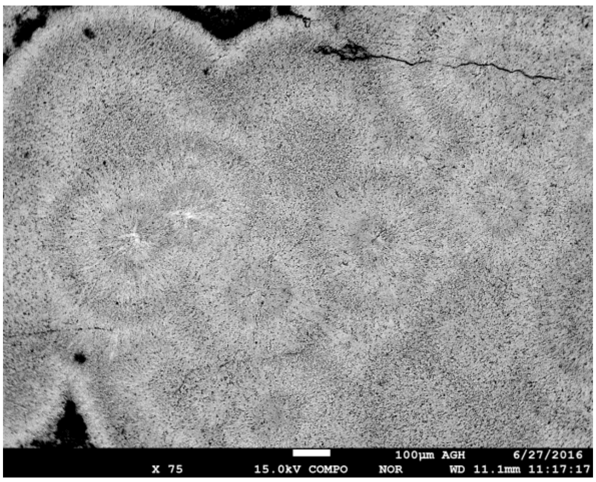
Next analytic research were made at Critical Chemical Elements' Laboratory by AGH-KGHM with the use of electron microprobe. Samples contained ore copper minerals, performing in oxidant and sulphide form are being subjected. Research with the use of electron microprobe, confirmed an occurrence of ore minerals, stated with the using of previous methods. Additionally, it succeed to identify an appearance of small amounts of ore minerals in inclusions and chalcocite veins, which wasn't state in earlier analyses.

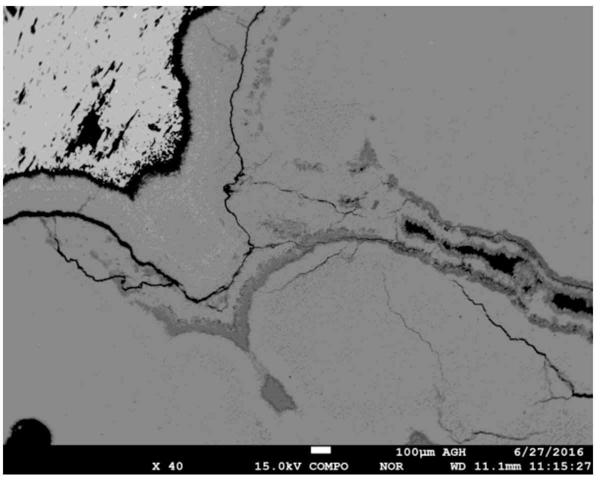
In analysed samples from Kibutu's lode were identified: a chalcocite, a chalcopyrite, a bornite and a tennantite . This minerals occur together, overgrow each other, filling all free spaces and rocks' blanks in dolomite.

In samples from siliceous dolomite, except for malachite mineralization , which after further analyses seemed to be dominating, a significant amounts of chrysocolla mineralization type was identified, that is hydrated copper silicates. Chrysocolla often have additional admixture of iron, aluminium or manganese, but in analysed samples increasing amount of this chemical elements wasn't stated.

Geochemical researches

Geochemical researches were made on dolomite's cupriferous profiles (B profile) and metamorphic sericite-talc slates with a hematite (D profile). Research were performed by HANDHELD XRF Delta spectrometer of USA production (Figure 5.45). On the grounds of field research necessity of R4.1 and R3.4 rocks profile's formations, signs of chemical composition variability of cupriferous dolomite were made on limited amount of samples. Averaged results of signs were tabulated (Table 5.10) and on the graphs (Figure 5.46).

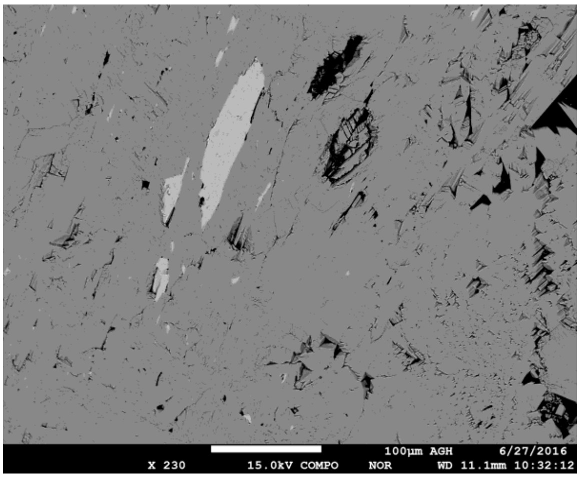


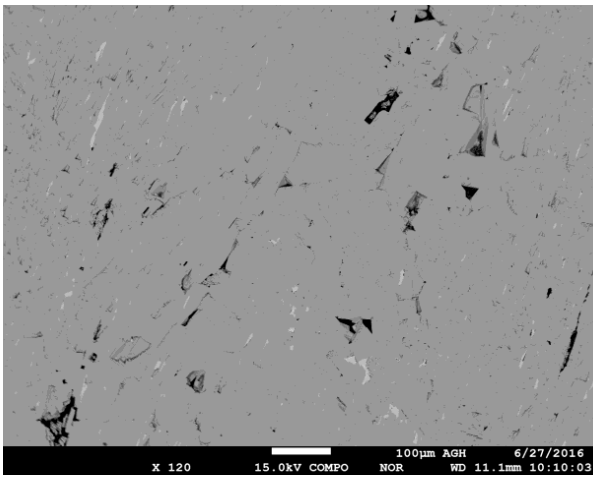


No.	SiO2	Al2O3	CaO	FeO	CuO	CoO	MnO	SO3	NiO	ZnO	MgO	Total
1	41.409	0.286	0.121	0.034	50.861	0.334	0.011	0.042	0.019	0.000	0.346	93.463
2	41.659	0.207	0.060	0.057	50.274	0.324	0.099	0.016	0.035	0.065	0.659	93.455
3	41.615	0.172	0.037	0.027	51.288	0.011	0.000	0.018	0.053	0.000	0.133	93.354

Fig.39. SEM microphotography – a chrysocolla of copper silicate with results (in weight %) from an electron microprobe. Results aren't sum to ~100%, because in measurement's result it came to dissolution of the part of carbonates and remove of OH groups from mineral's structures.

Results displays of a great variability of studying rocks' elemental composition. This implies that by estimation of sources and signing of rocks' chemical composition, should be made a great amount of their chemical analyse, and results of signing should be average. Performing chemical signs of a dolomite from a quarry shown, that they are incompatible with macroscopy observations of malachite's content in ore dolomite.

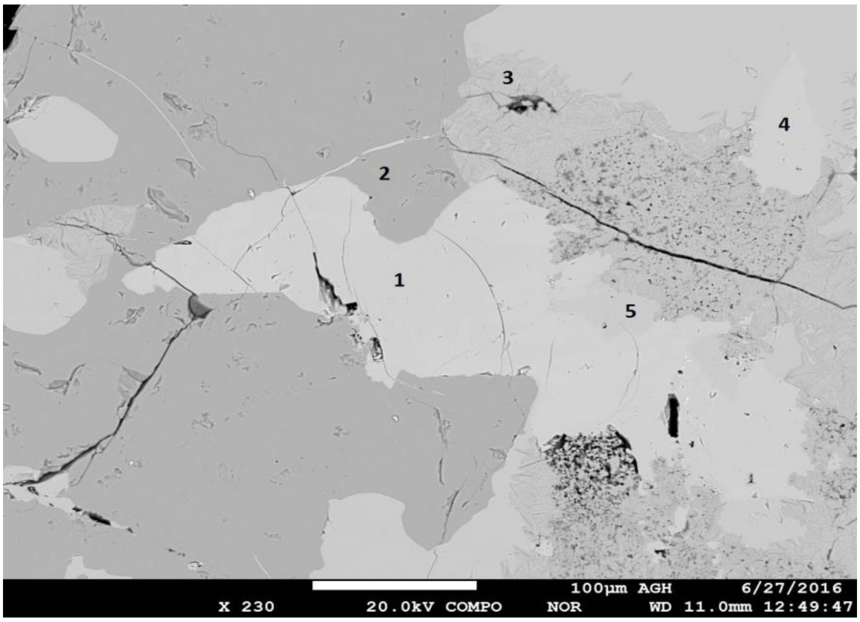




No.	SiO2	Al2O3	Cl	CaO	FeO	CuO	CoO	MnO	SO3	NiO	ZnO	MgO	Total
1	0.065	0.000	0.000	0.000	0.000	65.145	0.108	0.000	0.000	0.000	0.136	0.441	65.895
2	0.077	0.014	0.009	0.059	0.011	65.628	0.110	0.028	0.000	0.005	0.085	0.493	66.517

Fig.40 SEM photography is showing a homogenous structure of a malachite's surface. Below results (in weight %) from electron microprobe. Results aren't sum to ~100%, because in the wake of measurement, it could come to dissolution of the part of carbonates

and remove of OH groups from mineral's structures.



No.	In	As	S	Bi	Sb	Zn	Mn	Fe	Cu	Ag	Sn	Cd	Pb	Co	Se	Total
1	0.106	19.052	27.563	0.120	0.009	3.473	0.007	2.119	46.488	0.084	0.015	0.051	0.000	0.010	0.112	99.209
2	0.045	0.000	34.446	0.118	0.000	0.000	0.000	30.128	34.456	0.008	0.001	0.000	0.057	0.037	0.129	99.425
3	0.064	0.000	28.947	0.111	0.000	0.000	0.000	0.602	67.349	1.886	0.009	0.028	0.000	0.002	0.079	99.077
4	0.055	19.250	27.571	0.167	0.026	6.302	0.004	1.119	45.134	0.069	0.000	0.031	0.062	0.024	0.124	99.938
5	0.050	0.000	25.408	0.212	0.000	0.011	0.000	10.934	63.225	0.120	0.000	0.012	0.002	0.027	0.100	100.101

Fig. 41. SEM microphotography of dolomite's sample with sulphides and results (in weight %) of analyse by an electron microprobe. 1 - a tennantite, 2 – a chalcopyrite, 3 – a chalcocite, 4 – a tennantite, 5 – a bornite.

Chemical analyses made on ore dolomite (cupriferous) of Kibutu's lode, show that copper in ore dolomite doesn't perform in malachite form only, but also in other forms, therein as sulphides also and diadochy substitution in other minerals. In comparison with research samples' results from a borehole in Kasonta's lode, are significantly smaller and amount to about 3,5% maximally, while in the case of Kasonta's lode it was almost 5%. Results of geochemical analyses performed for studying chemical elements on the graphs, marked on lode's wall photography, on which they were made.

Fig.42. The HANDHELD XRF Delta spectrometer and marking of metallic dolomite's elemental composition.

Tab.4.. A collation of average chemical analyses' results, made with a field spectrometer, on the three wall of cupriferous dolomite's fragments from Kibutu mine (weight %).

Metal	Pomiar 1	Pomiar 2	Pomiar 3
Cu	56,80	42,40	52,64
P	12,10	11,60	2,60
S	2,40	1,80	0,01
Fe	2,10	5,37	3,75
K	0,50	0,40	0,80
Zn	0,20	0,02	0,05
Mg	10,70	1,21	10,11
Ti	0,06	ppo	0,01
Zr	ppo	ppo	ppo
V	ppo	ppo	ppo
Ag	0,02	0,01	0,01
As	0,01	ppo	0,01
Co	ppo	ppo	ppo
Rb	ppo	ppo	ppo
Ca	15,11	37,17	30,01
Sr	ppo	ppo	ppo
suma	100	100	100

Tab. 5. A collation of copper content in metallic dolomite, in A, B, C profiles, in Kibutu quarry (A research were made by a portable Delta Handheld XRF Analyzer).

Ściana	**Lp.**	**Zawartość Cu [%]**
A	1	**0,5**
	2	**0,5**
	3	**1**
	4	**2**
	5	**1**

	6	**0,5**
B	1	**0,5**
	2	**1**
	3	**2**
	4	**1**
	5	**0,5**
	6	**0,5**
	7	**0,5**
	8	**1**
	9	**0,5**
	10	**0**
	11	**0**
	12	**1**
	13	**1**
	14	**1**
	15	**1,5**
	16	**2**
	17	**1,5**
	18	**1,5**
	19	**2**
	20	**2**
	21	**2,5**
	22	**3**

	23	**3**
	24	**3**
	25	**3**
	26	**3,5**
	27	**3**
	28	**3**
	29	**2,5**
	30	**2,5**
	31	**2**
	32	**1**
C	1	**0**
	2	**0**
	3	**0**
	4	**1**
	5	**1**
	6	**1,5**
	7	**0**
	8	**0**

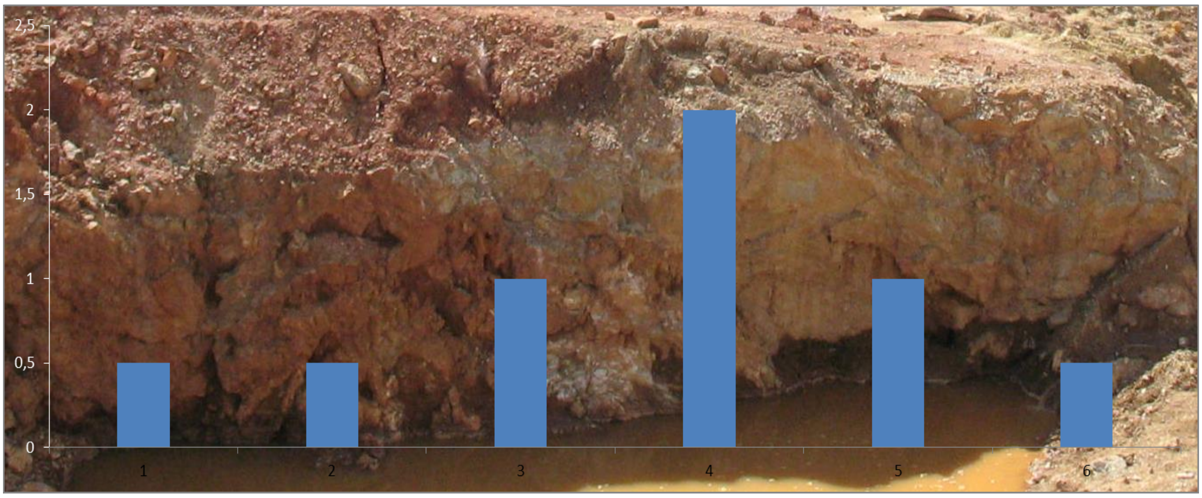


Fig.44. Kibutu lode. A profile. A variation of a copper content (in %) in metallic dolomite.

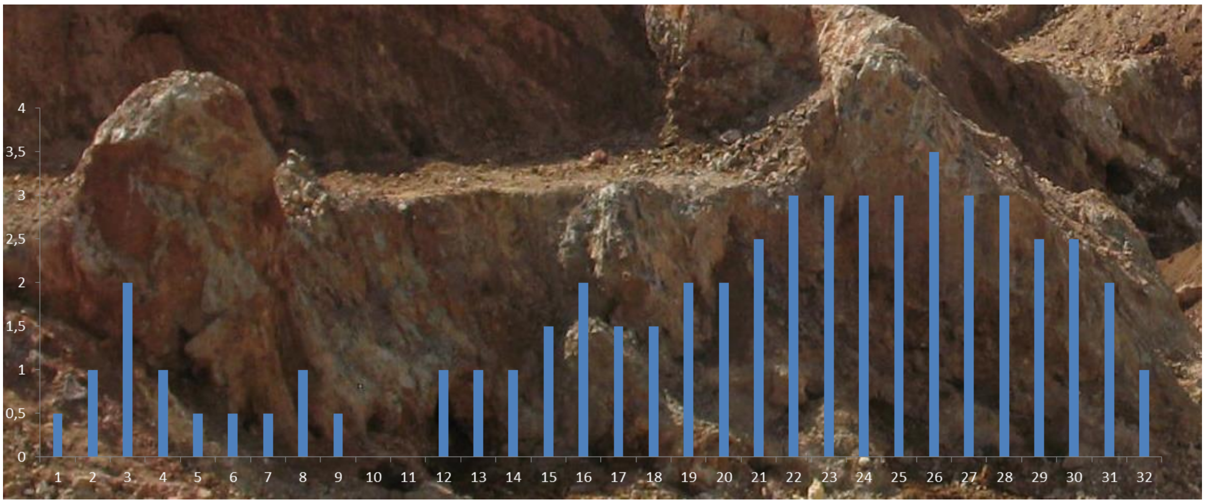


Fig.45. Kibutu lode. B profile. A variation of a copper content (in %) in metallic dolomite. Measurements were made in intervals of 50cm.

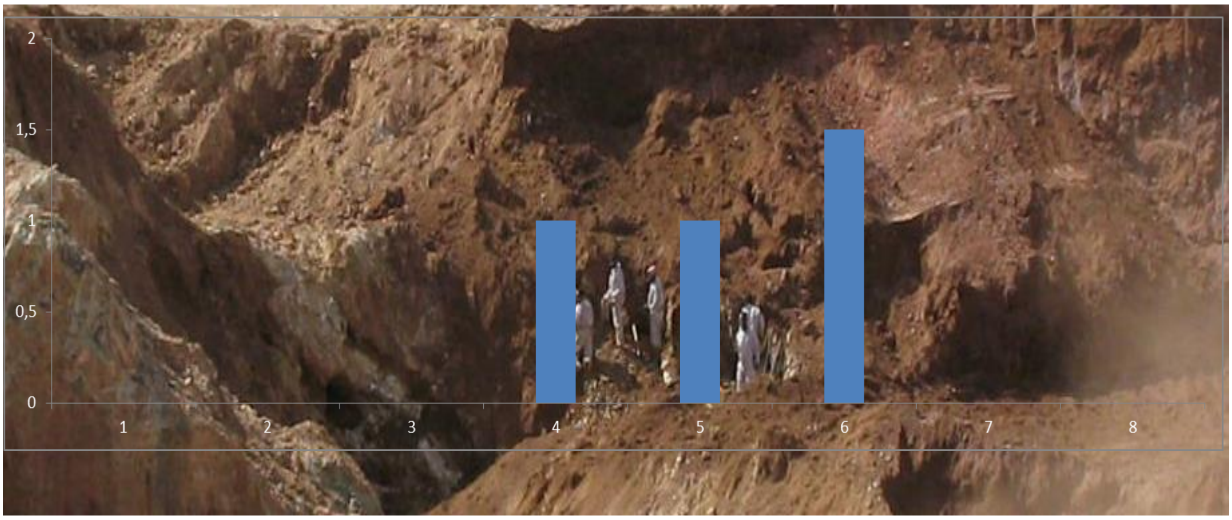


Fig.46. Kibutu lode. B profile. A variation of a copper content (in %) in metallic dolomite. An exploiting part of a lode.

Tab.6A. Kibutu lode. A R3-4 cupriferous dolomite. B profile. A content of marking chemical elements (ppm) (‘0’ means below a level of determinability) in a Kibutu quarry, part 1. Research were made by a portable Delta Handheld XRF Analyzer.

	Fe	Cu	Ti	Mg	V	Zr	Zn	As	Ag
1	47630	4510	4190	1050	210	177	190	25	0
2	25180	4260	2450	170	0	164	73	0	0
3	6782	1305	588	1115	0	45	28	8	76
4	21910	2935	1952	952	0	121	62	9	0
5	37550	1636	4071	760	252	278	25	8	53
6	182000	224000	3395	2104	0	47	1745	55	118
7	62610	5212	4206	175	0	419	73	0	56
8	30380	2494	0	281	0	16	20	0	0
9	32730	6746	6296	374	358	320	0	0	66
10	103000	166000	0	4399	0	0	5294	203	464
11	97000	14000	10200	7142	0	321	237	0	63
12	68400	5659	8721	163	0	638	85	0	0
13	29000	5060	11600	130	0	199	0	0	0
14	6089	1265	207	887	0	9	0	0	0

Tab.6B. Kibutu lode. A R3-4 cupriferous dolomite. B profile. A content of marking chemical elements (ppm) ('0' means below a level of determinability) in a Kibutu quarry, part 2. Research were made by a portable Delta Handheld XRF Analyzer.

Rb	Pb	Mo	Co	Sr	Cr	Th	Hg	Se	Ni
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
21	17	0	0	0	0	0	0	0	0
5	25	7	6	5	0	0	0	0	0
71	23	0	14	38	114	28	0	0	0
0	0	0	25	0	0	0	49	11	0
20	0	0	13	0	0	23	0	0	0
0	0	0	7	0	0	0	0	0	59
57	109	0	14	56	126	39	0	0	46
45	0	0	0	0	0	428	111	0	0
0	34	0	32	0	132	48	0	0	57
0	0	0	0	0	274	35	0	0	0
0	76	0	0	0	320	0	0	0	0
0	0	0	0	5	0	0	0	0	0

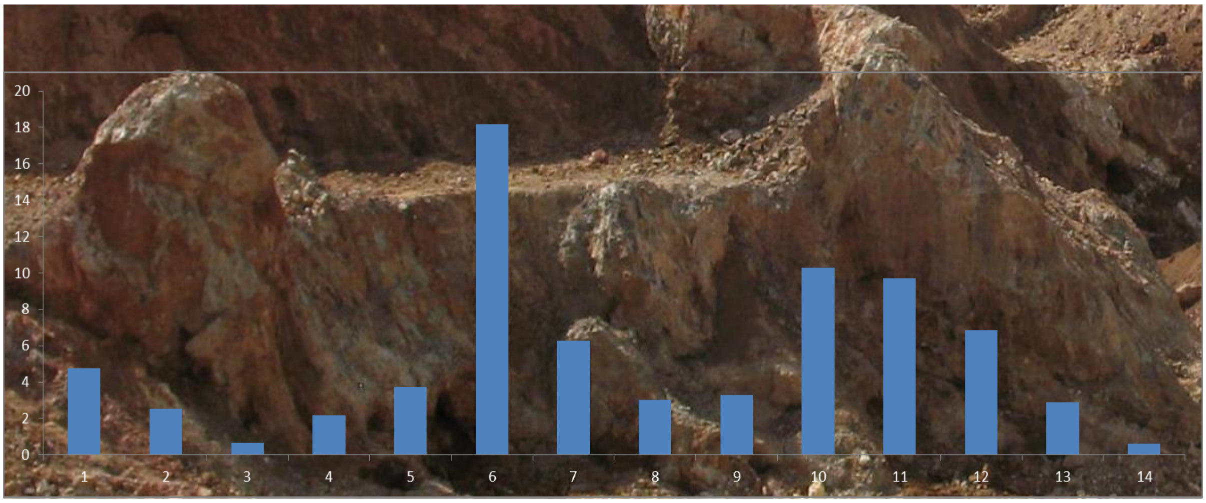


Fig. 47.Kibutu lode. B profile. A variation of a Fe content (in %) in metallic dolomite. Measurements were made in intervals of 100 cm.

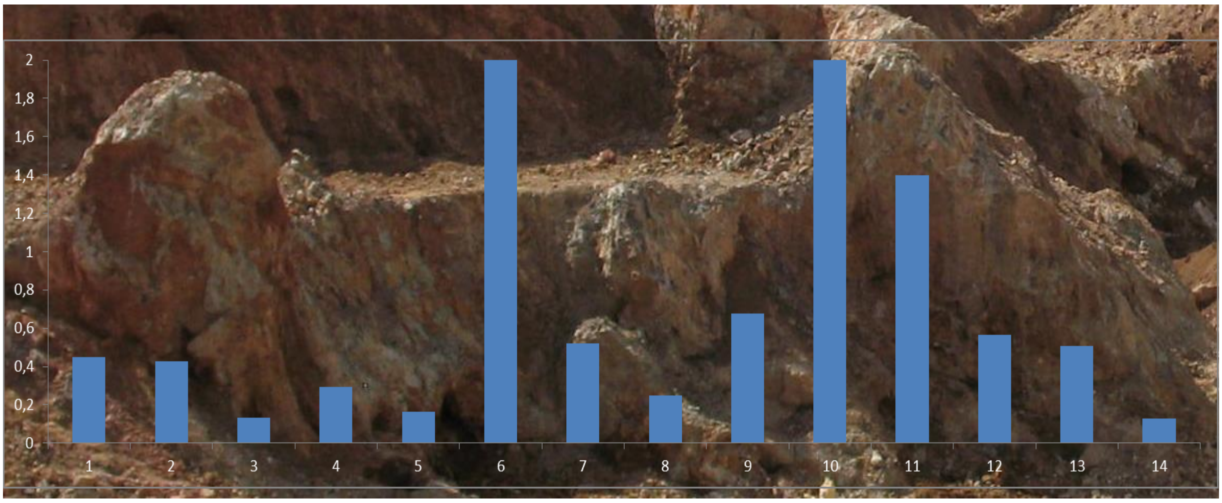


Fig. 48. Kibutu lode. B profile. A variation of a Cu content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

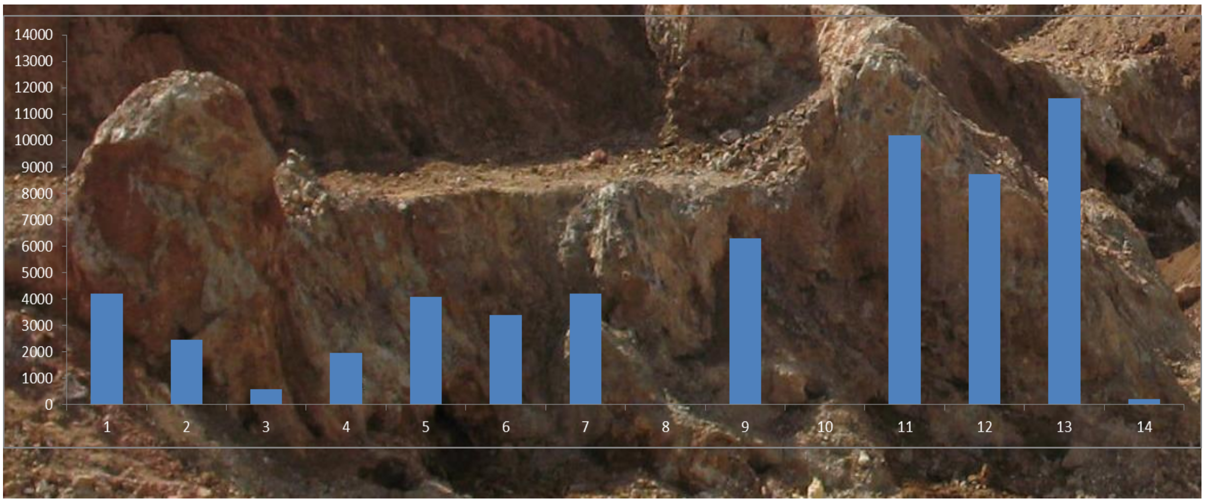


Fig. 49.Kibutu lode. B profile. A variation of a Ti content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

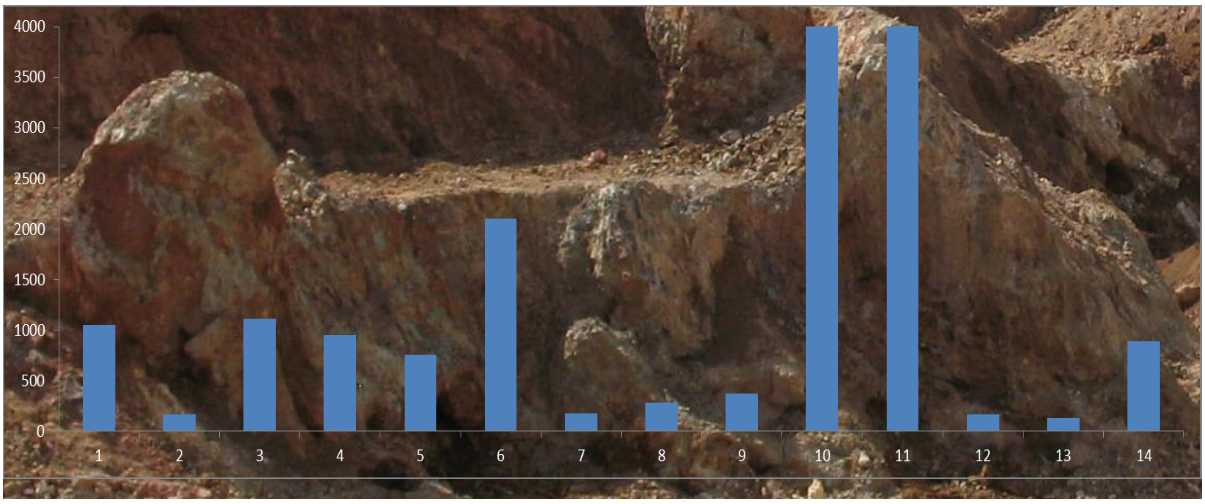


Fig. 50. Kibutu lode. B profile. A variation of a Mg content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

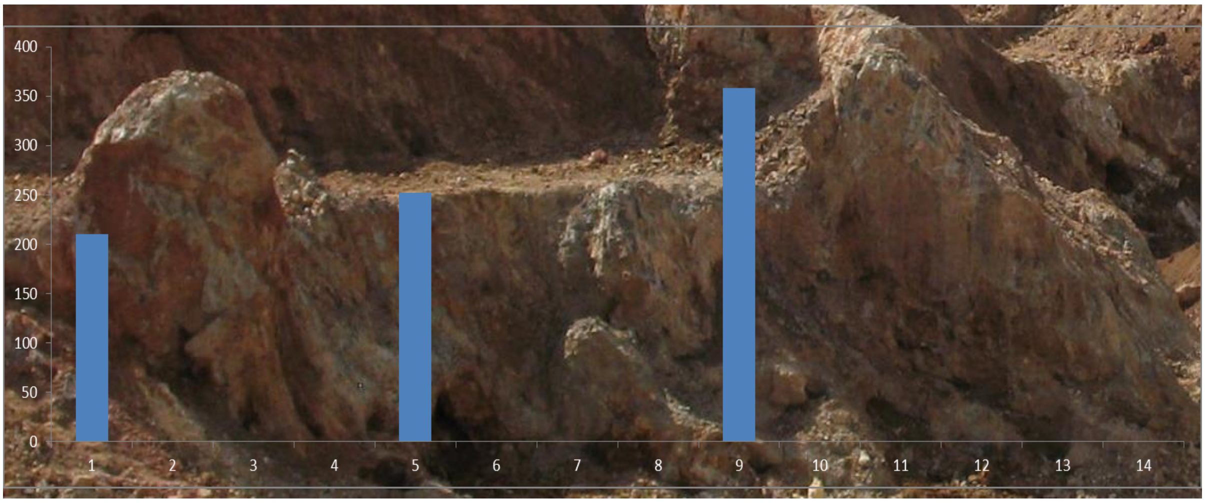


Fig. 51. Kibutu lode. B profile. A variation of a V content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

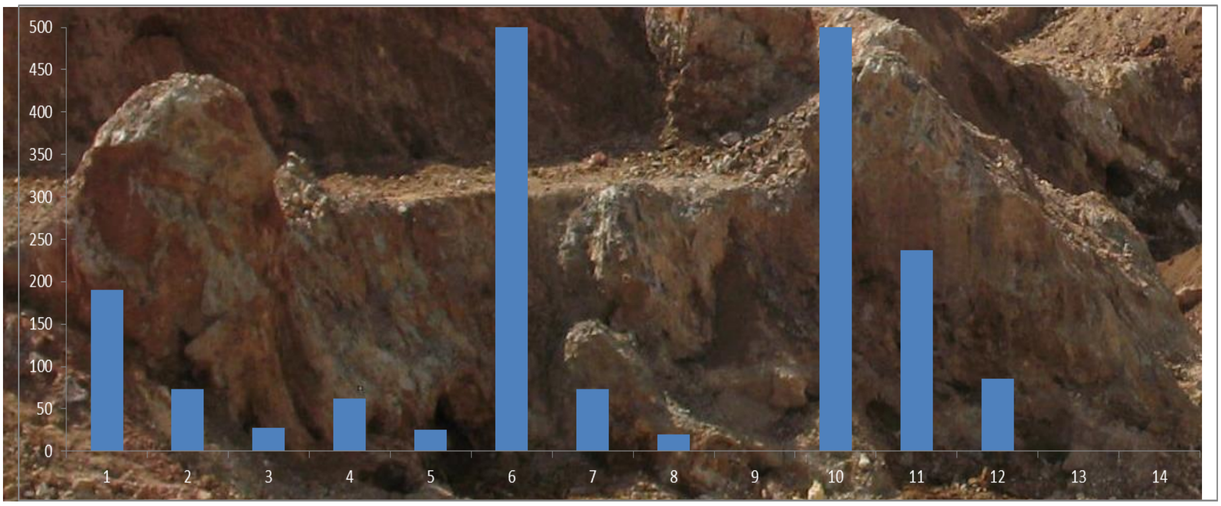


Fig. 52.Kibutu lode. B profile. A variation of a Zr content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

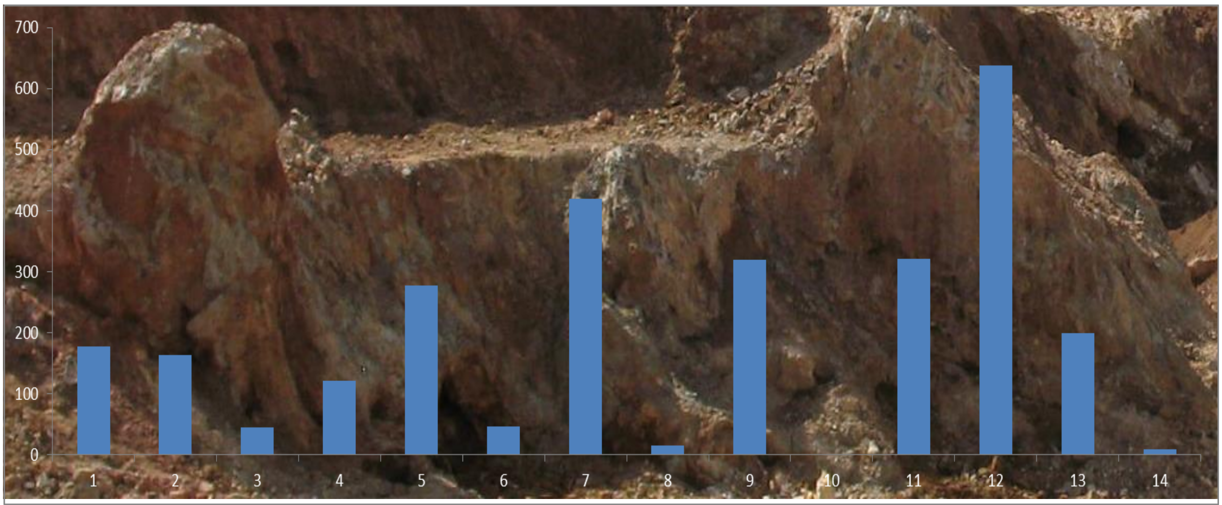


Fig. 53.Kibutu lode. B profile. A variation of a Zn content (in %) in metallic dolomite. Measurements were made in intervals of 100cm

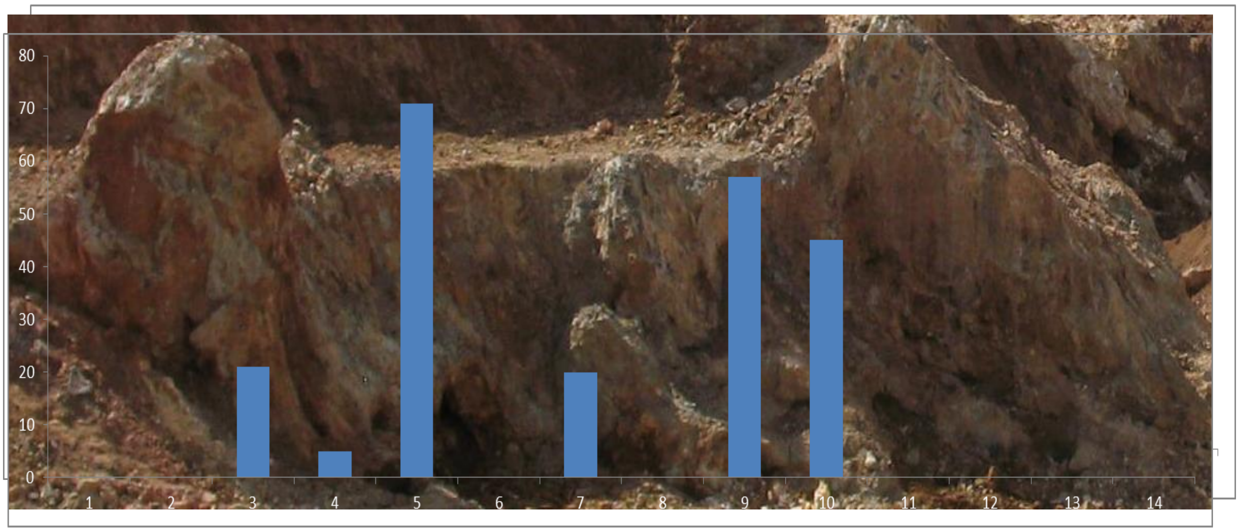


Fig. 56. Kibutu lode. B profile. A variation of a Rb content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

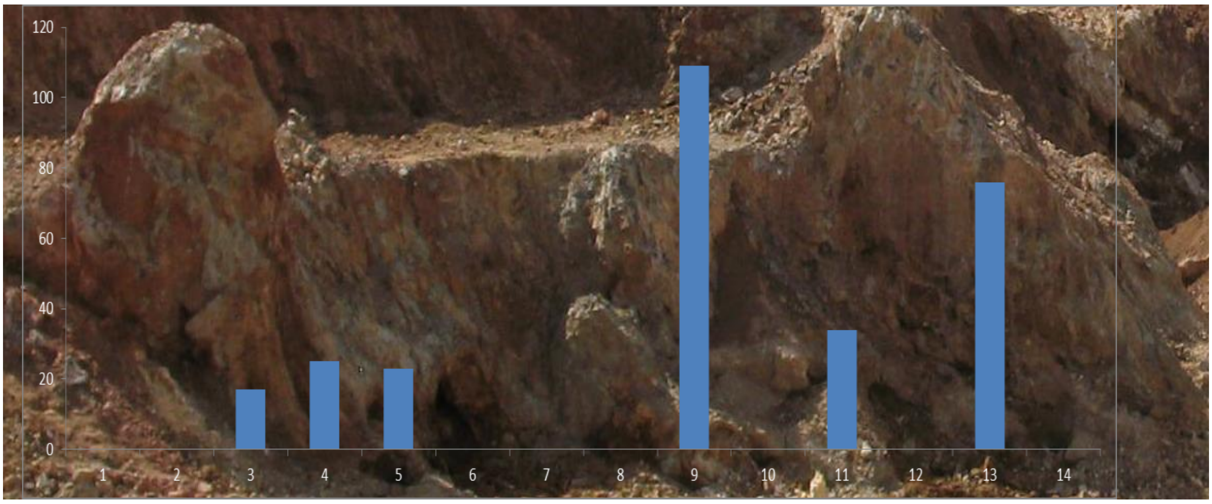


Fig. 57. Kibutu lode. B profile. A variation of a Pb content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

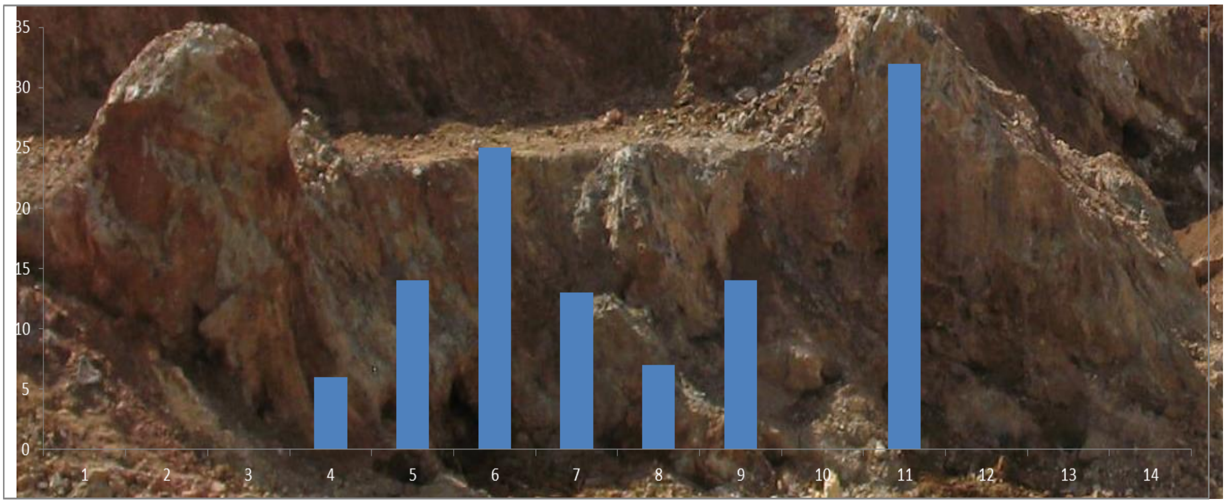


Fig. 58. Kibutu lode. B profile. A variation of a Co content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

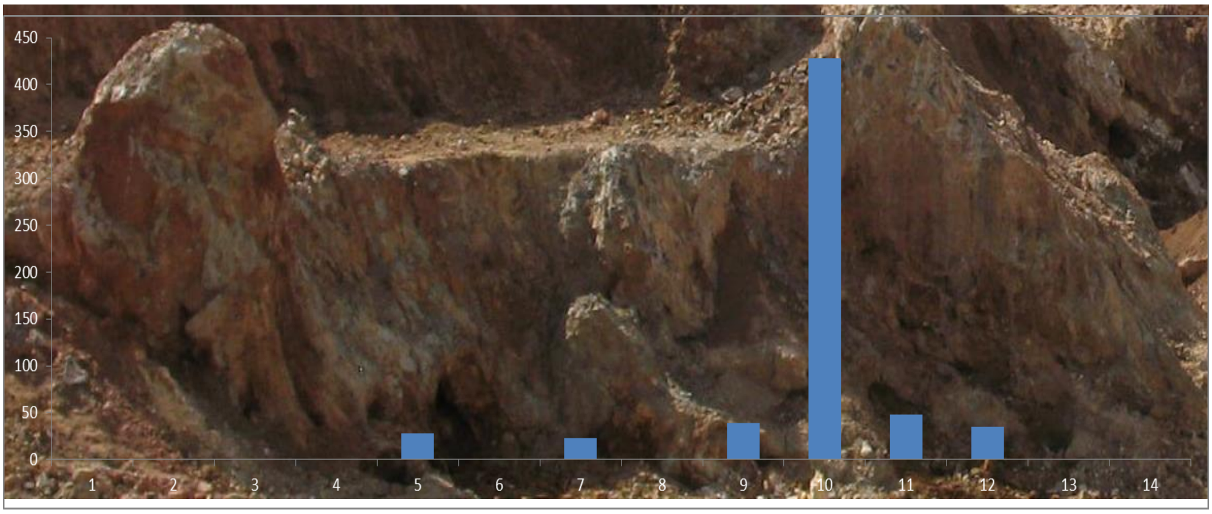


Fig. 59. Kibutu lode. B profile. A variation of a Cr content (in %) in metallic dolomite. Measurements were made in intervals of 100cm.

Localization of Kajuba's lode

Lode is located in a distance of about 60 kilometres on the north from Lubumbashi, in the direction to Likasi town. After travelling of this distance by the asphalt, it is necessary to leave at north direction and travel by a field way about 4 kilometres to a place, where severing bridge on a small river is located. After crossing over the river and travel about 2 kilometres, we get through an area of Kajuba's lode. The lode is worst recognizes, because regular mining works aren't conduct in it, and the analyse were conducted only at single, small outcrops.

Fig.60. Kibutu's lodge localization.

Basic parameters of Kibutu's lode

Lode has dimensions about 2,0 x 1,5 km and geological structure as well as genesis similar to Kibutu's lode . In fore-shaft's profiles, made by local miners, 5-8 meters of thickness terra rossa layer is observed, which contain nesting absorption of malachite, mainly in a sole.

In the area between Lubumbashi and Likasi a series of fold are observed, with very steep, saggy wings . Their axis have generally NE-SW course, with a deflection in north part of an area at W-E direction. Mentioned area intersect a set of tectonic fault in different sizes. One of them with NE-SW route also, is located from a small distance from Kajuba's lode and it isn't eliminated, that it was a main way of migration for dilutions which mineralised rocks and leading to create Kajuba's lode. Hypothetically, a river flows between an asphalt way and a lode, has exactly a river bed in the area of tectonic fault. Kajuba's lode is located in the district of metamorphic and secondarily mineralized slits of upper and middle riphean. Same Kajuba's lode appears in the ore dolomite area, classify to R2.1 formation. In the area of a site, dolomites fill almost vertically.

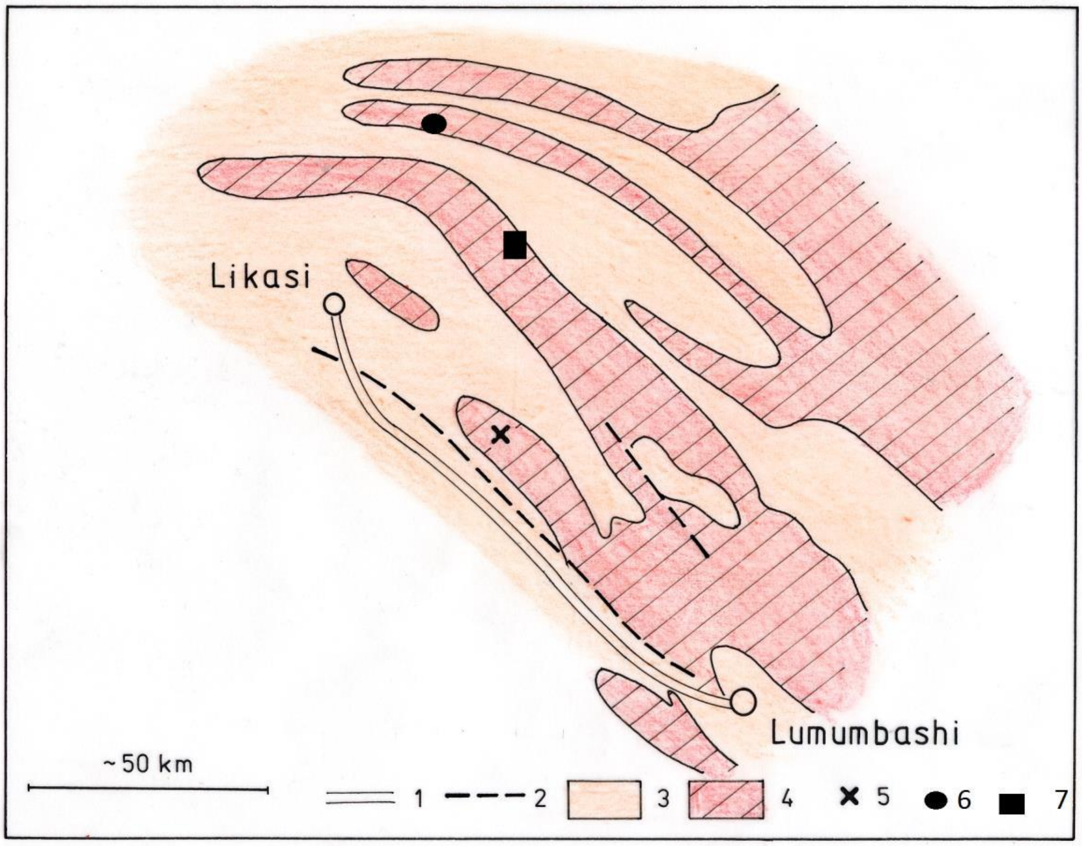


Fig.61. A schematic geological drawing of research area, localized on the north from a Lubumbashi (Shabad, 1956). 1 – ways, 2 – tectonic faults, 3 – rocks of upper riphean period, 5 – Kibutu lode, 6 – Renzo lode, Kajuba lode.

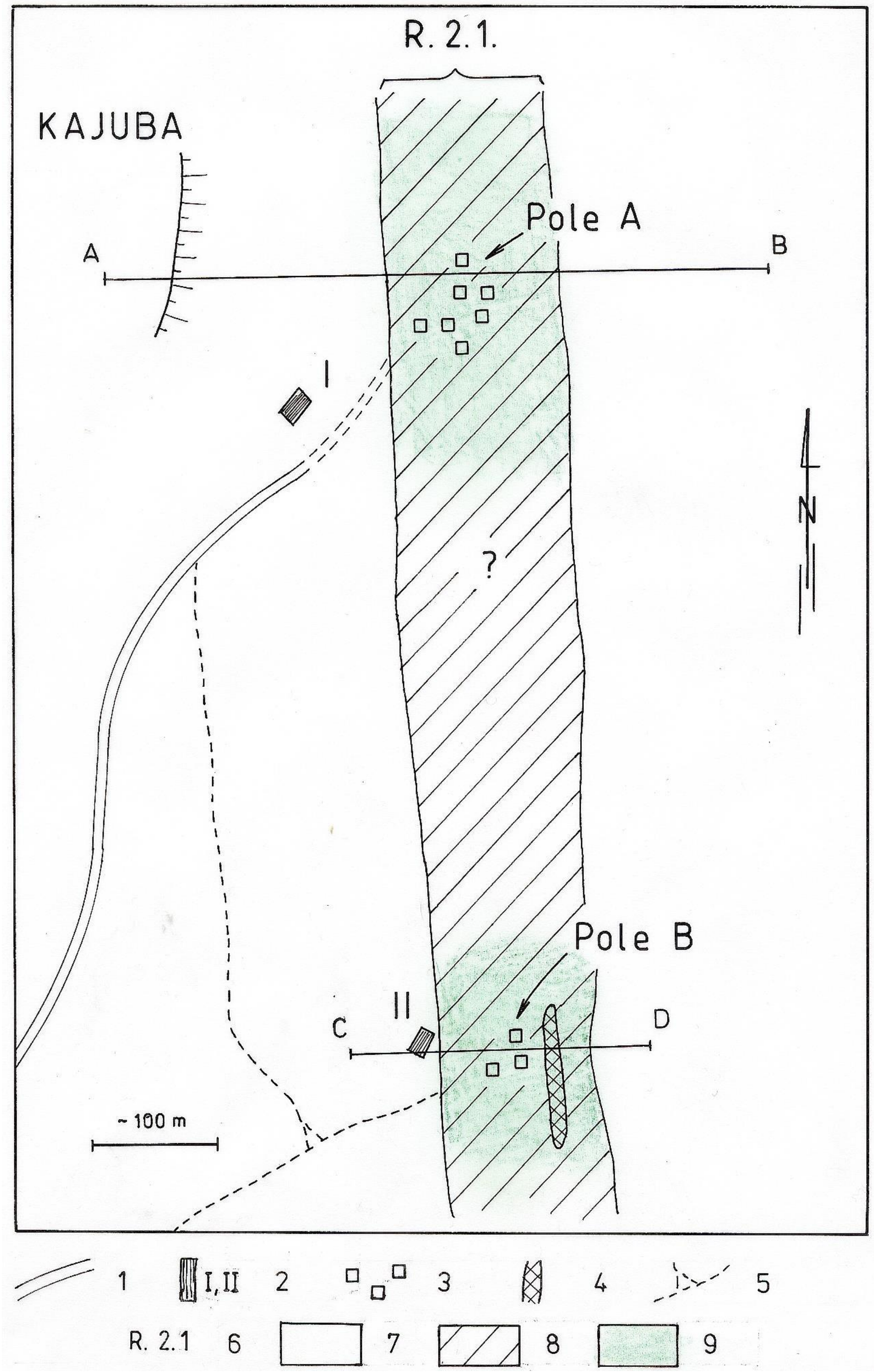


Fig.62. A schematic draft of metallurgic dolomite's appearing in Kajuba lode. 1 – ways, 2 – localization of employers' bases, 3 – mining fore-shafts, 4 – silicate dolomite, 5 – forest paths, 6 – geological formation with a metallic dolomite, 7 – rocks surrounding a metallic dolomite, 8 – copper lode sphere with an area which wasn't geological recognizing, 9 – areas of malachite's appearing in A and B exploitation fields.

The lode is located in the area of a narrow anticline, built from ore dolomites of R 2.1 series, which in the deepest parts have sulphides. In surface parts, i.e. under covered by terra rossa sole, they passing to dolomites with oxides and carbonate metals. In this residue, absorptions of malachite are lied, which originally presented in ore dolomite. Lode has N-S extension, with little aberration to E-W. Field observations allow to make initial, approximate geological intersections through Kajuba's lode. From N-S intersection follows that both A as well as B exploitation field, are located on hills amount by few meters, in comparison with located between them narrow and shallow valley. Both localization of exploitation fields (A and B) as well as an area morphology suggest, that between studying fields in stones' layers, a malachite doesn't appear. In order to better recognition of an area between A and B fields, necessary will be an use of technically drilling series to a depth of dolomite's level occurring . Carefully browsing dredge material crumbs – ore dolomite in A field, encountered for single crumbs of ore dolomite with silicates. This silicates are represented mainly by chalcopyrite and bornite. To research from A field samples of ore dolomite and rocks contain malachite was chosen, so represented by typical strain, occurring in lode . This samples were subjected by chemical analyses with the use of portable, field DELTA Mining and Geochemistry Handheld XRF Analyzer spectrometer. Results of analyses are insert in a table and on the graphs. This research shown a very little amounts of copper, in all studying samples it was an amount not passing of 1%. In relation to analysed in previous chapter Kibutu's lode, amounts of copper in A field in Kajuba's lode are little.

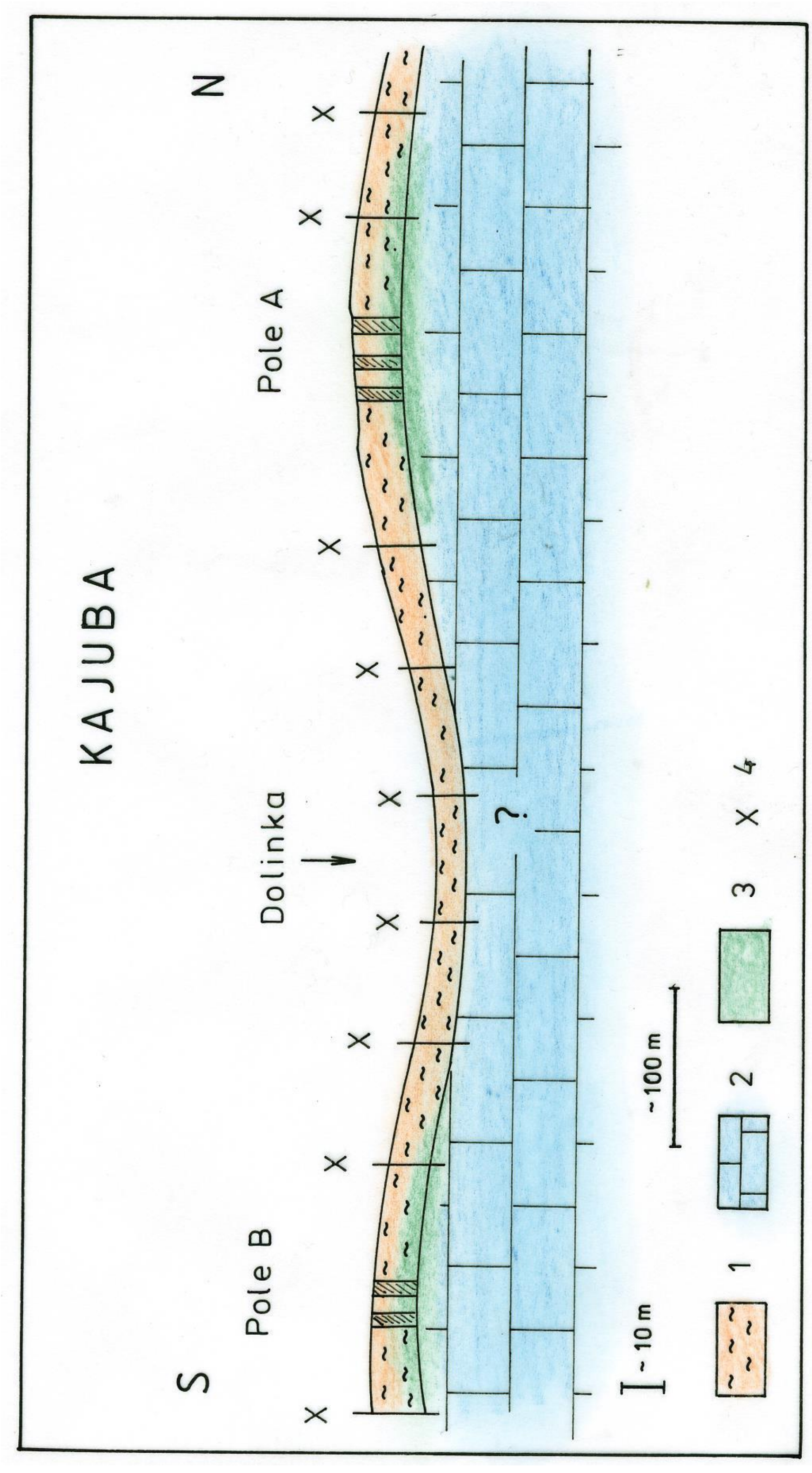


Fig.63. A schematic geological intersection of Kajuba lode, at north-south direction. 1 – red soils, 2 – metallic dolomite, 3 – spheres of malachite's appearing, 4 – places of proposed drillings.

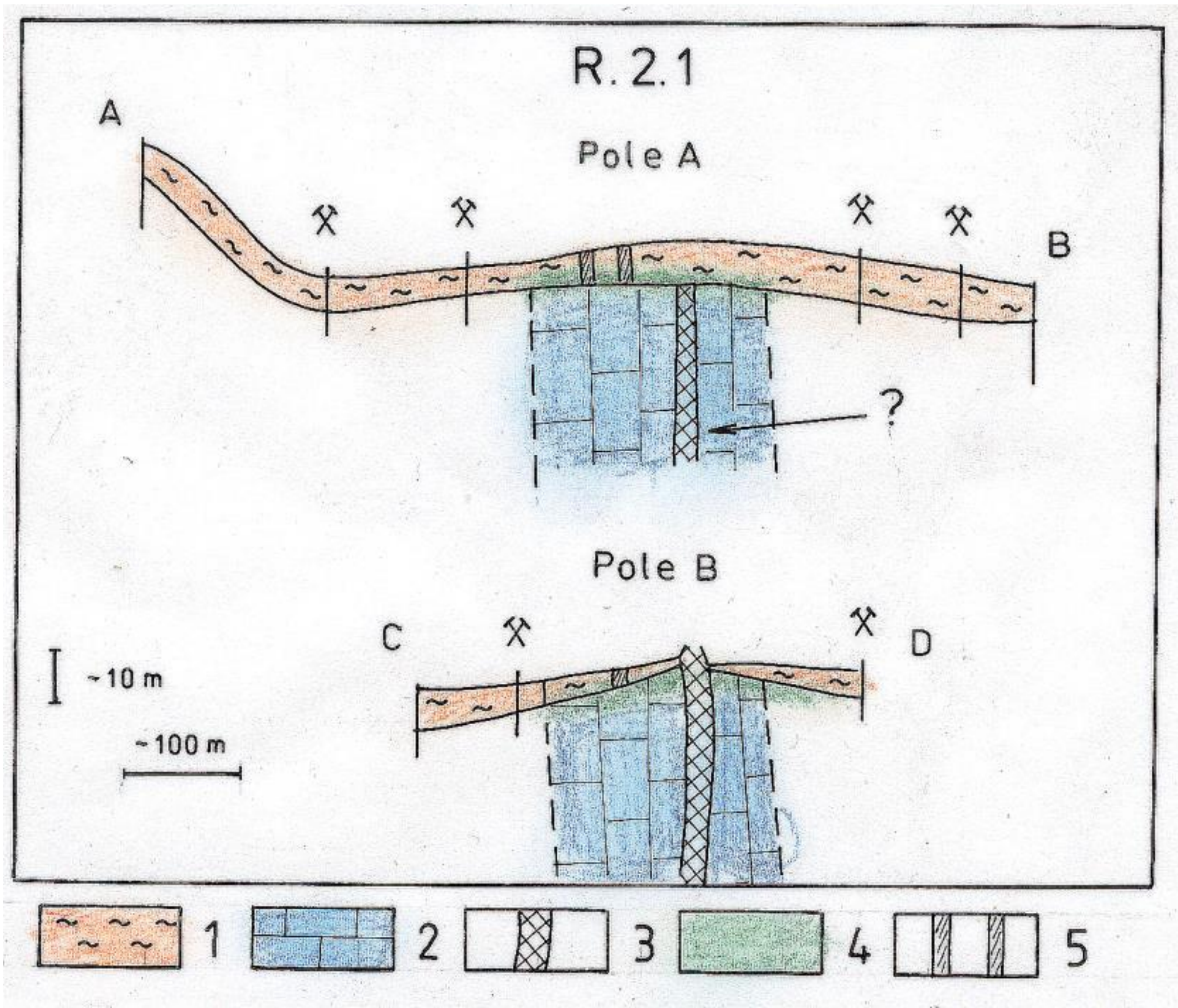


Fig.64. Geological intersections of Kajuba lode. Upper – intersection in the east-west direction within the north exploitation field (field A). Lower – intersection in the east-west direction within the south exploitation field (field B). 1 – terra rossa, 2 – metallic dolomite, 3 – silicate dolomite, 4 – spheres with a malachite, 5 – miner’s mining fore-shafts.

Tab.7. Kajuba's copper lode – results of geochemical analyses (ppo – below determination level) of rocks' samples from Kajuba lode (field B).

Składnik	Próbki					
ppm	Ka1	Ka2	Ka3	Ka4	Ka5	Ka6
Fe	24,26	69,6	4,42	9,27	2,89	13,87

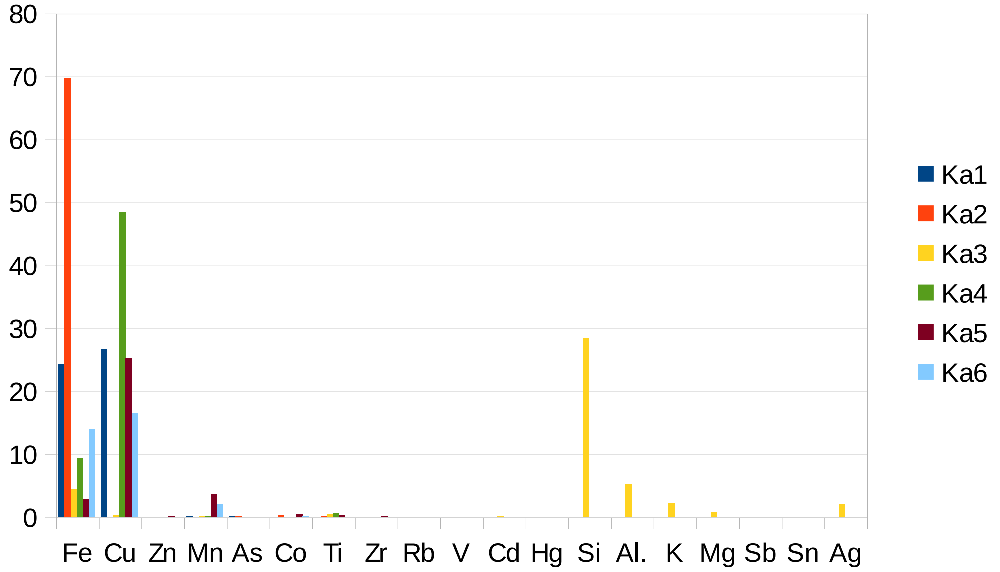


Fig.65. A collective graph of metal's content in studying rocks' samples from Kajuba lode (field A) (results in ppm).

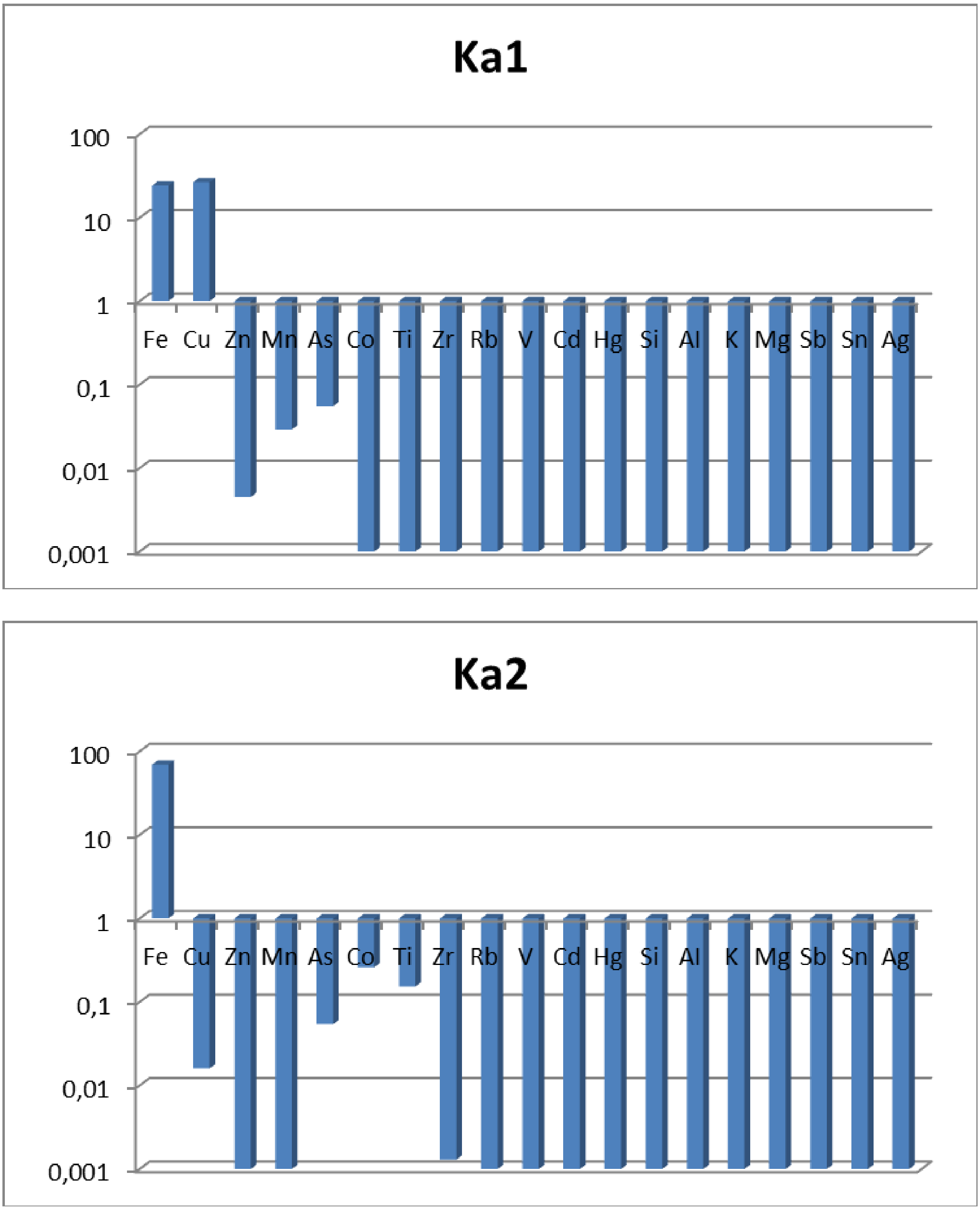
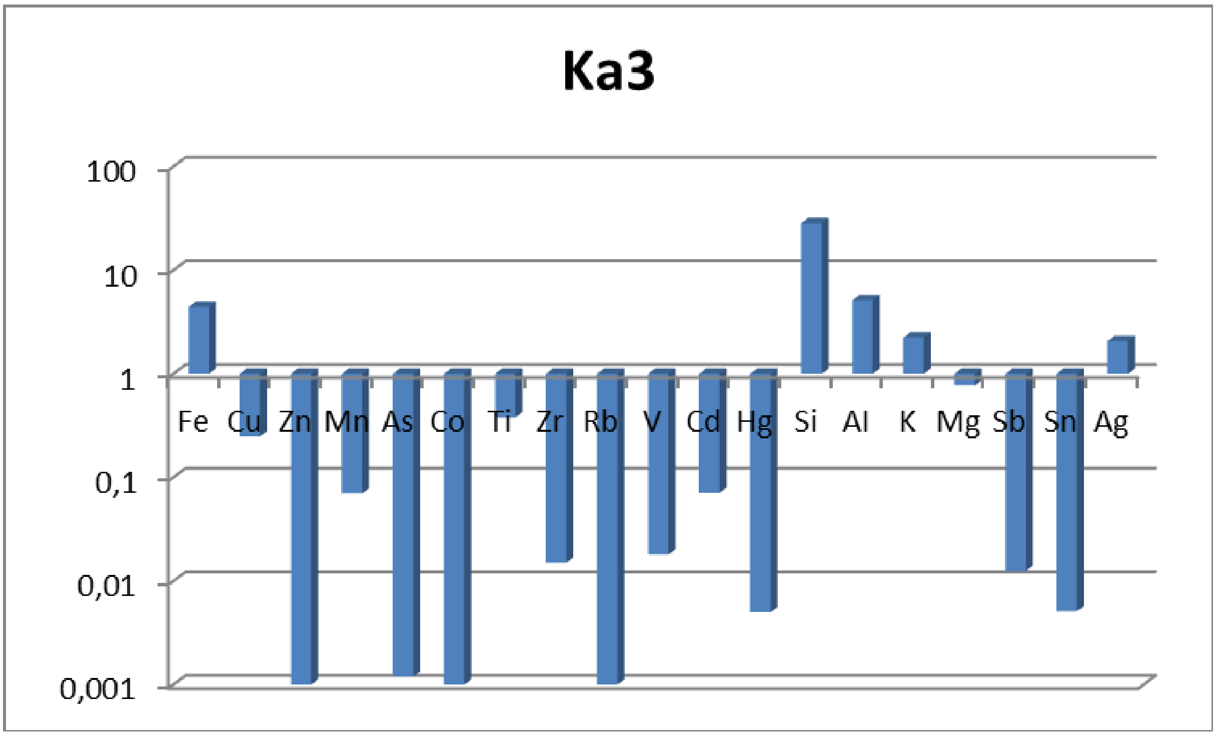


Fig.66. Graphs of metals' content in Ka1 and Ka2 samples, Kajuba lode (results in ppm).



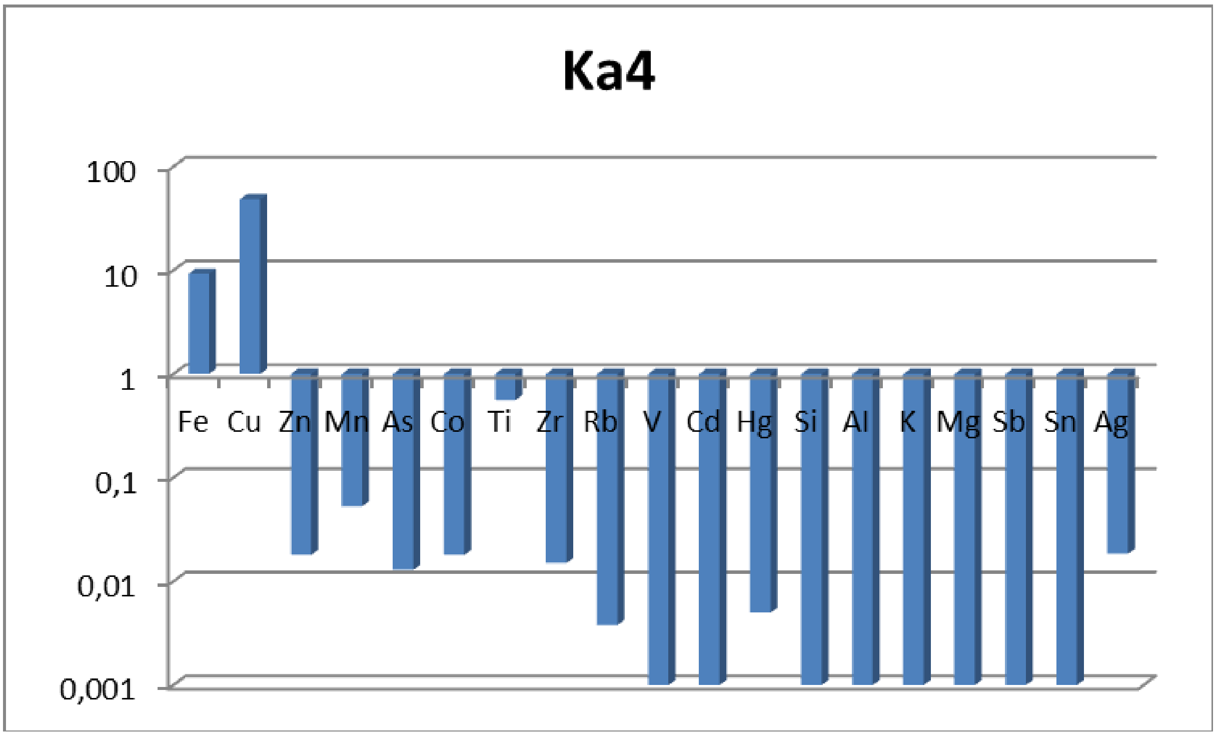
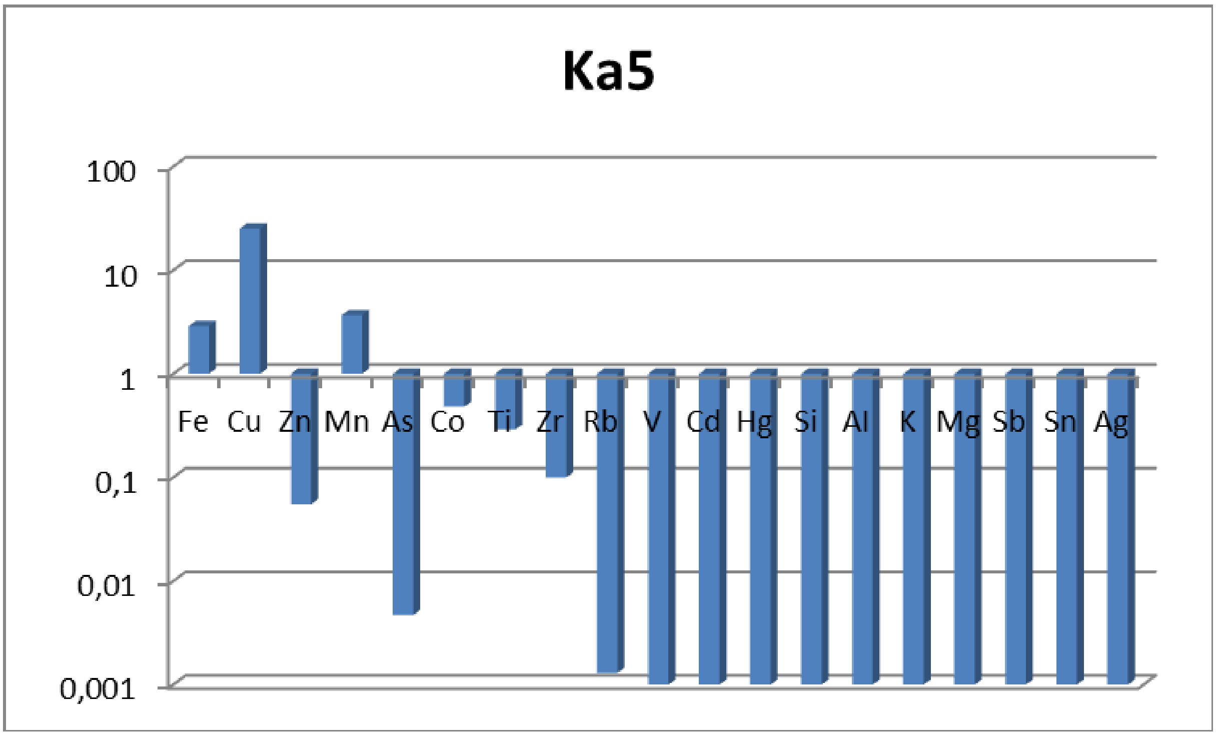


Fig.67. Graphs of metals' content in Ka3 and Ka4 samples, Kajuba lode (results in ppm).



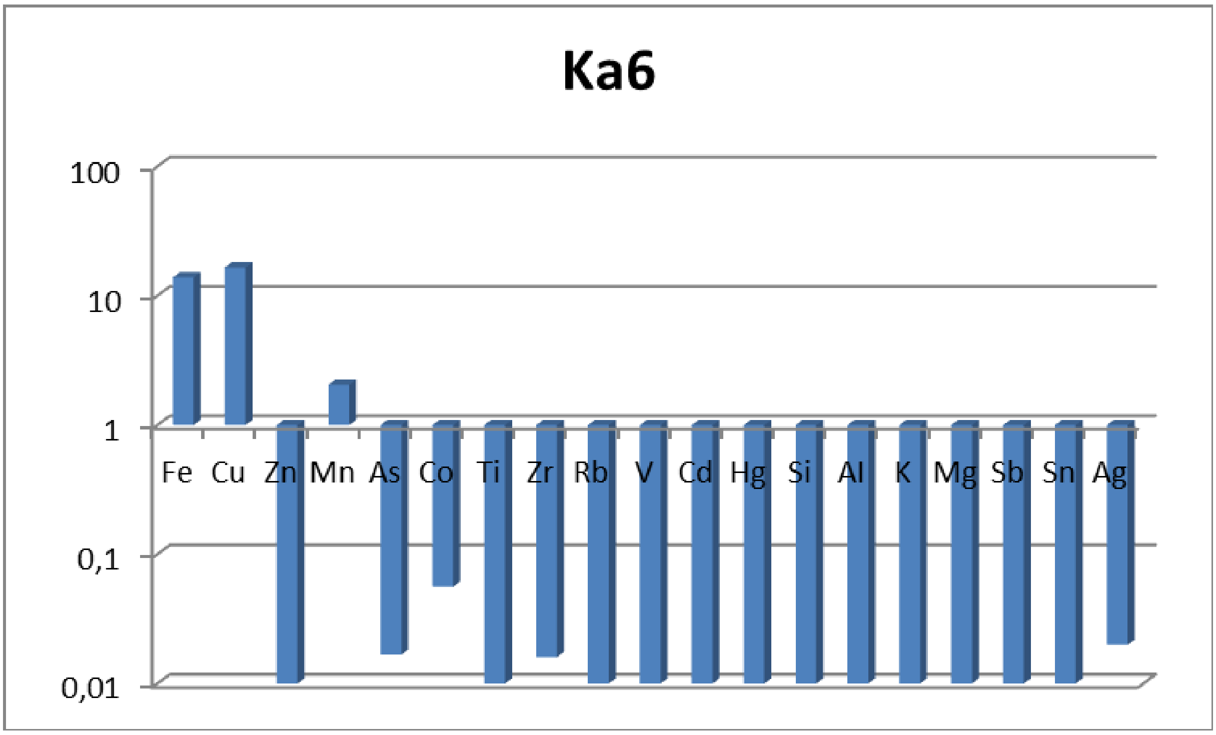


Fig.68. Graphs of metals' content in K5 and Ka6 samples, Kajuba lode (results in ppm).

Tab.8. Content of chosen metals in concretions with a malachite, localized near fore-shaft in B exploitation field. Research were made by a portable Delta Handheld XRF Analyzer and it shows a content of single chemical elements.

Kajuba (%) Pole B				
Metals	Probe Ka7	Probe Ka8	Probe Ka9	Probe Ka10
	Kaj1	Kaj2	Kaj3	Kaj4
Fe	9,5	4,68	5,93	7,68
Cu	1,31	0,9	1,04	1,40
Mn	2,98	1,36	1,26	1,92

Mineralogical and petrographic research of Kajuba's lode

Microscopy analyses of samples, gathered in a field, were made. Each microscopy analyses were similar to each other in significant way, so presenting are selective results, which should be treat like average and typical for studying area.

Also analytic research were made in Critical Chemical Elements' Laboratory by AGH-KGHM, with the use of electron microprobe. Samples, which contained copper ore minerals, occurring in the form of sulphides. Research with the use of electron microprobe affirmed an occurring of absolute with the using of earlier ore minerals' methods. Additionally, it succeed to identify an occurrence of small amounts of silver in inclusions and chalcocite's veins , similar as in Kibutu's lode. In analysed samples from Kajuba's lode were identify: a chalcocite, a chalcopyrite and bornite.

In analyses samples chalcopyrite mineralization was dominated, in the form of inclusion and fillings a chalcocite occurred, and in small amounts – a bornite. In one of samples it succeed to identify a tiny grain (10 micro-meters of length) of tetrahedrite. Its presence weren't stated by other methods and in other samples, but on account of it, that with the identify and quite often occurring of tetrahedrite in samples from a Kibutu's quarry, it create an isomorphic series. It is a chance, that it can be occurring in bigger amounts. Unfortunately, a limited amount of samples didn't allow to confirm this state.

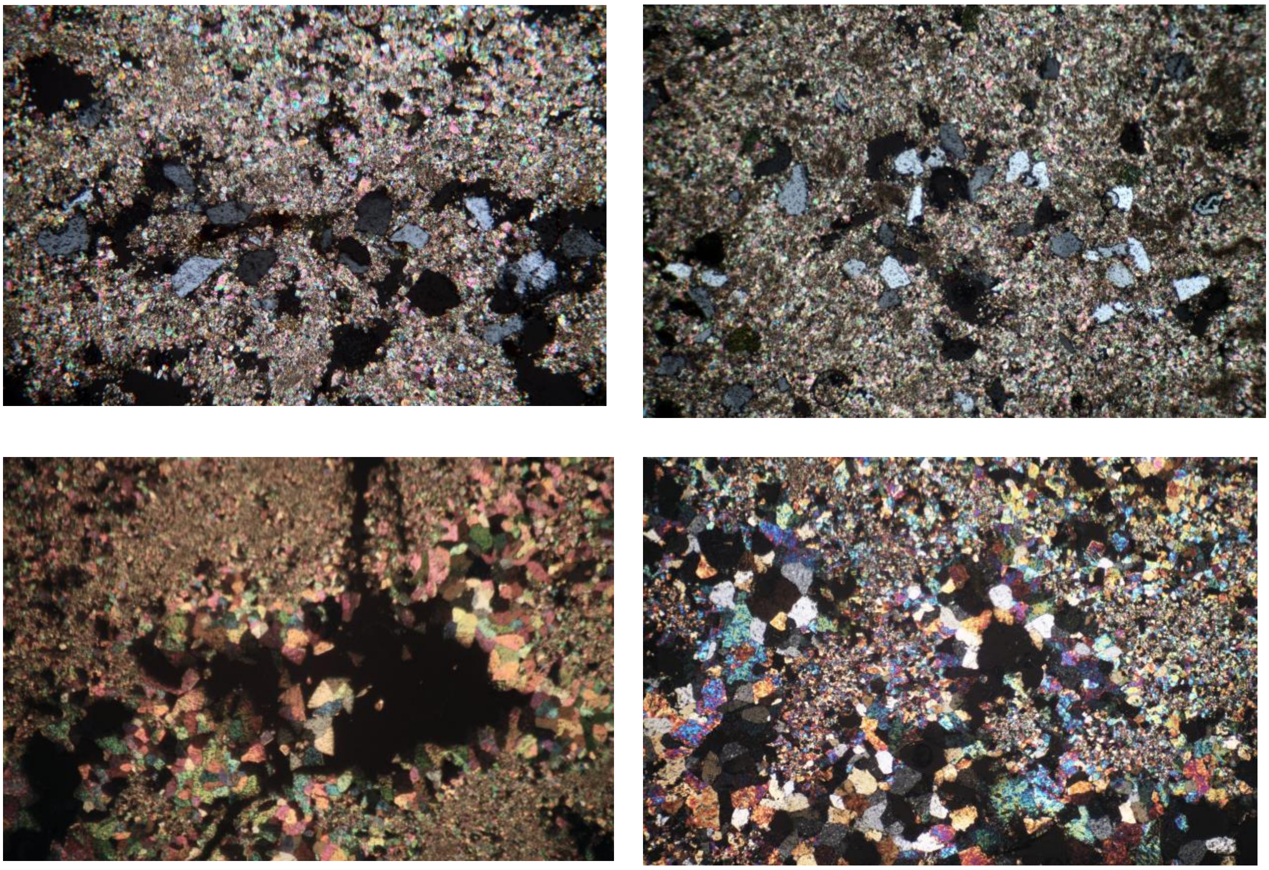
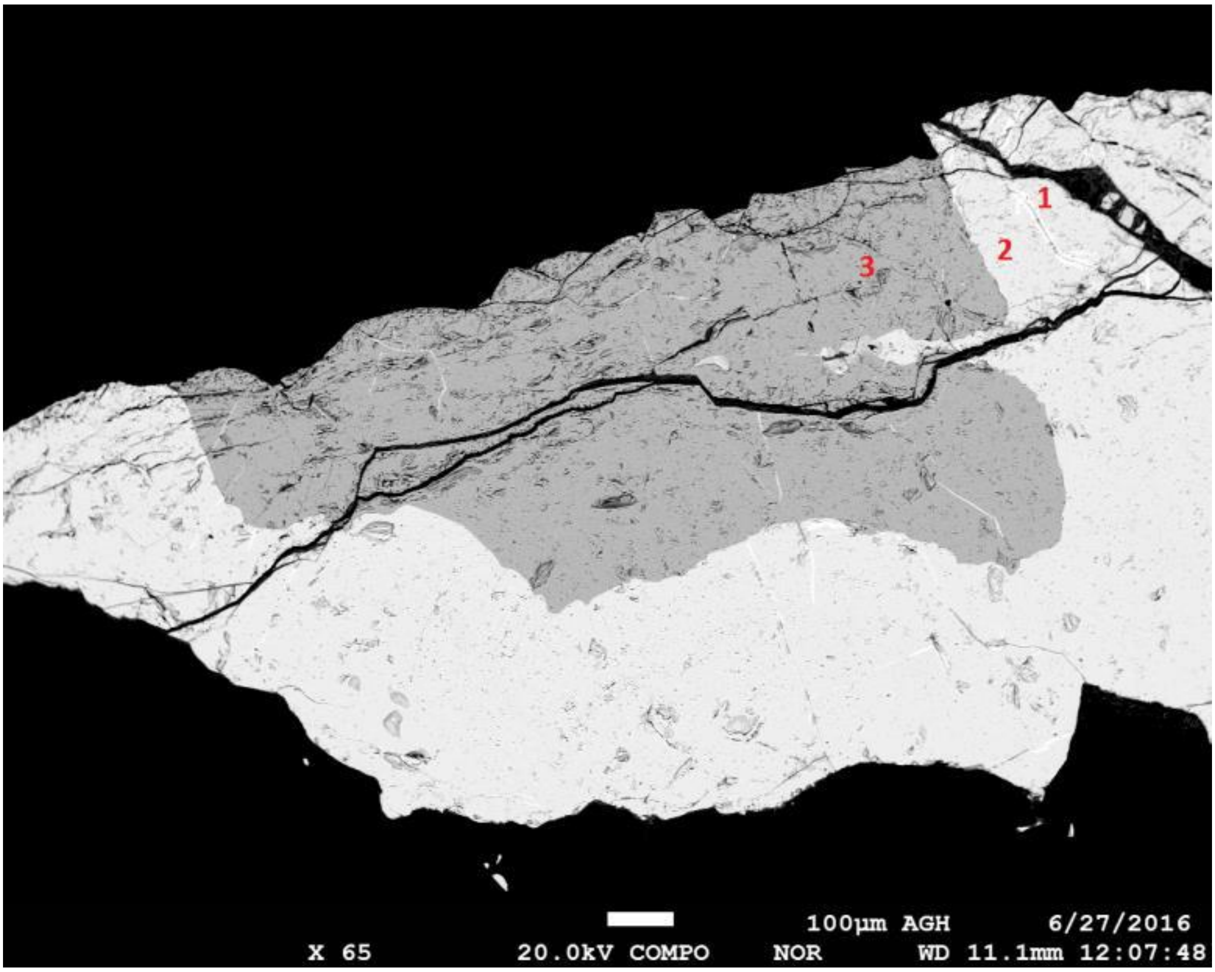


Fig.69. Kajuba lode. Field A. Examples of dolomite's structures, appearing under red soil. A – a dolomite with single, diffuse grains of quartz, B – a dolomite with quartz's grains, which underline velvet rock's stratification, C – a dolomite with sulphides (dark spots are sulphides), D – a dolomite with variable crystallization. Polarised microscopy, X polarizers, zoom 120x.

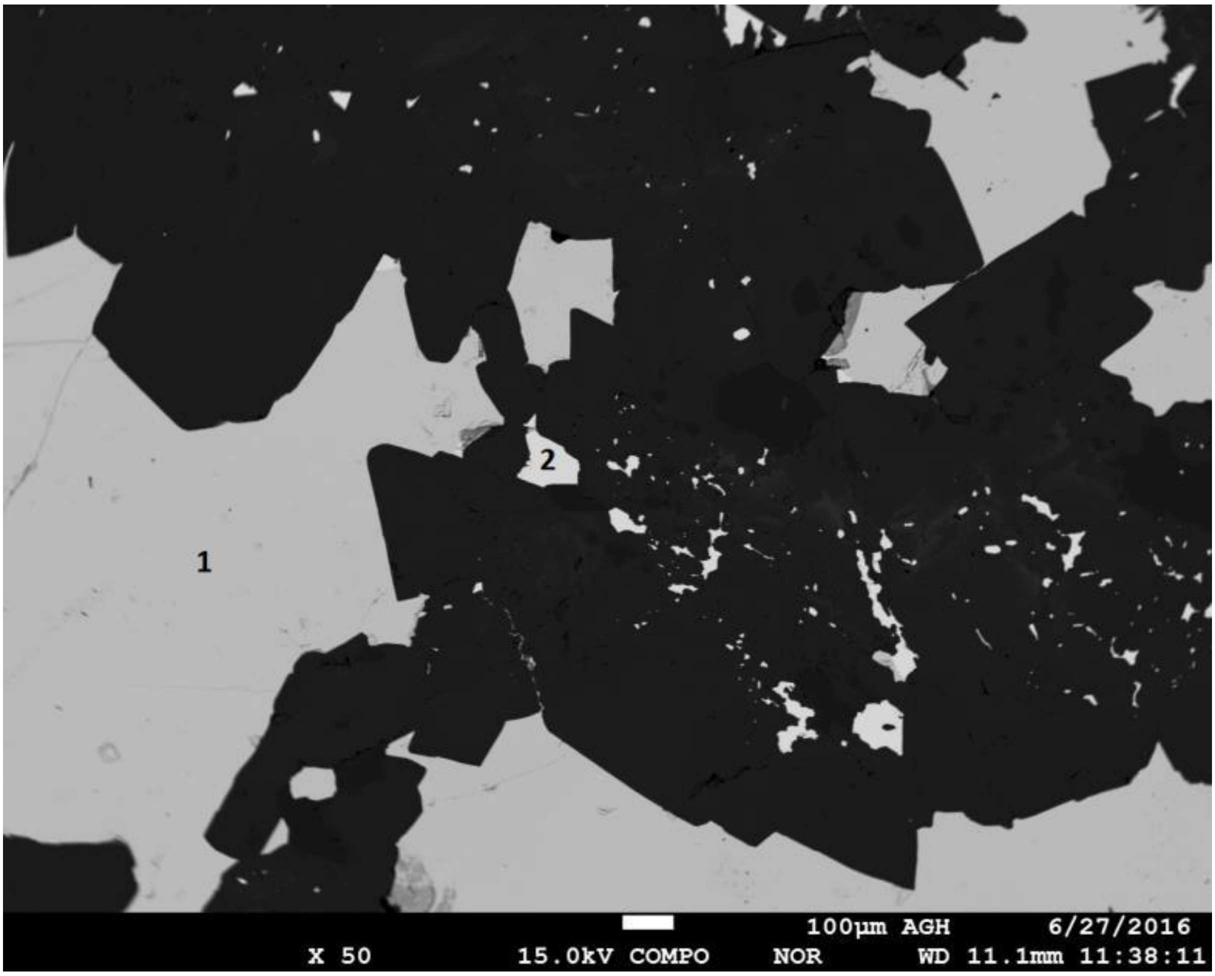
Present condition of Kajuba's lode recognition , allow only for initial qualification of mineralogical – petrographic character of rocks presenting here. Ore dolomite, with appears under red soil, was recognised only initially, based on its crumbs, which were carried out on a surface by miners, during exploitation of 'wild' fore-shafts of A and B field's. This rocks were matched to a stratigraphy scheme of lode, quoted by literature. Macroscopy research allowed to recognise by ore dolomite following minerals: a dolomite, a calcite, a siderite, a malachite, a manganite, a goethite, a hematite, a rhodochrosite and a gypsum. In this stone material, came across for single crumbs of dolomite with silicates, though mainly were dominated fragments of weakly ore, mainly diffuse malachite's ore of dolomite. Kajuba's lode, although is located in older creations than Kibutu, has a character approximate to it. In it appear two types of complex mineralization, i.e. malachite (M) in upper part and lower – dolomite (D).



No.	In	S	Bi	Mn	Fe	Cu	Ag	Sn	Cd	Pb	Co	Se	Total
1	0.028	22.486	0.100	0.007	2.013	75.387	0.278	0.012	0.021	0.050	0.004	0.136	100.522
2	0.059	25.484	0.104	0.000	11.328	62.362	0.171	0.023	0.009	0.061	0.011	0.002	99.614
3	0.080	34.360	0.174	0.000	30.334	34.258	0.000	0.011	0.012	0.063	0.030	0.000	99.322

Fig.70. SEM micro-photography of dolomite sample's with sulphides and results (in weight %) of an electron microprobe's analyse. 1 – a chalcocite (a vein), 2 – a bornite, 3 – a chalcopyrite.

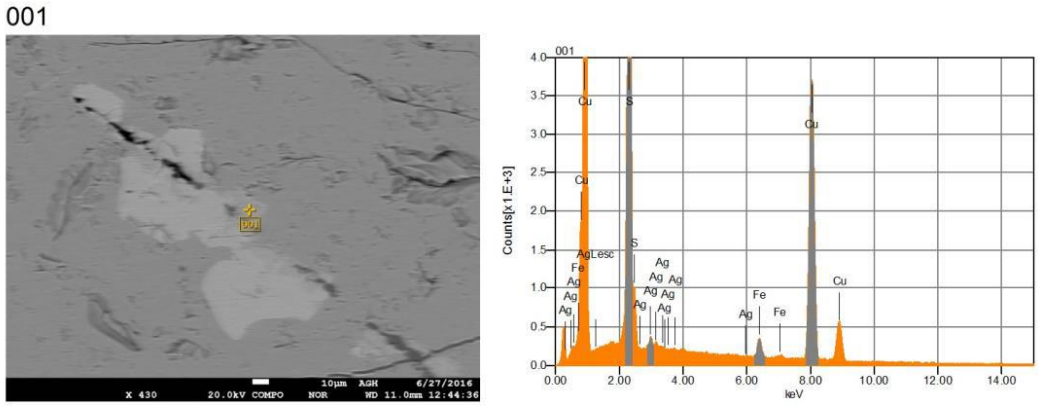
Upper lodes are airing malachite (M), where a malachite appears, with other minerals, in terra rossa soils and in ore dolomite's roof – but in this case amount of malachite is less and hasn't got economic base to profitability of its mining. Dolomites lode (D) also consists of two parts. Upper airing part contains products of initial silicates airing. Lower part of dolomite lode (D) is a dolomite with silicates of copper and iron.



No.	In	S	Bi	Mn	Fe	Cu	Ag	Sn	Pb	Co	Se	Total
1	0.058	34.459	0.169	0.000	30.045	34.159	0.006	0.014	0.041	0.028	0.056	99.035
2	0.015	25.853	0.127	0.012	11.425	62.089	0.064	0.016	0.043	0.003	0.000	99.647

Fig.71. SEM micro-photography of dolomite sample's with sulphides and results (in weight %) of an electron microprobe's analyse. 1 – a chalcopyrite, 2 – a bornite.

A contact between silicate sphere and airing sphere in ore dolomite is located on unknown depth, for its evaluation necessary will be making of at least few orientated drillings.A resource of malachite in Kajuba's lode aren't very big, especially if an occurring of malachite in red soils, limitate to field A and B only. If only M lode is extended also between A and B fields, resources of malachite should be recognized as average and interesting. A range of M lode should be check by the same schedule of drillings. D lode is less mineralised with copper (2-3% of sulphides all together), but a thickness of this layer, based on Kibutu's lode can be significant. A raw material, originate from its lode require other sample and differently conducting metallurgic process than it is in the case of malachite's' ore from Kibutu's ore. This lode is located in one of the fields of American concessive mining concern. Probably, after more précising geochemical analyse, it wasn't decide for starting of mining works in this place. By bordering localizations with a huge amount of copper, Kajuba's lode seems to be less attractive in point of economy. However, local people for a small scale mined an ore by own forces, by digging deep fore-shafts, by with an ore is bringing on the surface. Rocks are crumbing and sorting, and so initially processing product, catch to a local purchase or for illegal markets, about which in oral message, a local pastor was mentioned during a conversation.

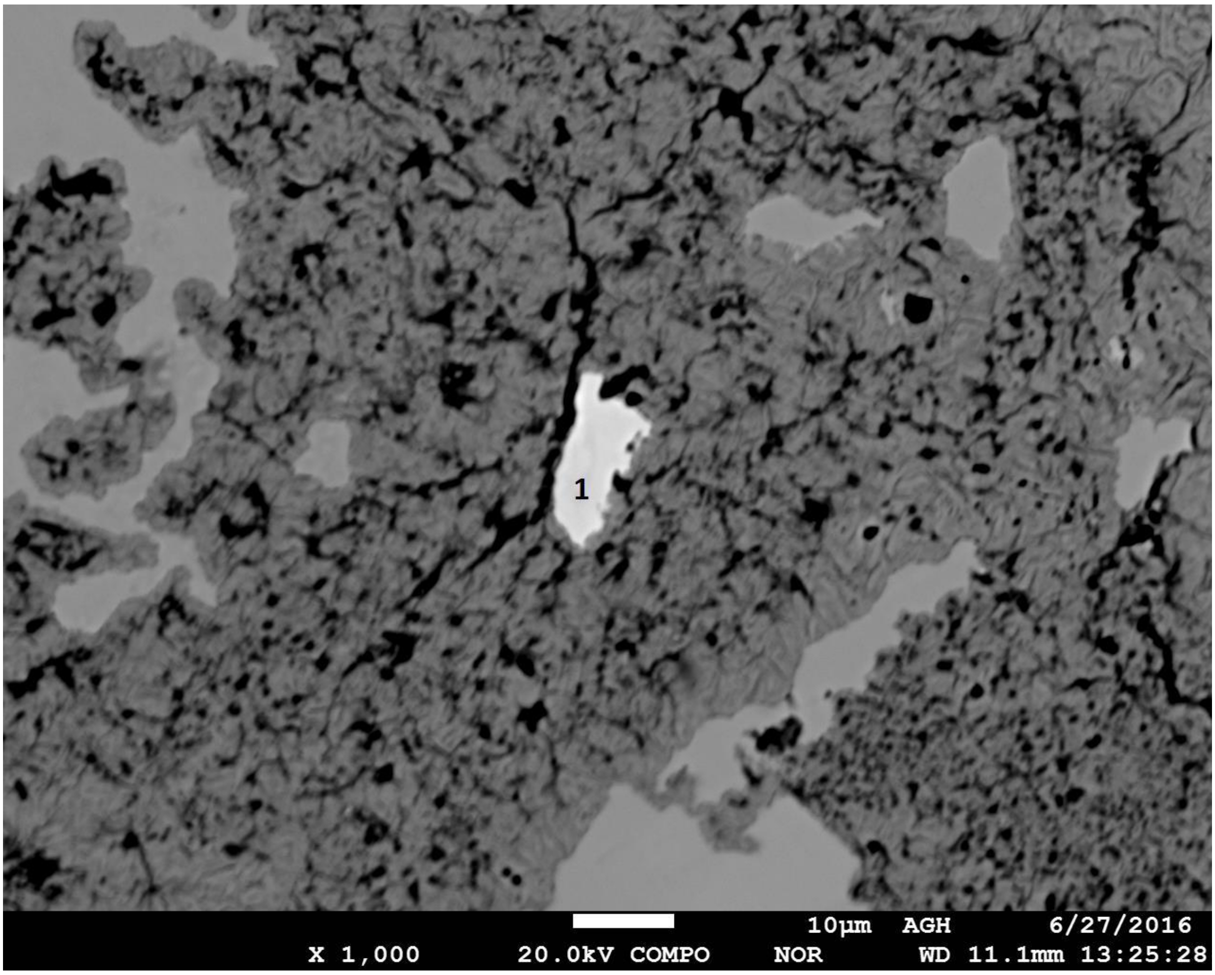


Volt : 20.00 kV
Mag. : x 430
Date : 2016/06/27
Pixel : 1280 x 960

Acquisition Condition
Instrument : 8530F
Volt : 20.00 kV
Current : ---
Process Time : T3
Live time : 55.58 sec.
Real Time : 60.00 sec.
DeadTime : 8.00 %
Count Rate : 8536.00 CPS

Chemical formula	mass%	Atom%	Sigma	Net	K ratio	Line
S	26.86	42.19	0.01	3551639	4.6565622	K
Fe	2.19	1.98	0.01	134768	0.5066234	K
Cu	69.67	55.24	0.04	2328216	14.2411410	K
Ag*	1.28	0.60	0.01	91873	0.1915452	L
Total	100.00	100.00				

Fig.72. SEM micro-photography of dolomite's sample with sulphides and EDS analyse (made by a countershaft of electron microprobe). In part of venoms a presence of a silver was identified.



No.	In	As	S	Bi	Sb	Zn	Mn	Fe	Cu	Ag	Sn	Cd	Pb	Co	Se	Total
1	0.021	3.527	25.236	0.318	23.152	7.196	0.016	0.818	40.133	0.295	0.164	0.046	0.090	0.024	0.042	101.078

Fig.73. SEM micro-photography of dolomite's sample with sulphides and results (in weight %) of an electron microprobe's analyse. 1 – a tetraedrite.

Slags

Slags' mineralogical research provide information about phases creating in a blast furnace. Their chemical composition is often richer from natural raw materials, from with they are creating, which is a result of a variation of slag alloy's crystallization conditions.

Research results describing below, concern slags creating from copper melting of ores gained from Kibutu's lode. In this region the main raw material, leading to copper obtain, is a malachite, which is obtaining from local lodes. A malachite has a secondary origin, because it created as the result of silicates airing, located in dolomite's lode roofs. They are covered by red clays, which composing a residue after airing carbonate rocks. A malachite's ore contains even to 56% of gravimetric copper, additionally in it there are small

amounts of: a silver, an iron, a manganite, and also a rubidium, a tungsten as well as a zinc and others. Due to some mineralogy and chemical instability of ore obtain to cupper production, invariably essential is accurately leading of metallurgic process and such ingredients' selection so that in each melting, a process will be optimal and it would be obtain possibly the biggest amount of copper occurring in an ore. Except of a malachite, essential component of metallurgic batch are iron's raw materials, represented almost only by a hematite, obtained also from local lodes. At the same time, a few varieties of crystallographic hematite are used, both crystallise hematite – iron's glance, witch in this region occurs together with a limonite, as well as a fine-crystalline hematite with a siderite, and rarely occurring in a lode – a hematite mineralised by a malachite. Hematite's addition aim, is to absolve most amounts of oxygen in metallurgic process, which simplify cooper melting from a malachite.
A malachite is also treat as a flux, that is a component, which decrease a temperature of copper melting. It causes thus, a decrease of energy consumption in metallurgic process. In this way it reduces an expenditure on energy carrier, that is a black coal, which as one of necessary components to copper melting, have to be import from extensive distances more often. Presenting research were made to considerate a designation of optimal metallurgic process conducting of copper, received from a malachite. Essential element was also definite of admixtures kinds and their amount in metallurgic refuses. It is essential both in elaborate of refuse technology and alternative using of a components' part from after-production refuses, as well as at recognition of potentially danger for natural environment.

Components of slags were divided for four groups, in which assigned:

- an enamel;
- precipitations of metals (cupper);
- siliceous phases;
- oxygenic phases.

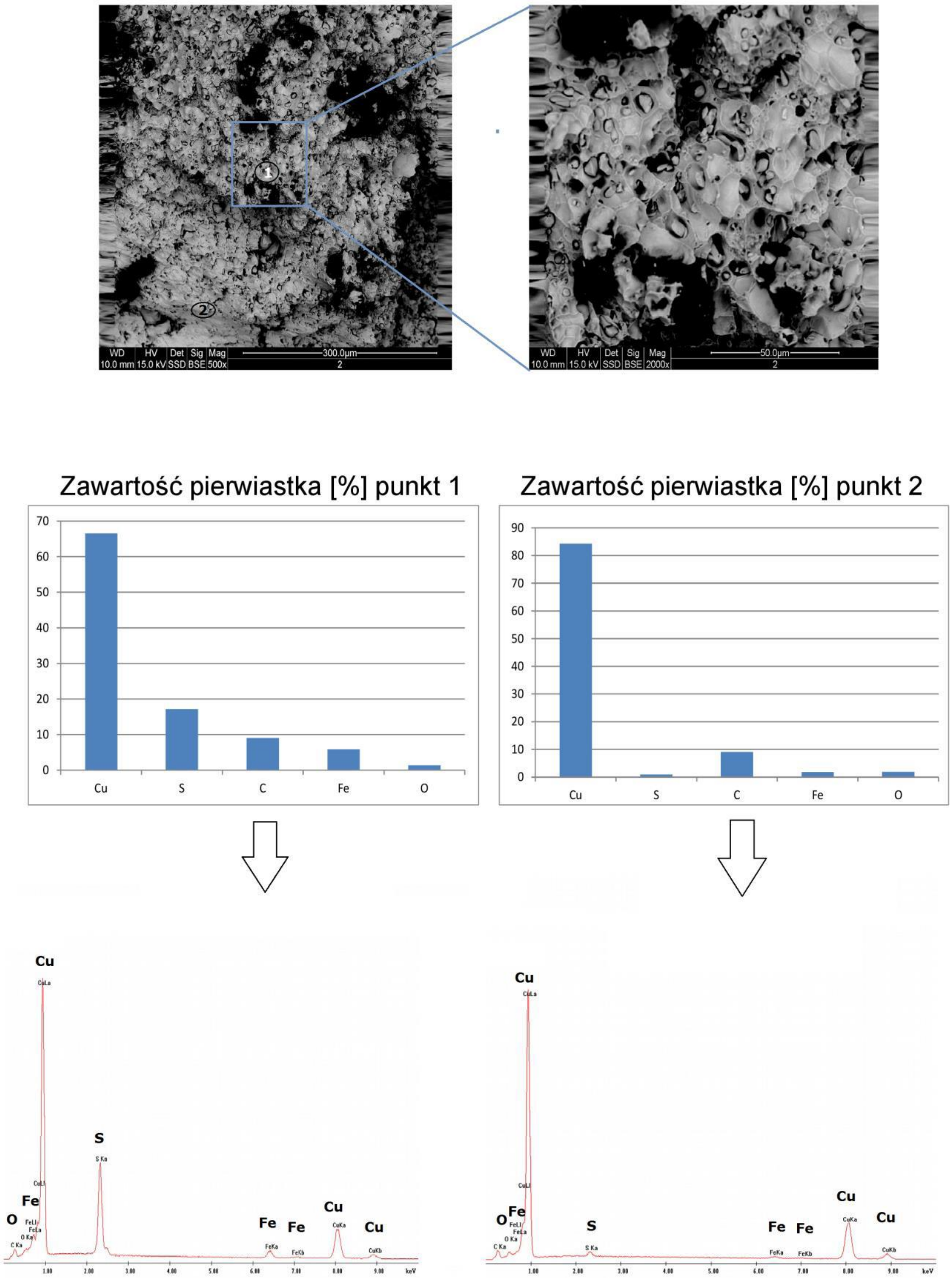


Fig.74. SEM micro-photography and EDS phantom of slag enamel with chemical analyse.

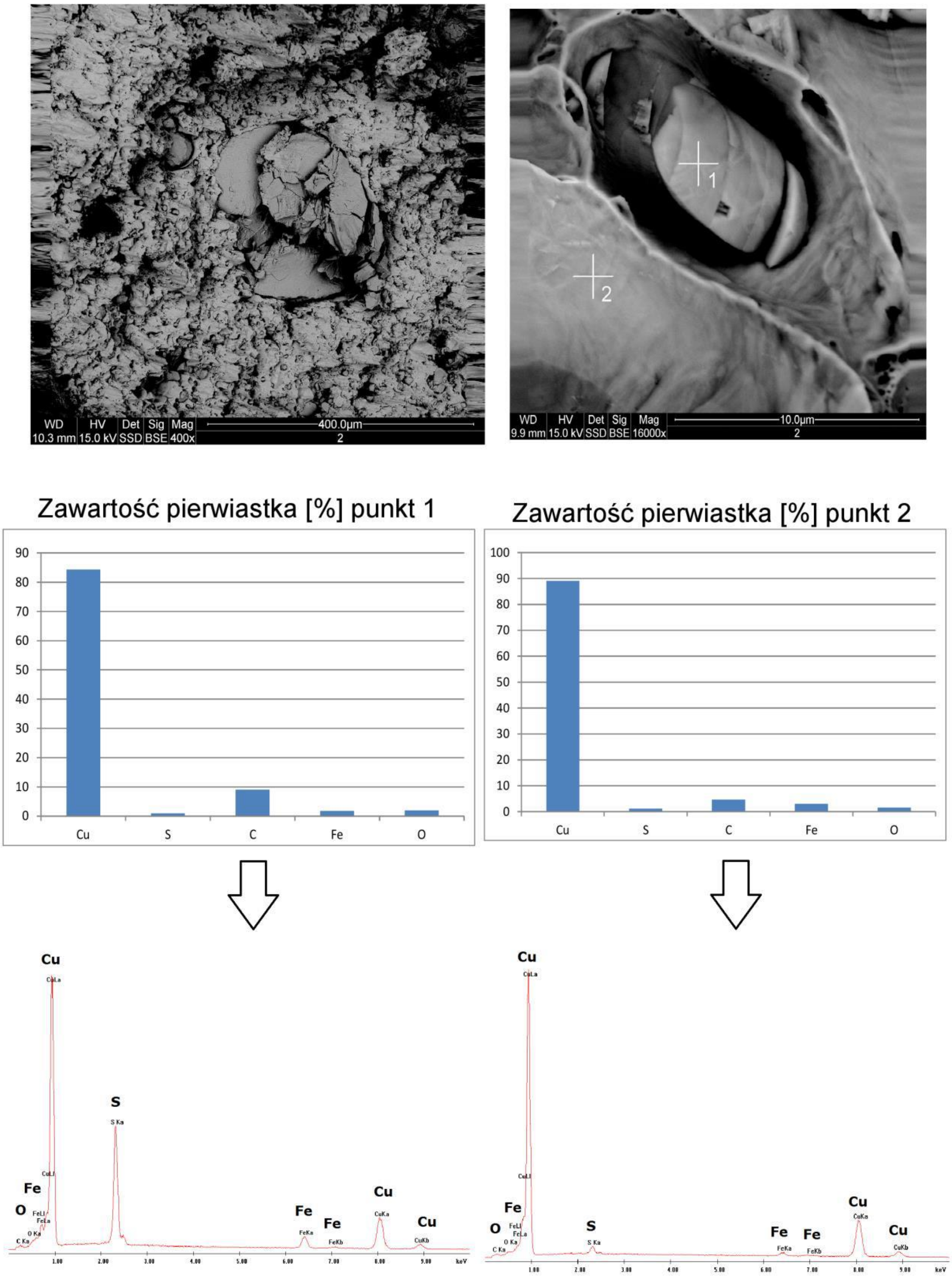


Fig.75.SEM micro-photography and EDS phantom of slag with precipitations of metals and chemical analyse of this.

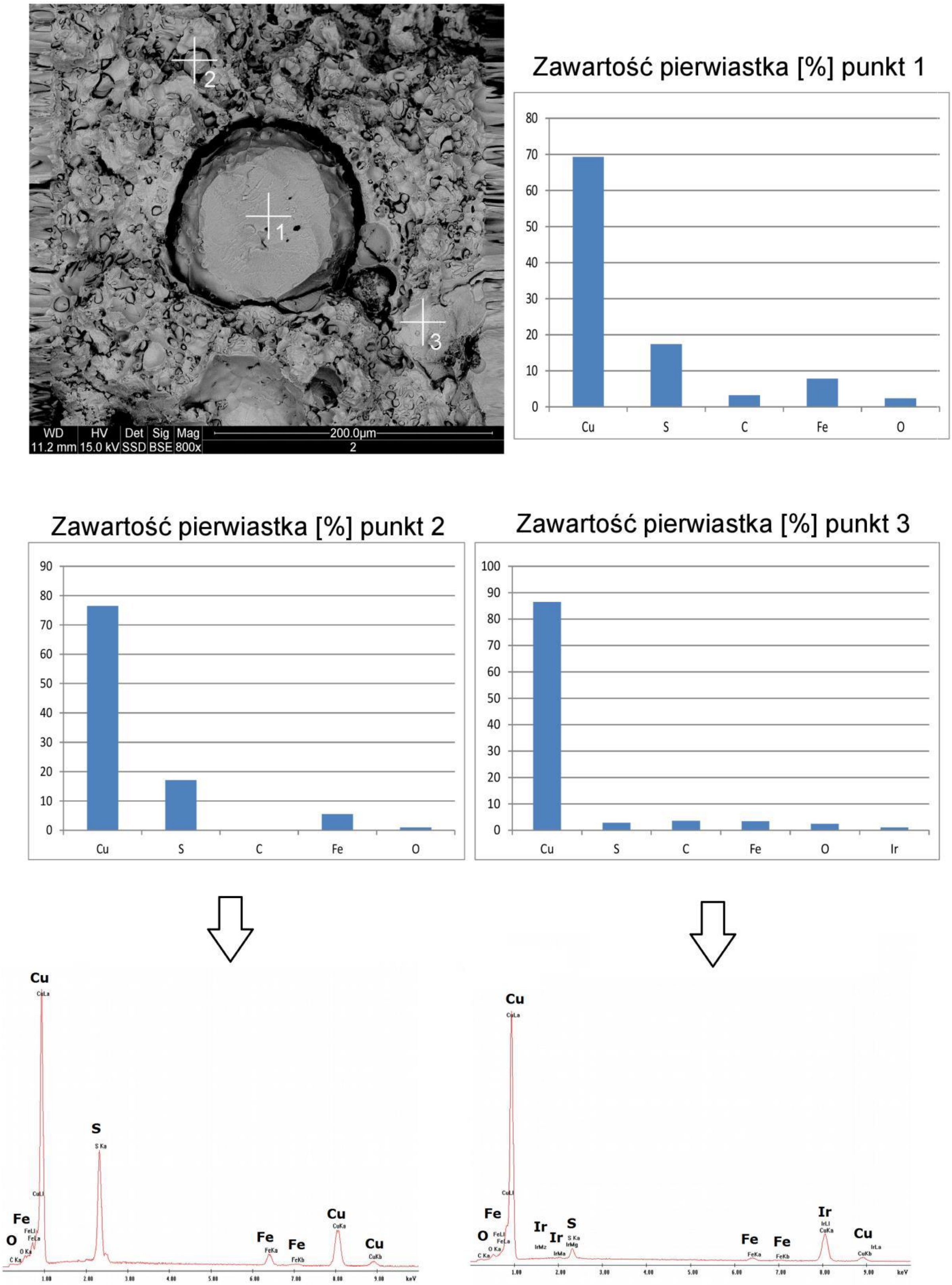


Fig.76. SEM micro-photography and EDS phantom of slag with copper grain and chemical analyse of this.

Macroscopic observations allowed to divide collecting material for: slags performing in the form of slag's sinters , in the form of an enamel and different types of after-metallurgic components clusters' , that are predominantly clusters of slags' fragments or small, often metallic immersions of metals.

Analysing microscopic images, it was stated that in slags, often than an enamel, secondarily shaped crystallites, oxidize metals and metallic remains from an ore perform. An enamel in slags demonstrates a differential rank of comportment, depending on the age of refuses. In slags directly coming from blast furnace, which weren't store yet, fragments of well-preserved, not-broking enamel in transmitted light are observed. In the wake of slags storing on spoil dumps, by the operation process of airing, it comes to an enamel's devitrification – on its surface a system of cracks appear, which lead to a sprinkle of an enamel for small fragments. Relatively small amount of an enamel is connected with cooling conditions of after-metallurgic products. Slag's alloy undergo cooling only in atmospheric conditions, which in Central Africa region don't foster of fast cooling. The slower is cooling, the smaller is amount of an enamel, whereas in bigger amount i.e. silicate phases are created (Sobczynski, 1999).

In enamel's surroundings precipitation of metals often occur. They connect with remains of not-reduced copper and to a lesser extent of iron oxide also (mainly of a hematite). Metallic precipitations create both round-orbicular structures as well as completely irregular.

Interesting effects were achieved during research with the use of scanning microscopy. This research allowed to observe a surface of slags, applying a zoom about 20 thousand times. Registered images are showing a porous surface of slags with inherent inside metallic scraps of copper (which are remains of ore melting process). Appearing glassy structure is irregular and porous. Thanks to chemical research and EDS spectrum, it can be observed, that in slags still appear huge amounts of a malachite and the content of copper even reach up to 84,3%.

Next analysed sample appeared a fine-crystalline structure of a copper with a fragment of erode enamel inherent in it. A content of a copper in this sample is higher than in previous and riches up to 89,09%.

In another analysed sample in fine-crystalline background a single, bigger grains of copper were inherent. A punctual content of copper in studying slags is high all the time and it doesn't decrease below 60%. An additional chemical analyse showed in studying sample a content of iridium above 1%.

A copper appear punctual in big accumulation, which probably connected with a process of ore enrichment with inadequate level of clean copper's retrieval at the same time. Copper's melting technology in blast furnaces by Kibutu's quarry (and bordering) is obsolete and necessary will be its modification and modernisation. In a composition of studying slags three groups of components were distinguished: an enamel, metallic precipitation and crystalline phases.

An enamel, which usually performs in domination towards other components, in this case fulfil rather a marginally function. It is caused by extension of slag's mass cooling time, in this case instead of a enamel, crystalline phases can appear secondarily (mainly as minerals from a pyroxene group). Long-time cooling allowed to form in many cases, right developing crystals of minerals mentioned above. Additionally, it was observed that this crystals appear in an aggregation.

Next to crystalline phases in studying slags, metallic precipitation were also distinguish, in significant majority was copper precipitations, and in single cases also an iron. It is connected with inadequate accurate and precise process of precipitation and enrichment of an ore.

Crumbs of refuses containing a metallic coper, determine about 3% in studying material.

In studying samples performed a variable amount of an iron, came from hematite's melting (averagely to a few %), as well as a sulphur, a silicon and small amounts of an aluminium. In studying samples didn't ascertain

mentioned, essential in point of economy, amounts of more precious chemical elements such as e.g. a gold, a silver.

Admittedly, an amount of metallic copper in refuses is little, but with a bigger production, wastages connected with a transmission of a pure metal to refuses, can be significant. Due to this, after ending of copper's melting and cooling of slags removed from a furnace, their reversing to renew metallurgic cycle will be recommended, in this way possible will we a recovery of metal from slags. This procedure of processing will improve a recovery of copper and reduce a transition of its toxic forms to a natural environment. By this method, a danger of environment pollution by copper as a heavy metal will decrease.

Environment conditions

Mining activity strongly influence on natural environment's condition, topography of the area and human life. Raw materials' mining, miner's and metallurgic works are significant interference in all environmental elements – soil, waters, air and living organisms.

Tab.9. An average amount of chemical elements in plants (values are given in ppm), in mines' region of cupriferous zone in Katanga (averaging results of 350 measurements from 11 locations, compared with NHANES – National Health and Nutrition Examination Survey norms) (Decrée S. and others, 2011).

Elements	3 to 10 km from lodge [ppm]	0-3km from lodge [ppm]	Max values NHANES [ppm]
As	10,8	17,8	8,24
Co	5,72	15,7	0,36
Mo	84,5	75,2	42,5
Ni	3,06	3,27	No data
Pb	2,93	3,17	0,64
U	0,018	0,028	0,008
V	0,21	0,22	No data
Zn	312	306	No data

Major controversy rising a localization of more and more amount of miner's installations near protection areas, e.g. by Okapi National Park. Mining has a long history in this place, but to this time it function for a small scale, conducted by local people, and a raw material was used locally. After introducing a mining on an industrial scale, a quality of waters worsen and all boundary sphere was degraded. Mining ores are sorting in a place, and a refuse, in with mercury's ions and cyanides can be find, are falling to a river, which is a danger for water's ecosystems as well as for a health and a life of people, who use a fluvial water. Conducting earth works reduce an area, with is settling by wild animals, who lose their habitats.

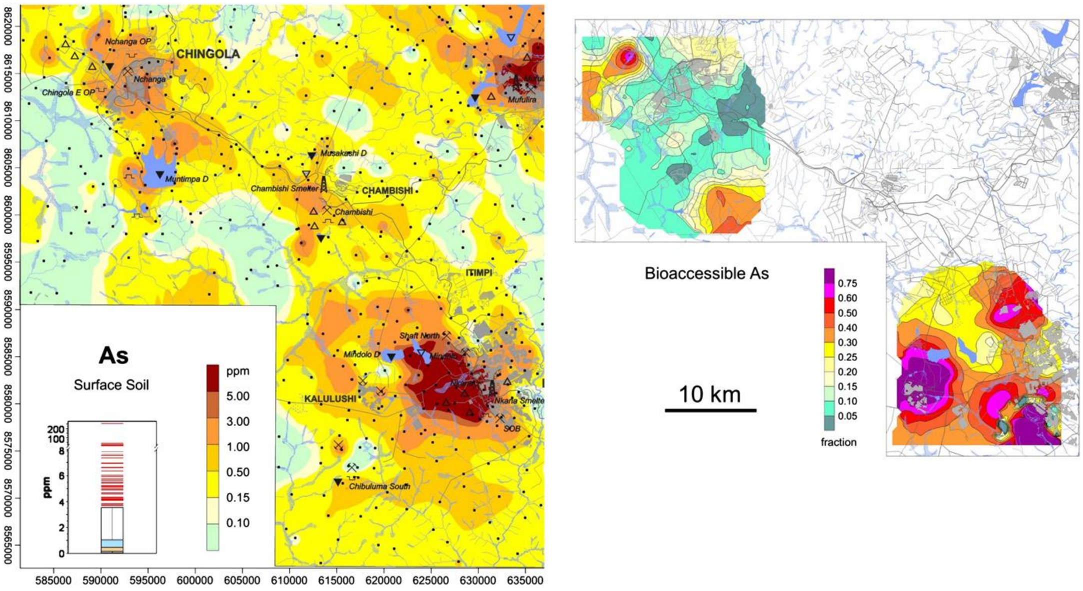


Fig.77. A map on the left side presents measurements of As amount in soil, a map on the right side presents a bioavailability of As (Ettler and others, 2011).

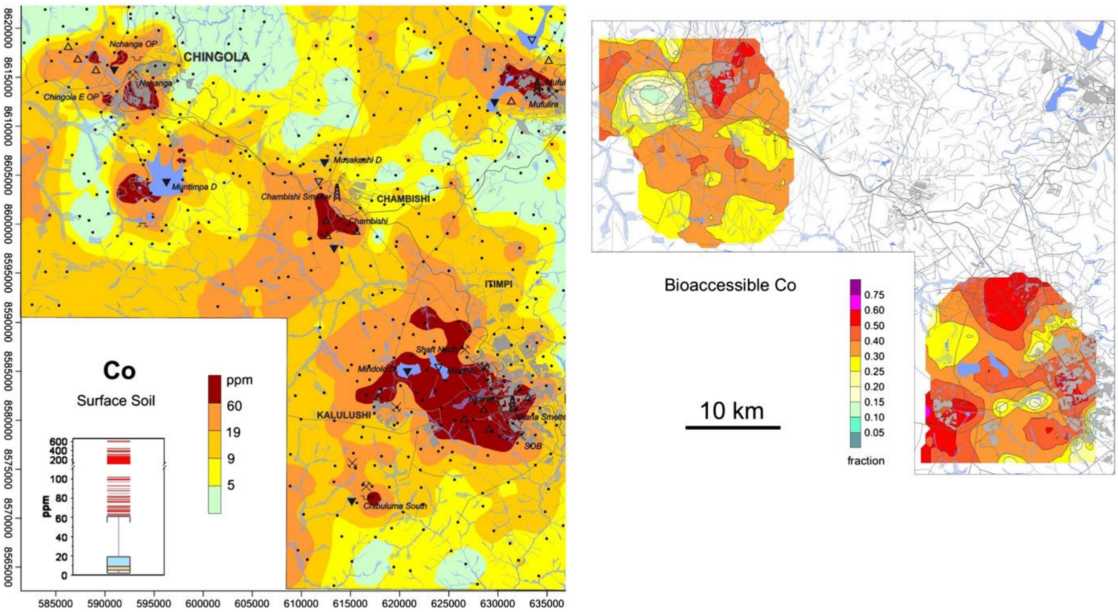


Fig.78. A map on the left side presents measurements of Co amount in soil, a map on the right side presents a bioavailability of Co (Ettler and others, 2011).

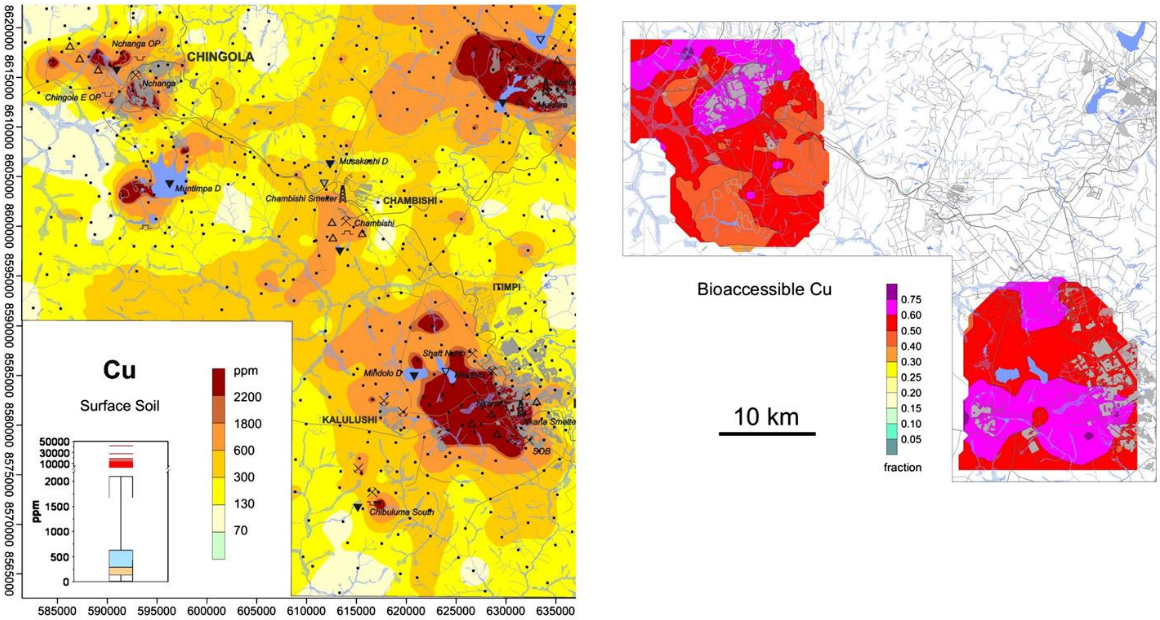


Fig.79. A map on the left side presents measurements of Cu amount in soil, a map on the right side presents a bioavailability of Cu (Ettler and others, 2011).

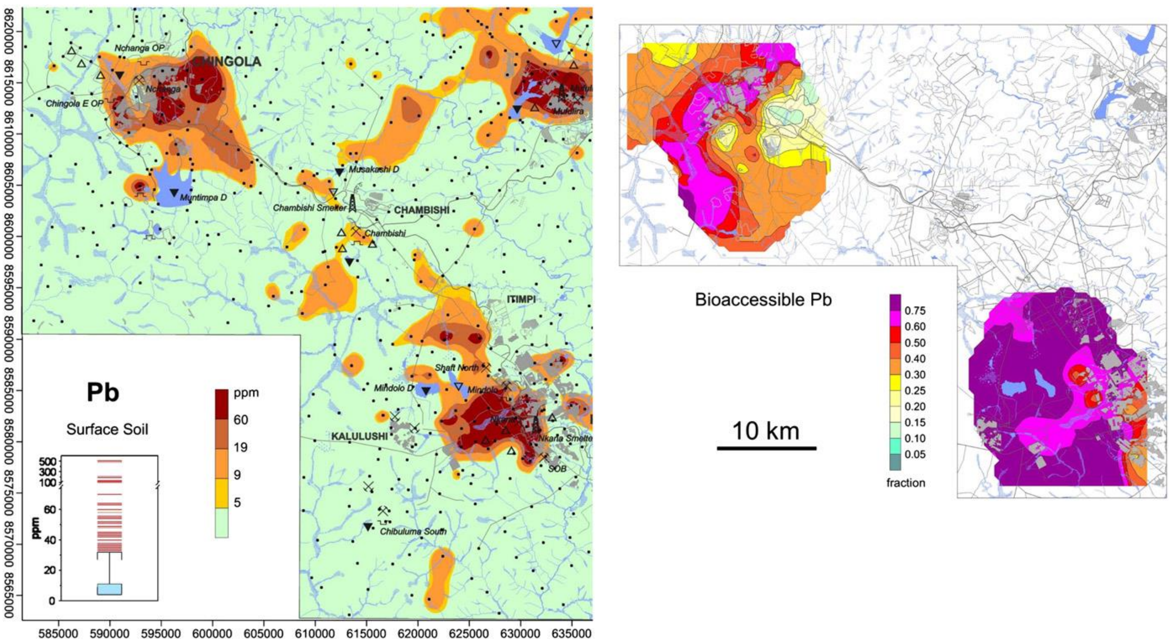


Fig.80. A map on the left side presents measurements of Pb amount in soil, a map on the right side presents a bioavailability of Pb (Ettler and others, 2011).

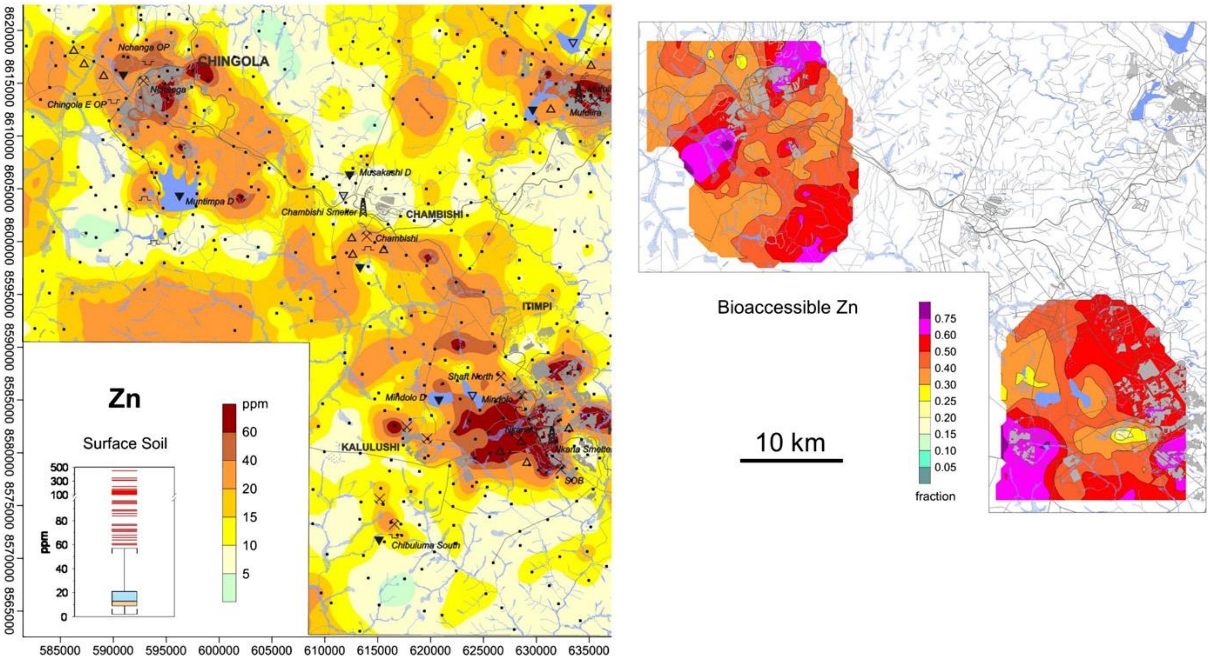


Fig.81. A map on the left side presents measurements of Zn amount in soil, a map on the right side presents a bioavailability of Zn (Ettler and others, 2011).

Next essential factors are after-mining and after-production refuses. Mining causes very big amounts of refuses. In Europe, in order to be able to dump them, special procedures are applying, from with it is necessary to settle with national governing bodies of environmental management. In the case of refuses, creating in Democratic Republic of Congo, there isn't any national supervisory governing body, there is no law, which can force mining empires to any pro-ecologic activities. Economy of refuses is so by their site, and only from them depend if they behave in ethic way or economically rewarding. Systems of environmental management such as appraisal of influence for environment, are now more often using device to environmental management, also in mining sector. In European countries or this from American continent they are essential in each investment. In the case of mining policy in DRC they aren't officially requested. A storage of refuses after ore's melting in wrong way, can lead to precipitation of harmful and potentially dangerous, because mobile, ions of chemical elements. After penetrating to drinking water, they can determine a danger for all ecosystems.

A danger also constitute a pollution of dusts with heavy metals and soils' arsenic and assimilate them by plants, including crops plants, which afterwards are consuming by people. As a result, on areas bordering with big mining and processing centres, it may impact to a significant focus of heavy metals in people's bodies. A studying group guided by Decrée

(Decrée and others., 2011) conducted on a large scale, measurements of chosen metals' content in crop plants, from fields located near mine and/or centres of metals processing (Table 8.1). This research shown, that it is occurring an appreciation of metal's amounts, in some cases it is even twofold transgression of norms, in regard to findings of World Health Organization : NHANES. Obviously, it should be assume, that natural level of metals in soils on the area of cupriferous zone is increasing, by the presence of metals in aboriginal rocks, from with soils created. However, as Ettler's research show and his group as well as Pourret's (Ettler and others, 2011; Pourret and others, 2016) areas near mines have this level significantly increasing (Figure 8.4-Figure 8.8).

Maps are presenting levels of individual chemical elements in soils, located near mines, on adjoining and distant areas. Geochemical research were made in cupriferous zone of north Zambia's region, from a distance barely several dozen kilometres from a Lubumbashi. So it can be assume that values of presenting geochemical background, will be approximate for an area mentioned in this thesis, which confirm initial results of research conducted by Pourret's team (2016) just on the area of cupriferous zone in DRK. It should be pointed out that geochemical background really provide about natural, high content of metals in soils, but their amount significant increase near mine's areas

Based on the analysis of literature, mineralogical and petrographic research of copper deposits in Kibutu, Kajuba, Renzo, and Lubumbashi area and slag generated in the process of their remelting, as well as the environmental analysis, we can draw the following conclusions:

- Deposits in Lubumbashi region consist of two parts.
- Subsurface deposits resulting from the oxidation of copper sulphides and reaction of by-products with carbonates - purely malachite deposits.
- Older deposits occur as dolomite sulphide mineralisation, with large variations of minerals: bornite, chalcopyrite, arsenopyrite, pyrite, and chalcocite.
- Copper ore from the subsurface (malachite) area can be remelted in furnaces, with the addition of haematite or magnetite.
- Copper present in the sulphide portion is not directly suitable for smelting process and should be enriched with flotation method, chemical method with acids, or other method.

- The copper content in the sulphide portion is up to 3%.
- Studies have shown that the covered deposits are small and are on the verge of profitability when it comes to extraction and processing.
- The phase composition of slag has been identified, the following have been distinguished:

-glass
-metal separation (copper, iron)
-silicate phases
-oxygen phases

- When analysing microscopic images, it was found that secondary formed crystallites, oxidized metals, and metallic ore residues are found in slag more often than glass.
- Glass in slag behaves differently, depending on the age of waste.
- Slag alloy is subject to cooling only in certain weather conditions, which are not conductive to rapid cooling in the region of Central Africa. The slower the cooling, the lower the amount of glass, but e.g. silicate phases are formed in larger amounts.
- Economically valuable elements, such as gold, silver, were not detected in the test samples.
- Debris containing metallic copper constitutes about 3% of the researched material, and it should be returned for remelting during the technological process. When applying additional technological processes, it seems possible to use copper slag for construction process (e.g. as a filler for concrete) and road construction (ballast used for paving roads).
- The following threats to the environment of the Democratic Republic of Congo have been identified: excessive deforestation, soil erosion, improperly stored mining and metallurgical waste, poaching, and water pollution.

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