CHAPTER II
CHARACTERISTICS OF GEOLOGICAL STRUCTURE

Involving in the structural plan in the framework of the Vang Tat area are sedimentary, effusive - sedimentary and meta - effusive at different level formations and intrusive ones of ultramafic – to - acidic composition formations. The ages of these formations range from old to young?

II - 1 - PETROSTRATIGRAPHIC CHARACTERISTICS

Late Proterozoic - Early Cambrian metasedimentary formation (PR_3 - €$_1$)

Sedimentary, effusive - sedimentary formations distribute at a wide area occupying more than a half of investigation area in the Vang Tat area, about 161 km^2. Involving in these formations, based on stratigraphic order, are:

The lower part consists of terrigenous, metaterrigeno - effusive formation bearing lenses of limestone, dolomite together with lenses or thin beds of effusive rocks of mafic - to - acidic composition.

Sedimentary, sedimentary - effusive formations distribute at a wide area, occupying more than a half of investigation area in the Vang Tat area, about 161 km^2. Involving in these formations, based on stratigraphic order, are:

+ The lower part of the stratigraphic section consists of quartz, occupying 50 - 52%, muscovite – sericite: 30% biotite: 2%, feldspate: 10%, the rest are sphene, epidote, tourmaline and hydroxide Fe. The structure of the rocks is oriental and clearly foliated with leucocratic and milanocratic belts as seen at the outcrop XX. 263 and corresponding thin section (photo II – 1) or a

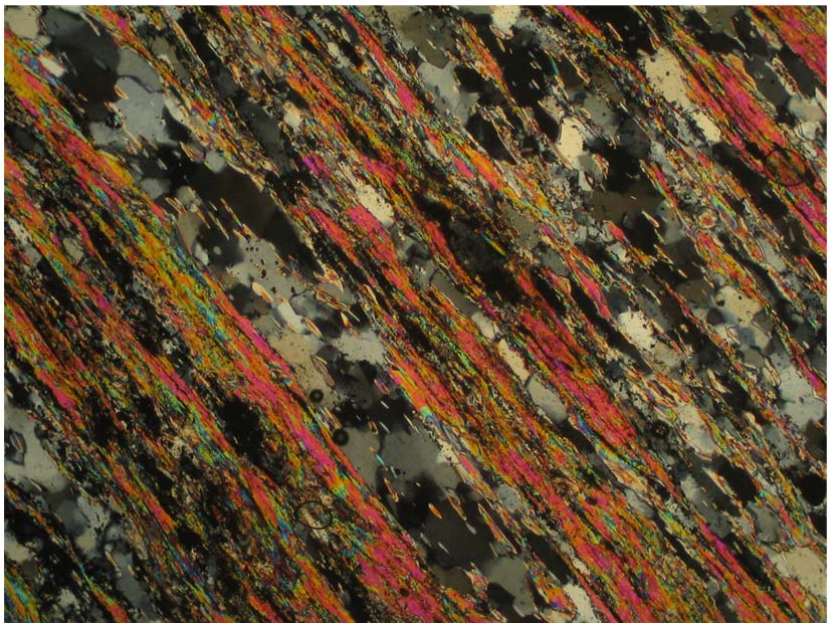

Photo II – 1: Quartz - sericite - muscovite schist
(Sample No. XX. 263. Nicol N^+, zoom: 480^x)

part of feldspar – quartz - mica schist with following composition: feldspar - 43%, quartz - 30%, biotite – muscovite - 30%, the rest are hydroxide Fe and ore. The rock is white grey mixed with brownish lines, fine - grained. Structure is oriental. Biotite here was muscovitized and chloritized as typically seen in a thin section of sample XX.156 through photo II – 2.

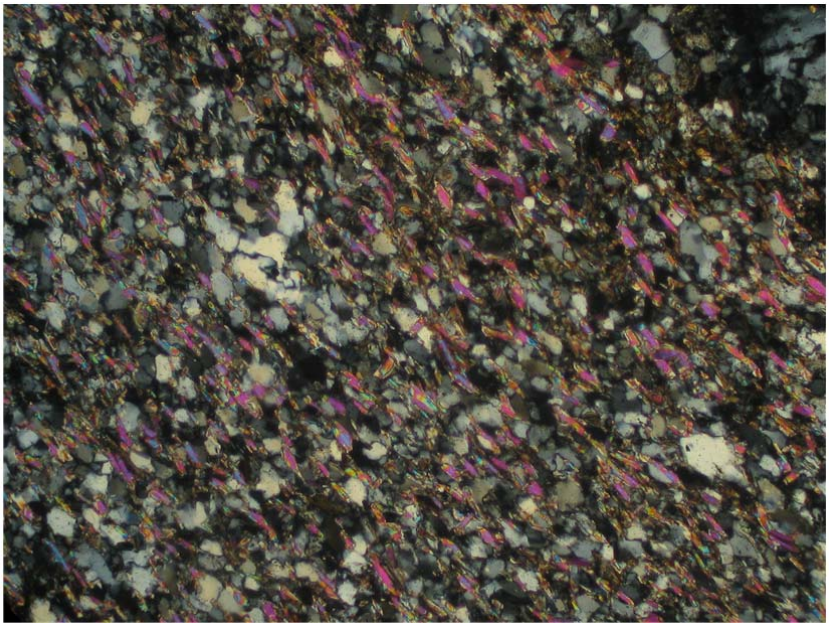

Photo II – 2: Altered feldspate – quartz – mica schist
(Sample XX. 156. Nicol N^+, Zoom: 480^x)

Intercalating in this member is a lense of a medium - grained quartzosed dolomite. Its thickness is about 15 - 20m, stretching to N - NW structural direction as seen at outcrop 236 through photo II - 3. Dolomite is fine - grained (dimension: >0.3 mm), irregular, at some places it was crashed into fine - grained assemblage. Light grey, massive rocks occupy 92%.

Under polarized, transparent microscope, dolomite is yellowish caused by light contamination of clay. Its cleavage is nearly not seen, however its cleavage can be seen in coarse grains with typical twins. In the dolomite lense, there are some quartz veins of about 0.3 - 0.5mm in thickness.

Intercalating in the lower part of the stratigraphic section, mafic - neutral formations were greenized. Rocks of this member were mostly hydrothermally altered, resulted in remaining some neutral plagioclase phenocrysts in the form of isometric small - sized plates with multiple twins and coloured minerals as seen at outcrop XX 213 and in some thin sections (photo II 4; 5).

The rock is grey green, fine - grained with massive structure. In its petrographic composition, chlorite occupies 42% which was formed during alteration of glass basement, plagioclase and coloured minerals. Neutral plagioclase phenocrysts in the form of isometric small - sized plates occupy about 14%. Twins were partly altered into chlorite. Besides, there are also hydroxide Fe and ore, etc.

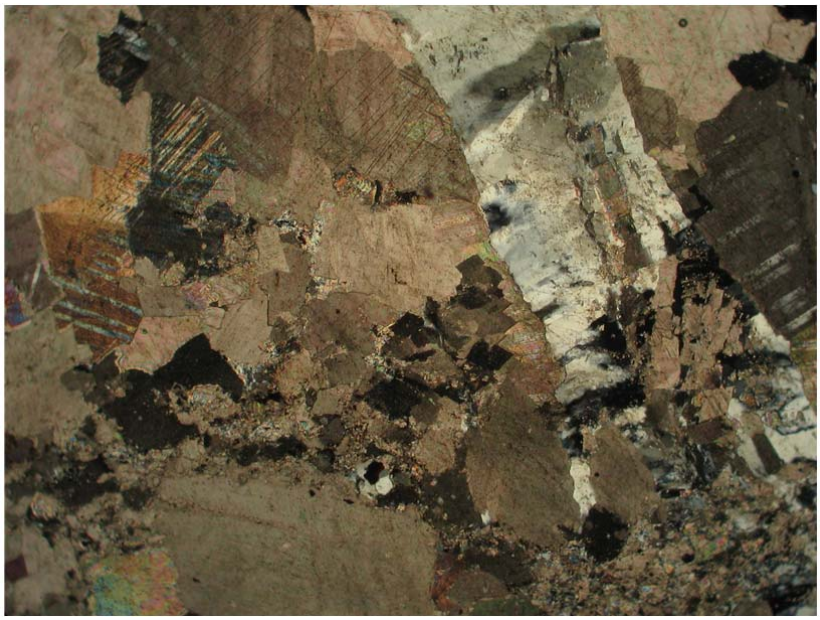

Photo II – 3: Dolomite penetrated by small - sized quartz vein
(Sample 236, Nicol N+, zoom: 240^{x})

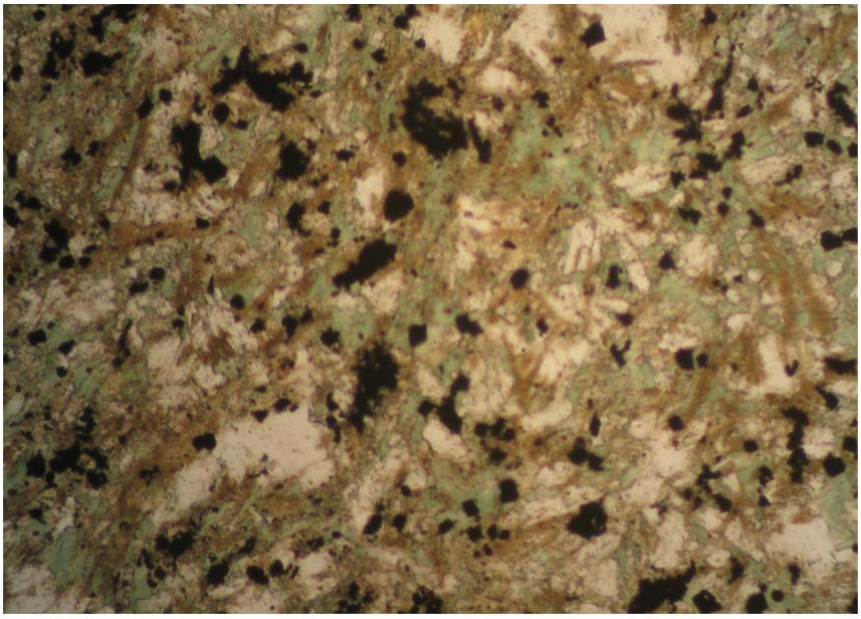

Photo II – 4: Mafic - neutral greenized effusive rock
(Sample XX.213; Nicol: N^-, zoom: 480^x)

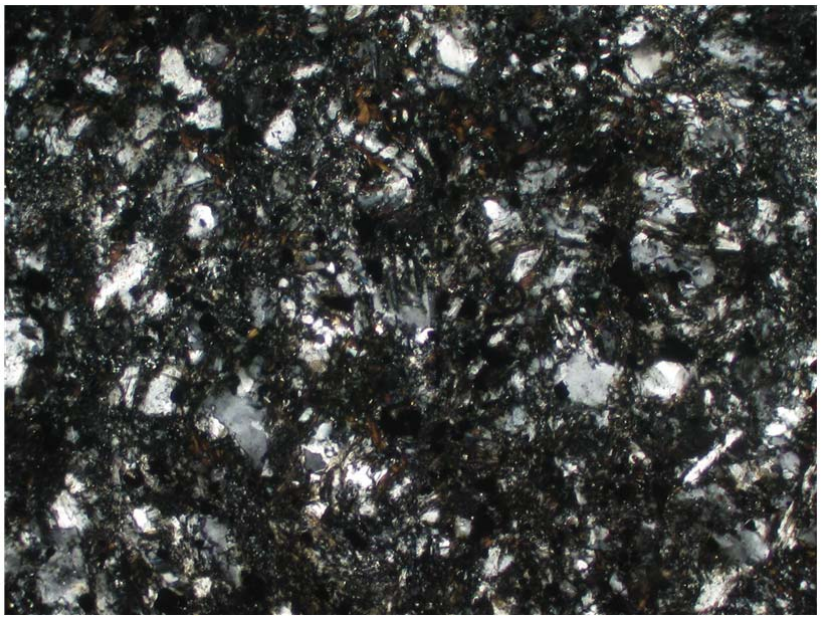

Photo II – 5: Mafic - neutral greenized effusive rock
(Sample XX.213; Nicol: N^+, zoom: 480^x)

+ Transferring upward to the upper part of the stratigraphy is altered effusive layer. The rock is blue grey, fine - grained with oriental structure.

Petrographic composition mostly includes quartz - silicon occupying 30%, residual feldspar occupying 42%, sericite derived (altered) from feldspar minerals occupying 28%, there are also fine - grained tourmaline together with zircon, sphene and epidote as seen at outcrop XX.216 with petrographic composition as shown by photo II - 5

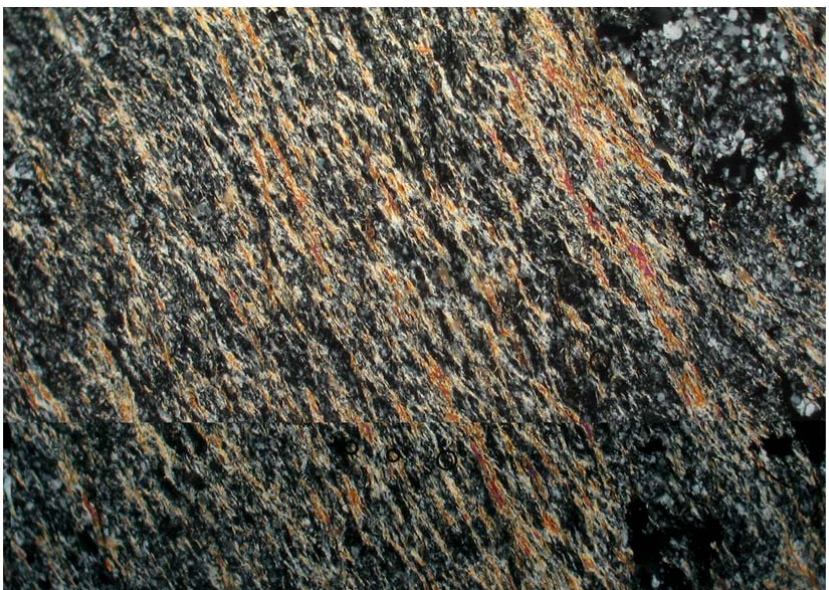

Photo II – 5: Altered acidic effusive rock with oriental structure
(Sample XX. 216; Nicol: N+; zoom: 240 x)

+ The high part is made of terrigenous formations including clayey aleurolite, which was metamorphosed to form quartz - sericite schist in some places there is also not thick quartzitic sandstone. The rock is greenish grey mixed with rose light belts with microfolded structure.

Petrographic composition includes, sericite, chlorite : 77%, quartz : 20%, the rest are a little of muscovite, feldspare, tourmaline, zircon and hydroxide Fe as shown in thin section XX.0060, photo II - 6.

Photo II – 6: Claystone mixed with aleurolite
(Sample XX 0060; Nicol: N^{+}; Zoom: 240^{x})

The top part of the section includes medium – to - thick bedded quartzite, their petrographic composition consists mainly of differently differentiated quartz: fine - grained quartz in the lower part; more coarse - grained quartz seen at more high part.

In the lower part of the quartzitic layer, terrigenous, acidic effusive formations were covered by a layer of oriently distributed fine - grained

quartzite. The rock is light yellow, consisting mainly of quartz (97%), the rest are muscovite, tourmaline, epidote, zoisite, zircon and hydroxide Fe as shown in sample XX.216/1 (photo II - 7).

Photo II – 7: Fine - grained quartzite with oriental structure
(Sample XX.216/1; Nicol: N^{+}; Zoom: 480 ^{x})

Transitting onto a quartzitic layer is quartzitic quartz sandstone. The rock is massive, grey black, fine - grained. Its petrographic composition includes mostly coarse part occupying 80%, in which quartz: 75%, feldspar: 4%, silicious pieces, quartzite, felsitic pieces, tourmaline, zircon. Cementing material is mosly sericitized clay: 20%. Typical for this layer is outcrop XX.1005 with thin section as shown by photo II - 8.

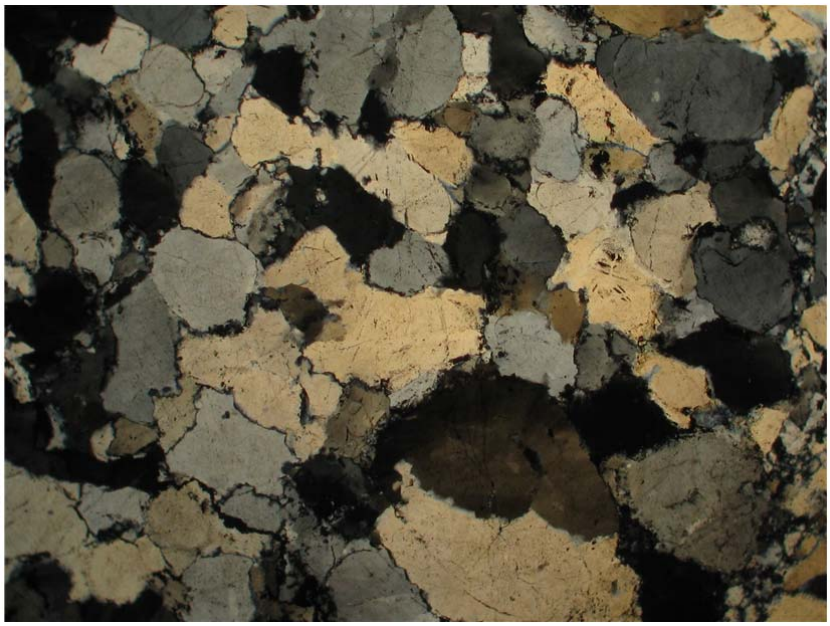

Photo II – 8: Quartzitic quartz sandstone

(Sample XX. 1005; Nicol: N^{+}; Zoom: 240^{x})

The upmost part consists of altered quartz aleurolite. The rock is strongly solidated, grey brownish with black spots. Cement was recrystalized composing of microscale, cryptocrystalline clay - sericite mixed with cryptocrystalline silicon. Detrital grains are mostly qoartz: 74%, feldspar: 5%, and the rest: muscovite, tourmaline, ziricon. The coarse part occupies 80%, while the fine - grained part as cement occupies 20%. Typical for this quartz aleurolite member is outcrop XX.3042, thin section as photo II - 9.

Photo II – 9: Quartz aleurolite
(Sample XX. 3042; Nicol: N^+; Zoom: 240 ^{x})

Thus, on the basis of the sections of and relationship between sedimentary, effusive - sedimentary and metasedimentary formations, these formations can be divided into 2 clear members.

+ The lower part consists of quartz – sericite - muscovite schist, feldspar – quartz - sericite schist intercalated with lenses of limestone, dolomite limestone. Transitting upwardly are metaterrigenous rocks in the form of mafic - neutral effusive and altered acidic effusive layers.

+ The high part consists mainly of terrigenous rocks including clayey schist mixed with leurolite, quartzite and monomineral aleurolite (mostly fine - grained quartz).

Comparison between the Nui Vu Formation (PR_3 - €$_1$*nv*) distributed in the same structural zone and the said one shows that both Formations are correspondent. On the basis of this fact, above - mentioned metasedimentary

and effusive - sedimentary formations can be thought to be correspondent with Late Proterozoic - Early Cambrian formations.

b) Cenozoic effusive basaltic formations

Cenozoic effusive basaltic formations are limitedly distributed. In some locations, these formations are remained as protobody, at other places they were strongly eroded to be remained as tigerskin form on the structural basement. These formations are mostly distributed at a NE corner of the survey and investigation area.

These formations include basalt olivine. The rock is black greenish, fine - grained with hard massive structure and porphyric texture with intersectional basement.

Composition of phenocryst includes olivine occupying 7%, pyroxene: 10% and plagioclase.

Composition of basement includes plagioclase microcrystals occupying 50%, pyroxene and fine - grained olivine: 20%, basic glass and ore.

The thin section photographs No XX. 026 (photo II – 10) shows clearly this formation.

Photo II – 10: Basalt olivine through a thin section
(Sample XX. 026, Nicol: N^{+}, Zoom: 240 ^{x})

Basalt olivine bodies have been met at the South of Noong Key Uc area. On the satellite images, these bodies are relatvely leucocratic which are clearly differed from surrounding rocks.

Besides basalt olivine, there has also been met tuff basalt. The rock is brown grey with spots, its structure is massive and texture is detrital with altered glass ash.

Petrographic composition includes:

- Debris: quartz: 2 – 3%; pyroxene: 5%, carbonate fragments, micro - grained lime, fragments of quartz - sericite schist, sericite clay, basaltic fragments, fragments of altered glass, etc.
- Cemented materials: mostly altered volcanic glass.

Tuff basalt is seen in following thin section XX. 0054 and photo II – 11.

Stratigraphycally, sedimentary and metasedimentary formations overlie on the said formation, at some places, these formations in the frorm of vent penetrated through this formation. Comparing with basalt olivine formation and their tuff from Tay Nguyen plateau of Vietnam, the said formations can be rationally attributed to Cenozoic age.

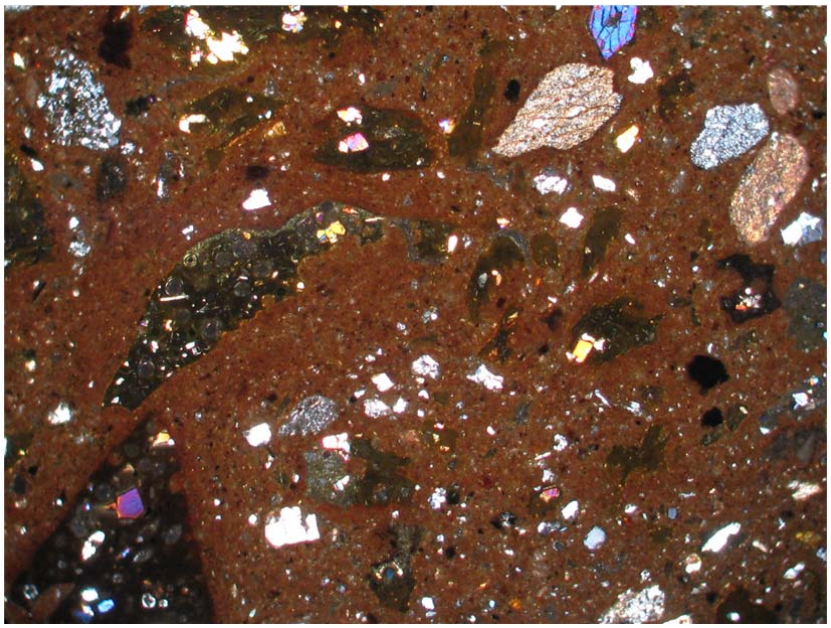

Photo II – 11: Tuff basalt (Sample XX. 054; Nicol: N^+; Zoom: 240 ^{x}).

II – 2 – INTRUSIVE FORMATIONS

In the framework of the 1/25,000 scale survey and investigation area intrusive formations occupy 35% of the whole territory, which are aged in from Early Paleozoic to Late Mesozoic? They are of different composition ranging from acidic - ultraacidic to mafic - ultramafic. Referencing and comparing with intrusive formations in the region, main intrusive formations in the working area can be named as follows:

A - Late Ordovician - Early Silurian intrusive granite porphyry formations.

Intrusive granite porphyry formations aged in Late Ordovician - Early Silurian (γ O_3 – S_1) are exposed mainly at the SE part of the working area. They are big batholitic bodies which are very fine in the Sport images. The results of survey and pertographic analysis of these batholitic bodies show that intrusive formations here are porphyraceous granite, porphyraceous granite biotite, medium – to – coarse - grained granite biotite.

Intrusive coarse - grained porphyraceous granite, porphyraceous granite biotite formations are pink grey, big - sized phenocrysts of feldspar K. Petrographic composition includes phenocrysts of feldspar K of more than 12mm in dimension occupying 55%, clayey, sericitezed idiomorphic plate - form of smaller side plagioclase occupies 14%, quartz is in the form of idiomorphic occupies about 27%. Besides, there is also fully chloritized biotite, some plates of which were replaced by muscovite. Involving in the rock's composition there are also zircon, sphene, apatite, ortite and hydroxide Fe of uncondiderable amount.

The analytical results of thin sections taken from this massif indicate that the common composition of the rock is mainly composed of feldspare K occupying about 35 - 55% and then plagioclase and quartz.

Alteration processes of rocks are sericitization and argillization of feldspare and plagioclase while biotite was partly replaced by muscovite and chlorite.

Typical texture of the rock is porphyraceous, massive structure which are typically expressed in thin sections: XX. 4255; XX. 4274; XX. 5040; XX. 5041 (photos: II – 12, 13, 14, 15).

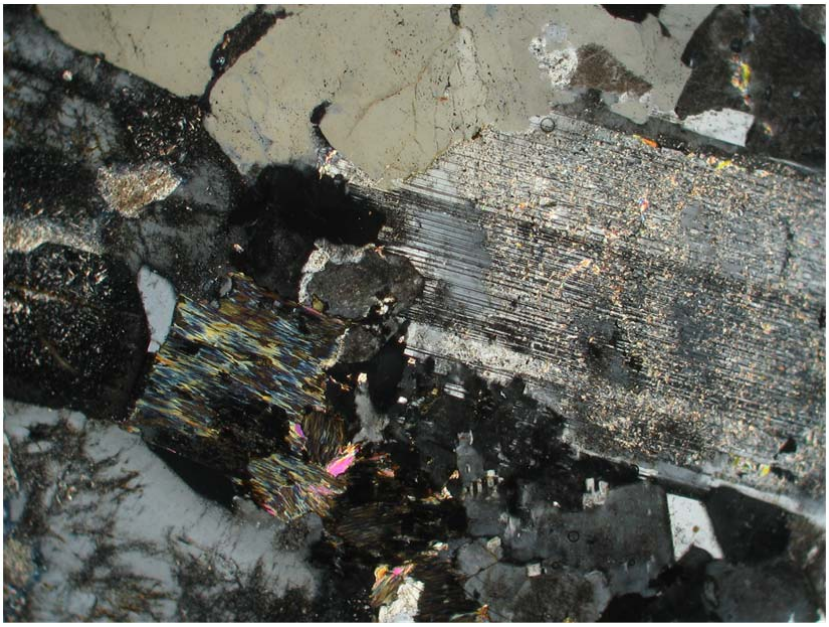

Photo II – 12: Coarse - grained porphyraceous granite
(Sample XX. 4255; Nicol: N $^{+}$; Zoom: 240^{x})

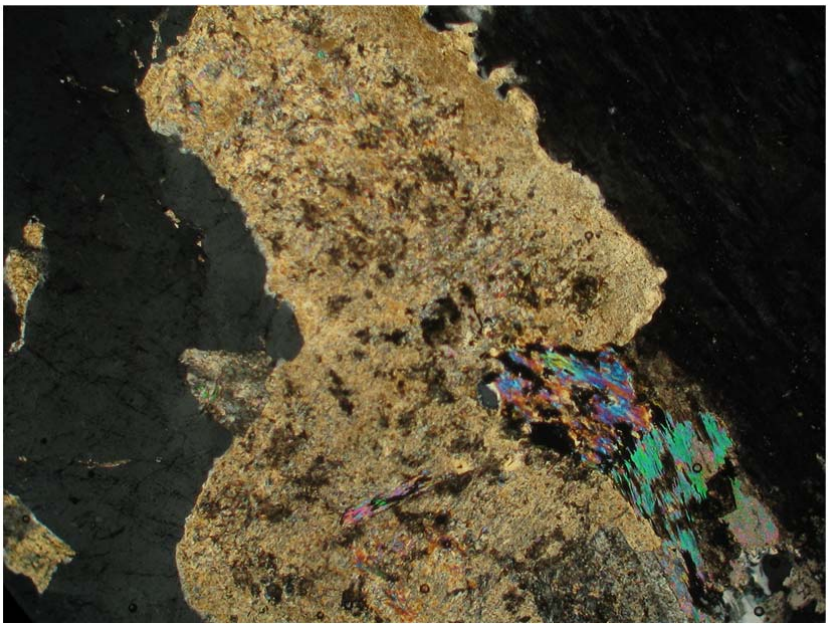

Photo II – 13: Coarse - grained porphyraceous granite
(Sample XX. 4274; Nicol N $^{+}$; Zoom: 240^{x})

Photo II – 14: Coarse - grained porphyraceous granite
(Sample XX. 5040; Nicol N $^{+}$; Zoom: 240^{x})

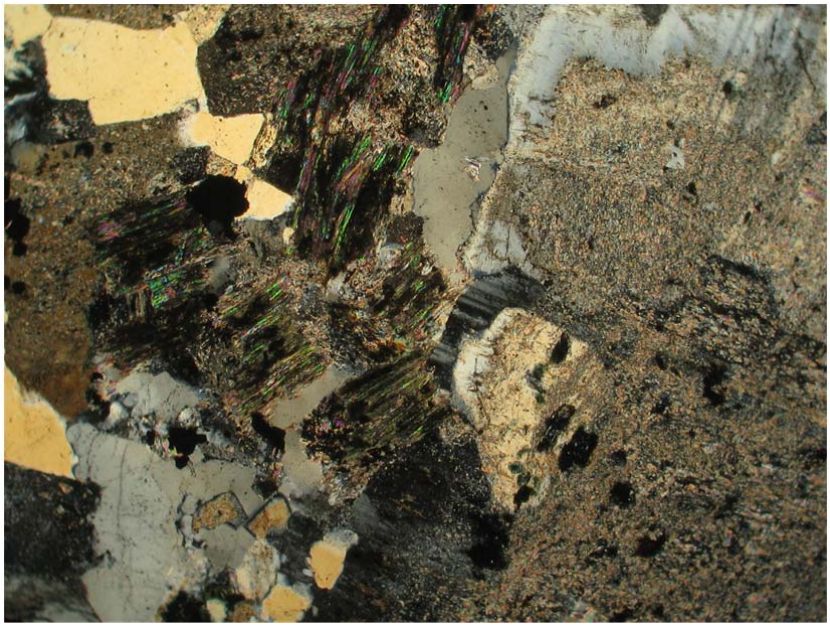

Photo II – 15: Coarse - grained porphyraceous granite
(Sample XX. 5041; Nicol N^+; Zoom: 240^x)

Comparing pertographic, structural, textural characteristics of the rocks of these formations and their typical alteration features with that of the well studied rocks of Dien Binh complex from Kon Tum structure in Vietnam indicates that batholithic bodies distributed at the SE part of the survey area are corresponding to that of Dien Binh comples in Vietnam. The dating of the rocks of Dien binh comples by U - Pb isotope method gives results of about 451 ± 3 Ma (Maluski et al – 1999, 2000 – France), thus, attributing these formations to the Late Ordovician - Early Silurian in age is quite rational. However some data on dating by Ar - Ar isotope method give more young age. These data might be given from analysis of biotite altered during Permian - Triassic time.

b) Devonian intrusive granodiorite and leucocratic granite formations (γ D)

Devonian intrusive granodiorite and leucocratic granite formations are mainly distributed in the framework of the Western part of the working area with exposed area of about 43 km^2. This is a big batholithic body, developing on over the Sekaman area to the West part of the survey area. On the sport images, their surface is relatively fine indicating an eroded relief.

The results of survey and analysis of petrographic composition show that their composition includes strongly argillized plagioclase occupying 50 – 52%; quartz of isomorphic and irregular forms: 15 - 20%; feldspar K in the form of subhedral plate: 15 - 20%, their big - sized plates are of mosaic texture

with plagioclase. Coloured minerals are biotite and strongly chloritized: 15 - 20%, with some strongly epidotized and zoisitized parts. Besides, there are also seen sphene and hydroxide Fe. All these specifications are expressed on the photo II – 16.

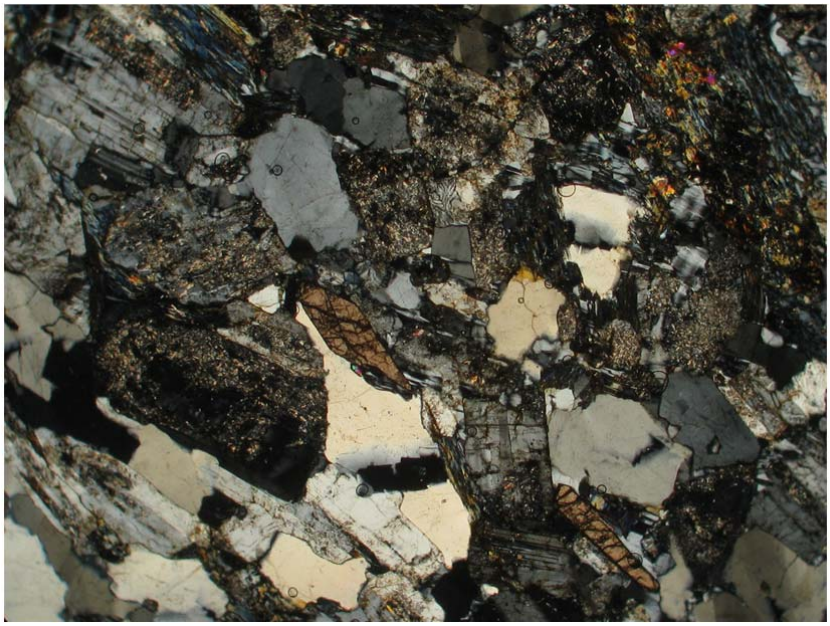

Photo II – 16: Altered granodiorite
(Sample XX. 104; Nicol N^{+}; Zoom: 240^{x})

The rock is opaque white, transparent white and greenish black grey. Its texture is subhedral.

Besides granodioritic formations, there are granite biotite formations in their differential range. The rocks are cataclastic due to their distribution close to faults. Their typical alteration is epidotization.

The dating of biotite derived from these rocks by K - Ar isotope method given an age of 396.6, in combination with mineral resources investigation data obtained by JICA Consultant, this is rationable that the age of these formation could be Devonian.

c) Carboniferous leucocratic intrusive granite formations (γ C)

Intrusive formation attributed to the Carboniferous age on the basis of comparison with the development of intrusive formations established by JICA Consultant at the South of the exposed site of these intrusive bodies. All of them are on the same topographic belt, having the same tone of satellite images.

Attributed to the Carboniferous age, the rocks were exposed at the SE corner of the survey area in the form of big - sized batholith, occypying tatal area of about 11 km^2.

Although the collected data are unadequate, so the batholithic bodies attributed to Carboniferous age are composed of granite formations poor in biotite. The rocks are leucocratic, medium - grained and quite differed from the above - mentioned Late Ordovician - Early Silurian intrusive formations.

The rock composes mainly of feldspar K: 50%; plagioclase: about 15%; quartz: 31%; completely – altered – into - chlorite biotite occupies small amount, there are also zircon, orthite and ore.

Feldspar K is mainly semiautomorphic, plate - form microcline with typical network - form twins, its dimension under microscope is 0.5 - 1.5 mm. Semiautomorphic, plate - form plagioclase was mostly sericitized as seen on a photo II - 17, or typical microcline phenocryst (photos II 17, 18).

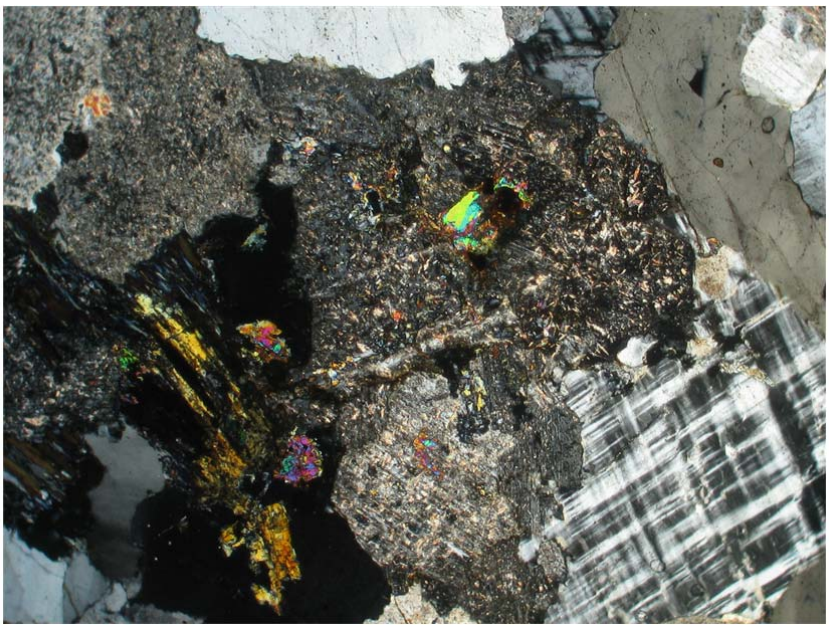

Photo II – 17: Poor - in - biotite granite
(Sample XX. 4229; Nicol N^{+}; Zoom: 240^{x})

In difference from Late Ordovician - Early Silurian granite porphyry formations, occurrences of Cu, Co, Se, etc were powefully developed in the said magmatic formations.

The dating of biotite given from granite formations distributed at the South of the survey area by K - Ar isotope method gives the age of 301.5 Ma, which is corresponding to Late Carboniferous (C_2).

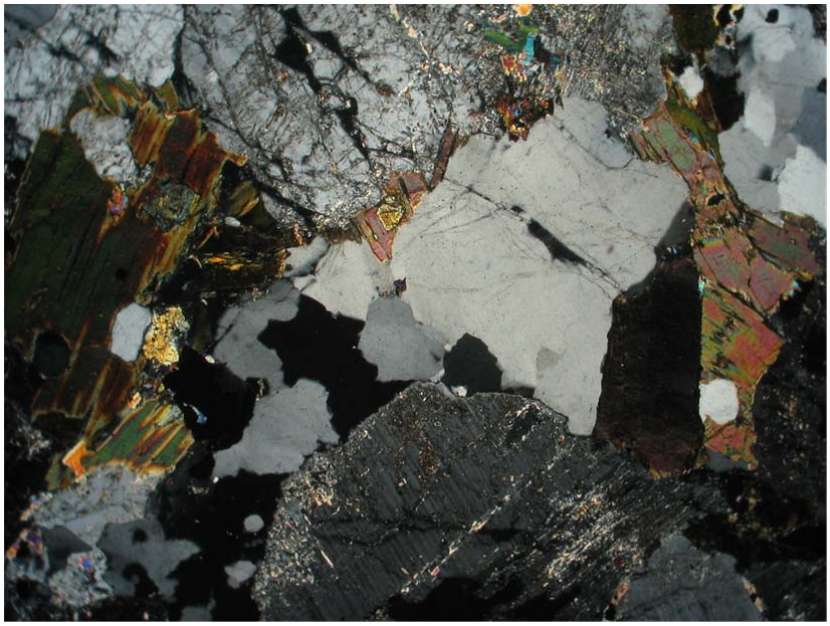

Photo II – 18: Poor – in - biotite granite
(Sample XX. 3262/2; Nicol N^{+}; Zoom: 240^{x})

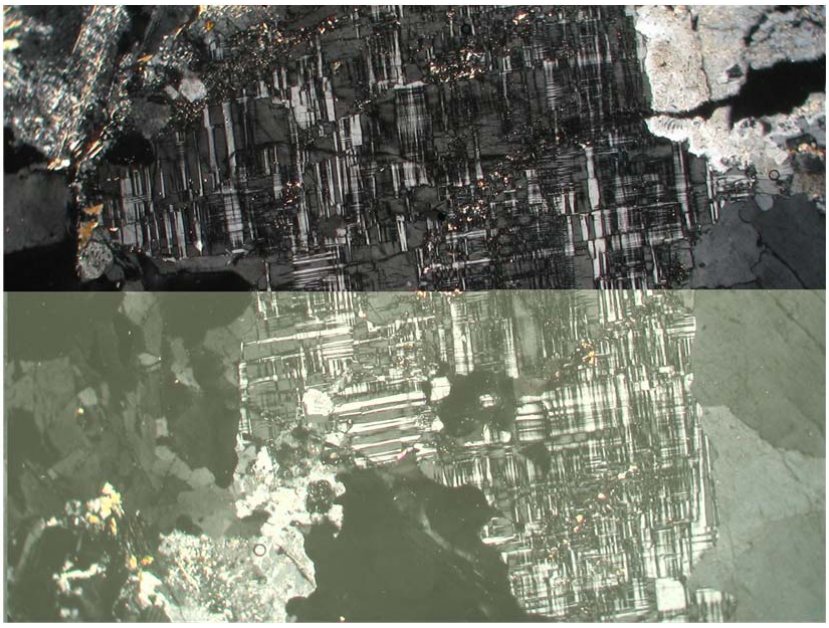

Photo II – 18: Typical microcline's crystals of poor - in - biotite granite
(Sample XX. 3262/2; Nicol N^{+}; Zoom: 240^{x})

d) Middle Triassic intrusive ultramafic and mafic formations.

Intrusive ultramafic and mafic formations are not much exposed in the working area following a belt of submeridional direction along a deep - seated fault of the same direction. These are dyke bodies penetrated through sedimentary terrigenous formations as well as through the older intrusive ones.

Their distribution area of these bodies is about 10.5 km^2. Their big massifs are isometric.

Their composition consists mainly of much altered pyroxene. The results of petrographic analysis show that:

Residual pyroxene occupies 5%, residual plagioclase occupies nearly 2%, tremolite and actinolite occupy 73%, the rest are sericite, epidote, cacbonate chlorite and ore.

The primary rock is determined to be fine - grained gabbro.

Typically, the rocks are strongly altered, Related to these massifs are high chemical aureolas of Ni, Co, V, Cr, etc.

Typical rocks of these formations are seen on thin section XX.1094 with demonstrative photo II – 19.

Photo II – 19: Gabbro with residual pyroxene
(Sample XX. 1094; Nicol N^+; Zoom: 240^x)

Besides the big above - mentioned intrusive bodies, there are also existed ultramafic dykes which were strongly altered into tremolite penetrated through Devonian granite formations. These dyke bodies were almost altered into tremolite - serpentinite - talk formation (sample XX.146) or into tremolitic formations (sample XX.3095) consisted maily of needle – stick - like crystals of these minerals as seen in corresponding thin section (photos II – 20, 21).

Thus, it is obviously that mafic and ultramafic formations are in penetrative relationship with older formations including Devonian intrusive batholithic bodies. Their comparison with mafic magmatic occurrences in

adjacent regions indicate that composition, texture, structure of these formations are corresponding to that of rocks of the Chaval Complex in almost the same geological structure, while the age of the Chaval complex was determined by Rb - Sr isotope method to be of 243Ma, at the same time by Sm - Nd isotope method to be of 213 Ma, that are corresponding to Middle Triassic.

Typical alteration of rocks as described by the results of petrographic analysis is listwaenization, which is related to rare and precious mineral resources in later hydrothermal process.

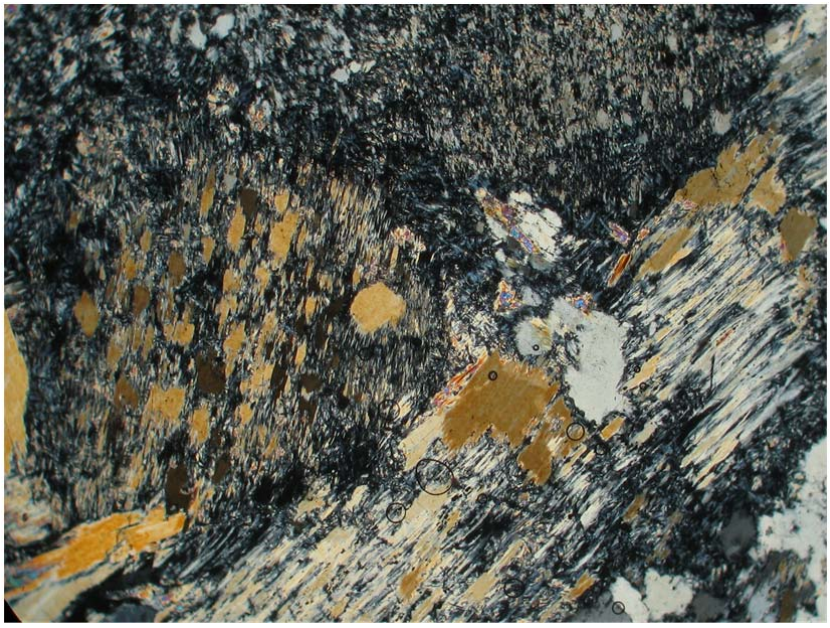

Photo II – 20: Tremolite – actinolite - talk rock
(Sample XX. 146; Nicol N^{+}; Zoom: 240^{x})

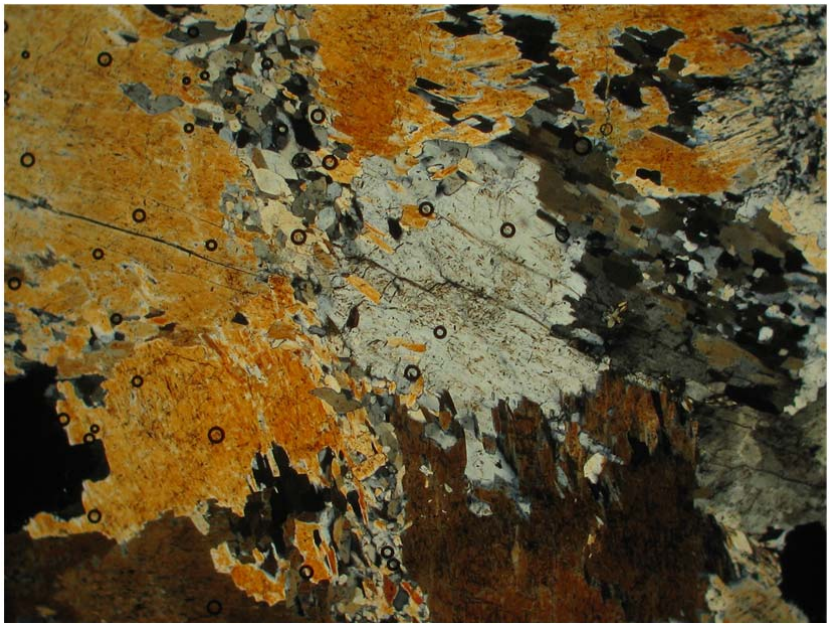

Photo II – 21: Tremolite rock

(Sample XX. 3095; Nicol N^{+}; Zoom: 240^{x})

e) Jurassic rich – in - tourmaline leucocratic granite intrusive formations

In the framework of the survey area, there is only found a satellite - form isometric rich In - tourmaline intrusive granite massif which is exposed near southern boundary.

The rock is transparent white and muddy white, irregular - grained with tourmaline.

Its petrographic composition includes mainly idiomorphic, irregular, sericitized, argillitized plagioclase (some its plates are of 4 - 6mm in dimension), occupying 50 – 55%; feldspar - K with network twins, occupying 15 – 20%. There are also quartz, muscovite and tourmaline occupying 2%. Its typical features can be seen through sample XX.150/1 and photo II – 22 hereunder or at outcrop XX. 204.

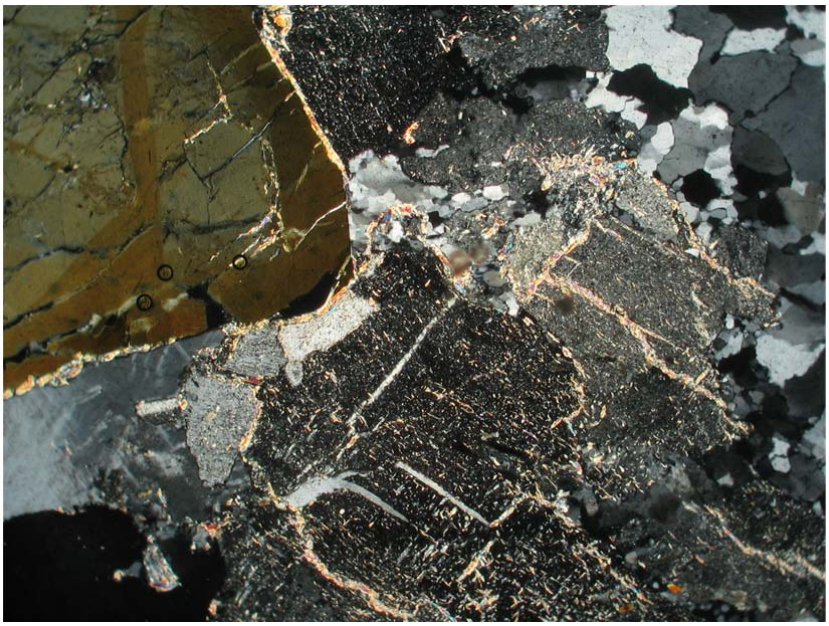

Photo II – 22: Tourmaline - bearing leucocratic granite.

(Sample XX. 150/1; Nicol N^{+}; Zoom: 240^{x})

The rock's typical alterations are greisenization, tourmalinization at internal - and outernal contact of the rock. Their comparison with formations of that type in adjacent regions with the data of dating by K – Ar method being

185.7 Ma, that is corresponding to Jurassic or corresponding to the Ba Na complex in Vietnam.

f) Undiscriminated leucocratic lamprophyre

Lamprophyric formation is occurred in a limited area, found only at SW part of the Van Tat gold mine. It expresses as a leucocratic lamprophyre - kersantite dyke with petrographic composition mainly consisted of biotite (35%), altered feldspar (45%), chlorite, apatite and ironiferous ore.

The rock is leucocratic, fine - grained, well crystallized.

Typical texture is lamprophiric.

It is obviously that, development areas of lamprophyre - kersantite aere the places, where a lot of geochemical haloes of Sn, Bi and high - level heavy minerals aureolas of chromite and gold, etc.

So far, the existence of dykes of leucocratic lamprophyre and related mineralization are the aslects that need to make clear in the future.

Typical place, where lamprophyre kersantite occurs, is outcrop XX. 3127, its petrographic features are well demonstrated in the thin section and its photo II – 23.

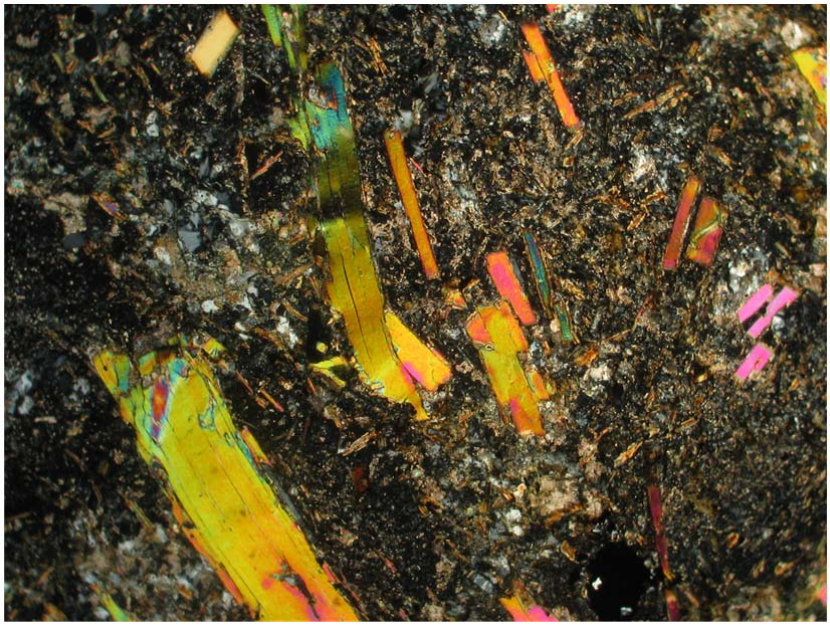

Photo II – 23: Lamprophyre kersantite
(Sample XX. 3127; Nicol N^{+}; Zoom: 240^{x})

II – 3 – DESTRUCTIVE FAULTS AND FOLDS

In the 1/25,000 scale survey and investigation area, faulting and folding activities are intensivelly developed, creating different massifs and folds of different scales. The results of survey allow dividing them as follows:

a) Destructive faulting activities

The destructive faulting activities in the 1/25,000 scale preliminary survey and investigation area are focused in two directions:

- Sublatitudinal direction,
- NE - SW direction.

+ Faults - frac tures develop along submeridional direction (?).

This destructive system is considered as the oldest one related to a destructive zone of regional scale, stretching over and cutting through the whole area. Accompanying with this tectonic destructive system are a series of mafic dykes developed to the same derection and a milonitization zone developed along internal and outernal boundaries between Devonian intrusive formations.

This destructive system has a poweful development history, and it might be the strongest system in the forming period of mafic intrusive bodies, the age of which is corresponding to that of Cha Val complex (243 Ma ÷ 213 Ma), that means Middle Triassic.

This destructive system is developed more powefully in the Western part of the survey area, creating an intensive milonitization zone while in the Eastern part, it created shear cleavages cutting terrigenous formations into the belts of submeridional direction.

The analytical results of Devonian intrusive rocks show the appearances of strong milonitization as indicated by following photos (photos II – 24, 25, etc.).

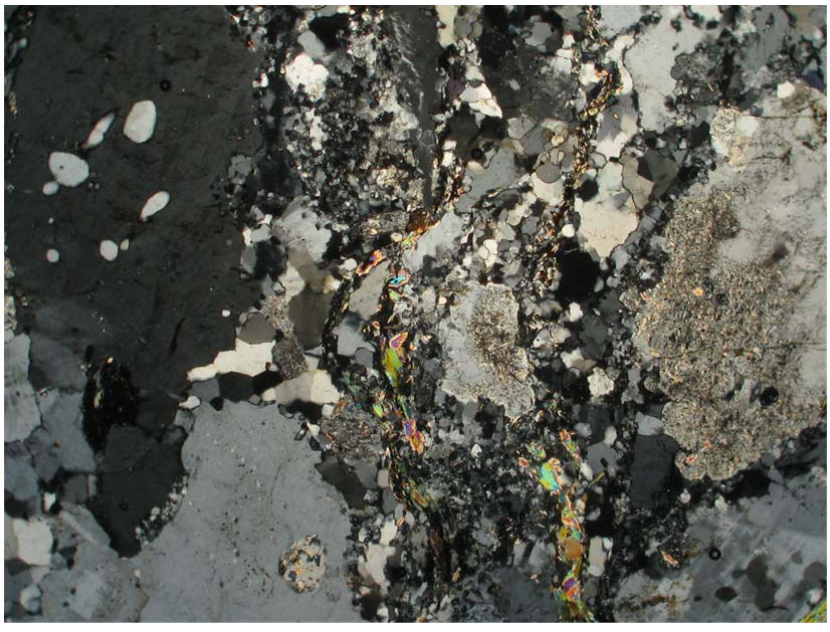

Photo II – 24: Cataclastic granite
(Sample XX. 141; Nicol N^{+}; Zoom: 240^{x})

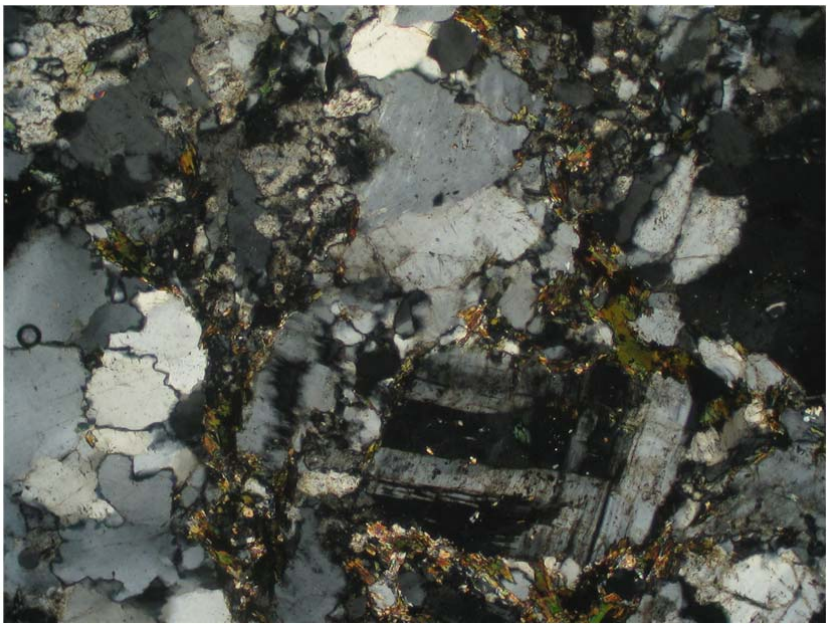

Photo II – 25: Cataclastic granite
(Sample XX. 189; Nicol N^{+}; Zoom: 480^{x})

Systems of faults and fractures of submeridional direction are mainly developed at the North of the survey - prospecting area, while at the South their appearance seems to be weaker.

+ Faults and fractures of NE - SW system.

The NE - SW faults and fractures are mainly distributed at the SE part of the survey area. This faulting system is developed in the framework of the Ordovician - Silurian intrusions and younger Carboniferous - Permian formations. They play a role as boundary between the old and young intrusive formations. This system is localy acted at the SE part of the survey area.

At the Northern and central parts, this system has cut and shifted destructive system at certain distance.

b) Folding activities

The folding activities in the survey - prospecting area are of regional character, manly expressed on the exposed areas of terrigenous rocks.

In the survey - prospecting area, there is a great folding structure including 2 synclines surrounding an anticline, which develops to submeridional direction, streaching throughout the prospecting area. Besides, there occur also isometric uplifted domes of local scale.

+ Lineament folds

- Western syncline

This is a big syncline related to deep - seated fault developed along the syncline’s axis extending from the north to the south. Mafic and ultramafic

intrusive bodies are found to develop along this syncline's axis. The two wings of the syncline consist of terrigenous rocks including clay, metasiltstone. In the western wing of which, there possibly occur chemical sedimentary formations, whereas, in the the eastern wing, there are developed acidic and mafic effusive formations.

The results of survey indicate the western wing has been strongly folded resulting in deeper dipping angle, while the eastern wing is more gradually sloped, expressing clearly by dipping to the east of the syncline's axis surface.

- *Eastern syncline*

This is a synclinorium codirectional with that of main structure, where main terrigenous formations are developed. This folding system is discontinuous There is evidence of interruption occurrences and short folds in scale, but based on the attitude of their branches, these folds are correspond to symmetrical synclines. Along axes of synclines, there occurred accompanied ore mineralizations such as iron ore beds, gold - bearing areas which point to a role of faults along synclines' axes as bodies bearing ores to develop into terrigenous formations of related flanks.

- *Lineament anticlines*

The lineament anticlines are mainly developed in the central part of the survey area, being a part of a lineament folding system intercected between the above - mentioned synclines. Anticline, on the axis of which are developed young intrusive formations, was also clearly separated by faulting system of submeridional and NE - SW directions. Similar to the west syncline, the two flanks of the anticline are asymmetrical, the dip of the rocks in the west flank is slope, while the rocks in the east flank are dipping more gentle.

+ Uplifted dome structure

The system of uplifted dome structure in the surveyed area is mainly developed in its SE corner, where develop Early and Late Paleozoic intrusions. Uplifted domes are of relatively wide scale, in which still have not found mineralization occurrences, whereas, there have been found numerous evidences of greisenization, tourmalinization as well as tin and tungsten mineralization occurrences.

In general, the structure of the surveyed area is relatively complicated, developing from Proterozoic to Mesozoic with its structural plan developed mostly in Priterozoic - Paleozoic and it had been destroyed in Late Paleozoic and Early and Late Mesozoic, which created favourable conditions for mineralization development in it, especially Au, Fe, Ni, Co, Sn, W mineralization related to certain geological structures.