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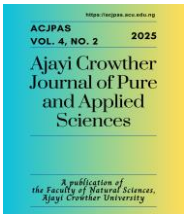

Article

Mineral Chemistry of Talc Schist in Wonu-Apomu Area, Southwestern Nigeria

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Abstract

Talc schist occur within the Precambrian basement complex rocks of Wonu-Apomu area, southwestern Nigeria and have been investigated with divergent views on their nomenclature and petrogenesis. Earlier research works on the origin of talc schist in Nigeria have been inconclusive due to insufficient compositional data, the earlier studies relied mainly on geochemical data, however, this research is unique because mineral chemistry was utilized for the first time to elucidate the transition phases and evolution of talc schist in the study area. Field mapping on a scale of 1:25,000 was carried at Wonu-Apomu area. The petrographic analysis, Scanning Electron Microscope-Energy Dispersive Spectrometry (SEM-EDS) and Electron Probe Micro-Analysis (EPMA), were carried out to determine the mineral morphology and chemistry. The petrographic analysis, the SEM-EDS and the EPMA revealed that the talcose rock samples comprises mainly of talc, anthophyllite, Cr-bearing clinochlore, olivine, tremolite, amesite, saponite, serpentine (antigorite), ferrichromite and magnetite. Two major groups of talc schist were distinguished, from the mineral chemistry plots. The first group is made up of talc-chlorite with FeO concentration of 2.86-4.69 wt.% and $Mg/(Mg+Fe_{total})$ of 0.92-0.95, while the second group is the talc-magnesian saponite with FeO concentration of 11.51-14.01 wt.% and $Mg/(Mg+Fe_{total})$ of 0.77-0.79. The mineral chemistry analysis revealed that talc and saponite of the talc schist had low TiO_2 content of (0.00-0.02 wt%) which are characteristic of dunite-type magma. The Electron Probe Micro-Analysis revealed the alteration phases in the talc-schist, with talc composition ranging from pure talc to talc-chlorite, talc-chlorite-saponite and talc-chlorite-saponite-antigorite-chrysotile. The mineral chemistry further revealed that the talc schist is a dunite-type magma which is boninitic in composition.

Keywords: Talc schist, Talc-Chlorite, Talc-Magnesian-Saponite, Mineral Chemistry, Transition phases.

1. Introduction

Talc is a hydrated magnesium layered-silicate having a chemical formula of $Mg_3(Si_2O_5)$ or $Mg_3Si_4O_{10}(OH)$ and belonging to the phyllosilicate group of minerals [1]. Talc is formed from diverse geological processes including; hydrothermal alteration of mafic and ultramafic rocks, contact or regional metamorphism of ultramafic rocks, low grade thermal metamorphism of siliceous dolomites and dolomitic carbonates and alteration of serpentinised rocks.

Wonu-Apomu area lies between latitudes 7°15′ and 7°30′ N and longitude 4°00′ and 4°15′E within the schist belts of the southwestern Nigerian Basement Complex (Figure1). The geology of the study area consist of migmatites, amphibolites, lherzolite, talc schist, quartzite, quartz schist, granites and pegmatite (Figure1).

The lithology of the Basement Complex of Nigeria can be grouped into migmatite-gneiss-quartzite complex, the schist belts, and the Pan-African intrusives [2,3], cross-cut by minor felsic and mafic intrusives. The schist belts of Nigeria comprise of low-grade metasediment dominated belts trending in the N-S direction. They are more prevalent in the western half of Nigeria and are described to be of Upper Proterozoic supracrustal rocks, that were folded within the migmatite-gneiss-quartzite complex [4]. The rock types of the schist belts include psammites, quartzites and quartz schists, biotite schists, muscovite schists, graphitic schists, talc schists banded iron formations and carbonate rocks (marbles or dolomitic marbles). Other minor rocks include amphibolites, amphibole schists, talc schists, serpentinites and pyroxenites, metaconglomerates and calc-silicate rocks [5-14].

Previous studies on composition and petrogenesis of the amphibolites and talc- schist belts relied solely on geochemical analysis [16, 17]. However, Ajayi [17] revealed that these rocks were probably altered derivatives of the ultramafic bands associated with the basic volcanics from which the amphibolites were derived. Also, Adeleye [18] revealed the presence of chromium-bearing chlorite (clinochlore), as essential mineral constituents in the talc-schist of Apomu and Ilesha areas.

Consequently, this study aims at utilising, petrographic studies, Scanning Electron Microscope-Energy Dispersive Spectroscopy (SEM-EDS), Electron Microprobe Analysis to highlight the mineralogy, mineral chemical composition of mineral phases in the talc schist, so as to unravel the transition phases of the talcose rocks in Wonu-Apomu Area.

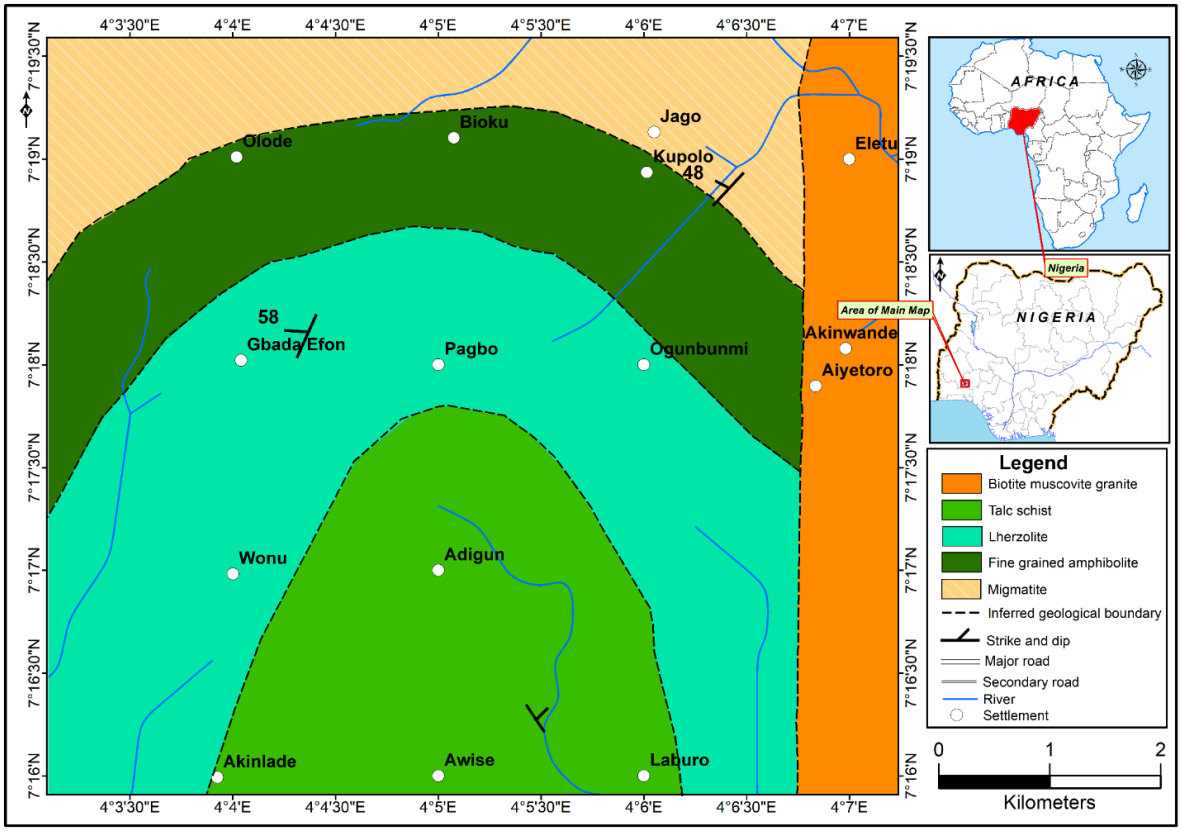

Figure 1: Geological map of Wonu-Apomu area.(modified after Adeleye [19])

2. Materials and Methods

Field study and laboratory analyses were carried out. Geological field mapping on a scale of 1:25,000 was carried at Wonu-Apomu area using topographic map, geologic hammer, compass - clinometers and Global positioning system (GPS). The laboratory work involved sample preparation, petrographic study, Scanning Electron Microscope-Energy Dispersive Spectrometry and Electron Probe Micro-Analysis. Thin and polished sections prepared from the rocks were subjected to petrographic analysis, Scanning Electron Microscope-Energy Dispersive Spectrometry (SEM-EDS) and Electron Probe Micro-

Analysis (EPMA), were all carried out at the Department of Geology, University of Johannesburg, Johannesburg, South Africa.

3. Results and Discussion

3.1 Petrography of the talc shist

The petrographic analysis revealed that the talc schist is composed of talc and talc-chlorite constituting up to about 80% with lesser proportions of anthophyllite, Cr bearing clinichlore, tremolite, actinolite, serpentine (antigorite), ferritchromite, magnetite and olivine (Figure 2).

3.2 SEM EDS of the Talc Schist

The SEM-EDS of talc schist from Wonu-Apomu area showed the presence of olivine (forsterite) and ferritchromite (Spectrum 2) (Figure 3). The SEM-EDS of the talc schist showed manganese-bearing ferrichromite in aluminosilicate matrix (Spectrum 16), some unaltered olivine (Forsterite) (Spectrum 17), in graphite-bearing chloritic groundmass (Figure 4).

Chromite is an ubiquitous accessory mineral in all the talc samples with an average mode of 1-3 %. Pods and lenses of chromite are aligned, revealing foliation in the talc schist. Ferritchromite occurs as distinct and highly reflective rim around chromite with or without, an outer rim of magnetite. The boundary between chromite and ferritchromite is commonly sharp, just as the boundary between ferritchromite and magnetite.

The SEM-EDS of talc schist from Ibadan-Apomu area showed the presence of magmatic fluid rich in allanite (Spectrum 1) and monazite (Spectrum 2),which altered olivine (Forsterite) (Spectrum 3) and pyroxenes to produce amesite, chlorite, diabantite, saponite, tremolite, actinolite, anthophyllite, ferritchromite, magnetite and secondary carbonate (Figure 5). The pervasive nature of the fluid was observed in almost complete destruction of the olivines, pyroxenes and other primary minerals and replacement with REE-bearing minerals, such as, monazite and allanite. The petrography and SEM clearly showed the possibility of two parent sources for the talc bodies. The talc-rich purer variety with extensive carbonates might be sourced from the metasedimentary schist, while those with higher impurities are probably derived from the alteration of the Fe-rich tholeiitic and komatitic rocks.

3.3 Mineral Chemistry

3.3.1 Mineral chemistry of Talc-chlorite-saponite

Representative mineral chemistry of the talc schist of Wonu-Apomu are presented in Tables 1a and b. The talc composition ranged from pure talc to talc-chlorite, talc-chlorite-saponite and talc-chlorite-saponite-antigorite-chrysotile.

From the results of the mineral chemistry two major groups of talc schists were distinguished, they are, the talc-chlorite with FeO concentration of 2.86-4.69 wt.%; $Mg/(Mg+Fe_{total})$ content of 0.92-0.95 (Tables 1a-b) and the second which is the talc-magnesian saponite with FeO concentration of 11.51-14.01 wt.% and $Mg/(Mg+Fe_{total})$ content of 0.77-0.79 (Table 2). The structural formula of saponite calculated for sample TC4/28 is $Ca_{0.5}(Mg_{4.8}Fe_{1.2})Si_8O_{22}(OH)_4$. The low TiO_2 content of the talc and saponite (0.00-0.02 wt%) (Tables 1 and 2) are characteristic of dunite-type magma. The talc bodies are associated with pyrrhotite, pentlandite and chromite ores.

A plot of the amesite, saponite and talc and saponite composition on the triangular diagram of Alt *et al.* [20] and Nimis *et al.* [21] showed gradual decrease in MgO content from amesite to talc through Mg-saponite (Figure 6). The chemistry of the Mg-saponite and talc in the talc schist of Wonu-Apomu area (Figure 7) showed that they are ore associated saponites and olivine and pyroxene associated saponites derived from hydrothermal alteration of ultramafic rocks. As shown in Figure 8 the talc bodies vary from talc-chlorite to diabantite, which is also a variety of chlorite.

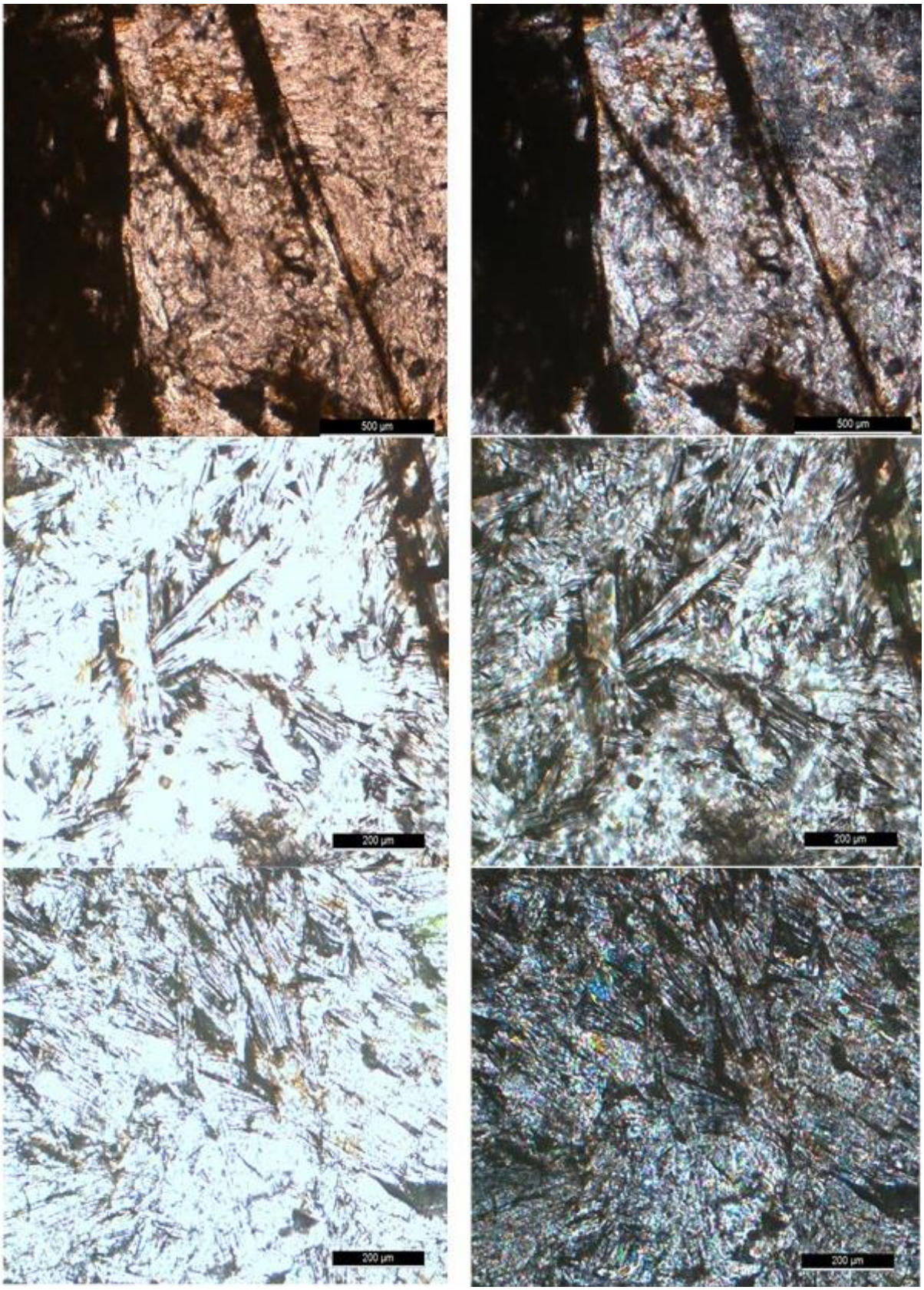

Figure 2: Photomicrograph of talc schist from Wonu-Ibadan-Apomu area showing olivine and pyroxene alteration to antigorite/chrysotile, tremolite - asbestos (top) and talc-chlorite (bottom). Note the complete replacement of original matrix mass by antigorite (± chlorite) on the left. Under one direction polarization of light (left) and cross-polarised light (right).

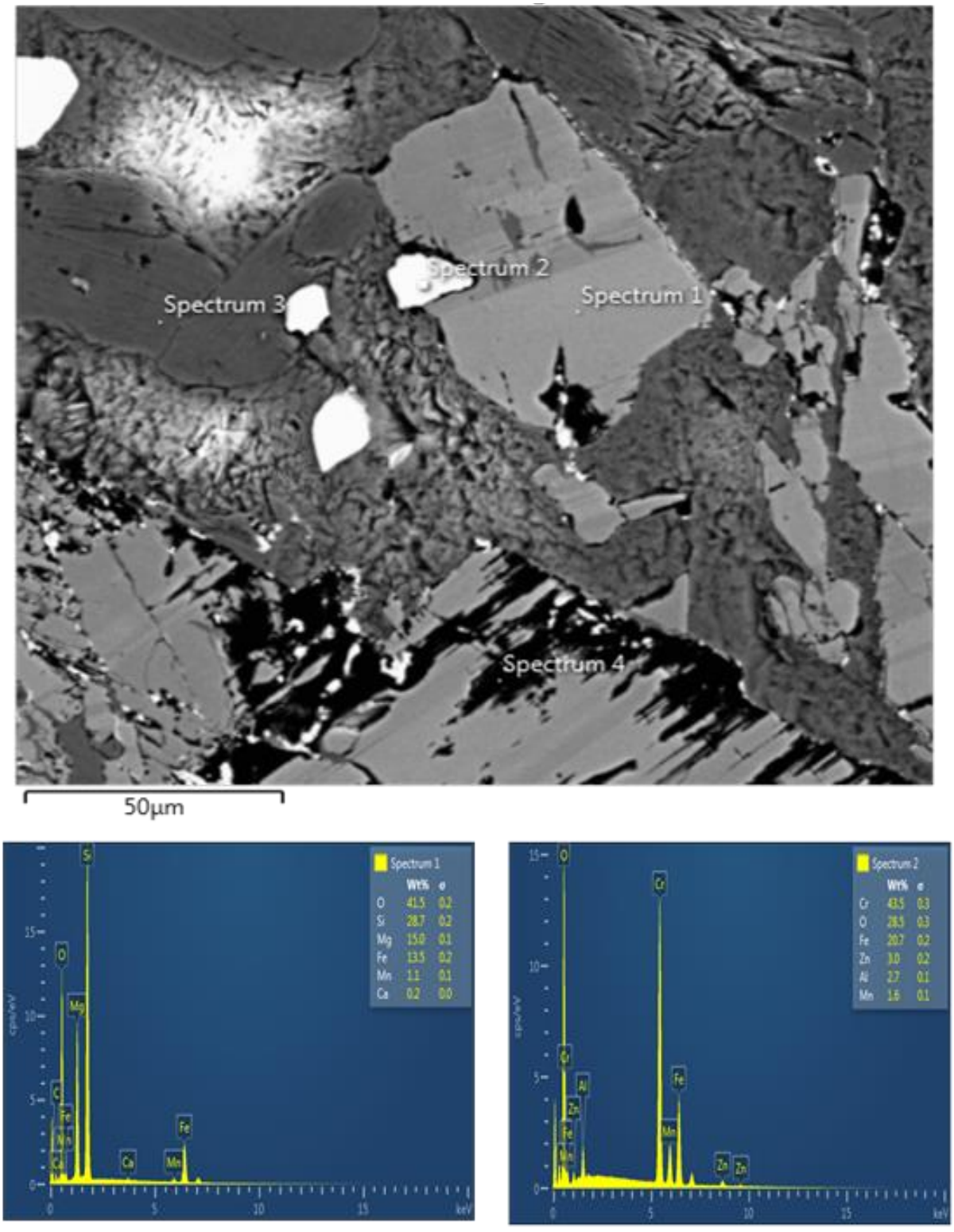

Figure 3: SEM-EDS of talc schist from Wonu-Apomu area showing olivine (Forsterite) (Spectrum 1), Ferritchromite (Spectrum 2), olivine (Forsterite).

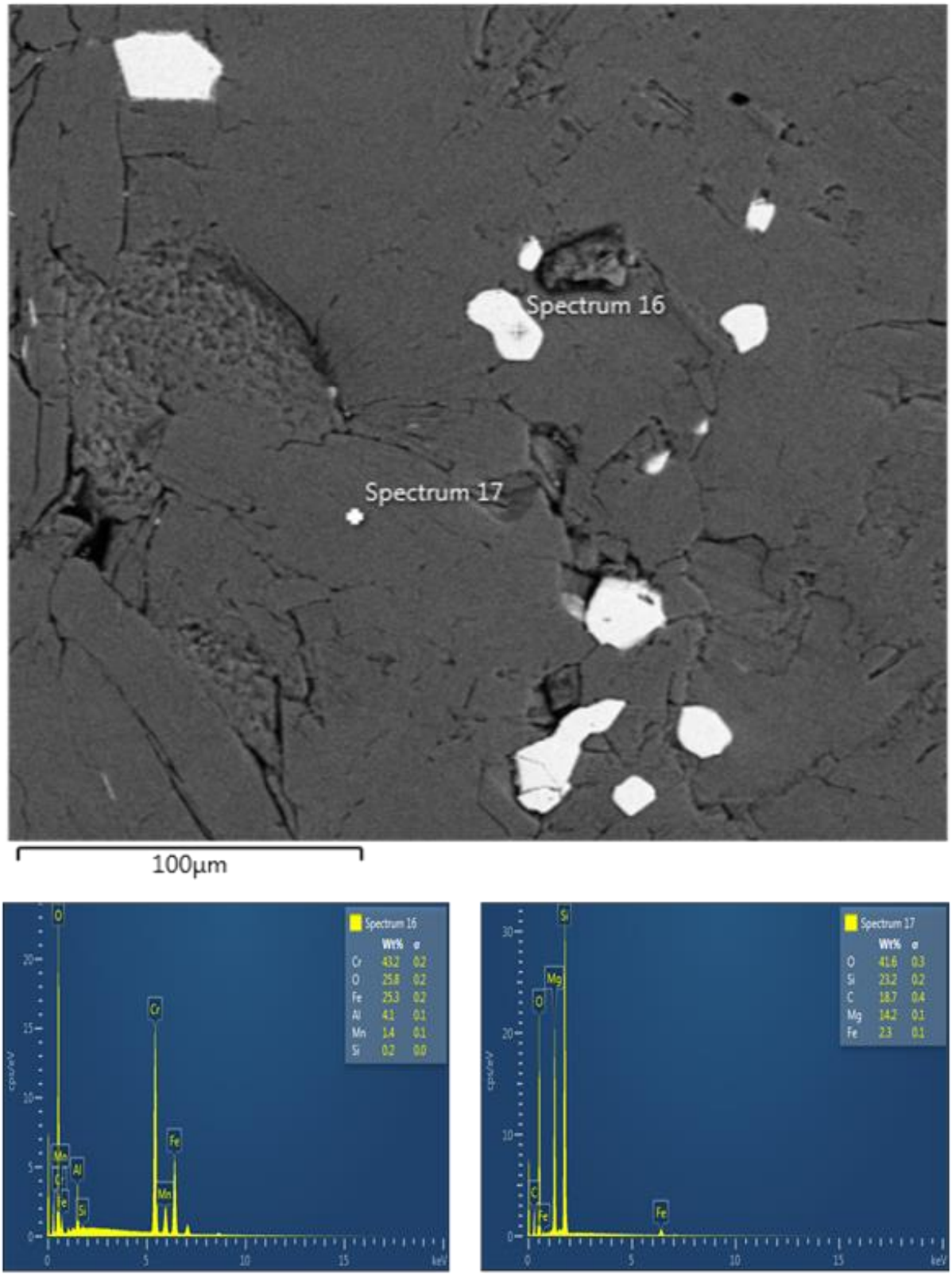

Figure 4: SEM-EDS of talc schist from Wonu-Apomu area showing manganese-bearing ferrichromite in aluminosilicate matrix (Spectrum 16), unaltered olivine (Forsterite) (Spectrum 17), in graphite-bearingchloritic groundmass.

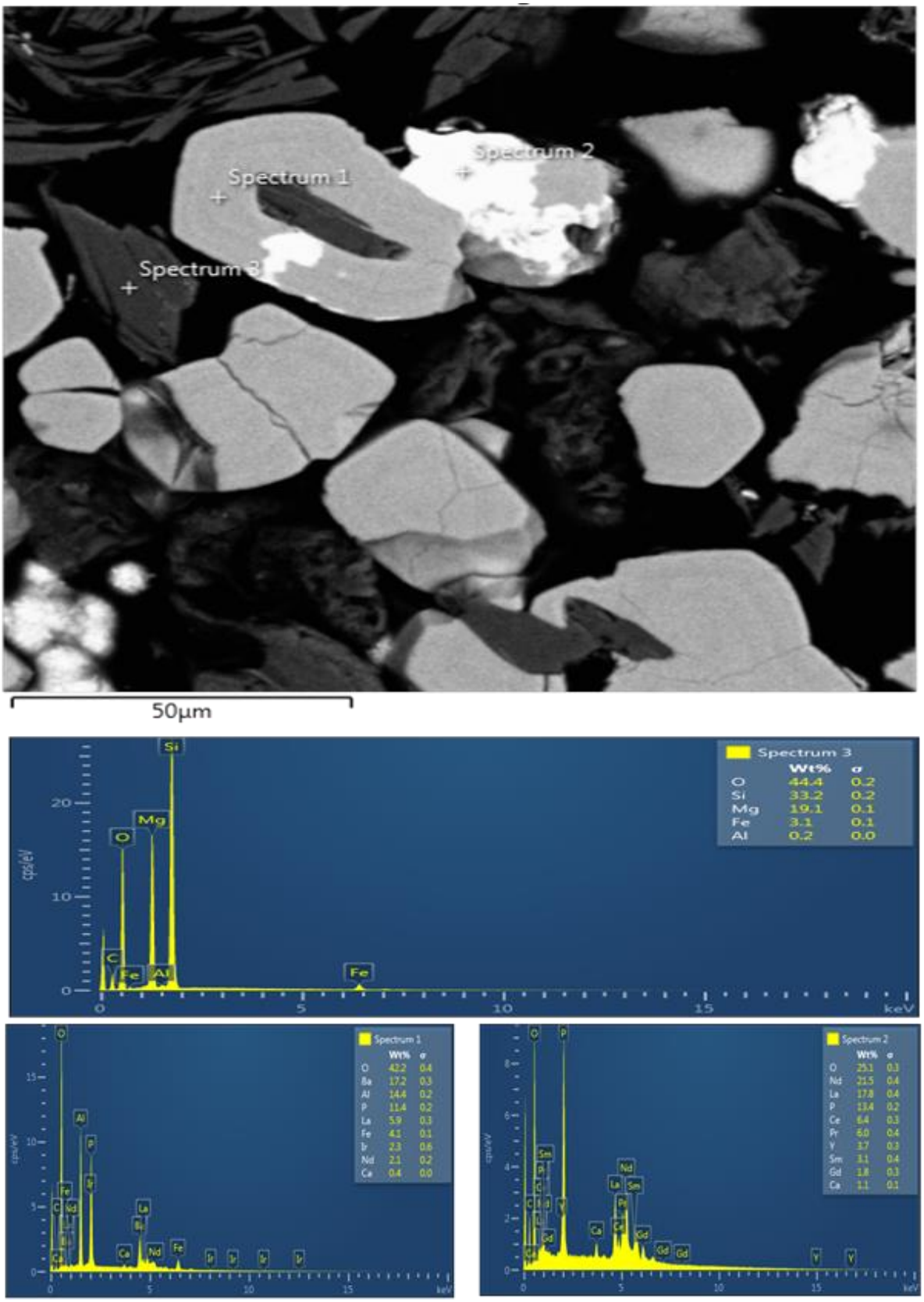

Figure 5: SEM-EDS of talc schist from Wonu-Apomu area showing allanite (Spectrum 1), monazite (Spectrum 2), altered olivine (Forsterite) (Spectrum 3) and secondary carbonate.

Table 1(a): Mineral chemistry of talc sample TC3 of Wonu-Apomu area

	TC3/1	TC3/2	TC3/3	TC3/4	TC3/5	TC3/6	TC3/7	TC3/8	TC3/9	TC3/10
SiO_2	61.25	62.69	62.26	61.21	62.36	60.98	60.55	61.22	62.13	63.30
TiO_2	0.01	0.02	0.01	0.00	0.01	0.02	0.02	0.00	0.01	0.00
Al_2O_3	0.35	0.32	0.38	0.32	0.30	0.38	0.41	0.36	0.29	0.38
FeO	3.21	3.29	3.21	3.17	3.23	3.22	3.13	3.17	3.23	3.12
MnO	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02
MgO	27.92	28.48	26.72	28.14	28.77	29.90	28.99	28.12	27.38	27.93
CaO	0.04	0.00	0.02	0.03	0.01	0.01	0.01	0.03	0.02	0.00
Na_2O	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.05	0.01	0.03
K_2O	0.04	0.00	0.03	0.02	0.00	0.00	0.01	0.05	0.02	0.00
Cr_2O_3	0.07	0.07	0.09	0.07	0.09	0.08	0.11	0.08	0.09	0.11
NiO	0.21	0.22	0.22	0.22	0.24	0.21	0.22	0.2	0.22	0.18
H_2O	4.57	4.67	4.58	4.58	4.67	4.64	4.58	4.58	4.60	4.68
Total	97.74	99.82	97.57	97.82	99.74	99.50	98.10	97.88	98.03	99.75
Formula units based on 22 (O, $OH)_2$)										
Si	8.029	8.042	8.149	8.018	8.013	7.880	7.926	8.015	8.104	8.104
Al iv	0.000	0.000	0.000	0.000	0.000	0.058	0.063	0.000	0.000	0.000
Al vi	0.054	0.048	0.059	0.049	0.045	0.000	0.000	0.056	0.045	0.057
Ti	0.001	0.002	0.001	0.000	0.001	0.002	0.002	0.000	0.001	0.000
Cr	0.007	0.007	0.009	0.007	0.009	0.008	0.011	0.008	0.009	0.011
Fe	0.352	0.353	0.351	0.347	0.347	0.348	0.343	0.347	0.352	0.334
Mn	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.003	0.002
Mg	5.456	5.446	5.213	5.495	5.511	5.759	5.657	5.488	5.324	5.330
Ni	0.022	0.023	0.023	0.023	0.025	0.022	0.023	0.021	0.023	0.019
Ca	0.006	0.000	0.003	0.004	0.001	0.001	0.001	0.004	0.003	0.000
Na	0.010	0.010	0.008	0.010	0.010	0.010	0.010	0.013	0.003	0.007
K	0.007	0.000	0.005	0.003	0.000	0.000	0.002	0.008	0.003	0.000
OH*	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
TOTAL	**17.947**	**17.933**	**17.823**	**17.960**	**17.964**	**18.090**	**18.041**	**17.963**	**17.871**	**17.865**
Y total	5.896	5.881	5.659	5.924	5.940	6.142	6.039	5.923	5.758	5.754
X total	0.022	0.010	0.015	0.018	0.011	0.011	0.013	0.025	0.009	0.007
Al total	0.054	0.048	0.059	0.049	0.045	0.058	0.063	0.056	0.045	0.057
Fe/Fe+Mg	0.061	0.061	0.063	0.059	0.059	0.057	0.057	0.059	0.062	0.059

Table 1(b): Mineral chemistry of talc sample TC4 of Wonu-Apomu area

	TC4/1	**TC4/2**	**TC4/3**	**TC4/4**	**TC4/5**	**TC4/6**	**TC4/7**	**TC4/8**	**TC4/9**	**TC4/10**
SiO_2	60.87	61.29	61.36	59.51	63.50	62.95	61.99	63.50	62.93	63.93
TiO_2	0.00	0.02	0.00	0.01	0.02	0.00	0.01	0.01	0.00	0.00
Al_2O_3	1.62	0.36	0.34	0.33	0.35	0.24	0.39	0.36	0.08	0.31
FeO	3.26	3.19	3.30	3.31	3.37	3.25	3.23	3.25	3.13	3.27
MnO	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.01	0.02
MgO	26.58	28.23	28.36	30.95	25.37	28.60	28.10	27.88	29.16	26.77
CaO	0.00	0.02	0.01	0.00	0.01	0.00	0.03	0.01	0.00	0.01
Na_2O	0.03	0.04	0.04	0.04	0.04	0.02	0.03	0.03	0.01	0.03
K_2O	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01
Cr_2O_3	0.06	0.1	0.06	0.08	0.08	0.05	0.11	0.06	0.01	0.08
NiO	0.26	0.25	0.28	0.26	0.27	0.26	0.28	0.25	0.27	0.28
H_2O	4.56	4.59	4.60	4.60	4.60	4.69	4.63	4.70	4.70	4.67
Total	97.27	98.12	98.38	99.12	97.64	100.08	98.84	100.07	100.30	99.38
Formula units based on 22 (O, $OH)_2$)										
Si	8.005	8.007	8.001	7.752	8.282	8.053	8.035	8.110	8.034	8.204
Al iv	0.000	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000	0.000
Al vi	0.251	0.055	0.052	0.000	0.054	0.036	0.060	0.054	0.012	0.047
Ti	0.000	0.002	0.000	0.001	0.002	0.000	0.001	0.001	0.000	0.000
Cr	0.006	0.010	0.006	0.008	0.008	0.005	0.011	0.006	0.001	0.008
Fe	0.359	0.349	0.360	0.361	0.368	0.348	0.350	0.347	0.334	0.351
Mn	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.001	0.002
Mg	5.211	5.498	5.512	6.010	4.933	5.454	5.430	5.308	5.549	5.121
Ni	0.028	0.026	0.029	0.027	0.028	0.027	0.029	0.026	0.028	0.029
Ca	0.000	0.003	0.001	0.000	0.001	0.000	0.004	0.001	0.000	0.001
Na	0.008	0.010	0.010	0.010	0.010	0.005	0.008	0.007	0.002	0.007
K	0.002	0.002	0.000	0.002	0.002	0.000	0.002	0.000	0.000	0.002
OH*	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
TOTAL	**17.871**	**17.964**	**17.975**	**18.224**	**17.691**	**17.929**	**17.933**	**17.863**	**17.961**	**17.773**
Y total	5.856	5.942	5.963	6.409	5.395	5.872	5.884	5.744	5.925	5.558
X total	0.009	0.015	0.012	0.012	0.013	0.005	0.013	0.009	0.002	0.010
Al total	0.251	0.055	0.052	0.051	0.054	0.036	0.060	0.054	0.012	0.047
Fe/Fe+Mg	0.064	0.060	0.061	0.057	0.069	0.060	0.061	0.061	0.057	0.064

Table 2: Mineral chemistry of saponite in the talc samples of Wonu-Apomu area

	TC4/27	TC4/30	TC4/33	TC3/20	TC4/28	TC4/29	TC3/30
SiO_2	57.23	55.29	55.80	52.75	58.68	53.18	55.25
TiO_2	0.01	0.00	0.10	0.00	0.00	0.01	0.01
Al_2O_3	0.22	0.47	1.85	0.20	0.26	0.37	12.35
FeO	14.01	12.70	12.91	3.14	11.51	4.69	3.26
MnO	0.89	0.82	0.55	0.01	0.75	0.02	0.02
MgO	26.61	25.11	27.49	31.75	24.29	29.37	17.68
CaO	0.43	0.36	0.23	0.01	0.37	0.00	0.06
Na_2O	0.03	0.06	0.06	0.02	0.02	0.02	0.06
K_2O	0.00	0.01	0.00	0.00	0.00	0.00	0.16
Cr_2O_3	0.08	0.05	0.06	0.04	0.06	0.04	0.04
NiO	0.12	0.15	0.15	0.23	0.16	0.19	0.16
H_2O*	0.00	4.38	0.00	4.25	4.49	4.22	4.41
Total	99.63	99.40	99.20	92.40	100.59	92.11	93.46
			Formula units based on 22(O, OH)				
Si	7.509	7.565	7.318	7.435	7.828	7.550	7.510
Al iv	0.034	0.076	0.286	0.033	0.041	0.062	0.490
Al vi	0.000	0.000	0.000	0.000	0.000	0.000	1.489
Ti	0.001	0.000	0.010	0.000	0.000	0.001	0.001
Cr	0.008	0.005	0.006	0.004	0.006	0.004	0.004
Fe	1.537	1.453	1.416	0.370	1.284	0.557	0.371
Mn	0.099	0.095	0.061	0.001	0.085	0.002	0.002
Mg	5.204	5.122	5.374	6.671	4.831	6.215	3.582
Ni	0.013	0.017	0.016	0.026	0.017	0.022	0.017
Ca	0.060	0.053	0.032	0.002	0.053	0.000	0.009
Na	0.008	0.016	0.015	0.005	0.005	0.006	0.016
K	0.000	0.002	0.000	0.000	0.000	0.000	0.028
OH*	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Total	**18.473**	**18.403**	**18.534**	**18.549**	**18.151**	**18.419**	**17.519**
Y total	6.862	6.692	6.883	7.073	6.223	6.802	5.467
X total	0.068	0.070	0.048	0.007	0.058	0.006	0.052
Al total	0.034	0.076	0.286	0.033	0.041	0.062	1.979
Fe/Fe+Mg	0.228	0.221	0.209	0.053	0.210	0.082	0.094

Several deformation episodes affected the dunitic and peridotitic rocks in this area as observed on the field during field mapping and the geological map produced. In this type of polymetamorphic setting, chlorites could be formed under two different situations. Those that syn-crystallised with amphiboles as pseudomorphs of clinopyroxenes and orthopyroxenes, that is, formed contemporaneously with

amphiboles at temperatures below 500 ºC, and those that grew after spinel. Their relative high degree of tschermakite substitution indicates conditions of retrograde amphibolite to greenschist facies metasomatism corresponding to greenschist facies and temperature of about 500 ºC.

$$2NaCa_2Mg_4AlAl_2Si_6O_{22}(OH)_2 + 8SiO_2 = CaMg_5Si_8O_{22}(OH)_2 + Ca_2Mg_3Al_2Al_2SiO_6O_{22}(OH)_2 + 2NaAlSi_3O_8$$

Pargasite Quartz Tremolite Tschermakite Albite

Antigorite is formed from olivine while talc is formed from orthopyroxene. The presence of greenschist hornblendes, tremolites and actinolites indicated that hydrous episodes are responsible for the serpentinisation of the peridotite [22]. Deformation episodes led to shearing of rocks and provision of permeable zones. Occurrence of the tremolites are related to these fracturing events. A few tremolites have a characteristic outward form within clinopyroxenes with chemical composition identical with those formed from hydrous fluids with which they are contemporaneous. The precipitation of the tremolites occurred before the faulting that took place along with serpentinisation.

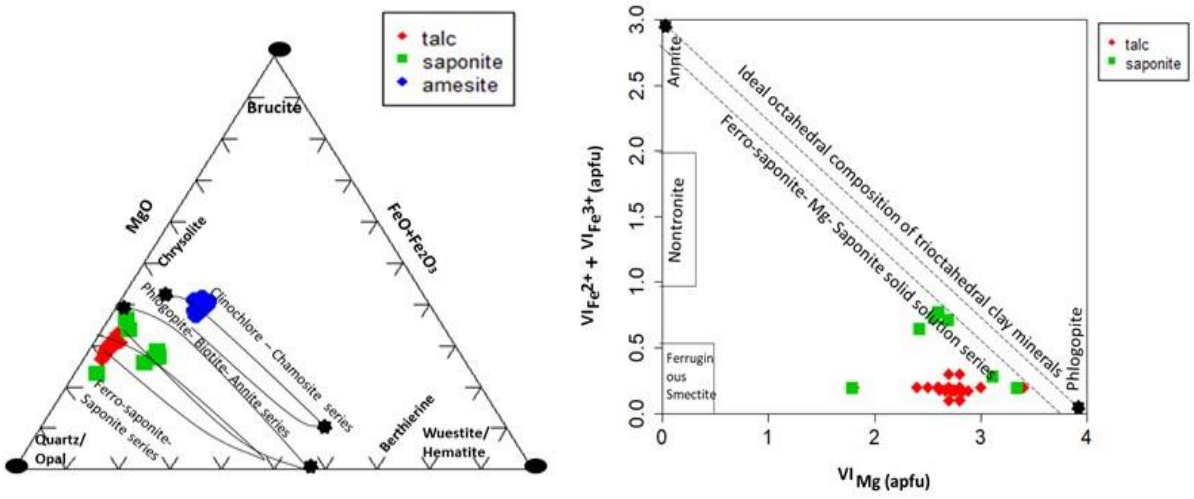

Figure 6: Mineral chemistry of the chlorite, Mg-saponite and talc within talc schist of Wonu-Apomu area (after [21]).

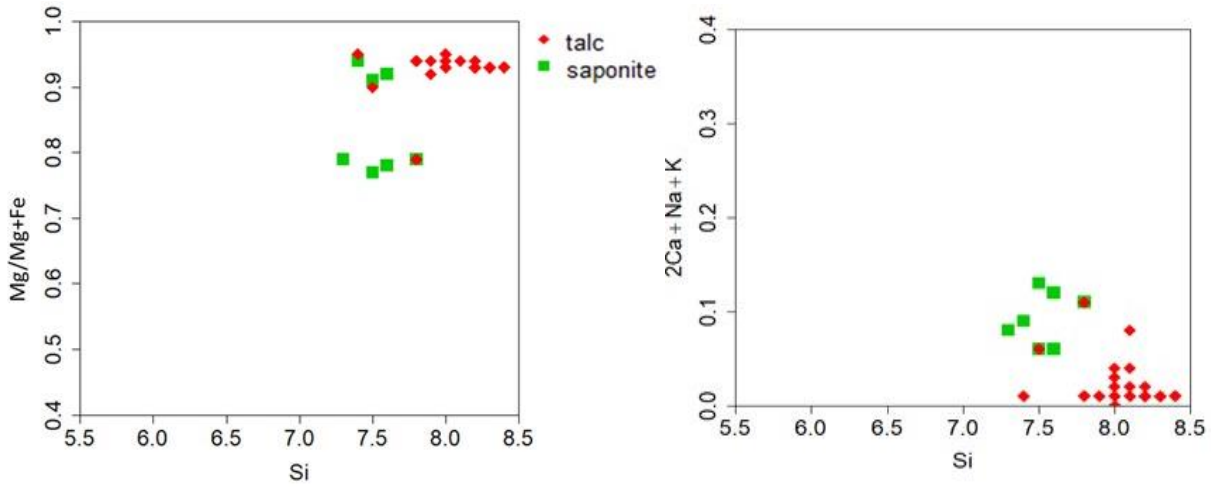

Figure 7: Mineral chemistry of the Mg-saponite and talc within talc schist of Wonu-Apomu area indicating ore associated saponites, and olivine and pyroxene associated saponites of hydrothermally altered ultramafic rocks of arc and boninitic affinity (after [20; 21]).

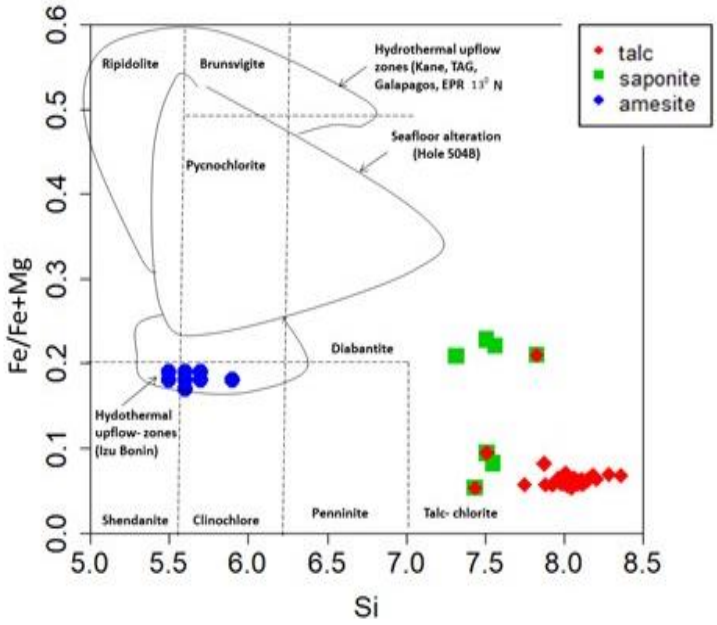

Figure 8: Chemistry of amesite, Mg-saponite and talc in the Wonu-Apomu area showing hydrothermal alteration ofboninitic composition ([23; 21]).

4. Conclusion

The results of the petrographic analysis, the Scanning Electron Microscope-Energy Dispersive Spectrometry (SEM-EDS) and Electron Probe Micro-Analysis (EPMA) revealed that the talc schist of Wonu-Apomu area is composed of talc, anthophyllite, Cr-bearing clinochlore, tremolite, amesite, saponite, serpentine (antigorite), ferrichromite,magnetite and traces of olivine. From the mineral chemistry plots, two groups of talc schist were identified, they are, the talc-chlorite with FeO concentration of 2.86-4.69 wt.% and Mg/(Mg+Fe_{total}) content of 0.92-0.95 and the second which is the talc-magnesian saponite with FeO concentration of 11.51-14.01 wt.%; Mg/(Mg+Fe_{total}) content of 0.77-0.79. The mineral chemistry plots elucidated the alteration phases in talc-schist, with talc composition which ranged from pure talc to talc-chlorite, talc-chlorite-saponite and talc-chlorite-saponite-antigorite-chrysotile. In conclusion, the mineral chemistry revealed that talc-schist is a dunite-type magma which is boninitic in composition.

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