Report for reconnaissance mineral exploration work in Stan Terg license, Drazna license and Viti license (exploration license areas of Vardar Minerals Ltd. in Kosovo)

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Prepared for
Vardar Minerals Ltd.
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1. Introduction

Vardar Minerals Ltd. holds six license areas for mineral exploration in the Republic of Kosovo as follows: Stan Terg license area – Mitrovica Project; Orlan license and Brvenik license – Drazna Project; Viti, Viti-North and Viti-East license areas – Viti Project (Fig. 1.1). The present report is a summary of the recognition exploration fieldwork and preliminary petrography and mineralogy study, done by Murgana Geological Consulting Ltd. The three project areas were visited in November 2017. The fieldwork undertaken has the character of preliminary exploration study combining traverse geological and alteration mapping and sampling for petrography and chemistry analyses. The results are incorporated in MS Excel tables, ArcGIS shapefiles, MS Word texts and folders with field and thin-section photographs. All data entries are linked by at least one common field – locality. Geological information is based on the 1:100,000 scale geological maps of Kosovo, updated with new data where possible. The tables contain point data with information regarding lithology, structures, weathering, alteration style and intensity, mineralisation, samples, field photographs etc., all with codes in the tables. Alteration database include up to two types of alteration for a single rock type at a given locality and the intensities of alteration are scaled by as follows: 1-trace, 2-weak, 3-moderate, 4-strong. Where possible, field data are corrected based on microscopy alteration analysis. Alteration maps are constructed with overlapping polygons for different alteration styles or different intensities of rocks alteration types. The applied systematics of alteration zones follows the classification of Corbett and Leach (1998). The map contains two additional alteration types, which are certain field indicators for hydrothermal processes (silicification) and presence of sulphide mineralisation (gossan). Linear objects are used to present narrow lithological bodies (dykes, sills) and zones of alteration. The detail and accuracy of the alteration maps are directly linked to the scale and style of field mapping. For some areas, the interpretation of the alteration style or intensity is extended far from the points of observation and this should be taken in consideration for further interpretations.

Fig. 1.1. Location of the three project areas in Kosovo.
2. Mitrovica Project

2.1. Geological background and regional geology setting

Stan Terg license area is located in Northern Kosovo, north of the town of Mitrovica (Mitrovicë) and to the east of Ibar River. The property has an area of approximately 50 km², characterised by low-altitude mountainous topography (Fig. 2.1). On a regional scale, the area is located within the Late Alpine Tethyan Orogenic Belt and more specifically within the External Vardar Sub-zone of the Vardar Zone. The basement is comprised of ophiolites and a metasedimentary mélange affected by polymetamorphic overprint (not exceeding greenschist facies conditions). A volcanic-sedimentary complex of Oligocene to Early Miocene age represents the cover sequence. The volcanic and volcaniclastic rocks are reported to be predominantly of trachytes with subordinate andesites and latites (Hyseni et al., 2010, Palinkas et al., 2013). From metallogenic point of view the area is located within the central part of the Trepča Metalogenic Belt (the Belo Brdo - Stan Terg - Hajvalija Zone of the Belt, see Kolodziejczyk et al., 2012; Palinkaš et al., 2013).

The focus of the undertaken fieldwork exploration campaign was the southern part of the Stan Terg license area. Profile mapping (geological, structural and alteration mapping) was accompanied by sampling for further analytical investigations (petrography, mineralogy, geochemistry, and infrared spectroscopy). This part of the present report will only discuss geological setting in the investigated southern part of the license referred to as Stan Terg South area (Fig. 2.2.). Some of the observations are made outside the outlines of the license area in order to gain as much information as possible in well-outcropped sections along road-cuts or river gorges.

![Figure 2.1. Mitrovica project area](image)
2.2. Geological overview

2.2.1. Basement Unit

The Vardar zone basement rocks crop out in the southernmost part of the investigated area as well as in a narrow NNE-SSW strip along one of the more prominent rivers – Leskov River. The basement comprises two tectonic units – metasedimentary unit of supposed Triassic age and Ophiolite Unit of still disputed Triassic or Jurassic age (age references are according to the official 1:200,000 and 1:100,000 scale geological maps of Kosovo). The contact between the two units in the Doljanska River in the central parts of the license area is interpreted as a major SW-NE steep to vertical tectonic contact with uncertain kinematics. Field observations indicate a possible dextral strike-slip movement.
The Triassic metasedimentary unit represents a greenschist facies section of phyllites or chlorite-sericite schists with large (map-scale) lenses of metabasites (diabases). The metasedimentary section comprises also subordinate intercalations of calc-schists and boudinaged layers of metasandstone or metabaulelrites. Metabasites are well-exposed in the southern part of the area. In a map view they constitute lens-shaped bodies with long axes parallel to the main structural trend in this part of the Vardar Zone (NE-SW). Due to high rheology contrast, the contacts of the mafic layers with the metasediments are often sheared (e.g. at locality M5, M6 where the metabasites are NE-thrusted onto the phyllites – Fig. 2.3. a). The phyllites and chlorite-sericite schists are grey to greenish very fine-grained metamorphic rocks with pelitic protolith (Fig. 2.3. b). These are metamorphosed at low greenschist facies conditions during at least two tectono-metamorphic events. This is evident from the presence of two metamorphic foliations that developed at similar P/T conditions. The calc-schists and metabaulelrite intercalations correspond to a primary sedimentary layering in the formation. The main structural trend in this part of the Vardar Zone is outlined by the orientation of the main metamorphic foliation in the phyllites with NW-SE trend and varying inclinations due to imposed refolding (Fig. 2.3. c and d). The second metamorphic foliation developed axial parallel to isoclinal folds and shares the same NW-SE strike but is generally steeper. In many places, the two planar fabrics define a pronounced intersection lineation (pencil cleavage lineation). In most of the observed outcrops a third spaced fracture cleavage was observed but the limited data hinders any conclusions for its relationships with the main metamorphic fabrics.

Figure 2.3. Characteristic features of the Basement Unit. (a) NE-vergent thrust marks the contact between metabasites and phyllites; (b) gray phyllites with two metamorphic foliations; (c) and (d) structural diagrams showing the general trend of the metamorphic foliation in the Vardar Zone metamorphic rocks.
The Ophiolite Unit was observed in only few outcrops close to the tectonic contact with the phyllites – localities M1084 to M1088. The section is composed of black to dark green partially serpentinised ultramafic rocks with steep metamorphic foliation parallel to the NE-SW trending contact with the phyllites. The unit crops out in the northern part of the Stan Terg License area, and will be a focus of future field exploration works.

2.2.2. Volcanic-sedimentary Tertiary Complex
The Tertiary cover rocks in the Stan Terg South area are subdivided into three units – Basal Conglomerate Unit, Volcaniclastic Unit and Volcanic Unit. According to the official geological maps, the age of the unit is Middle Miocene (Bogdanović et al., 1982). Unpublished data of Palinkas, commented in Palinkas et al. (2013) give an Oligocene (26-23 Ma) age of the trachytes. However, it is not clear whether the Stan Terg volcanics are contemporaneous to the emplacement of the trachytes. Therefore, Bogdanović et al., (1982) suggest multiple magmatic events from Middle Oligocene to Middle Miocene (Fig. 2.4.).

![Figure 2.4. Image cropped from 1:100,000 scale geological map of Kosovo, map sheet K34-42. Note the multiple magmatic pulses in the Oligocene and Miocene. The volcanic-sedimentary unit in Stan Terg license area is interpreted as Miocene in age.](image)

The Basal Conglomerate Unit (Fig. 2.5.) overlies the basement rocks unconformably. This relatively thin layer of polymictic conglomerate to breccia-conglomerate in places is not present everywhere so thus, its thickness varies from zero to a few tens of metres. In many parts of the area, the Tertiary stratigraphy starts directly with the Volcaniclastic Unit. The polymictic breccia-conglomerate is composed of clasts from the basement and volcanic clasts with sandy matrix. However, the upward transition to the monomictic volcaniclastic rocks is rather fast and difficult to trace on the field. This transition is mainly marked by the disappearance of the basement clasts in the rock.
Figure 2.5. Outcrops of the Basal Conglomerate Unit. (a) Conglomerate, composed almost entirely of volcanic clasts with some quartz pebbles, probably derived from the basement; (b) large blocks of clast-supported conglomerate; (c) breccia with small phyllite clasts and volcaniclastic material as clast and in the matrix.

The Volcaniclastic Unit is a part of the wide spread Late Oligocene – Early Miocene Volcano-sedimentary complex that developed along the Vardar Zone. In Stan Terg South, this unit crops out in vast areas in the hills west of Trepčanska River as well as in the foothills of Sokolica and Majdan peaks. The average thickness of the unit is about 150 m. The rocks are volcaniclastic sediments – monomictic volcaniclastic conglomerate and gravelite (lapilli) with much finer in grain-size tuff beds as subordinate intercalations. The unit follows upward with a normal stratigraphic transition above the basal conglomerate or is discordantly overlying different parts of the Mesozoic basement units.

From the base to the top, there is, although not very pronounced, gradation from clast-supported conglomerate with average size of the clasts about 15-20 cm to matrix supported conglomerate with smaller clasts that alternate with gravelites. The coarse volcaniclastic layers are interbedded with tuffs in the upper part of the sequence. The thickness of the tuff beds is usually about 1-2 m. Some observations on the field as well as in the petrography work indicate that volcaniclastic material is probably related to two different volcanic centers. The difference in the clasts of the conglomerate corresponds also to the different intensity of alteration. The lapilli clasts in the conglomerate are composed of plagioclase K-feldspar and amphibole. Biotite and quartz are observed in varying amounts in the different. The sandy matrix of the conglomerate has a similar mineral composition, and only amphibole is not that common. On the other hand, biotite in the matrix is in well-shaped and relatively large hexagonal flakes. The tuffs are composed of crystalloclasts of plagioclase and feldspar with very little quartz observed occasionally and mafics - biotite and amphibole, vitroclasts and lithoclasts. Lithoclasts are of two types, corresponding to two types of volcanic source: i) thrachite/latite and dacite in composition and ii) more acid – rhyolitic composition. Similarly, the vitroclasts are of two types – intermediate composition and acidic volcanic glass.
The Volcanic Unit builds up large part of the hills in the area. It is vast-outcropping in Majdän and Sokoloca hills where its thickness is estimated between 350 and 450 m. It probably represents a thick volcanic canopy, overlying the volcaniclastic unit that was partially eroded. The whole formation (possibly the whole volcanic-sedimentary cover sequence) dips gently to the west or southwest. Beside the voluminous volcanic rocks in the described hills, thin, flat-lying volcanic sills are found also within the volcaniclastic unit, usually in its upper section. Steep or vertical subvolcanic dykes – possible volcanic feeders – are observed to crosscut the volcaniclastic conglomerate and basement lithologies. The dykes are commonly with thickness in the range of a few meters, brecciated at their margins, possibly due to hydrothermal fracturing.

The Volcanic rocks are described as quartz-latites (Bogdanović et al., 1982). Our observations point to more dioritic composition and the rock is determined as dacite (see supplementary materials, Petrography analyses of thin sections). Its geochemistry was not investigated during this research and the suggested classification should be considered as provisional. Macroscopically, the volcanic rocks are grey to beige in colour, with large phenocrysts of K-feldspar – probably sanidine, with long axes commonly between 2 and 5 cm, sometimes with twinning (Carlsbad type). Other porphyry minerals, although much smaller than the sanidine, are plagioclase and amphibole. The fine-grained matrix is grey to slightly purple coloured. There is a magnetic mineral phase in the rock (magnetite). From thin-section petrography analyses it is evident that the rocks are composed of two types of plagioclase (fine-grained and larger porphyry grains which has the composition of Andesine - \( A_{0.32-0.38})\), K-feldspar phenocrysts with idiomorphic plagioclase inclusions, prismatic amphibole, clinoxyroxene and biotite. Quartz is as subordinate, rounded, often fractured clasts with diameter of about one millimetre. Accessory minerals are titanite, apatite and zircon. The matrix is of fine-grained prismatic plagioclase, xenomorphic quartz, K-feldspar and pyroxene + accessory minerals.

2.2.3. Quaternary and Pliocene-Quaternary deposits
This unit comprises two types of unconsolidated to weakly lithified coarse clastic sediments observed in the area. The first consists of alluvial deposits in the riverbanks of Ibar River and beside that, it covers part of the pre-Quaternary section in the far SW corner of the license area, it is of no interest to the present investigation. The second type is of very coarse, unsorted and non-lithified slope deposits or small basin deposits with bolder- to pebble-size of the clasts, and sandy matrix. They were observed in several places along smooth ridges. Their thickness is variable but a few observations point to about 5 to 10 metres and the clasts are derived from the underlying volcanic and volcaniclastic units. Those deposits were only transected in a few places and limited data were collected. The available geological maps also lack detail data about their extent and outlines, which might be important for future exploration activities.

2.3. Alteration and mineralisation
The fieldwork in the southern part of the Mitrovca project area was directed to identifying types of alteration with indication for the alteration intensity if possible. A relatively large area of argillic alteration of varying intensities and several smaller centers of advanced argillic alteration have been identified. Field and petrography observations show development of a propylitic and argillic alteration. Relying on the available data, it is not possible to reconstruct their temporal evolution and spatial distribution of the latter. The presence of secondary chlorite and carbonate minerals and the absence of epidote are indicative for rather an “outer propylitic” than “propylitic” type of alteration (see Corbett and Leach, 1998). The outer propylitic alteration differs from the “ordinary” propylitic alteration in its mineral assemblage, and develops farther away from the heat source than the “ordinary” propylitic alteration. Phyllic alteration is not typical. It is observed occasionally, as weak to trace overprint in volcanic and volcaniclastic rocks. A more pronounced alteration style occurs in a small, probably fault-bounded lens of volcaniclastic rocks in the Leskov River gorge. Key minerals for the different alteration facies observed on the field and in thin-sections are chlorite and carbonates for the propylitic zone; clay minerals for the argillic zone and quartz, alunite diaspore for the advanced argillic zone. The mineralogy of the clay group minerals should be further studied by other techniques. During fieldwork alteration mapping and thin-section analyses, a scheme of 4 intensity levels was used.
and incorporated in the database (see tables for alteration) – unaltered rocks (NA), trace (1), weak (2), moderate (3) and strong (4) alteration. Link between alteration (with style and intensity), structures and mineralisation is provided by tables. Field and thin-section data indicate the presence of disseminated and vein-hosted sulphide mineralisation in rocks with commonly moderate to strong argillic alteration (Volcaniclastic Unit and Volcanic Unit). The veins are usually showing stockwork characteristics and dominantly have black coloured infill due to advanced oxidation. Summarising the structural data for the veins, it appears that their dominant trend is E-W to ENE-WSW. A second rank trend is N-S to NNE-SSW. Only in a few localities fresh pyrite-quartz veins and pyrite ± chalcopyrite veinlets were observed (e.g. the foothills of Majdan peak). Disseminated pyrite was also commonly observed in volcanic and volcaniclastic rocks with strong argillic alteration. Field alteration mapping was undertaken to provide a first pass interpretation of the primary alteration distribution and to determine priority areas of interest for follow-on mapping in more detail. Secondary copper minerals (e.g. malachite) were described on the field. In some places, the clayish matrix of the strongly altered volcanic rocks might contain malachite presented as disseminated in the matrix as well as in small aggregates. The observed features however, could also be result of a green colouration of the clay minerals. Geochemical analyses of samples from such localities will return data that can help in further interpretation. Majdan peak should once again be pointed out as the area where most of the described features were observed.

2.3.1. Alteration in the Basement Units

The field identification of alteration styles in low-metamorphic grade metasedimentary rocks in general, is an ambiguous task since many products of the regional greenschist facies metamorphism could resemble products of hydrothermal alteration. In general, the phyllites of Mitrovica area, for example, are in fact low-grade chlorite-sericite schist, often with certain silicification, again related to the regional metamorphic overprint. Field studies could not reveal if those rocks were affected by phyllic (sericite + quartz) or propylitic (chlorite + quartz) hydrothermal alteration.

In several places in the southern part of the project area, the fieldwork indicated that basement phyllites are affected by argillic type of alteration. This was observed in relatively narrow zones related to the emplacement of Tertiary dykes. Macroscopically, the alteration zones are marked by a relatively fast transition from fresh gray to greenish coloured schists or phyllite to soft yellow to orange coloured rocks which is related to the formation of clay minerals and possibly cryptocrystalline micas (Fig 2.6.). Generally, the basement phyllite show good resistivity to alteration. Several outcrops of the basal conglomerate of the Tertiary complex show strongly altered matrix and clasts with volcanic origin and completely preserved (unaltered) clasts of the basement phyllite or schists. Therefore, the discovery of alteration zones within the basement rocks could be an indirect indication for quite an intense hydrothermal fluid activity. Argillic alteration of the basement rocks is described on the field in the southernmost part of the property. Probably the alteration in the phyllite is linked to dykes and related fluids.

The Vardar Zone basement lithologies are characterised by a veining events with different ages indicated by observation of folded or boudinaged quartz veins and veins that cross-cut the metamorphic fabrics (quartz but also quartz + calcite ± Fe-hydroxide veins). At this stage of exploration, it is not possible to link the later veining event to the hydrothermal system that alters the Tertiary cover rocks.
2.3.2. Alteration in the clastic units of the Tertiary Cover

The Basal conglomerate Unit and the Volcaniclastic Unit in the project area are affected by argillic alteration with varying intensities. Although this cannot be extended to the whole volume of the two units, either because lack of outcrops or limited field data in certain areas, in the majority of the observed sections it is noted that the high permeability of these clastic rocks allowed the alteration of large volumes of the formations. Field and thin-section observation indicate that the volcaniclastic material is derived probably from two, if not more, volcanic sources and the clastic material shows a slight difference in the alteration style. There is an increase of the alteration intensity going upward in the stratigraphic section and closer to the cap-volcanic rocks. Even in the Sokolica hill, where the overlying dacites show only traces of pervasive argillic alteration, the volcaniclastic rocks below are, again, moderate to strongly altered. Limited field data for the conglomerate to the south and north of Sokolica peak leave large gaps in the alteration data that need to be considered during following exploration works. Nevertheless, the collected information point to the important role of the cover competent volcanic rocks as a lid for the circulating fluids. The alteration style in the volcaniclastic rocks of the ridge west of Trepčanska River shows the same characteristics. Here the cap-volcanic rocks are missing, probably being eroded, but the rocks still show a progressive increase in the alteration, going upward in the section to the several spot-like areas in map view, where advanced argillic alteration occurs. Here, also some spots with gossanous oxidised rocks were found.

At the south foothills of Majdan peak, the argillic alteration affects in similar intense style almost all the outcropping clastic units (including the basal conglomerate), overlying completely unaltered basement. Alteration style in the clastic units is slightly different with several “levels” of moderate to strong advanced argillic alteration overprinting intense argillic facies of alteration. A plausible explanation of the observed features might be a more pronounced lateral migration of the acidic fluids channeled by some primary features in the rock (sedimentary bedding for example). Upward in the section the advanced argillic alteration becomes dominant entering the dacite section (Fig. 2.7.). The volcaniclastic rocks to the southwest of Majdan peak and at the saddle between Majdan and Sokolica peaks, are covered by quaternary sediments and alteration styles and intensities here are uncertain.
2.3.3. Alteration in the Volcanic Unit

In contrast to the Volcaniclastic Unit, the Volcanic Unit shows significant variation in the intensity of alteration and fast transitions or sharp contacts between zones of different styles or of different types of alteration. The unit is affected by argillic alteration ranging in intensity from trace (or even fresh rocks in some outcrops) to strong, sometimes with transitional or sharp contacts between zones with different alteration intensity (fig. 2.8).

The Sokolica Hill area is characterised generally by trace argillic alteration expressed by replacement of the plagioclase grains by clay minerals observed only along the margins of the grains. Amphiboles are unaltered or show brown to reddish colouring due to oxidation and weakly chloritised that can be related to incipient (trace) propylitic alteration. The matrix is also fresh. This is very typical for the central parts (hill-top), northern and western parts of the Sokolica Hill. To the east and in some extend to the south of the summit the volcanic rocks are affected by moderate to strong argillic alteration which developed along narrow zones up to several metres in width. To the side of these zones the dacites show, again, only trace argillic alteration. The argillic-altered volcanics are weaker and respectively more intense weathered.

At Majdan peak, the alteration system is rather different. Our observations are concentrated on the central and western part of the hill. As described above, the clastic unit that crop out at the base of the hill is affected by moderate to strong argillic alteration with narrow levels (flat laying zones) of advanced argillic alteration. On top of the clastic unit, the westernmost part of the volcanics are characterised by trace to weak argillic alteration and only narrow zones of several metres of width, where the alteration intensity changes sharply to moderate and strong. These weakly altered rocks are in a sharp contact with the main volume of the Majdan peak volcanics, which show characteristics of strong argillic alteration. The orientation of the contacts needs to be mapped in greater detail. However, based on the available field data, two general trends NNW-SSE and NE-SW can be suggested. East of the sharp contact and also up the hill so thus, upward in the stratigraphy, the alteration changes from strong argillic to advanced argillic. On the hilltop, the rocks are affected by advanced argillic alteration. From this observation and the idealised model (Fig. 2.9.), it is possible to conclude that the Majdan hill sits on top of one of the heat sources that causes the alteration in Mintrovica project area.
Figure 2.8. Alteration style and intensity in the dacites. (a) unaltered dacite with large sanidine phenocrysts; (b) zones of intense argillic alteration and preserved “blobs” of dacite with only trance argillic alteration; (c) strong argillic alteration resulted in full replacement of porphyry minerals by clay minerals and strong silicification in the matrix; (d) moderate advanced argillic alteration overprinting dacite with strong argillic alteration as shown by completely replaced plagioclase and K-feldspar; (e) strong advanced argillic altered dacite.

Figure 2.9. Idealised model for the mechanism of alteration processes in the rocks from Mitrovica project area.
2.4. Structural setting
Our structural data are rather limited for comprehensive structural analysis. However, the structural histogram plots of the strikes of the brittle structures measured in the area, reveal an important difference between the main orientation of the joints and the main trend of the faults (Fig. 2.10.). The NNW-SSE maximum in the strike of the faults corresponds well to the main trend of the structures in this part of the Vardar Zone in general. The second trend in the faults orientation is with E-W to ENE-WSW direction and overlaps with the main strike of the measured joints and master joints. Namely the E-W to ENE-WSE trending brittle structures are most commonly observed as hosts of thin mineralised veins (usually with oxidized sulphides or Qtz ± carbonite). This trend also corresponds to the main trend of the few dykes and zones of hydrothermal brecciation observed in the area. A plausible interpretation of the data is that the E-W trending structures are extension-fractures in a field where the NNW-SSE faults either could be shear fractures or structures that are close to parallel to the main compressional stress vector. A possible inheritance of the orientation of the main faults from the structures in the basement should also be considered. From exploration point of view, in Mitrovica project area, the sharp contacts of alteration zones with different intensities are parallel to one of the two major trends outlined above (E-W to ENE-WSW and NNW-SSE).

Figure 2.10. Diagrams for the brittle structures in the southern part of Mitrovica license area. (a) and (b) represent histograms of the strike of the brittle structures in 10 and 15 degrees class intervals respectively; (c) and (d) are analyses of the joints orientation (master joints excluded) in density plot (lower hemisphere) and strike-histogram; (e) and (f) are histograms of the strike of the faults only in 15 and 20 degrees class intervals respectively.
2.6. Conclusions and recommendations
The preliminary exploration work revealed that the southern part of the Mitrovica Project (Stan Terg South) is characterised by extensive voluminous alteration centered in two areas – Majdan peak and the ridge west of Trepčanska River. The two areas are characterised by a transition from weak-moderate to moderate-strong argillic alteration and moderate-strong advanced argillic alteration with gossan spots in the centers. The Majdan peak is characterised by much larger zone of advanced argillic alteration with a diameter of about 700-800 m in map view. Both areas show presence of sulphide mineralisation in veins as well as disseminated but chemical analyses data will be critical for further interpretations regarding mineral exploration perspective.

Field work and thin section studies of samples from Sokolica peak indicate that this area is relatively preserved from the pronounced alteration observed in the other two sections. Only the southern slopes of the hill that are largely covered by quaternary slope materials might present an interesting section for further investigation of the alteration and mineralisation.

All structural data discussed here are based on limited field data and should be used only as directions and not to be taken as comprehensive analyses of the structural evolution of the area.

Recommendations for further exploration works:
The undertaken mapping campaign clearly showed that the available geological maps are not reliable. Future work in the area should begin with detail conventional mapping in a scale appropriate for mineral exploration. The analysis provided in this report could be used to narrow down the areas of interest. Additional data regarding the intensity of the alteration and overlapping alteration styles will be a good contribution although quite difficult to obtain on the field. Alteration mapping, combined with field (better) or lab-based infrared spectroscopy and XRF analyses is probably the most effective approach here.

Geochemistry study of the volcanic rocks is important in order to properly classify the magmatic products. Geochemical study could be undertaken on few of the samples that are already collected. Isotope geochronology information might not be critical at this stage, although it will allow for linking the obtained magmatic ages with regional mineralising events and to help for better targeting in the future exploration activities.

Soil sampling and stream sediments sampling in the two highlighted areas – Majdan peak and the ridge west of Trepčanska River is the logical step going forward.

Zones with hydrothermal breccias have been detected during traverse mapping along the roads in the S and SE part of the area. Field observations indicate that in this area argillic alteration and probably zones of advanced argillic alteration could be linked to either dykes or faults with hydrothermal activity (including hydrothermal brecciation). Beside the few road-cuts and pavement outcrops, the area is with rather poor exposure. Therefore, a magnetic geophysical survey will be a powerful tool for further targeting in that area.

The northern half of the project area was not visited during the November fieldwork. This area is still interesting from mineral exploration perspective. We suggest a similar approach of investigation, starting with preliminary investigation by traverse mapping with sampling for chemistry, petrography and infrared spectroscopy analyses.
3. Drazna Project

3.1. Geological Background and Regional Geology Setting

Drazna project comprises two license areas named Orlan and Brvenik licenses with total area of about 64 km². The property is located next to the Kosovo-Serbia border about 25 km NE of Pristina, east of the Batlavsko (Bašlavsko) Lake. The property area is characterised by low-altitude mountainous topography cut by the Kaljatićka River and its tributaries (Fig. 3.1.). On a regional scale, the area is almost entirely within the NW-SE trending Volcanic-sedimentary Complex that developed in the Internal Subzone of the Vardar Zone, enclosing small section of the Serbo-Macedonian Massif in the NE part of the property. The volcanic-sedimentary complex is interpreted as Oligocene-Miocene in age (Vukanović et al., 1982) (Fig. 3.2). The emplacement age of the diorite porphyritic bodies in the Kiseljak deposit to the E (on Serbian territory) is reported to be 31 to 33 Ma (Marton et al., 2013). According to the 1:200,000 and 1:100,000 geological maps of Kosovo, the Internal Vardar Subzone is composed entirely of Tertiary rocks. The tertiary basin developed at the contact between the Lower Cretaceous flysch sediments of the Central Vardar Subzone and the high-metamorphic grade gneisses and amphibolites of the Serbo-Macedonian (Dardanian) Massif (Fig. 3.3.). The pre-Oligocene basement of the Internal Vardar Subzone is still unknown. To the west, the contact with the Central Subzone is interpreted as crustal-scale normal fault related to the opening of the Oligocene basin (Vukanović et al., 1982). To the east, the Tertiary volcanic and sedimentary rocks overly unconformably the high-grade Palaeozoic Serbo-Macedonian Massif.

The exploration fieldwork and sampling in the Drazna project was directed in gaining preliminary data about its geological characteristics in order to evaluate its perspective for future detailed mineral exploration. To achieve this objective, several field traverses were undertaken across the properties. The new information regarding the lithology and alteration is limited and the interpretation shown in the database is extended only to narrow “zones” along the mapped traverses.
Fig. 3.1. Geological map of the Drazna project area (after the official 1:100,000 scale geological map of Kosovo - Vukanović et al., 1982, with the two licenses outlined and location points for the field observations.)
3.2. Geological overview of the project area

3.2.1. Basement rocks

The contact of the Volcanic-sedimentary complex of the license area with the Central Vardar Subzone basement rocks is approximately parallel to the NW boundary of the property and no data were collected from that unit. To the east, adjacent to the border with Serbia, portions of the Serbo-Macedonian basement are exposed. It is composed of alternating biotite and two-mica gneisses (probably paragneisses), amphibolites (metagabbros and metabasalts) as elongated sheets or lenses and muscovite and two-mica schists. This variegated unit is metamorphosed in amphibolite facies conditions and the main high-grade foliation fabrics dips steeply to the east. On a larger scale, and according to the 1:100,000 geological map, the foliation trend outlines km-scale folds with N-S trending axial planes and steep to vertical axes. The section is affected by retrograde greenschist facies tectono-metamorphic overprint.
3.2.2. Volcanic-sedimentary Tertiary Complex

These are considered part of the so-called Lece Magmatic Complex (Marton et al., 2013 and references therein). Regional geological interpretations (geological maps of Kosovo in scale 1:100,000 and 1:200,000) suggest that the complex is characterised by alternating pyroclastic, volcanioclastic and volcanic rocks. These relationships are defined by a multilevel subvolcanic sill emplacement within the clastic unit below the voluminous volcanic cover-canopy at the top of the stratigraphy. The complex is subdivided here into Volcanioclastic Unit and Volcanic Unit.

The Volcanioclastic Unit builds up most of the Tertiary Complex in this area with a maximum thickness of about 200 m, although this is not consistent throughout the whole area. The base of the unit is composed of conglomerates with predominantly rounded volcanic clasts of various sizes (1-2 cm to 15-20 cm). Two types of clasts could be recognised on the field – one with grey-greenish matrix and the other – with red to purple matrix, both with mineral composition of andesitic rocks. The matrix of the conglomerate also shows variations in grain size from sandy to very fine-grained pyroclastic ash. Upward, the stratigraphy of the unit is characterised by alternating coarse- and fine-grained volcanioclastic rocks with upward fining observed in some of the coarser beds (Fig. 3.4.). The finer tuff beds are generally thinner than the conglomerate layers. The tuffs share similarities with the two types of clasts in the conglomerate layers, with either yellow to grey-greenish or red colours. The sedimentary layering in the unit is either subhorizontal or with large wavelength low amplitude undulations. The bedding dips gently to S and SSW or to NW and N probably due to the volcanism and contemporaneous faulting in the area.

![Image](image_url)

Figure 3.4. Characteristic features of the Pyroclastic Unit in Drazna project area. (a) alternation between coarse and fine-grained beds with bedding plane dipping 220/16; (b) alternating yellow and purple coloured volcanioclastic layers, gently dipping to the east; (c) gradation from coarse to fine-grained material within one volcanioclastic layer.
The volcanic rocks are as dykes, sills and large layers at the top of the Miocene volcaniclastic rocks. The few dykes observed on the field have steep to vertical contacts striking east-west. The flat lying unit of the cap-volcanics build up the highest hill-tops in the area. Due to advanced erosion in the Drazna area the thickness is less than 150 m and a thicker volcanic pile is exposed to the north on Serbian territory. At fresh outcrops the volcanic rocks are characterised by porphyritic texture defined by plagioclase and amphibole (in smaller amount), and very fine-grained matrix in which only biotite could be recognised on the field. The matrix is either grey to greenish or red. The two colours probably correspond to different volcanic impulses and is regarded as a primary feature (Fig. 3.5.). Petrography analyses show that the andesites are composed of ca. 20% porphyry minerals – plagioclase, amphibole and clinopyroxene and cryptocrystalline matrix with very fine grained plagioclase detected.

Steep E-W striking diorite dykes are emplaced within the Serbo-Macedonian basement unit. For these rocks, a link with the Tertiary volcanism in the area can be suggested but their age could be anything from late Variscan to present and needs further investigations.

Figure 3.5. Porphyritic andesite with gray (a) and reddish coloured matrix (b). The gray andesite is with trace propylitic alteration (chlorite overprinting amphibole) and weak argillic alteration in veins and in the plagioclase rims. The red andesite (b) is unaltered.

3.3. Alteration and mineralisation
The project area is located between two known mineral deposits – the Draznja Pb-Zn-Ag deposit (currently closed) at the west boundary of the property and the newly discovered Kiseljak porphyry copper-gold deposit (part of the Tulare ore field) in Serbia, adjacent to the border with Kosovo and, respectively, to the east border of the Drazna project. Furthermore, recently Esan, a Turkish Corporation, drilled and indicated certain gold reserves in their Prapashtica project located immediately south of Drazna project area (reports or other exploration data are not publicly available). Published data suggest that the area is characterised by several heat centers (centers of hydrothermal activity and related rock alteration) (Marton et al., 2013). Fieldwork data were collected along traverses and therefore spatial analysis of the alteration style and intensity is not possible at this stage. The size of the presented alteration domains and zones is underestimated due to the mapping approach and reconnaissance character of the fieldwork. The polygons outline only areas visited during the mapping.

In Drazna project area several relatively large domains of the Tertiary volcanic and volcaniclastic rocks are affected by weak propylitic alteration that is marked by secondary chlorite and carbonate minerals (“outer propylitic” alteration). The available data show two domains in the northeast of the project area and one larger domain along the Kaljić River. The propylitic zones are adjacent or partly overlap with the larger zones of argillic alteration. The outcrops along the
Kaljatička River are argillic altered but in the middle of that section the intensity is weak. Only in the western part, the argillic alteration is stronger and associated with hydrothermal brecciation and a zone of advanced argillic alteration (Fig. 3.6. a). In the parts with weak argillic alteration, the volcanic and volcaniclastic rocks show clay minerals replacement but only along network of fractures (Fig. 3.6. b). Areas of overlapping argillic and propylitic alteration zones are sometimes indicated by pervasive argillic replacement in the matrix, stockwork of carbonate veinlets (Fig. 3.6. c) and chloritisation in some of the crystalloclasts or lithoclasts. Often, narrow zones of strong argillic alteration striking ENE-WSW to E-W are found within the large domains of weak to trace argillic alteration (Fig. 3.6. d). A bend of argillic altered volcaniclastic rocks is indicated at the rim of the Palaeozoic basement in the eastern part of the area. Alteration is mostly weak with several “centers” or zones of more intense (moderate to strong) argillic alteration. Some of the rocks with strong argillic alteration show features that might indicate centers or inner zones of advanced argillic replacement. Beside the already described location, along the main river, similar relationships were observed in the southern part of the area (Fig. 3.6. f) as well as in the northwestern part, near Drazna mine. The central north part of the area is characterised by development of multiple zones with narrow halos of phyllic alteration in andesites with general WNW-ESE strike (Fig. 3.6. e). The main strike is again E-W to NE-SW. Narrow zones of intense argillic alteration with similar orientation, often accompanied by certain silicification (probably a transitional facies to advanced argillic alteration), are also observed in that section and in several other places, usually close to the contacts with the volcaniclastic unit.
Although observation points are limited, the majority of the veins have infill of oxidised sulphide minerals. Oxidised sulphides are occasionally found as disseminated grains in the matrix or inclusions in porphyry minerals.

3.4. Structural setting
The mapping traverses in the Drazna area allowed for collection of structural data for the brittle tectonics of the area. The main trend of the faults is NW-SE (Fig. 3.7. a). The majority of the observed
structures have normal fault kinematics with a vertical displacement within the range of few metres. E-W striking structures do not show significant maximum on the histograms but this orientation should be considered important as some of the observed dykes and hydrothermal breccia zones demonstrate similar orientation trends (also subvertical contacts with the host-rocks). The statistical analysis of the orientation of the joints in the volcanic and volcaniclastic rocks of the area (Fig. 3.7. c and d) show two main trends that can be interpreted as conjugated shear fractures in a system controlled by the NW-SE trending faults.

3.5. Conclusions and recommendations
The area shows characteristics of the presence of a hydrothermal alteration system, which possibly developed with multiple heat centers. At this stage, the whole project area is considered perspective for further exploration works. Going forward, conventional and alteration mapping campaigns should be planned for the immediate exploration activities. Structural control on the alteration style is evident from the multiple narrow, probably fault-related, alteration zones, dykes with alteration halos and zones of hydrothermal brecciation. Therefore, a structural analysis, for which data could be collected during the mapping, would be important for later interpretations. The character of the relief and outcrop conditions of the Drazna project area suggest that airborne geophysical survey will be of significant value for the exploration targeting. Soil and stream sediment sampling campaign could also be included in the next exploration stage, although these could be carried out after more precise targets are defined.
4. Viti Project
The Viti Project consists of three adjacent licenses (Viti, Viti-North and Viti-East) all regarded as part of one mineral exploration project (Fig. 4.1).

![Topography map of Viti project area, containing the three separate license areas: Viti-North, Viti and Viti-East.](image)

4.1. Geological background and regional geology setting
Viti Project occupies an area of approximately 300 km² in the southeastern part of Kosovo. Regionally, the rocks within the license can be affiliated to three of the main geological units of the area, namely External Vardar Subzone, Central Vardar Subzone and Internal Vardar Subzone (Fig. 4.2.). The boundaries between the latter represent major tectonic features (faults/shear zones – mostly steeply dipping to northeast to subvertical) that control the large-scale structure of the area but also the local structural patterns.

With respect to age and base and precious metals ore fertility, the rocks in the area can be divided in three major groups: 1) Pre-Cenozoic basement rocks; 2) Palaeogene (Oligocene in age) magmatic rocks (subvolcanic and volcanic, assumed as the source of the ore bearing fluids in the area), volcaniclastic and sedimentary rocks and 3) Neogene and Quaternary sediments.
4.2. Geological overview of the project area

4.2.1. Basement rocks

As basement rocks we refer to a variety of metamorphic rocks of both igneous and sedimentary origin that form the base of the Palaeogene-Neogene volcano-sedimentary cover. In the project area there are three large-scale basement units: 1) Palaeozoic (?) in age, greenschist facies sedimentary succession (schists, marbles, calc-schists, quartzites and different in size bodies of metabasic rocks and foliated granites; 2) Greenschist facies units of Jurassic basalts and related deep marine sedimentary rocks; 3) Upper Cretaceous flysch sedimentary rocks (polymictic conglomerates, sandstones and mudstones), that are isoclinally folded and show some evidence of a very low-grade (subgreenschist facies) overprint.

4.2.2. Volcanic-sedimentary cover complex

Two different age groups of rocks, form this complex: 1) Palaeogene (Oligocene) subvolcanic and volcanic rocks and related epiclastic (Fig. 4.3.) and pyroclastic (Fig. 4.4.) sedimentary rocks and; 2) Neogene (Upper Miocene and Pliocene) sediments (sands, clays and gravels).
The base of the Oligocene succession is composed of reddish polymictic breccia-conglomerates that contain large amount of rounded volcanic clasts of intermediate (latite, trachyte) composition. These are intercalating with yellowish-whitish to pale green tuffs and pyroclastic materials (including ignimbrites). The volcano-sedimentary succession was intruded by subvolcanic bodies and dykes of trachyte, latite and rarely of lamprophyre composition (see supplementary materials, Petrography analyses of thin sections). The subvolcanic bodies are irregular in shape and elongated in NNW-SSE direction. Similar is the general orientation trend of the dykes that follow the main structural trends in the area (see Fig. 4.27 – 4.29). The pyroclastic rocks and the subvolcanic bodies are similar in composition. The Oligocene volcano-sedimentary succession contains reef edifices, mostly corals (Fig. 4.5.). These directly overlie red beds or are associated with other clastic sediments. In some places the volcaniclastic rocks contain coral fragments and clasts of micritic limestones and travertine (Fig. 4.6.). The rocks are similar to those that form the volcano-sedimentary succession of Drazna area, described in chapter 3.2.2.
4.3. Alteration and mineralisation
The fieldwork on Viti project was carried in two separate areas, Viti-North and Viti-East licenses (Fig. 4.1.). The alteration and mineralisation features of the two mapping areas are presented in two separate chapters below.

4.3.1. Alteration and mineralisation of rocks from area Viti-North

Figure 4.7. Topography map of area Viti-North with the numbers of visited localities

a) Alteration and mineralisation within the basement rocks
In Viti-North license area (Fig. 4.7.), along Zhitinska River valley (the cross-section between localities V001-V006), close to the contact with an Oligocene subvolcanic body, the Upper Cretaceous anchizonal sediments are argillised and the alteration varies from weak to strong (Fig. 4.8., Fig. 4.9.), dependin on the proximity to the subvolcanic bodies. The argillic mineral assemblage is overprinted by trace propylitic alteration. In this area, due to the planar anisotropy of the metasedimentary rocks and circulation of fluids along the bedding and/or cleavage (especially in the fine-grained rocks of the basement), the alteration has a pervasive character. Veinlets of Fe-hydroxide (possibly oxidized Fe-sulphides) along structures of lower ranks are registered (Fig. 4.9).
**b) Alteration and mineralisation of the Oligocene sedimentary and volcaniclastic rocks**

The argillic alteration has been mapped in zones along fault structures and as areas of pervasive alteration around smaller or larger Oligocene subvolcanic bodies. As a whole, in the areas where the argillic alteration is pervasive, it is trace to weak (Fig. 4.10., locality V001), often represented by alteration of unstable phases such as volcanic glass in the tuffs. In two small areas, along Zhitinska River valley and close to the contact with an Oligocene subvolcanic body, the volcanic-sedimentary rocks show a strong argillic alteration. There, veinlets of azurite occur along smaller scale structures (Fig. 4.11., locality V003).

In some cases, especially closer to larger faults and contacts with subvolcanic trachyte and latite bodies, the volcaniclastic rocks are affected by more intense argillic alteration (Fig. 4.12.), with a presence of clay minerals after vitrinite clasts and chlorite after biotite, demonstrating propylitic alteration (Fig. 4.13.). The propylitic alteration is of lower temperature origin (“outer propylitic”) and overprints the argillic mineral assemblage.
c) Alteration and mineralisation of subvolcanic rocks (latites, trachytes and lamprophyres)

A strong pervasive argillic alteration is registered in a small trachyte body, located in Viti North license area, along Zhitinska River valley (locality V001). The argillic alteration is more intense along fault zones and areas with denser distribution of exfoliation fractures. The main alteration phases are clay minerals, which overprint mostly vitrinite but also the matrix and larger feldspar phenocrysts.

4.3.1. Alteration and mineralisation of rocks from area Viti-East

a) Alteration and mineralisation of basement rocks

The Jurassic metabasic rocks of Vardar Zone show pervasive style of mostly argillic alteration related either to swarms of subparallel faults (between localities V219-V223, fig. 4.14) or faulted basement, directly beneath covering Oligocene terrestrial sediments (around localities V238 and V239, fig. 4.15). A single small area of a randomly distributed trace propylitic alteration surrounded by low-intensity argillic alteration is registered in the central part of the license area. Moderate silicification of Jurassic metabasalts is mapped along two separate zones (possibly fault structures) around localities V036 and V-038. Along fault zones in several localities (V219 to V221) malachite ± azurite (?) have been identified (Figs. 4.14., 4.16., Fig. 4.17.). In some places, within the Upper Cretaceous anchizonal rocks, veinlets of Fe-hydroxide and zeolite (?) cross-cut the bedding/foliation at low angle (locality V-054).
Figure 4.14. Topography map of area Viti-East with the numbers of visited localities.
Figure 4.15. The easternmost area of license Viti-East. Locations V238 and V239 are closest to the center of the map, in the NW-SE oriented valley.

Figure 4.16. Malachite ± azurite (?) onto joint surfaces within Jurassic diabases from the greenschist basement.

Figure 4.17. Malachite ± azurite (?) in a fault gouge from a fault zone with a strike of ~160°.
b) Alteration and mineralisation of the Oligocene sedimentary and volcaniclastic rocks
A small area of trace to weak silicification has been documented at the south end of Begunce village, within Oligocene basal breccia-conglomerate and/or volcaniclastic rocks (locality V013, Fig. 4.14). There a level of pyroclastic rocks contains also fragments of corals (Fig. 4.18., Fig. 4.19.). The rock is weakly argillised. The coral fragments are more intensely altered so the calcite that forms the coral sept is almost replaced by quartz.

Figure 4.18. Strong argillic alteration in pyroclastic rocks that contain silicified clasts of corals and travertine.

Figure 4.19. A detail of a silicified coral clast, within intensely argillised pyroclastic rocks.

A second prospective locality, V239 (Fig. 4.15.) represents a polymictic breccia-conglomerate layer of the basal (continental type) Oligocene sedimentary unit, covered by tuffs, both of reported Oligocene age. These overlie greenschist facies Jurassic metadiorites, metagabbros and metabasalts from the Internal Vardar subzone basement. The basement rocks contain thin zones of high-intensity argillic alteration related to faults and tectonic joints. Away of the brittle structures, the basement rocks show trace argillic alteration and presence of chlorite, replacing femic minerals although, it is difficult to distinguish between metamorphic and hydrothermal chlorite. Within the sediments that cover the basement rocks, the alteration is strong argillic and affects mostly the matrix but also to some degree the clasts. Calcite veins are also present in the sediments (Fig. 4.20., Fig. 4.21.).

The two described localities share some common characteristics and show similarities with the alteration modes of sediment-hosted low-sulphidation gold deposits (for example Ada Tepe deposit in Eastern Rhodopes, Bulgaria, which is also hosted within Palaeogene terrestrial sedimentary rocks).
Figure 4.20. A sketch of the outcrop at locality V239, representing the relationships between the metamorphic rocks (at the base of the picture), which are covered by Oligocene terrestrial sediments. The entire succession is latterly covered by a thin layer of Quaternary sediments. Note that the faults within the basement that do not continue within the sediments. The basement rocks along the faults are highly altered and some of them host also calcite veins. The calcite veins within the sediments are rather rare. However, around some of the blocks as well as within the matrix, calcite rims and veins have been observed.

Figure 4.21. A detail from outcrop V239, showing a subvertical fault zone around which argillic alteration is registered. The fault strikes 76° and dips 85° to SSE.

c) Alteration and mineralisation of subvolcanic rocks (latites, trachytes and lamprophyres)

In the focus of our field studies was a large subvolcanic body located near villages of Stubla and D. Stubla (points from V029 to V058 on fig. 4.14.). Therefore we name the body “Stubla body’. Stubla body occupies an area of several square kilometers and represents an elongated in NNW-SSE direction subvolcanic intrusion of trachyte to latite composition (see supplementary materials, Petrography analyses of thin sections). The orientation of the body follows the trace of the main fault zones in the area. It intruded different in age and metamorphic grade basement rocks, as well as Oligocene volcano-sedimentary succession (mostly volcanlastic rocks). Intense argillic alteration is related to separate fault zones or areas with dense distribution of exfoliation joints while the entire body is weakly altered. (Fig. 4.22., Fig. 4.23.).

Figure 4.22. A strong argillic alteration of Stubla trachite body along a vertical, E-W striking fault zone (locality V-028).

Figure 4.23. A moderate to weak argillic alteration of Stubla trachite body along a SE to S dipping exfoliation joints (locality V-028).
The ore mineralisation within the subvolcanic rocks from Viti area is presented by rare occurrences of disseminated magnetite-hematite and pyrite grains. The magnetite likely magmatic in origin and often partly or fully replaced by hematite. Pyrite is not common and usually appears as single grains. In most of the visited localities within Stubla body, as well as within some of the smaller subvolcanic bodies in the area, Mn-hydroxide aggregates occur (see also the supplementary materials, petrography descriptions). These are mostly related to areas with dense distribution of tectonic or exfoliation joints as well as occurring in disseminated aggregates (4-5 mm in diameter) (Fig. 4.24.). Tectonic and exfoliation joints are often filled with Fe-oxides and Fe-hydroxides. In some places stockworks (Fig. 4.25.) made of Fe-hydroxides, Mn-hydroxides and hydrothermal quartz veins are presented (for spatial orientation of the veins see Fig. 4.29.).

Figure 4.24. A rock chip of trachyte (weak argillic alteration) with disseminated manganese hydroxide aggregates – locality V029.

Figure 4.25. Stockwork made of Fe-hydroxides, Mn-hydroxides and quartz veins in altered trachytes from Stubla body – locality V045.

Several relatively large subvolcanic bodies with similar composition and orientation occur to the west and northwest of Stubla body. These are also intruding similar basement and Oligocene volcaniclastic rocks. Their alteration style is similar to that of the Stubla body – weak pervasive argillic alteration and intense argillic alteration along fault zones and areas with dense distribution of exfoliation planes. Based on all these similarities, as well as on the close distance between these separated on a map view subvolcanic bodies, we would suggest that all these can be considered as apophyses of the apical part of a larger porphyry pluton, the latter occupying a larger area and forming a slightly elongated in NNW-SSE direction body. Its shape (almost round, see Fig. 4.26.) and spatial position corresponds to the circular (possibly buried caldera) structure, revealed well by the magnetic studies of the area.
4.4. Structural setting
The structure of the area is dominated by several first-rank faults that separate main tectonic zones. The faults are NNW-SSE striking, steep dipping to ENE structures with supposed reverse-fault kinematics (after the regional interpretations, incorporated in the official geological maps). The lower rank subordinate failures show similar orientation pattern of predominantly strike-slip kinematics. Larger NNW-SSE faults are steep to vertical with dextral strike-slip to oblique-slip kinematics. Faults of lower ranks are either conjugated with the larger structures from the main NNW-SSE trend and thus, representing different synthetic to antithetic structures or form damage zones due to tensile stress. The latter represent usually E-W or SW-NE striking swarms of faults or wider damage zones where the rocks also show more intense (argillic) alteration. Comparing the spatial position of fault and dyke/contacts of subvolcanic bodies, it is clear that they share a common orientation (Fig. 4.27 and Fig. 4.28). Structural diagrams and field relationships illustrate the fact that the emplacement of the Oligocene magmatic rocks and their later deformation was controlled by the studied fault system. Most of the dykes and subvolcanic contacts are oriented NNE-SSW and trace Riedel type of failures, conjugated with some of the larger faults. Other dykes and contact surfaces are oriented parallel to the main fault system and thus striking NNW-SSE. A few dykes are oriented at high angles to the main fault direction and thus occupying room, probably opened along either antithetic (sinistral strike-slip to oblique-slip) faults or failures of tensile nature (Fig. 4.27 and Fig. 4.28). Similarly, the spatial distribution and orientation of different types of veins is controlled by larger faults and related secondary and third rank structures (Fig. 4.27 and Fig. 4.29). The main vein trend is oriented at high angles to the main fault directions and, geometrically, in a dextral strike-slip regime, would represent spaces, formed as tension fractures (gashes) located parallel to the main compressive stress $\sigma_1$. 

Figure 4.26. An approximate trace of a possible larger plutonic body (black dashed circle). The shape is after a speculation with the spatial distribution (in a map view) of the subvolcanic bodies. The area underlined with the grey dashed line is a possible continuation of the same magma chamber to the northwest or a separate shallow magma chamber (for details see the attribute table of geology layer in ArcGIS project). The purple line outlines the border of Viti license area.
4.6. Conclusions and recommendation

4.6.1. Conclusions

The alteration and mineralisation in different types of rocks from these two areas show some common characteristics.

The alteration within the basement rocks is mostly of argillic and propylitic type. In a few localities silicification has been observed as well. The alteration, in general, varies in its intensity from trace to weak and moderate, and in a few cases to strong. Different types of alteration are related to separate faults and/or fault and damage zones of larger fault structures, as well as to the contact areas of Oligocene subvolcanic bodies and dykes of trachyte, latite or lamprophyre composition (supplementary materials – ArcGIS project). Due to their lithology peculiarities, the basement rocks are prospective as hosts to carbonate replacement and vein type epithermal deposits.

Mapped alteration in the Oligocene sedimentary and volcaniclastic rocks is related to fault structures, dykes and larger subvolcanic bodies of trachyte, latite and lamprophyre composition the latter being emplaced within the Oligocene volcaniclastic-sedimentary succession. The alteration within the Oligocene sedimentary and volcaniclastic rocks from Viti area varies in its intensity. It is generally trace to weak with limited zones of moderate to strong intensity. The alteration is of argillic, propylitic, phyllic and silicic type.

The alteration of the subvolcanic bodies and dykes is of argillic or propylitic type and varies in its intensity. All of the mapped dykes show moderate to weak, and rarely strong argillic alteration. In the areas with pervasive argillic alteration the latter is of trace to weak character.

Alteration mapping carried out as part of this reconnaissance program has identified certain alteration zones. The alteration suggests a shallow level of the magmatic-hydrothermal system.
(although probably below the advanced argillic zone). The few occurrences of more intense silicification along zones in the basement and a single occurrence of weak pervasive silicification within volcaniclastic rocks, in which the Oligocene subvolcanic bodies are emplaced, suggest that the present day erosional level is below or aside of the possible zone with advanced argillic alteration. Low and intermediate sulphidation related mineralisation are the primary targets in this area, although potential exists also for deeper porphyry related mineralisation. Geophysical data suggests that the part of the apical area of a possible larger magma chamber was probably downthrown and buried beneath Neogene-Quaternary sediments in a recent graben feature. Potential for advanced alteration exists in this area as a result.

4.6.2. Recommendations
The fieldwork accomplished showed that different approaches should be considered for the different license areas in Viti Project. We would recommend a detailed exploration (including structural and alteration) mapping at an appropriate mineral exploration scale for areas Viti-North and Viti-East. The alteration mapping should be accompanied by SWIR and XRF analyses.

Due to the thick Neogene-Quaternary sediment cover in Viti area (central license area) and lack of outcrops, the exploration activities there should start with geophysical (magnetic) studies.

Geochemistry study along profiles that cross the zones of intense argillic alteration in Stubla body and related smaller subvolcanic bodies, as well as in Oligocene volcaniclastic rocks would underline the possible low-sulphidation targets. In order to avoid soil sampling in young sediments, a detailed mapping of the Quaternary sediments is required. Isotope geochronology information might be useful at this stage. It will allow for linking the obtained magmatic ages with regional ore forming processes and to help for better targeting in the future exploration activities.

Sampling of the direct soil cover of the Miocene sediments in the area, as well as collecting of samples is recommended given the possible analogue to Lithium mineralisations similar to Jadar deposit, Northwest Serbia.
5. References


