



Studies in the distribution of heavy minerals in cassiterite-bearing sediments of alluvial tin fields in Ropp Mesozoic younger granite complex of north central state, Nigeria

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Abstract

Heavy minerals are significant in the analysis of depositional environment and to identify source of grains. This paper aim to provide the distribution and origin of the heavy mineral concentrated in the cassiterite bearing sediments of the alluvial tin fields of the Ropp complex. A total of 10 selected mineral concentrate samples were dried and separated from other light minerals using bromoform. Mineral identification was done using binocular microscope. The heavy mineral samples obtained were analyzed for qualitative mineral examination in order to identify mineral compositions for each locality and their percentage. The mineral assemblages documented in the samples include: Ilmenite (3% to 27%). Cassiterite (2 to 14%), Zircon (2 to 16%), magnetite (0 to 17%), tourmaline (5 to 11%), rutile (2 to 8%) and monazite (2 to 7%). The ZTR Index calculated from the result of heavy minerals analysis for the selected samples is 59%. All samples collected contained cassiterite grains in various amounts. From the mineral assemblage, the source of cassiterite originates from the mineralized quartz veins that cut granitic rocks as well as the metasedimentary rocks in the area. The presence of monazite which is always in association with cassiterite also confirms that the cassiterite bearing sediments are of granitic origin. The study shows that the samples are mineralogically immature and most of the heavy minerals have been derived mainly from igneous rocks and little part from low to medium grade metamorphic rocks of the Ropp complex.

Keywords: heavy minerals, cassiterite, ZTR index, sandstone, Ropp complex

Introduction

Provenance studies are key elements of basin analysis, as it provides basic information regarding the tectonic origin of a particular basin. Information about the source of sediments may be obtained from the examination of the various clasts present [26, 2]. The most important aspect of provenance studies is the identification of source rock, tectonic settings, transport history and diagenetic modification of the resulting sediments.

The heavy minerals are also termed accessory minerals with specific gravities higher than 2.89. Heavy minerals are volumetrically minor population, usually less than 1% by weight, of a terrigenous rock. Because these minerals are denser than quartz, they will settle at the bottom of an alluvial layer. If the minerals are composed of economic minerals such as gold or cassiterite, they will give an economic potential to the area. However, conventional heavy minerals such as ilmenite, magnetite, zircon, tourmaline, garnet and epidote do not have much economic implications, but could become an indicator of provenance and is often used in the field of sedimentology [12].

Ultrastable minerals like cassiterite, rutile, tourmaline and zircon strongly resist chemical weathering and thus may be taken to normalize the quantity of nonresistant constituents. As a consequence, the ZTR (zircon–tourmaline–rutile) maturity index was proposed by [14].

The study of heavy minerals is an important and useful tool as it bears characters of the source rocks from which it is derived [29] was the first person to stress on the need to study

the heavy minerals to know the history of sedimentation which has useful implications for the exploration of hydrocarbons [18]. stated that the heavy mineral suites are not only controlled by provenance, but also affected by weathering, transportation, deposition and post-depositional alteration. Their studies help for deciphering composition and tectonic history of provenance [26].

Because heavy minerals are sensitive indicators of provenance [19], it is important to understand their distribution in placer deposits. Since very little information is available on the distribution of heavy minerals in the study area, studies were carried out to identify the mineral species present and their provenance.

Geological Setting and Study Area

The Ropp Complex is bounded by an extensive arcuate and polygonal ring dyke which encloses basement rocks and a prominent central massif of rugged Younger Granite hills. Some of the central hills rise more than 300m above the plateau surface and form conspicuous landmarks. Both volcanic and plutonic cycles are distinguished in the Ropp complex. The cycle of the granitic intrusion was initiated by a coarse-grained granite porphyry similar to that of the Jos-Bukuru Complex, followed by a succession of biotite and riebeckite granites. Later in the intrusive cycle, there was a recurrence of granite porphyry, hornblende biotite granite and late biotite granites. The volcanic cycle include the quartz porphyries, rhyolite and explosion breccia and early basic dykes [5].

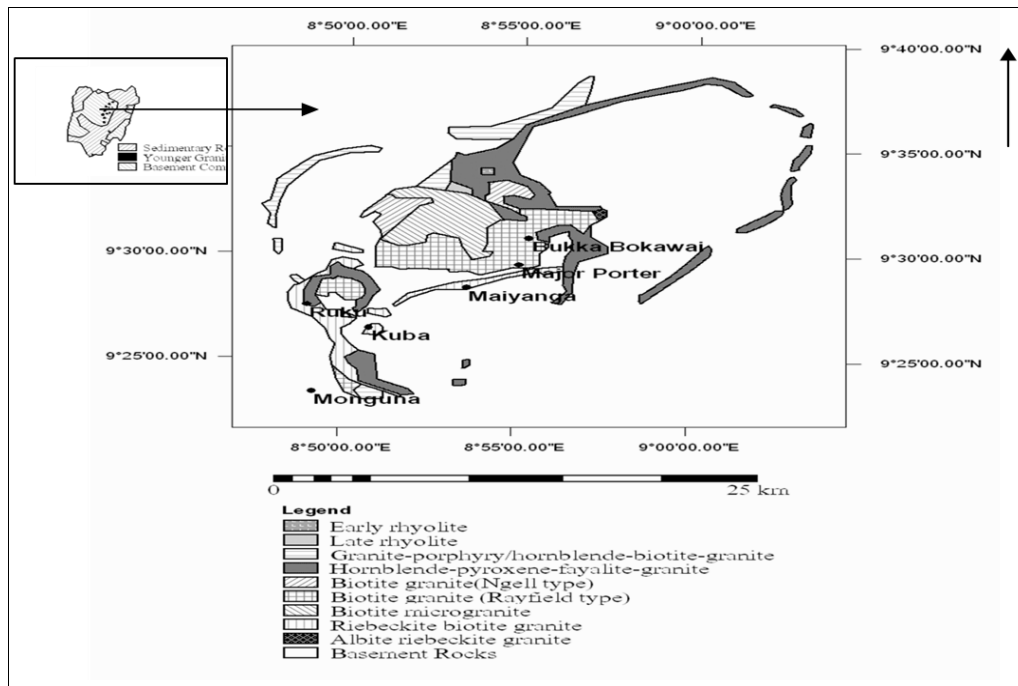


Fig 1: Location map of Ropp complex [5].

Both a volcanic and a plutonic cycle can be distinguished in the Ropp complex. Rhyolite, explosion breccias and quartz-porphyrines occur in the northern section of the structure but these are of limited areal extent in comparison with the volcanic rocks in many other complexes north of the Jos plateau [10]. The cycle of granite intrusion was initiated by a coarse-grained granite-porphry similar to that in the Jos-Bukuru complex, followed by a succession of biotite-and riebeckite-granites. Later in the intrusive cycle there was a recurrence of granite-porphry, hornblende-granite and late biotite granites. The succession of the rock types is similar to that of the Jos-Bukuru complex and the rocks themselves are almost identical [30, 27]

The structural pattern of the complex has been determined by the discordant superposition of two major fracture system [22, 16] s. The earlier Sho system, which has controlled the emplacement of the majority of intrusion, has been truncated and partly obliterated by the later system of Mangu fractures on the eastern side. The Sho fractures are mainly arcuate owing to the relative isotropy of the Older Granite on the western side of the structure. By contrast, the later Mangu fractures, which traverse heterogeneous and foliated rocks, assume a polygonal pattern. Major block subsidence is the controlling mechanism of emplacement. The intrusion of the magma has followed segmentation and foundering of individual blocks within the extensive area of superimposed fractures [23, 11, 15].

Owing to the excellence exposures in many part of the complex it is possible to see certain element of the structure in three dimensions [23, 24, 9]. The screens of the earlier phases preserved along both the horizontal roof fractures and vertical ring faults often provide a clear illustration of the mechanism and sequence of intrusion. In some instances it has been possible to estimate the extent of subsidence. The field evidence suggests that the volume of the magma is small in comparison to that of the adjoining Jos-Bukuru and Sha-Kaleri complexes and that further erosion would leave only a network of the feeder ring-dykes cutting the basement as in the case of the Dagga Allah dykes. This

interpretation is in complete antitheses to that of the [7, 28]] who ascribed the irregularity in the shape of the massif to the incomplete removal of the cover of older rocks. The sequence of intrusion in the Ropp complex is summarized in the following:

A. Granitic cycle

1. Late dolerites
2. Mongor granite-porphry
3. Kaskara biotite-granite
4. Yelwa pyroxene-granite and granite-porphry
5. Ruku riebeckite-biotite-granite-granite
6. Durowa albite-riebeckite-granite
7. Butra riebeckite-biotite-granite
8. Kassa biotite-granite
9. Bukka Bakwai biotite-granite
10. Gana biotite-granite
11. Kwop biotite-granite
12. Sho granite-porphry and hornblende-granite

B. Volcanic cycle

1. Quartz-porphyrines
2. Rhyolite and explosion breccias

Throughout the first stage of the granitic cycle, there is a progressive increase in alkalinity towards riebeckite-granites. The initiation of the second stage with the Yelwa pyroxene-granite corresponds to the central stage of the Jos-Bukuru cycle, with the intrusion of the Shen hornblende-fayalite-granite. The Kwop, Gana and Bukka Bakwai biotite-granites correspond respectively to the Jos, N'gell and Rayfield-Gana phases of the Jos-Bukuru complex.

The study area is in parts of Ropp Complex which is located southeast of the Jos Bukuru Complex in North Central Nigeria. The complex is known for its whitish riebeckite granites and extensive kaolin and tin mineralization, and a long mining history. It was the second largest tin producer in the Nigerian Younger Granite Province [5]. The study area is situated in Barkin Ladi LGA within latitude 9°15'00"N to

9°30'00" and longitude 8°45'00" to 8°52'30"E of the Federal Survey Map sheet 189 Kurra NE (Figure 1.1).

The study covers an area of approximately 375Km². The area is accessible by tarred roads, untarred roads, footpaths and cattle tracks. The area is marked by high topography averaging about 1350m above sea level. The complex is bounded by extensive actuate and polygonal ring dykes which enclose basement rocks and prominent central massif of rugged younger granite hills. The drainage pattern of the area is radial and essentially controlled by the distribution of younger granite outcrops. The major river system in the study area is the River Kurra and its tributaries, draining into Monguna and Tente provinces, where dams are constructed.

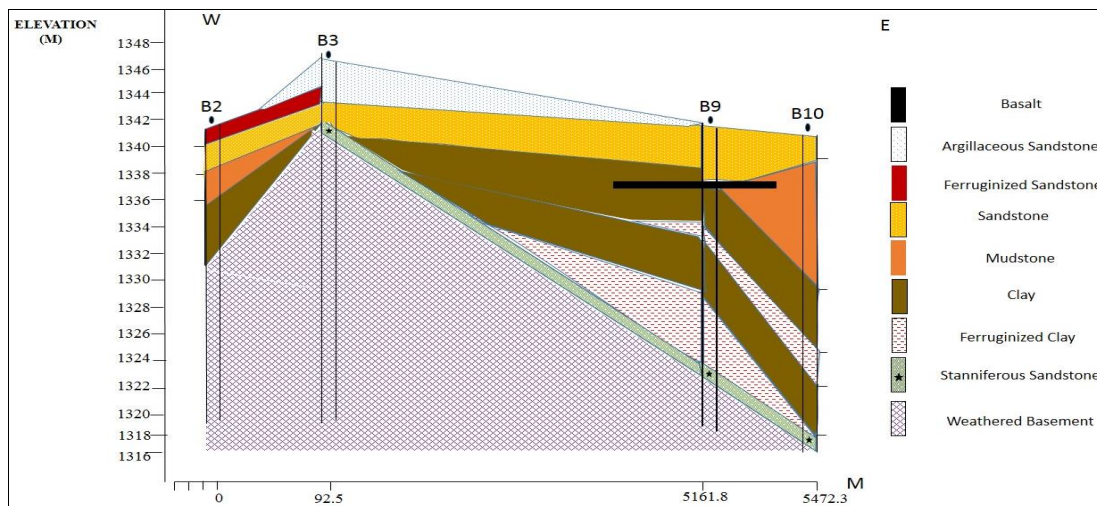
Experimental Procedure

The heavy mineral analysis was carried out in the Sedimentology Laboratory of the Department of Geology, Ahmadu Bello University Zaria. The sediments were sieved to obtain the very fine to fine sand fractions (4phi) which are commonly analyzed because it is the size fractions that is likely to contain the highest percentage of heavy minerals. Two grams from each of the samples was weighed and poured into the centrifuge tubes containing 10mls of the heavy liquid (bromo form).

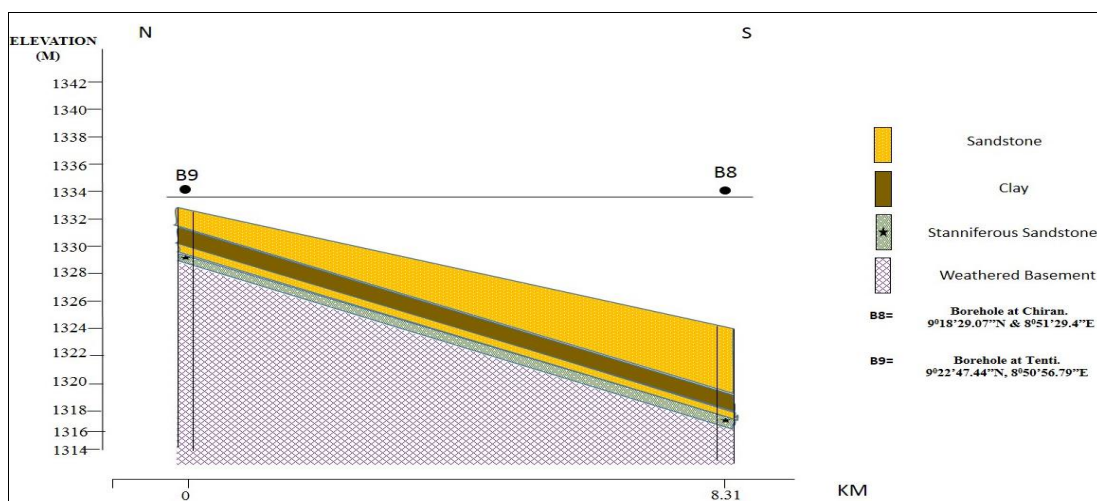
The centrifuge tubes were inserted in their respective holes

in the centrifuge and the cover closed before running the machine for 10 minutes. Acetone was used to clean and deodorize the bromo form in the heavy minerals. Furthermore, Magnetic separations was carried out to facilitate the identification of opaque heavy minerals. Although the Frantz electromagnetic separator may be used for separating minerals, it is slow and the sample can be contaminated by impurities such as rusts and left over minerals from previous separation; so, a hand magnet was used and this was very invaluable in telling the difference between magnetite and ilmenite and other opaque minerals [21].

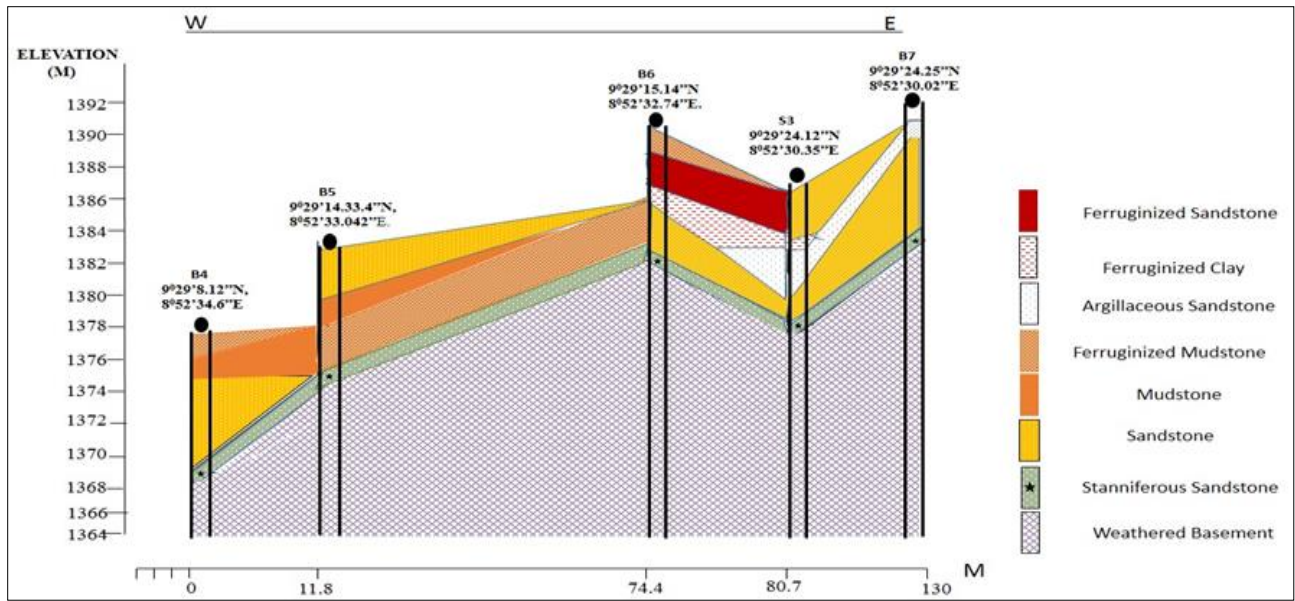
Furthermore, the heavy minerals, as was described in Figure 3 (A_E) were identified and examined with the aid of a binocular microscope. The percentage of heavy minerals in each sample was determined using Fleet method [10, 20] by counting all the grains in the mount (manually). A graph paper was taped on the glass plate and a heavy mineral sample were randomly scattered on it. Individual minerals in each square were identified based on their physical properties. Whenever possible, at least 200 heavy minerals were identified and counted from each slide, which is a sufficient number for characterizing abundances of common species [18, 19]. The "ZTR" index was calculated using the percentage of the combined Zircon, Tourmaline and Rutile grains for each sample according to the formula below.



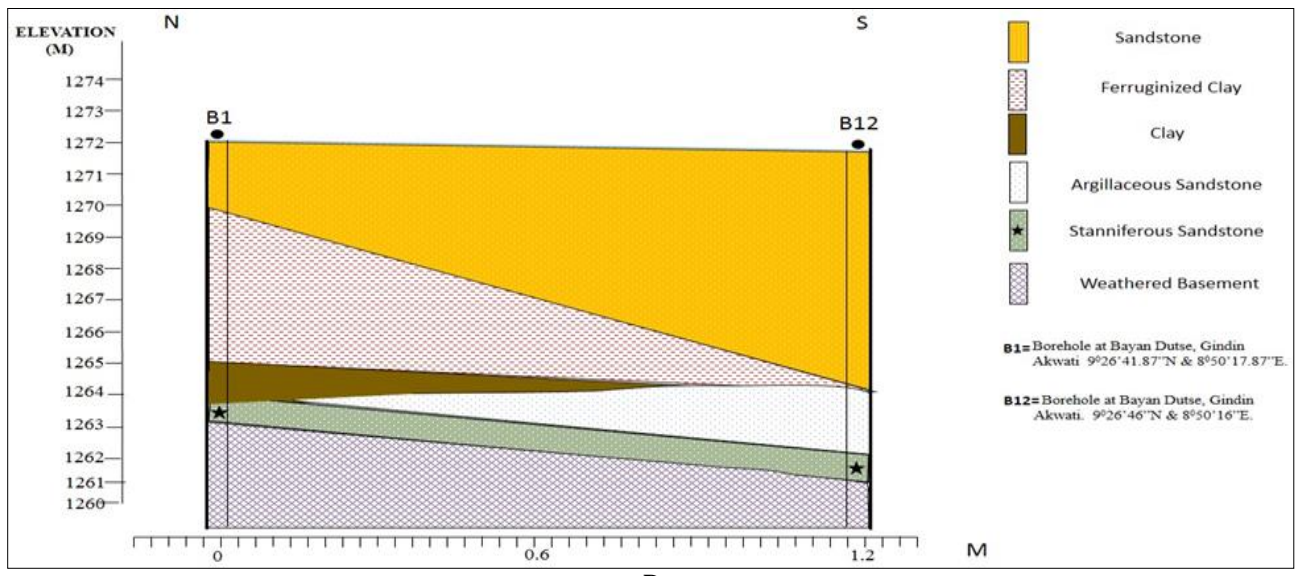
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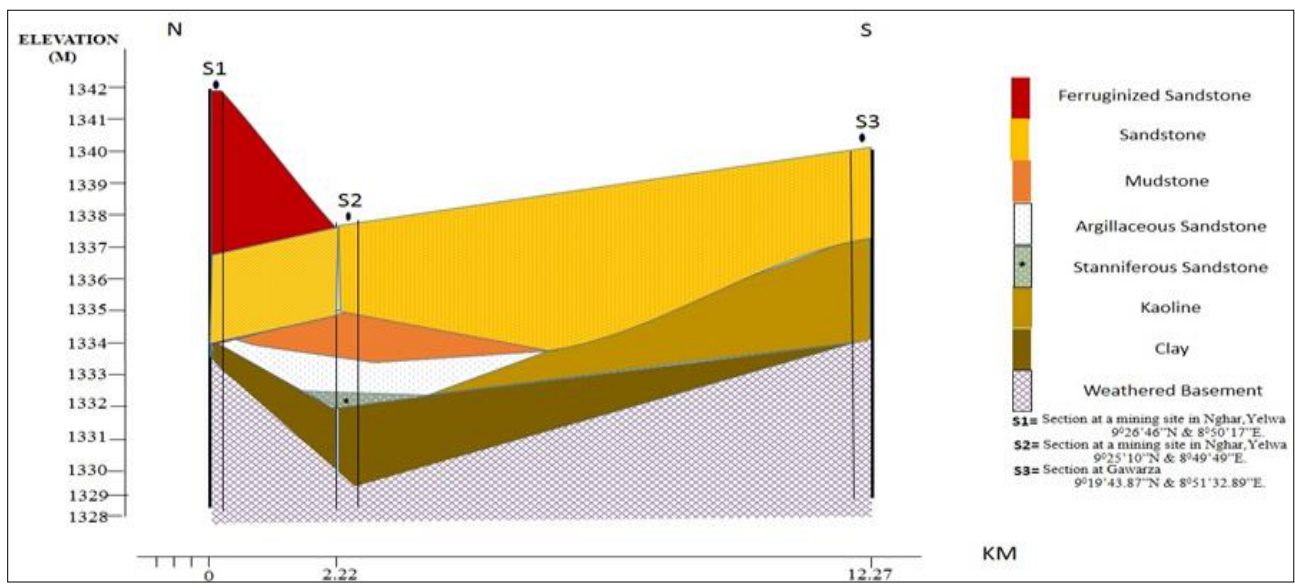
B



C



D



E

Fig 2(A-E): Correlation of logged sections and boreholes, showing the distribution and location of the sampled cassiterite bearing sandstone in the study area.

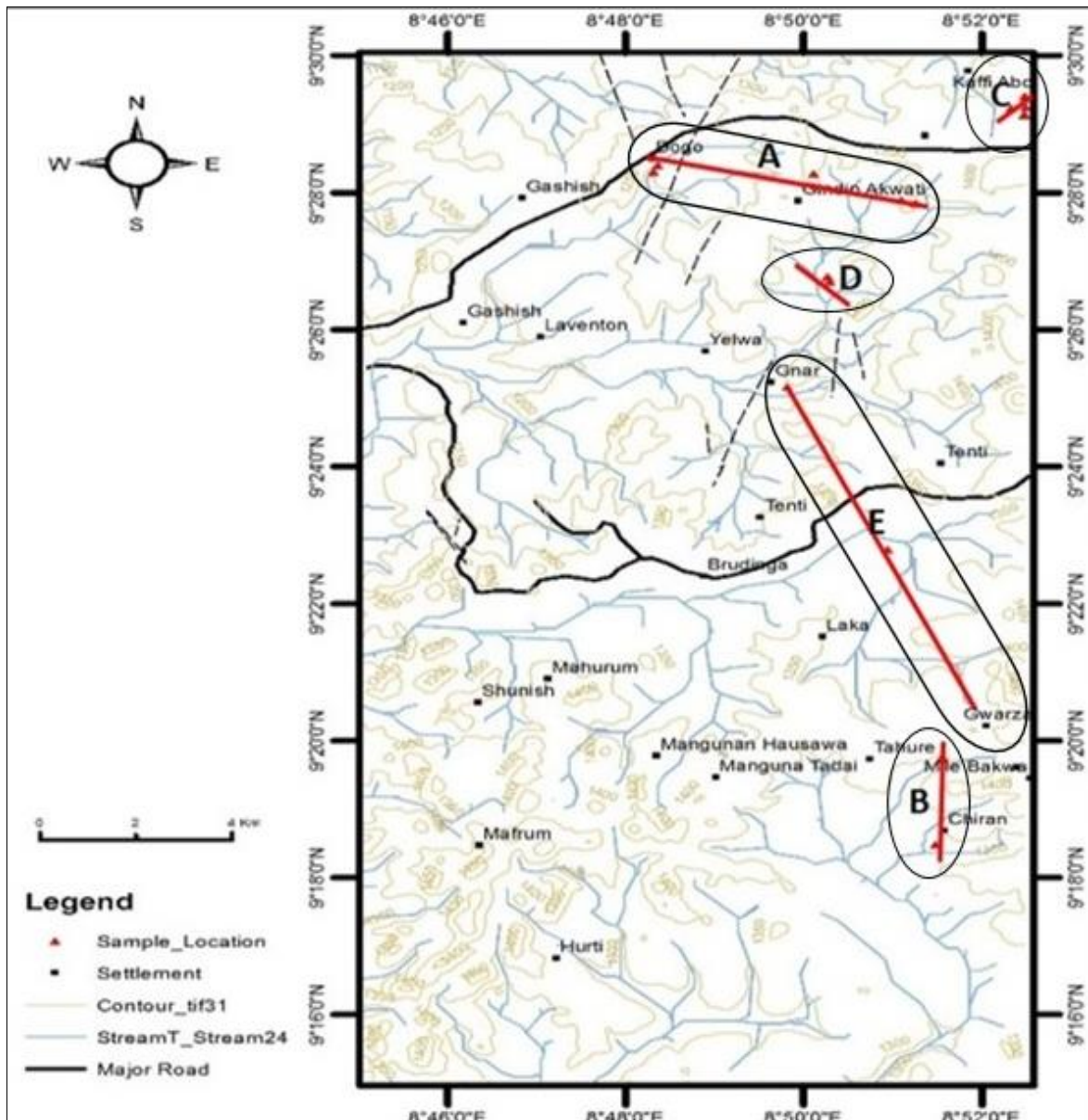


Fig 3: Map of study area showing valleys of alluvial tin fields (circled); Red lines indicates correlated logged borehole.

$$ZTR\ INDEX = \frac{ZIRCON + TOURMALINE + RUTILE}{TOTAL\ NO.\ OF\ NON\ OPAQUE\ HEAVY\ MINERALS} \times 100\%$$

The calculated index is expressed in percentage to ascertain the mineralogical maturity of the sediment. ZTR <75% implies immature to sub mature sediments and ZTR >75% indicates mineralogical matured sediments. Apart from the ZTR index, various frequency percentage plot of both pie charts were made for each sample.

Results and discussion

The heavy mineral of the studied area show an abundance of both non-opaque and opaque minerals. From the study of the heavy mineral assemblages, it is found that zircon, tourmaline, rutile, cassiterite, ilmenite, magnetite, monazite and garnet occur persistently in all the studied samples. From the (Table 2), Ilmenite is the highest identified mineral, ranging from 3% to 27%. Cassiterite is the second most identified mineral, ranging from of 2 to 14%, followed by Zircon (2 to 16%), magnetite (0 to 17%), tourmaline (5

to 11%), rutile (2 to 8%) and monazite (2 to 7%). The lowest heavy mineral occurrence is garnet with (0 to 5%). Rutile is a common accessory mineral in high temperature and high pressure metamorphic and igneous rocks. According to [25], Rutile is a non-silicate mineral occurring as an accessory constituent of igneous rocks and many granites, diorites and their metamorphic derivatives such as gneisses and amphibolite’s. Rutile is used as a source of titanium. The ZTR Index calculated from the result of heavy minerals analysis for the selected samples varies from 35% to 78%, with an average index of 59%. The ZTR indices suggest that almost all the locations contain mineralogical immature sediments and have short distance of travel except sample NGR which indicates a mineralogical mature sediment. The heavy minerals were derived mostly from igneous and metamorphic rocks. Heavy minerals such as garnets are derived from metamorphic terrenes whereas, rutile, zircon, and tourmaline indicate igneous source rocks. Zircon grains without inclusion indicate their derivation from pegmatite [11, 4]. The colourless sub-angular to sub-rounded zircon grains indicate their derivation from igneous

source rocks. Tourmaline occurring as prismatic grains with green bluish type and brown colour indicate granite and pegmatite derivation [17]. The garnets are less sensitive to diagenesis [6, 8] and their presence reflect metamorphic source for the sediments. Almost all samples collected contain cassiterite grains in various amounts. From the mineral assemblage, the source of cassiterite originates from the mineralized quartz veins that cut granitic rocks as well as the metasedimentary rock in the area. The presence of monazite which is always in association with cassiterite also

confirms that the sandstone originate from a granite pegmatite [9, 20]. Opaque minerals (magnetite and ilmenite) indicate chemical leaching of the sediments. Opaque minerals are mainly derived from crystalline igneous rocks both acidic and basic. Higher proportion of opaque mineral indicates an igneous source. It is therefore, apparent from the above study that the bulk of the heavies of the stanniferous sandstone are mineralogical immature and have been derived from igneous rocks and little part from low to medium grade metamorphic rocks.

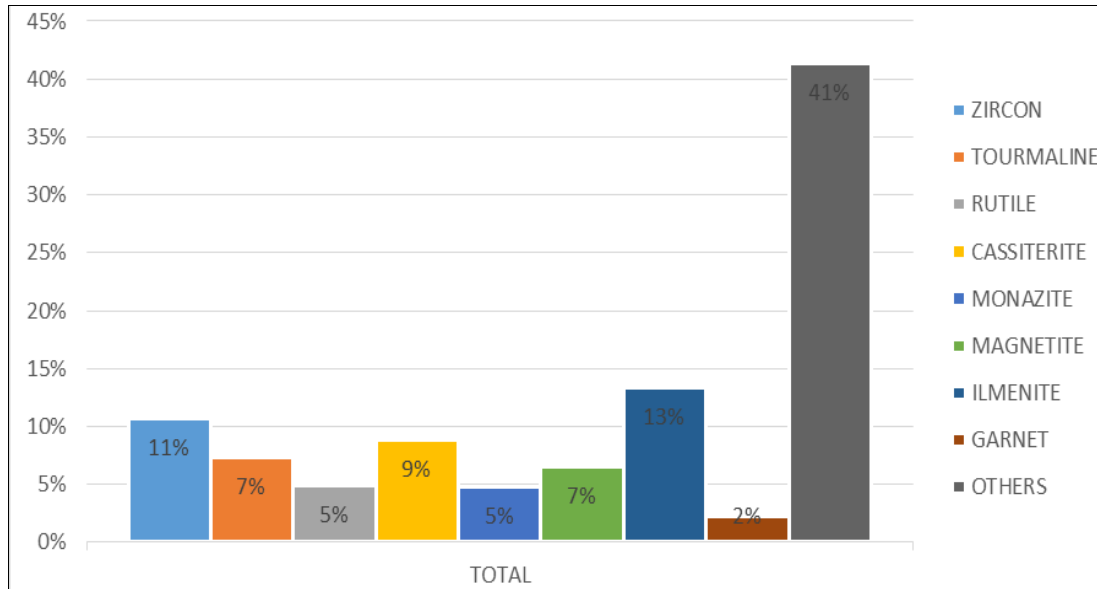


Fig 4: Percentage composition of all minerals present in the studied samples

Table 1: Heavy minerals within the cassiterite bearing sandstone in the study area

Samples	Zircon	Tourmaline	Rutile	Cassiterite	Monazite	Magnetite	Ilmenite	Garnet	Others	Total	ZTR	ZTR INDEX
BD1	18	23	15	19	12	7	13	8	94	209	56	59%
BD2	22	17	12	22	14	3	22	7	85	204	51	54%
KA2	4	13	7	27	9	13	28	9	93	203	24	35%
CHR	24	13	16	20	7	20	28	2	78	208	53	65%
TNT	15	15	8	23	5	43	47	2	90	248	38	56%
DG1	23	12	12	5	15	13	36	4	107	227	47	66%
RYM1	33	15	16	22	6	24	12	10	69	207	64	63%
RYM2	26	15	5	18	12	15	33	0	79	203	46	61%
NGR	32	18	8	4	9	0	59	2	86	218	58	79%
GMS2	29	15	4	27	12	0	5	4	93	189	48	53%
TOTAL	226	156	103	187	101	138	283	48	874	2116	485	
AVERAGE	22.6	15.6	10.3	18.7	10.1	13.8	28.3	4.8	87.4		48.5	59%

Table 2: Percentage of heavy minerals within the cassiterite bearing sandstone in the study area

Samples	Zircon	Tourmaline	Rutile	Cassiterite	Monazite	Magnetite	Ilmenite	Garnet	Others	Total
BD1	9%	11%	7%	9%	6%	3%	6%	4%	45%	100%
BD2	11%	8%	6%	11%	7%	1%	11%	3%	42%	100%
KA2	2%	6%	3%	13%	4%	6%	14%	4%	46%	100%
CHR	12%	6%	8%	10%	3%	10%	13%	1%	38%	100%
TNT	6%	6%	3%	9%	2%	17%	19%	1%	36%	100%
DG1	10%	5%	5%	2%	7%	6%	16%	2%	47%	100%
RYM1	16%	7%	8%	11%	3%	12%	6%	5%	33%	100%
RYM2	13%	7%	2%	9%	6%	7%	16%	0%	39%	100%
NGR	15%	8%	4%	2%	4%	0%	27%	1%	39%	100%
GMS2	15%	8%	2%	14%	6%	0%	3%	2%	49%	100%
TOTAL	11%	7%	5%	9%	5%	7%	13%	2%	41%	100%

Conclusion

The heavy mineral study shows that the cassiterite bearing sediments are mineralogically immature and have been derived mainly from igneous rocks and little part from low to medium grade metamorphic rocks of the Ropp complex. The source of cassiterite originates from the mineralized quartz veins that cut granitic rocks as well as the metasedimentary rocks in the study area.

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