Geological and Geoelectrical Prospecting for Manganese Ore within Tashan-Kade In Tegina Sheet 142, North-Central Nigeria

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ABSTRACT

Although manganese has attained the status of elements in critical global demand, the deposit in Tashan-Kade has remained hitherto unreported and yet to be appraised. This study is a preliminary attempt to appraise the deposit by delineating its surface spatial extent and ascertaining its subsurface thickness, through surface lithologic mapping and 2D geoelectrical prospecting. The 2D geoelectrical data was acquired with ABEM Terrameter (SAS 4000) and twenty one metal electrodes arranged in Werner Alpha field array, along a 100 m long traverse oriented along outcrop foliation dip direction. The geoelectrical data comprised electrical resistivity (ER) and induced polarization (IP) measurements. The data was processed and interpreted using RES2DINV software. The lithologic outcrops are migmatitic schist, amphibolites, granite and manganese ore. The migmatitic schist and amphibolites strike NW – SE and dip 30°W. Broken particles of the migmatitic schist are attracted by a horse shoe magnet, indicating magnetite content. Samples of the manganese ore were inert to dilute mineral acids, thereby precluding rhodochrosite. The ore shows a schistose texture and a sooty residue, which are indications of pyrolusite. The 2D inverse ER and IP models respectively reveal ER values lower than 200 Ωm and IP values higher than 2 ms in the western part of the traverse. The geoelectrical values agree with observations of rubbles of manganese ore outcrops on the western part of the traverse. The ER and IP values are respectively lower than 80 Ωm and 2 ms where the outcrops of the ore bodies are continuous sheet-like bodies. A surface spatial extent of 540,000 m^2 of manganese ore deposit was delineated between longitudes E 6°11' 45" to E 6°12' 00" and latitudes N 10°8' 10" to N 10° 9' 00", from inferred subsurface extension captured from 2D geoelectrical models and outcrop locations of the ore. The spatial area and 8 m mean subsurface ore thickness obtained from the 2D geoelectrical models constitute 4, 320,000 m^3 gross volume for the ore deposit.

Keywords: Manganese ore, critical global demand, 2D geoelectrical models

INTRODUCTION

The recent (October, 2018) commissioning of Pb-Zn ore processing plant in Cross River State of Nigeria is a demonstration of the country's commitment to develop the solid mineral sector to augment revenue from the petroleum industry. However more attractive opportunities lie in the minerals that have been declared to be in critical global demand. One of such minerals is manganese. Up till date, the manganese deposit in Tashan-Kade area of northern Nigerian basement has neither been reported in contemporary geosciences literature nor attention given to its spatial delineation. Surface lithological mapping and 2D geoelectrical tomography were conducted in this work for preliminary prospection and delineation of the deposit in Tashan-Kade.

Tashan-Kade lies within longitude E6°11'50" to E6°12'50" and latitude N10°5'0" to N10°5'40" of Tegina Topographic Sheet 142, within the part of Northern Nigeria Massif called Birnin Gwari Schist Belt (figure 1)

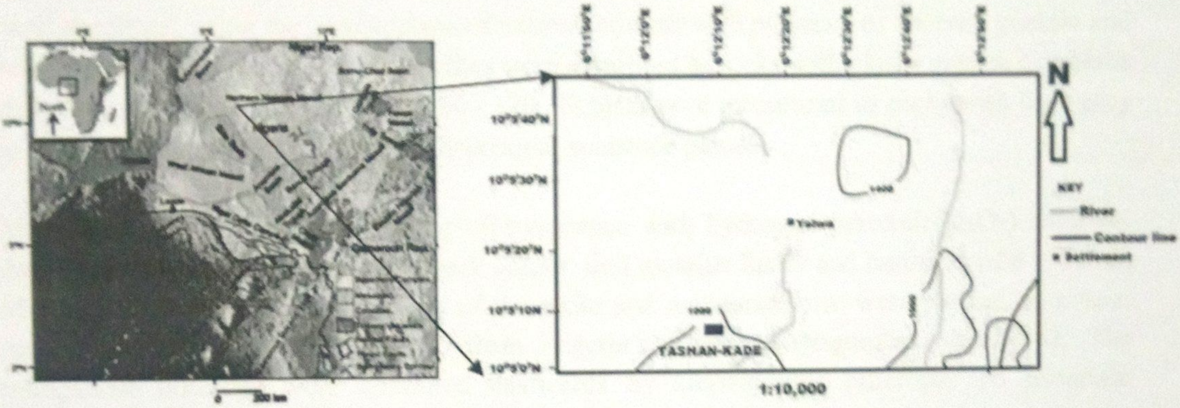

Figure1. Location of Tashan-Kade

Wright and McCurry (1970) first reported lenses of manganese ore in the western part of Northern Nigerian Massif. They remarked that the ore occurs as manganiferous layers interbedded with quartzite. Obaje (2009) documented manganese ore deposits within present states of Katsina, Kebbi and Zamfara- all in the western part of Northern Nigerian Massif. Moon *et al.* (2006) emphasized that mineral prospecting studies are crucial for discovering, qualifying and quantifying new deposits, even during exploitation, in order to expand reserves and to increase project span. They added that rock and soil sampling, chemical analysis and geophysical techniques constitute the traditional procedure for discovering and characterizing new mineral deposits. Cortes *et al.* (2016) employed the combination of resistivity method and geological mapping to delineate copper sulphide mineralization within metamorphosed, silicified and fractured sandstone in the northern edge of Camaqua sedimentary basin in southern Brazil. They associated low resistivity (less than 20 Ωm) with the ore deposit. Moreira *et al.* (2016) employed low resistivity (between 73 and 300 Ωm) to delineate supergenic manganese ore within regolith interval in Heliodore region of southern Minas Gerais in southern Brazil. Viera *et al.* (2016) characterised manganese ore deposit in Itapira, south-eastern Brazil, with high chargeability of about 20 mv/v, from 2D IP surveying. Srigutomo *et al.* (2016) also associated low resistivity and high chargeability (greater than 10 ms) with manganese ore deposit.

Libbey *et al.* (1948) remarked that most of mined manganese consists of one or both of two oxides, namely psilomelane and pyrolusite. The description and identification of igneous rocks in hand specimen, using texture and mafic mineral index was given by Chernicoff and Whitney (2007). They were able to identify granite, granodirite, diorite, gabbro, peridotite, rhyolite, dacite and basalt. They further combined mineral content with grain size and foliation to identify slate, phyllite, schist, gneiss and amphibolites. Gandhi *et al.* (2016) classified configuration of ore mineral deposits into sheet bodies, vein bodies and lensoid or lenticular bodies.

METHODOLOGY

Lithologic mapping of the rocks was conducted. The igneous rocks were identified on the basis of texture and mafic colour index (MCI). Felsic rocks contain 0 – 15% feldspar and quartz. Granite is a felsic in which potassium feldspar (pale orange to pink coloured minerals) is greater than plagioclase feldspar (light gray coloured minerals). Metamorphic rocks were identified in hand specimen, using the combination of mineral content with presence or absence gnessic and schistose mineral foliation. Amphibolites were identified as rocks with glossy greenish or black minerals, with cleavages meeting at 60°/ 120°. Schists were recognized as rocks with light gray to gray minerals that split along unidirectional schistose planes.

Manganese ore was identified using effervescence with hydrogen peroxide(H_2O_2) solution, dark gray colour, brownish black streak colour, dull metallic luster and hardness of 6 – 6.5 on Mohr Hardness Scale. The outcrops of the rocks and manganese ore were plotted on a base map produced on 1: 10,000 scale from Nigeria's Tegina Topographic Sheet 142. The manganese outcrops were delimited eastwards by amphibolites outcrops. To ascertain subsurface continuity of the ore westward, a 2D geoelectrical survey was conducted along a 100 m long westward traverse, close to the westward limit of the amphibolites. The traverse starting position is N10°8'8.29" and E6°11'55.28". The 2D geoelectrical data was acquired with ABEM Terrameter (SAS 4000), using the Werner Alpha geometry with twenty electrodes arrayed along outcrop dip direction. The starting electrode spacing (minimum electrode spacing) was 5 m. This was expanded consecutively in multiples of 2, 3, 4 and 5 to give six levels of measurements and 63 data points. RES2DINV computer program was used to process and interpret the 2D geoelectrical data. The resistivity of manganese ores (< 300 Ωm) given by Keller and Frischknecht (1970), Cortes *et al.* (2016) and Moreira *et al.* (2016) guided the identification of manganese ores in the inverse resistivity subsurface model. The identification was supported by manganese ore IP values (> 10 ms) given by Srigutomo *et al.* (2016). Subsurface intervals with resistivity < 300 Ωm and IP > 10 ms were recognized as bearing manganese ore. The identified subsurface extension of the manganese ore bodies was combined with its outcrop locations to delineate the spatial extent of the deposit. The area of spatial extent of the deposit was manually determined. The gross volume of the ore was estimated as the product of its average thickness and the spatial area.

DATA PRESENTATION AND ANALYSIS

LITHOLOGIC OUTCROPS

Outcrops found during the surface lithologic mapping are schist, amphibolites, and granite and manganese ore. The schist and amphibolites strike NW – SE (140°) and dip 30°W. The schists are light gray in hand specimen. This suggests presence of biotite or hornblende, and quartz. One of such outcrops is figure 2.

Figure 2. Biotite or hornblende and quartz bearing schist
(E6°12'32.33" ; N10°8'27.61")

Some of the schists display migmatitic texture. An example of this is outcrop shown in figure 3.

Figure 3. Schist displaying migmatitic texture
(E6°12'1.07" ; N10°8'5.86")

Figure 4 is one of the amphibolite outcrops. The rock is dark green in colour, banded and fine grained. The green colour and 60°/ 120° cleavage pattern seen in magnifying hand lens suggest that amphiboles predominantly compose the rock.

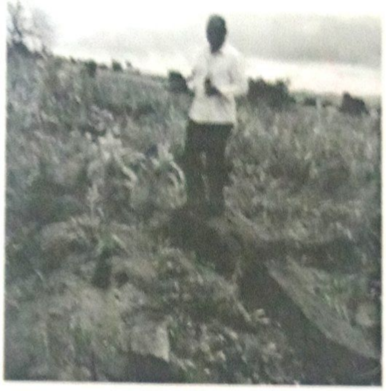

Figure 4. Amphibolite outcrop
(N10° 8' 11.09"N: E6° 12' 2.62")

The granite outcrops bear many schist zenoliths. These granites belong to the Older Granite series that intruded into the older basement. Figure 5 is representative of the Older Granite outcrops.

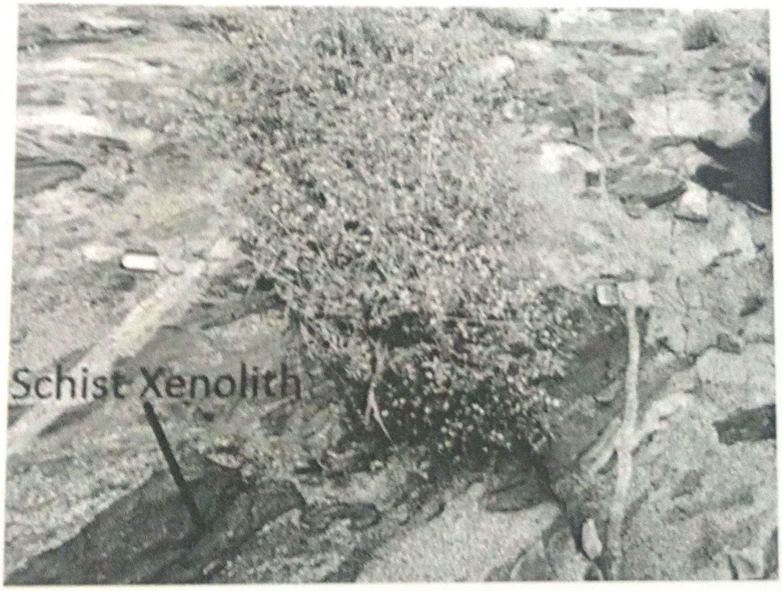

Figure 5. Schist zenolith bearing Older Granite outcrop
(N 10° 8' 41.30"; E6° 12' 50.51")

Pieces of fragments of the migmatitic schist are attracted by a horse- shoe magnet. This indicates the presence of magnetite in them. Figures 6 and 7 are some outcrops of the manganese ore.

Figure 6. Manganese ore outcrop
(N10° 8' 6.74" ; E 6° 12' 2.18"E)

Figure 7. An outcrop of manganese ore
(N 10° 8' 17.38"; E 6° 12' 4.15")

Samples from the outcrops stain hands black and are dark gray in colour. They display dull metallic luster, give a black streak, and exhibit schistose texture. They are identified to be pyrolusite. They are unaffected by dilute mineral acid, and give a hardness of 6 – 6.5 on Mohr scale. This indicates that manganese carbonate ore (rhodocrosite) is absent in the samples.

Figure 8 shows the locations of the various lithologic outcrops and the 2D geoelectrical traverse starting location.

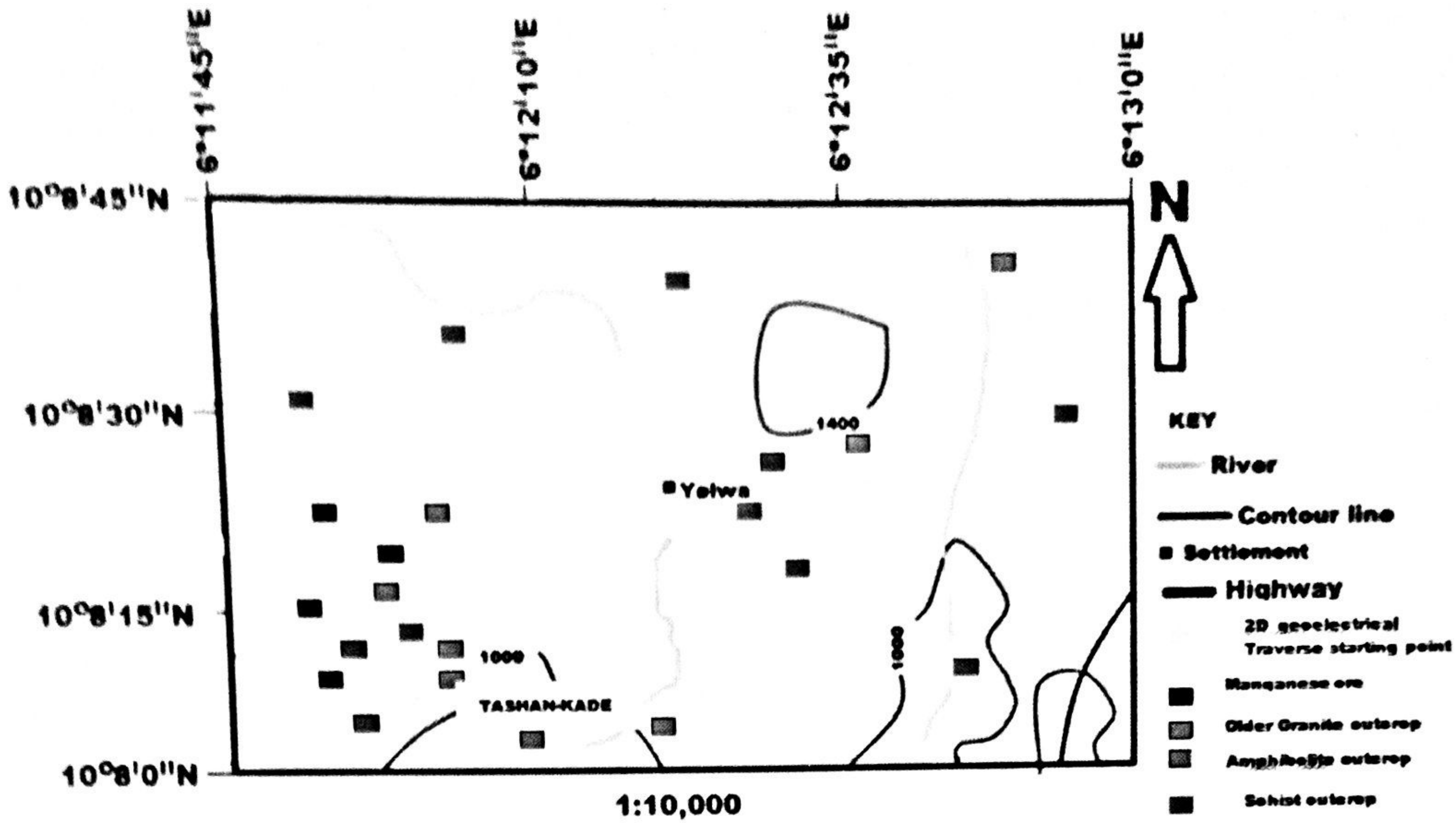

Figure 8. lithologic outcrops and 2D Geoelelectrical traverse starting point locations