

Reassessment of Chromite Concentration in Serpentinite Bodies of Tunga-Kudaku, North-Western Nigeria

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Abstract: Chromium is an alloying metal which improves the property of steel. For this reason it is needed in the steel industries for its metallurgical and refractory properties. This research aim at evaluating the concentration of chromite mineralization within the serpentinites rock settings of Tunga-Kudaku area within Anka, North western Nigeria. A total of more than twenty (20) surface samples were collected. Thirty five (35) of subsurface samples were collected from drill core channels. The samples were used for thin-section and geochemical analysis using a standard laboratory techniques. The result of Ore microscopy shows zoning of the chromite with an inner Cr rich core with low reflectance, an intermediate zone richer in iron and a magnetic margin with the highest reflectance sowing accessory disseminated Cr grains and zoned with the cores having 56% Cr₂O₃ which decrease to 32% at the margin. The result of geochemical analysis revealed that the chromite found in podiform mode crystallization have chemical composition in range of 3.29 – 48.24% Cr₂O₃ which can be used in steel industries for both refractory and metallurgical purposes.

Keynote: Exploration, Ore Microscopy, Geochemistry, Serpentinite and Ore Geology

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I. Introduction

Chromium is an alloying metal which improves the property of steel. For this purposes it is needed in the Steel Industry both for its metallurgical and refractory properties. The chief chromium ore is chromite found in serpentinites which hydrothermal ultramafic rocks are found in Fold Mountain and tectonic belt regions of the world. The type localities of Northwestern Nigeria include the serpentinites bodies of Ribath, TungaKudaku, Maikwanaga and Sado in the Anka schist belt, and the MallamTanko serpentinites body in the Chafe – Wonaka Schist belt.

Ultramafic rocks are known to be associated with basic igneous rocks and depending on their environment of emplacement, can be divided into those intruded into a stable Precambrian platform region such as the Bushveld Complex of South Africa or those of tectonic mobile belt of plate margins.

The latter case of serpentinites in tectonic region obtains in Northwestern Nigeria. This region is part of the Nigerian Basement Complex which have undergone four cycles of tectonic deformation of the crust. Beginning from the Liberian Orogeny of (2,800 ± 20ma) through the Eburnian Orogeny of (2,000 ± 200ma) and the Kibaran Orogeny of (1100 ± 200ma) down to the Pan-African Orogeny of (600 ± 150ma) according to (Grant 1978 Ogezi 1977, Ajibade1980). It is believed that the serpentinites bodies of this region are emplaced in the final phase of Pan-African Orogeny.

The region is assumed to be within the mobile belt and a metalorganic province, (Ogezi 1977, Woakes 1988), by virtue of its cyclic metamorphism and remobilization of Archean crustal rocks possibly by the collision of the Congo and West African plate margins. Serpentinites are widely believed to be found within regions of tectonic activity, where oceanic and continental plate margins are being consumed and in regions of plate accretion. The case of Nigeria can be regarded as a region within passive plate margins. In such regions of the world transform faults are usually the sites for the emplacement of Alpine-type serpentinites which are products of partial melting of upper mantle rocks that have been raised under “cold extrusion” to the crustal subsurface. It is not surprising therefore to find the arrangement of the Sado, Maikanaga, TunganKudaku and Ribah serpentinite bodies along a possible fault lineament bordering the eastern margin of the Anka Schist belt (Ogezi 1977).

Chromite mineralization within these bodies are found in podiform and disseminated grains. Following the report of its possible concentration, the economic values satisfactory to the needs of the Steel Industries is yet to be evaluated. Thus, this research aim to evaluate the concentration of chromite mineralization within the serpentinites rock settings for possible exploitation.

II. The descriptions of Study Area

The TunganKudaku serpentinite bodies occur within the Anka Local Government Council Area of Zamfara State in North-Western Nigeria. It is located between latitudes $11^{\circ} 50'N$ to $12^{\circ} 05'N$ and longitudes $5^{\circ} 55'E$ and $6^{\circ} () E$ as shown in figure 1. This covers parts of the sheets Anka 52 SE and Gwashi 75 NE. The area is about 120 square Kms and covers other rock types.

The relief is generally low, being an area of serpentinite intrusion into phyllite metasediments and gneisses. The topography to the west is made up of a medium to coarse grained porphyritic biotite granite which rises to a peak of 460.92m above sea level. Generally the topography is gentle and undulating. The drainage pattern is generally dendritic characteristic of the basement complex drainage patterns. Fracture and fault zone are expressed by the straight channels of the stream beds after the manner of their trends. Most of the streams drain northwards to the Zamfara River. They sometimes follow NS and NE-MW fracture zones of the underlying rocks.

III. Local Geology of the Study Area

Major part of Northwestern Nigeria is made of the Basement Complex rocks comprising migmatites, gneisses; older granites, metasediments (old and younger), metavolcanics, quartzites, basic and ultramafic rocks (serpentinities) and pegmatites (Russ 1957). The region is assumed to be within the mobile belt and a metallogenic province, (Ogezi 1977, Woakes et al.,1987), by virtue of its cyclic metamorphism and remobilization of Archean crustal rocks possibly by the collision of the Congo and West African plate margins. The metasediments are divided into the older metasediments and the younger metasediments. The older metasediments are the quartzite and amphibolite within the gneisses of this region near Anka and in the Maru sheet. They exist as relics and only close observation will reveal their presence.

The younger metasediments on the other hand were supracrustal covers which were folded within the gneisses. A great deal of them have been eroded but where they are preserved within the keel of gneisses they form great belts of Phyllites and Mica schists. They are characterized by folding with fold axis in the N-S direction. These metasediments are argillaceous in origin with green schist facies metamorphism. They are lustrous, fine grained and mineralogically consist of sericite, quartz and mica plus accessory epidote. When the original sediment is arenaceous, metamorphism transforms it to quartzite. These are also regarded as psammiticmetasediment. They are massive and weathered as irregular blocky and pebbly rocks. The Anka metasediments are host of the TunganKudaku serpentinite body. The gneisses outcrop extensively east of Anka schist belt host the Maikwanaga and also serpentinite bodies. The gneisses strike $340^{\circ} NW$ and dip almost vertically to the west near Maikwanaga. The gneisses there are typical of the paragneiss classified by Russ, 1957. They represent evidence of a reworked basement complex of Liberian $2,800 \pm 200$ ma and Eburnian $2,000 \pm 200$ ma. They are highly deformed with fractures trending in the E – W 070° direction and NW – SE 340° strike direction cross-cutting the outcrops. The gneisses are weathered in places and are covered by overburden. Exposures are characterized by whalebacks of outcrops and at river beds. Mineralogically the gneisses consist of microcline biotite – plagioclase feldspar and quartz minerals often forming coarse porphyroblasts. The gneisses show uneven texture and structure, showing cataclastic phenomenon of crushing and subsequent welding of feldspar and quartz with undiagnosed extinction. These structures are characteristic of gneisses in tectonically deformed regions.

The Older Granite range in composition from siliceous to intermediate granites. They are syntectonic and are intrusive into the metasediments. The biotite granite and granodiorites are preponderant in this area. At Tsearetavaillage the biotite granite is medium to coarse grained. Compositionally, it consists of quartz, microcline, subordinate plagioclase feldspar (albite-oligoclase) microperthite biotite, hornblende and accessory sphene. In age the older granites are Pan-African 600 ± 150 ma. Structurally they are deformed with foliations and fractures in the E-W and NE-SW directions. In area the older granites covers about the third of the study area.

Late stage hypabyssal intrusions relating to older granites are restricted to a few small pegmatoidal-alplite and granitic dykes around Anka town. Pegmatites are products of late stage magmatic activity. The pegmatite consist of feldspars and quartz minerals. They are however barren of minerals like tourmaline, Beryl and so on.

The TunganKudaku serpentinite body is a hydrated peridotite or dunite rock as shown figure 1. The body is 14000m in length and 700m in width. It is believed to have been intruded into schist by cold extrusion. Evidence for this is supported by the sharp contact between the host rock and the serpentinite. Mineralogically the rock consist of Antigorite as the main serpentinite mineral with subordinate fibrous chrysotile mineral found to be localized in the fissures. The serpentinites are the products of hydrothermal fluid and meteoric water alteration of peridotite (Olivine 90% and pyroxene 10%) and dunitic rocks. The parent minerals have been destroyed by the effects of hydrothermal alteration. Where evidence of the parent Olivine + pyroxene minerals exist, they occur as porphyroblast, being the result of cataclastic deformation caused by the tectonic effect of

squeezing of peridotitic rocks from deep within the mantle to their final destination in the crust. Mineralization is in podiform and disseminated chromite grains. Color when fresh is dull metallic, iron-black and brownish-black.

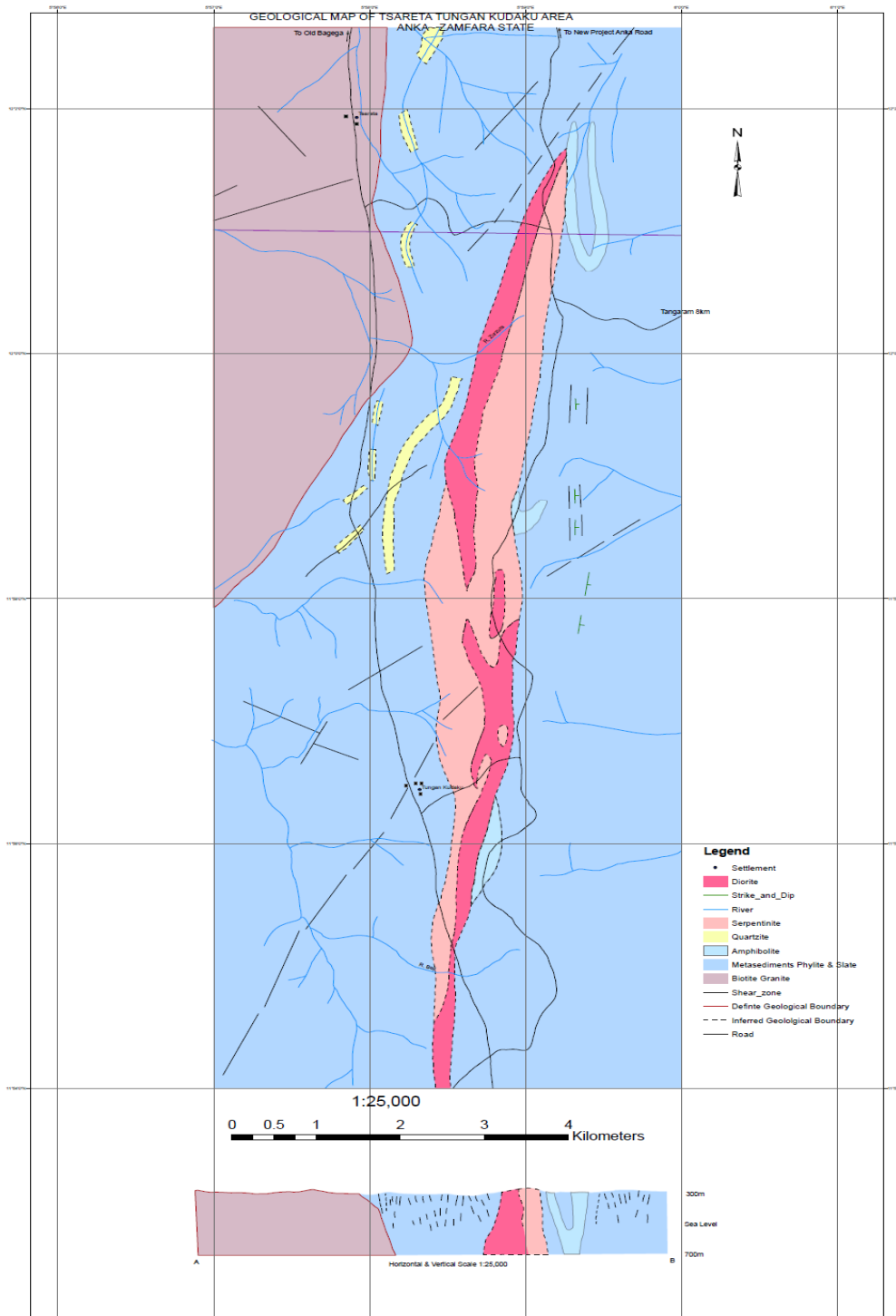


Figure 1: Geological Map of the Study Area

IV. Methodology

The location of 2 boreholes at profiles 1 and 2 near the village of TunganKudaku was based on geological and geophysical investigations, which tend to support the concentration of rich chromite pods on the surface within the area.

Rotary type of drilling was employed, using a Russian Rig, the Ziff 300 model. The range 0 – 16.35m which is the depth of overburden or weathering, was penetrated with the 108mm diameter bit. This dimension is the

same as the casing barrels which was done immediately after. Core Drilling commenced at depth 16.35m using the 5mm core barrel with core catcher. Recovery was high except in highly fractured zones with chrysotile, fibrous minerals in fissure veins. The borehole 1 was bottomed at the depth of 85 meters. Sampling of borehole 1 was done at 2m interval using a core splitter. The other half of split core were returned to the core box for future reference. The sampled (half) core was used for thin section studies, polished blocks and chemical analysis.

Most surface sampling was done by random method. A total of more than 20 surface samples were collected but only true representative ones were submitted for thin section and chemical assays. They include samples from the different rock types of the study area which are Granites, Gneisses, Diorites, Hornblendite, Serpentinite, Quartzite and Chromite pods.

Subsurface samples include all channel and drill cores. A total of 35 samples were collected from borehole 1 alone. The samples were used for thin section; polished blocks and chemical analysis.

At the NSRMEA Laboratory, all serpentinite samples collected for the determination of major elements and chromite were cleaned, dried and crushed in a laboratory mechanical jaw-crusher. The samples were further pulverized by fine grinding in an agate mortar and in a pulverizing machine.

Colorimetric method of determination was used for all core samples and surface samples submitted. This was done using the following procedure.

A mixture of sodium carbonate and sodium nitrate was fused with a known weight of the test sample (bower) and the fused cake dissolved in water and then filtered. The filtrate is made up to a known volume in a standard flask. The solution was then run on a spectronic 20D – spectrophotometer. Absorbance was measured as 365 – 370 wavelength. The readings are compared against a standard chromate solution containing sodium carbonate and sodium nitrate. The concentration is measured in percentage.

V. Result and Discussion

Petrographic Studies

Petrographic study of slides from borehole 1 revealed two groups or a divide indicating variation in the relative abundance of antigorite and chrysotile. Opaque minerals are subordinate and represent about 3% of modal composition.

Samples with Abundance of Antigorite

Antigorite dominates in eleven of the samples examined in this group. These include slides BH-1/KO/6, BH-1/KZO/7, BH-1/KZO/10, BH-1/KZO/12, BH-1/KZO/13, BH-1/KZO/17, BH-1/KZO/20, BH-1/KZO/22, BH-1/KZO/28 and BH-1/KZO/30. The minerals show a lath-like, sometime, platy morphology giving the rock an aggregate structure and sometimes form in clusters of needle-like crystals. It is likely that the antigorite was formed as a result of the alteration of mineral and pyroxene though evidence of pseudomorphs of these minerals are few. The brownish stain patches are commonly observed and attributed to oxidation of iron. In a few samples within this group, tiny veinlets of chrysotile run through the antigorite groundmass e.g in slides BH-1/KZO/12 and BH-1/KZO/10 respectively.

Also present are opaque for chromium oxide in disseminated grains occurring as subhedral – euhedral grains and generally scattered within the antigorite matrix.

Samples with relatively high proportion of Chrysotile

This group is represented by samples BH-1/KZO/3, BH-1/KZO/5, BH-1/KZO/8, BH-1/KZO/9, BH-1/KZO/23, BH-1/KZO/32, with a marked reduction of antigorite mineral and an increase in the amount of chrysotile. Two reasons can be advanced for this phenomenon.

A cursory glance at the numbers of the samples will reveal that they are near surface samples and therefore are in direct contact with meteoric water responsible for their final alteration from antigorite to chrysotile.

Where the samples are distant from the surface as is the case with BH-1/KZO/23 and BH-1/KZO/32, fracture zones would have served as conduits for the transportation of meteoric waters necessary for their secondary alteration. Otherwise deep samples that are compact have little chrysotile and abundant antigorite, the latter is believed to be the product of alteration by hydrothermal fluids of peridotite rocks (olivine and pyroxene). In all cases of the two groups of slides therefore, antigorite and chrysotile with or without lizardite are the three minerals often reported as serpentine minerals in serpentinite bodies.

Ore Microscopy: The polished block shows evidence of a texture that have recrystallized in some grains from subhedral to anhedral texture. The texture is typical of cataclastic deformation as evident in a transform fault region. Ore microscopic studies show zoning of the chromite with an inner Cr rich core with low reflectance, an intermediate zone richer in iron and a magnetic margin with the highest reflectance have similarly shown from microprobe analysis of accessory disseminated chromite grains in the Maikwanaga serpentinite near Anka, that they are similarly zoned with cores having 56% Cr₂O₃ which decrease to 32% at the margins. It show a polished section of a chromite pod depicting polygonal cracks of aggregate chromite

minerals. Other accessory minerals associated with the chromite in dissemination of the polished core serpentinite include pyrite and chalcopyrite.

The other slide shows mainly plagioclase feldspar (Pg) and Hornblende (Hb) as the phenocryst minerals. Quartz occurs as an accessory mineral (Qtz). The hornblende shows alteration to a mineral with blue + green + yellow interference colours; possibly Epidote.

A mineral vein, brown hornblende (Hb) with cleavage angles well defined is the main mineral, with sub to euhedral crystals. Under plain polarised light, it shows pleochroism from brown to green. Quartz (qtz) crystal showing undulose extinction. Not all the hornblende crystals exhibit pronounced cleavage.

Under Plane Polarised Light, serpentinite (sp) are yellowish in colour with opaque minerals (Op) oxides of Iron and Chromite. Under Crossed Nicols, crystal of quartz (qtz) in a matrix of Antigorite (An) showing characteristic mesh texture, and fissures filled with Chrysotile.

Geochemistry: Deduction from the tables of analysis show that the SiO₂ content for serpentinites of TunganKudaku is between 7.62 – 48.47 for surface sample (Table 1). This shows a decrease of silica content compared to the result of samples on Table 4 representing ultramafic rocks of Orogenic belts that have suffered very little serpentinization effect. Their SiO₂ content range between (39.55 – 49.2%). An explanation for this result is the possible leaching out effect of silica by meteoric waters within the reaches of the surface rocks.

As the depth of sampling increases, results of core sample indicate less leaching effect of silica (Table 2) with the range of (20.21 – 36.87%) silica. Therefore the result of serpentinization is more of the effect of hydrothermal fluid than of meteoric water and have the preponderance of antigorite minerals being more in core samples from depth than those of surface and near surface sample (chrysotile minerals).

There is a relative increase in Al₂O₃ abundance in the serpentinite of TunganKudaku as compared with the ultramafic bodies of Orogenic belts in Table 4. Likewise the Fe₂O₃ content show relative abundance increase. The average Cr₂O₃ content of unmineralized serpentinites of TunganKudaku compare favorably well with those of ultramafic rocks of Orogenic belts Tables 2 and 4. However the mineralized (enriched) podiform chromite of TunganKudaku Table 2 and 3 give favorable values of metallurgical and refractory grade chromite for industrial use. The snag of disadvantage lies in its mode of mineralization that is, it does not become enriched or continuous with depth. This was proved with the drilling of boreholes 1 and 2. It is not impossible that the podiform chromite found at surface level can be found at depth. The implication lies in probing deeper. Drilling operation is therefore recommended to exceed the 85 metre present level in order to confirm this thinking.

Magnesia (MgO) was found to be a major oxide element of serpentinites (core samples) but are low in the surface samples (Table 1). This is due to the effect of weathering and leaching. Amongst unaltered and rocks in table 4 it reaches a value of 48.53% on the high side. Other oxide elements are insignificantly low or are found in traces. CaO is generally low in all ultramafic rocks. This is one reason why vegetation with stunted growth reflect the presence of ultramafic rock as evidenced in this zone.

VI. Conclusion

Based on field, petrographic, and geochemical evidences, the ore fluid may have been derived largely from fracturing, metamorphic dewatering and crustal devolatilization of sedimentary and gabbroic protolith of the host rocks. Isotopic studies of fluid components of the quartz veins will further confirm the propose origin according to past literature in related field (Kreiter, 1968; Best, 2003).

In a nut shell, the chromite found in podiform mode of crystallization at TunganKudaku are confirmed to have chemical composition in the range of 3.29 – 48.24% Cr₂O₃/which can be used in the steel industry for both refractory and metallurgical purpose. Exploration for economic commercial size chromite is therefore recommended to identify buried serpentinite bodies which could carry rich pods; within areas close to Gabbro/Serpentinite contact and in highly faulted zones.

Appendix

Table 1: CHEMICAL COMPOSITION OF SURFACE CHROMITE SAMPLES (PODIFORM) FROM TUNGAN - KUDAKU

| OXIDES | AH 2 | AH 4 | AH 4a | AH 10 | AH 11 | AH 14 | AH 14a | AH 14b |
|--------------------------------|-------|-------|-------|-------|-------|-------|--------|--------|
| TiO ₂ | 0.83 | 0.19 | 0.96 | 0.10 | 0.17 | 0.43 | 0.19 | 0.33 |
| Al ₂ O ₃ | 7.25 | 11.88 | 7.50 | 11.50 | 12.13 | 9.13 | 7.30 | 8.25 |
| FeO | 33.74 | 19.04 | 34.44 | 16.94 | 12.74 | 16.40 | 14.00 | 13.72 |
| MnO | 0.65 | 0.025 | 1.03 | 0.19 | 0.09 | 0.05 | 0.05 | 0.06 |
| MgO | 5.60 | 3.53 | 6.71 | 4.31 | 3.22 | 3.19 | 4.68 | 2.59 |
| CaO | 0.31 | 5.32 | 0.37 | 3.19 | 5.39 | 0.22 | 0.17 | 0.22 |
| Cr ₂ O ₃ | 3.29 | 3.17 | 4.31 | 4.93 | 4.97 | 48.24 | 44.33 | 45.08 |
| K ₂ O | | | | | | | | |

| | | | | | | | | | | | | | | |
|-------------------------------|-------|--------|------|-------|-------|-------|-------|-------|--|--|--|--|--|--|
| H ₂ O | | | | | | | | | | | | | | |
| CO ₂ | | | | | | | | | | | | | | |
| P ₂ O ₅ | | | | | | | | | | | | | | |
| TOTAL | 70.21 | 81.895 | 92.3 | 79.98 | 84.12 | 83.44 | 80.59 | 77.29 | | | | | | |

ANALYSED BY: National Metallurgical Development Centre, Jos Laboratory

| OXIDE | AH 14c | AH 15 | AH 16 | AH 18 | AH 19 | AH21 | AH22 | AH23 | AH25 | AH26 | AH27 | AH28 | AH29 | AH30 | AH31 |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| SO ₂ | 2.4 | 22.48 | 34.15 | 13.99 | 15.63 | 12.19 | 18.99 | 15.71 | 34.05 | 26.05 | 48.47 | 44.37 | 23.04 | 8.46 | 10.11 |
| TiO ₂ | 0.1 | 0.48 | 0.73 | 0.43 | 0.48 | 0.65 | 1.04 | 0.19 | 0.27 | 0.42 | 0.42 | 0.26 | 0.17 | 0.26 | |
| Ad20 | | | | | | | | | | | | | | | |
| Wed | 15.4 | 19.05 | 15.12 | 2.24 | 2.38 | 1.08 | 23.20 | 61.22 | 12.22 | 11.48 | 11.48 | 11.30 | 17.64 | 2.24 | 2.52 |
| Mno | 0.96 | 0.19 | 0.26 | 0.08 | 0.07 | 0.10 | 0.32 | 0.65 | 0.07 | 0.19 | 0.19 | 0.19 | 0.28 | 0.12 | 0.07 |
| MgO | 3.29 | 6.77 | 3.91 | 6.49 | 1.01 | 5.20 | 8.23 | 7.45 | 12.98 | 11.77 | 3.83 | 1.41 | 1.28 | 3.47 | 2.94 |
| CaO | 0.1 | 0.17 | 3.25 | 0.11 | 0.11 | 0.17 | 0.14 | 0.11 | 1.12 | 0.56 | 4.14 | 7.00 | 0.28 | 0.06 | 0.11 |
| Cr ₂ O ₃ | 46.22 | 1.77 | 1.14 | 33.31 | 30.10 | 36.35 | 2.25 | 2.03 | 1.39 | 0.89 | 0.76 | 1.00 | 0.25 | 41.28 | 0.26 |
| K ₂ O | | | | | | | | | | | | | | | |
| H ₂ O+ | | | | | | | | | | | | | | | |
| CO ₂ | | | | | | | | | | | | | | | |
| TOTAL | 80.57 | 64.17 | 73.81 | 65.65 | 57.08 | 62.94 | 68.08 | 68.62 | 54.12 | 55.46 | 83.54 | 80.17 | 58.07 | 54.39 | 54.78 |

Table 2: Chemical Analysis of TunganKudaku Drilled Core Serpentine Samples Analytical Method: Colorimetric

| OXIDES | BH1/KZO1 | BH1/KZO2 | BH1/KZO3 | BH1/KZO4 | BH1/KZO5 | BH1/KZO6 | BH1/KZO7 | BH1/KZO8 | BH1/KZO9 | BH1/KZO10 | BH1/KZO11 | BH1/KZO12 | BH1/KZO13 | BH1/KZO14 | BH1/KZO15 | BH1/KZO16 | BH1/KZO17 |
|--------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| SiO ₂ | 35.20 | 36.87 | 35.69 | 35.55 | 35.07 | 34.70 | 35.56 | 34.28 | 33.15 | 32.86 | 32.96 | 34.07 | 25.33 | 24.40 | 20.21 | 30.42 | 30.67 |
| TiO ₂ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Al ₂ O ₃ | 3.56 | 5.49 | 3.13 | 2.39 | 4.24 | 6.13 | 3.21 | 4.25 | 3.37 | 3.86 | 4.77 | 3.33 | 19.03 | 11.98 | 2.86 | 2.86 | 9.30 |
| Fe ₂ O ₃ | 6.01 | 5.43 | 7.23 | 6.61 | 7.87 | 9.75 | 9.10 | 10.16 | 7.41 | 9.90 | 8.89 | 10.05 | 10.16 | 9.49 | 9.87 | 11.59 | 9.30 |
| MnO | 0.18 | 0.13 | 0.18 | 0.05 | 0.23 | 0.16 | 0.05 | 0.05 | 0.13 | 0.13 | 0.10 | 0.10 | - | - | - | - | - |
| MgO | 38.54 | 37.74 | 39.49 | 38.81 | 39.08 | 35.85 | 37.06 | 33.89 | 37.45 | 32.34 | 31.40 | 31.06 | 36.93 | 39.08 | 35.98 | 37.33 | 38.01 |
| CaO | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na ₂ O | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| K ₂ O | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| P ₂ O ₅ | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cr ₂ O ₃ | 0.92 | 0.63 | 0.99 | 0.70 | 0.76 | 0.01 | Tr | 0.01 | 0.01 | 0.02 | Tr | Tr | 0.19 | 1.22 | 1.54 | 0.37 | 0.53 |
| Total | 84.41 | 86.29 | 86.71 | 84.11 | 87.25 | 86.61 | 84.98 | 82.64 | 81.52 | 78.12 | 79.12 | 79.36 | 91.64 | 86.17 | 70.45 | 95.11 | 87.81 |

ANALYSED BY: NSRMEA LABORATORY

| OXIDES | BH1/KZO20 | BH1/KZO21 | BH1/KZO22 | BH1/KZO23 | BH1/KZO24 | BH1/KZO25 | BH1/KZO26 | BH1/KZO27 | BH1/KZO28 | BH1/KZO29 | BH1/KZO30 | BH1/KZO31 | BH1/KZO32 | BH1/KZO33 | BH1/KZO34 | BH1/KZO35 | BH1/KZO36 | BH1/KZO37 |
|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| SiO ₂ | 26.95 | 29.99 | 25.13 | 23.47 | 29.21 | 30.05 | 30.80 | 31.99 | 33.77 | 32.26 | 27.68 | 30.94 | 32.80 | 33.22 | 34.27 | 32.64 | 24.64 | - |
| TiO ₂ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10.16 | - |
| Al ₂ O ₃ | - | - | 15.87 | 4.09 | 4.20 | 1.08 | 1.74 | 32.71 | 26.24 | 20.76 | 18.42 | 30.13 | 25.34 | 2.63 | 20.68 | 9.81 | 14.32 | 12.23 |
| Fe ₂ O ₃ | 8.56 | 9.92 | 9.06 | 10.56 | 10.22 | 11.66 | 12.30 | 9.74 | 9.26 | 10.38 | 11.66 | 11.82 | 10.54 | 9.98 | 9.58 | 36.25 | 36.25 | 3.99 |
| MnO | - | - | 0.10 | 0.08 | 0.08 | 0.08 | 0.08 | 0.15 | 0.15 | 0.13 | 0.05 | 0.13 | 0.18 | 0.16 | 0.13 | 0.13 | 1.11 | 0.42 |
| MgO | 37.42 | 35.85 | 41.48 | 27.63 | 34.64 | 34.50 | 29.65 | 37.60 | 27.63 | 36.66 | 35.04 | 37.06 | 32.34 | 35.04 | 31.94 | 30.73 | 12.13 | 10.11 |
| CaO | 0.37 | 0.74 | - | - | - | - | - | - | - | - | - | - | - | - | 2.44 | - | 7.50 | - |
| Na ₂ O | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| K ₂ O | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| P ₂ O ₅ | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cr ₂ O ₃ | 0.30 | 0.13 | 0.15 | 1.46 | 1.34 | 1.61 | 2.25 | 2.08 | 1.76 | 2.03 | 1.70 | 1.44 | 1.69 | 1.42 | 1.04 | 1.47 | 0.45 | 21.63 |
| Total | 73.60 | 76.63 | 92.79 | 67.29 | 76.69 | 78.82 | 76.82 | 114.27 | 98.81 | 10222 | 94.65 | 112.12 | 10289 | 82.45 | 99.92 | 84.36 | 106.56 | 48.38 |

Table 3: Chemical Composition of Chromite Ores from TunganKudaku (Tk) and MallamTanko (Mt) Surface Pod Samples)

| OXIDES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Cr ₂ O ₃ | 35.11 | 38.04 | 33.85 | 32.85 | 31.30 | 29.41 | 24.10 | 34.60 | 33.57 |
| Fe ₂ O ₃ | | | | | | | 20.38 | 39.45 | 20.25 |
| NiO | 0.11 | 0.10 | 0.13 | 0.11 | 0.24 | 0.11 | 0.08 | 0.07 | 0.07 |
| TiO ₂ | 0.10 | nd | nd | nd | 0.10 | nd | 0.23 | 0.10 | 0.13 |
| CO ₂ | 0.05 | 0.08 | 8.03 | 0.03 | 0.21 | 0.09 | 0.20 | 0.33 | nd |
| CuO | nd | nd | nd | 0.02 | 0.04 | nd | nd | nd | nd |
| MnO | nd | 1.7 | nd | nd | 3.07 | 2.54 | nd | nd | nd |
| Cr/Fe | 2.7 | 2.19 | 3.27 | 2.29 | 11.55 | 11.90 | 1.31 | 1.78 | 1.66 |

1 – 6 Chromites from TK; 7 – 9 Chromites from MT

| % | 17 | 18 | 19 | 20 |
|--------------------------------|-------|-------|-------|-------|
| Cr ₂ O ₃ | 59.45 | 56.33 | 59.10 | 54.92 |
| Fe | 23.31 | 23.47 | 16.72 | 22.83 |
| Cr/Fe | 2.24 | 2.11 | 3.11 | 2.12 |

ANALYSES DONE BY: NMDC LABORATORY JOS

Table 4: Chemical Composition (Oxide Wt%) Of Ultramafic Rocks of Orogenic Belts

| OXIDES | 1 | 2 | 3 | 4 | 5 | 6 |
|--------------------------------|------|-------|--------|--------|--------|--------|
| SiO ₂ | 49.2 | 40.2 | 39.53 | 43.37 | 44.60 | 44.65 |
| TiO ₂ | 0.2 | | 0.01 | 0.15 | 0.16 | 0.08 |
| Al ₂ O ₃ | 2.4 | 1.7 | 0.93 | 1.19 | 4.18 | 3.50 |
| Fe ₂ O ₃ | 2.0 | 0.9 | 0.65 | 0.18 | | |
| Cr ₂ O ₃ | | | 1.01 | 0.56 | 0.37 | 0.59 |
| FeO | 6.8 | 9.3 | 7.62 | 7.41 | 8.30 | 6.81 |
| MnO | 0.2 | 0.2 | .012 | 0.14 | 0.09 | 0.14 |
| NiO | | | 0.32 | 0.14 | | 0.29 |
| MgO | 19.1 | 47.5 | 48.83 | 45.35 | 40.45 | 41.66 |
| CaO | 18.9 | | Tr | .079 | 1.72 | 2.02 |
| Na2O | 0.2 | | Tr | 0.15 | 0.11 | 0.23 |
| K ₂ O | 0.1 | | | Tr | 0.02 | 0.04 |
| P ₂ O ₅ | | | | Tr | | |
| H2O+ | 0.6 | 0.3 | 0.89 | 0.64 | | |
| H2O- | 0.2 | 0.1 | 0.16 | 0.06 | | |
| TOTAL | 99.9 | 100.2 | 100.15 | 100.13 | 100.00 | 100.01 |

Explanation of column headings.

- 1) Olivine pyroxenite, Union Bay, Alaska
- 2) Dunite, Union Bay Alaska
- 3) Dunite, Dun Mt, New Zealand
- 4) Harzburgite, Red Hills, Nelson New Zealand
- 5) Peridotite
- 6) Garnet Peridotite, Ugelvik, Norway

References

- [1]. Ajibade AC (1980) Geotectonic evolution of the Zungeru Region, Nigeria. Unpublished Ph.D.Thesis, University of Wales, Aberystwyth.
- [2]. Best, M. G. (2003). Igneous and Metamorphic Petrology, Blackwell Science, 2nd edition, 2003.
- [3]. Grant NK (1978) Structural distinction between a metasedimentary cover and an underlying Basement in the 600 my old Pan-African domain of Northwestern Nigeria. GeolSoc Am Bull89:50–58.
- [4]. Kreiter, V.M. (1968). Geological Prospecting and Exploration, Mir, Moscow, Russia, 1968.
- [5]. Ogezi AEO (1977) Geochemistry and Geochronology of Basement Rocks from Northwestern Nigeria. Unpublished Ph.D. Thesis, University of Leeds.
- [6]. RussW(1957) The geology of parts of Niger, Zaria and Sokoto Provinces. GeolSurv Nigeria Bull27:1–42.
- [7]. Woakes M, Rahaman MA, Ajibade AC (1987) Somemetallagenetic features of the Nigerian basement. J Afr Earth Sci 6:54–6.
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