minerals

MDPI

Supplementary Materials

Characterization and Suitability of Nigerian Barites for Different Industrial Applications

Itohan Otoijamun[1,2]*, Moses Kigozi[1,3], Adelana Rasak Adetunji [4] and Peter Azikiwe Onwualu [1]

[1] Department of Materials Science and Engineering, African University of Science and Technology, P.M.B 681 Abuja, Nigeria; mkigozi@aust.edu.ng (M.K.); aonwualu@aust.edu.ng (P.A.O.)
[2] National Agency for Science and Engineering Infrastructure, P.M.B 391 Garki Abuja, Nigeria
[3] Department of Chemistry, Faculty of Science and Education, Busitema University Uganda, P.O BOX 236 Tororo, Uganda
[4] Materials Science and Engineering Department, Kwara State University, P.M.B 1530 Malete Kwara, Nigeria; aderade2004@yahoo.com
* Correspondence: oitohan@aust.edu.ng; Tel.: +23-480-3849-0365

Abstract: This work aimed to characterize barite samples from selected different locations in Nigeria and determine their suitability for different industrial applications. The properties determined include mineralogy, chemical composition, morphology, functional groups, and specific gravity. Samples were obtained from ten locations in Nasarawa and Taraba states as well as a standard Working Sample (WS) obtained from a drilling site. The samples were characterized using Scanning Electron Microscope & Energy Dispersive X-Ray (SEM-EDX), Fourier Infrared Analysis (FTIR), and X-Ray diffraction (XRD). Specific Gravity (SG) was determined using the pycnometer method. Results of SEM-EDX analysis show that the WS has a BS-O empirical composition of 66.5%while the ten samples investigated had compositions of between 59.36% and 98.86%. The FTIR analysis shows that the functional groups of S-O, SO4-2, B-S-O, OH of the ten samples match that of the WS. Results of XRD show that the ten samples have the same elemental composition as the WS and all meet American Petroleum Institute (API) standard for industrial barite. Similar matching results are shown from EDXRF spectra intensity, position, and composition analysis of the ten samples compared to the WS. Specific Gravity (SG) results show that six out of the ten samples have SG above 4.2 which is the recommended minimum for API standard. The other four samples will require beneficiation to meet the standard for drilling fluid formulation. Using all the parameters of the assessment together, results show that while some (6) of the samples can be used for drilling fluid formulation, some (4) require beneficiation but all ten samples can be used for other industrial applications including healthcare, construction, plastic, cosmetics, paper, and rubber industries. The results of the study are being used to develop beneficiation protocols, procedures, and technology as well as new materials for the industries.

Keywords: Barite; Mineralogy; Industrial application; Beneficiation; Specific gravity;

Citation: Otoijamun, I.; Kigozi, M.; Adetunji, A.R.; Onwualu, P.A. Characterization and suitability of Nigerian barites for different industrial applications. *Minerals* **2021**, *11*, 360. https://doi.org/10.3390/min11040360

Received: 20 February 2021
Accepted: 24 March 2021
Published: 30 March 2021

1. Supplementary Figures

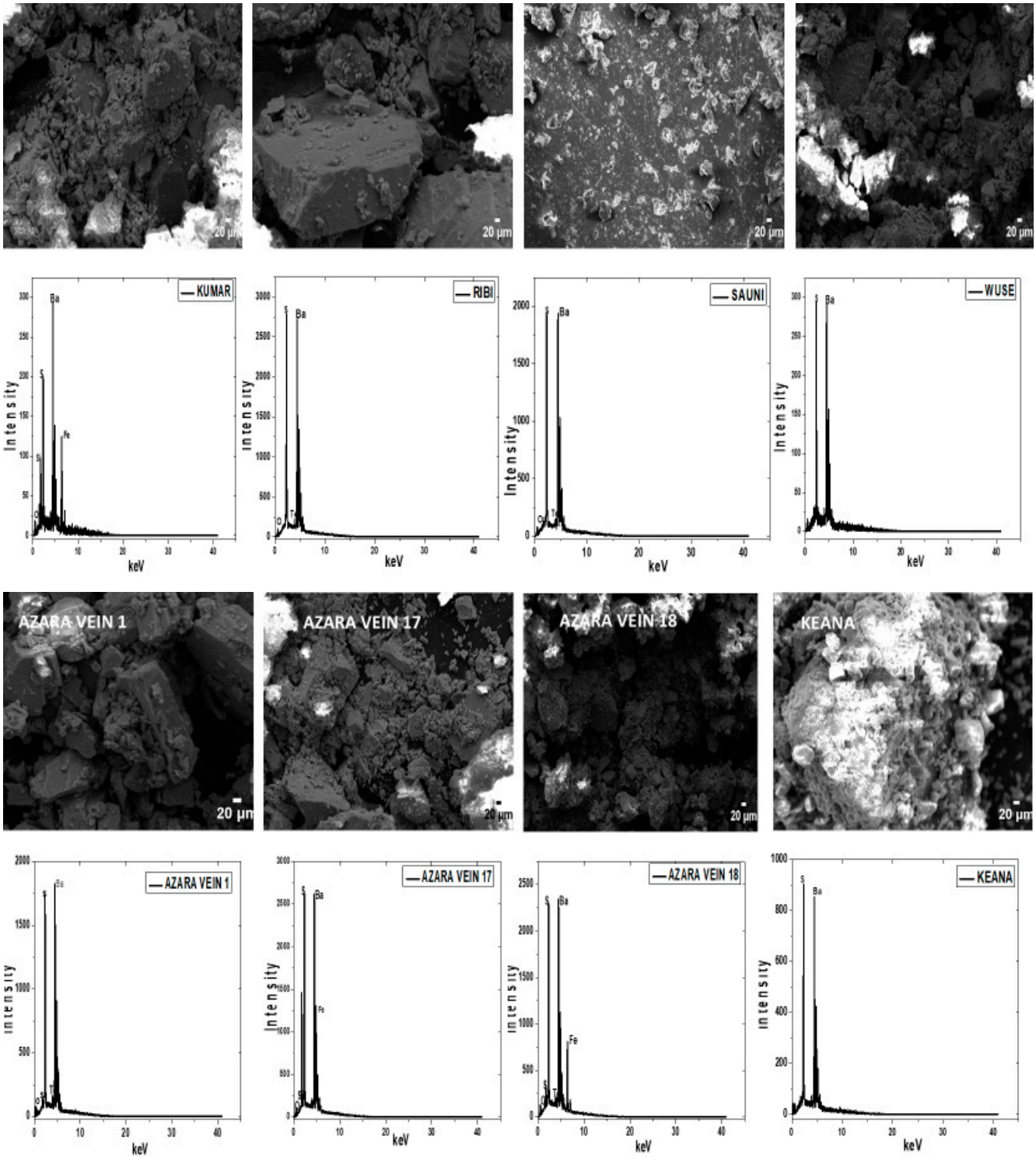

Figure S1. SEM-EDX morphology and sample element atomic percentages.

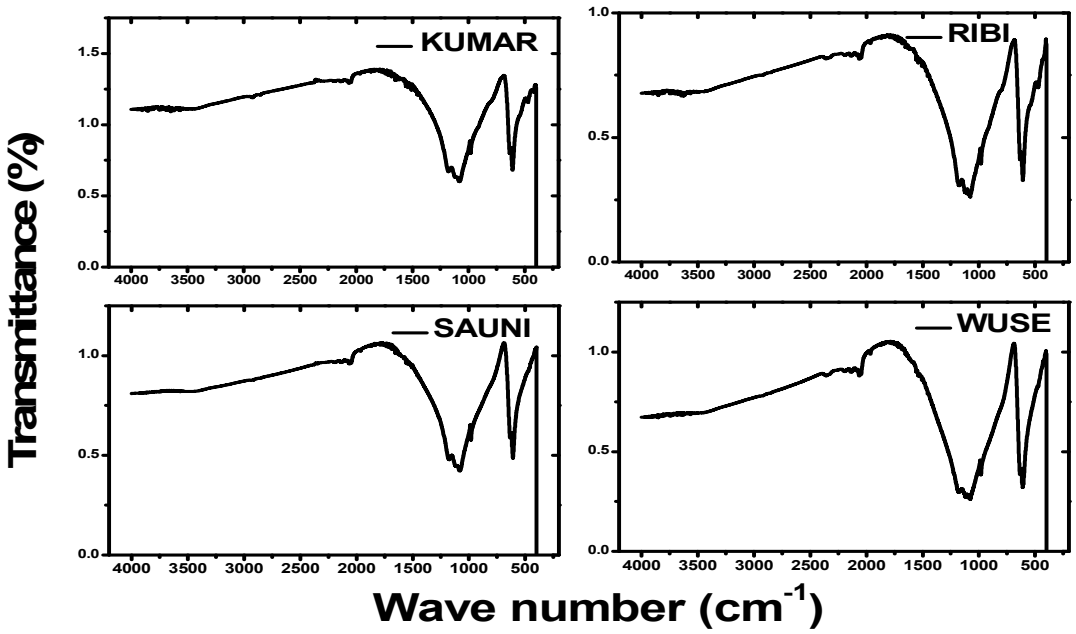

Figure S2. FTIR Spectra for the barite samples from different mining sites.

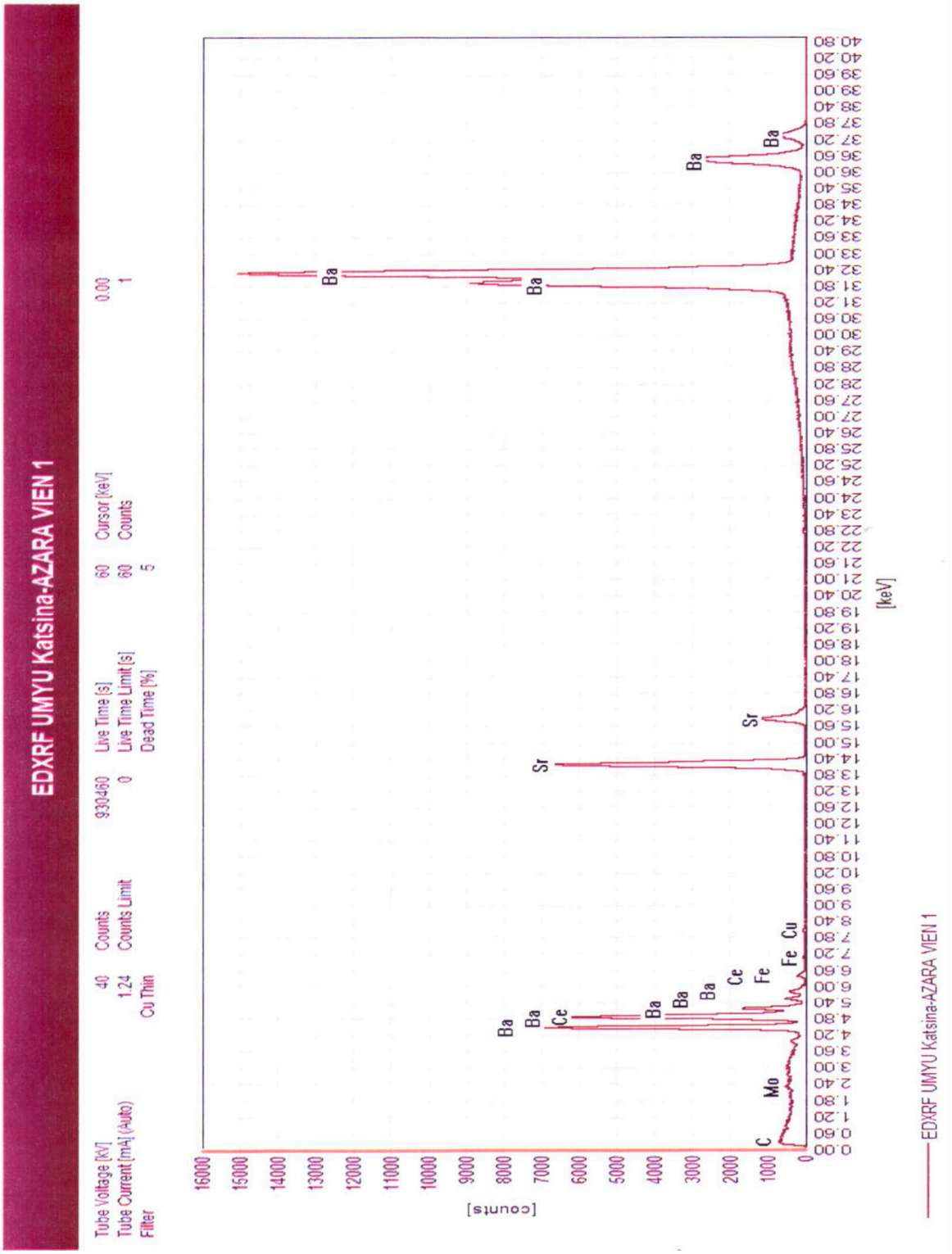

Figure S3. XRF spectra for barite samples from AZARA VEIN 1.

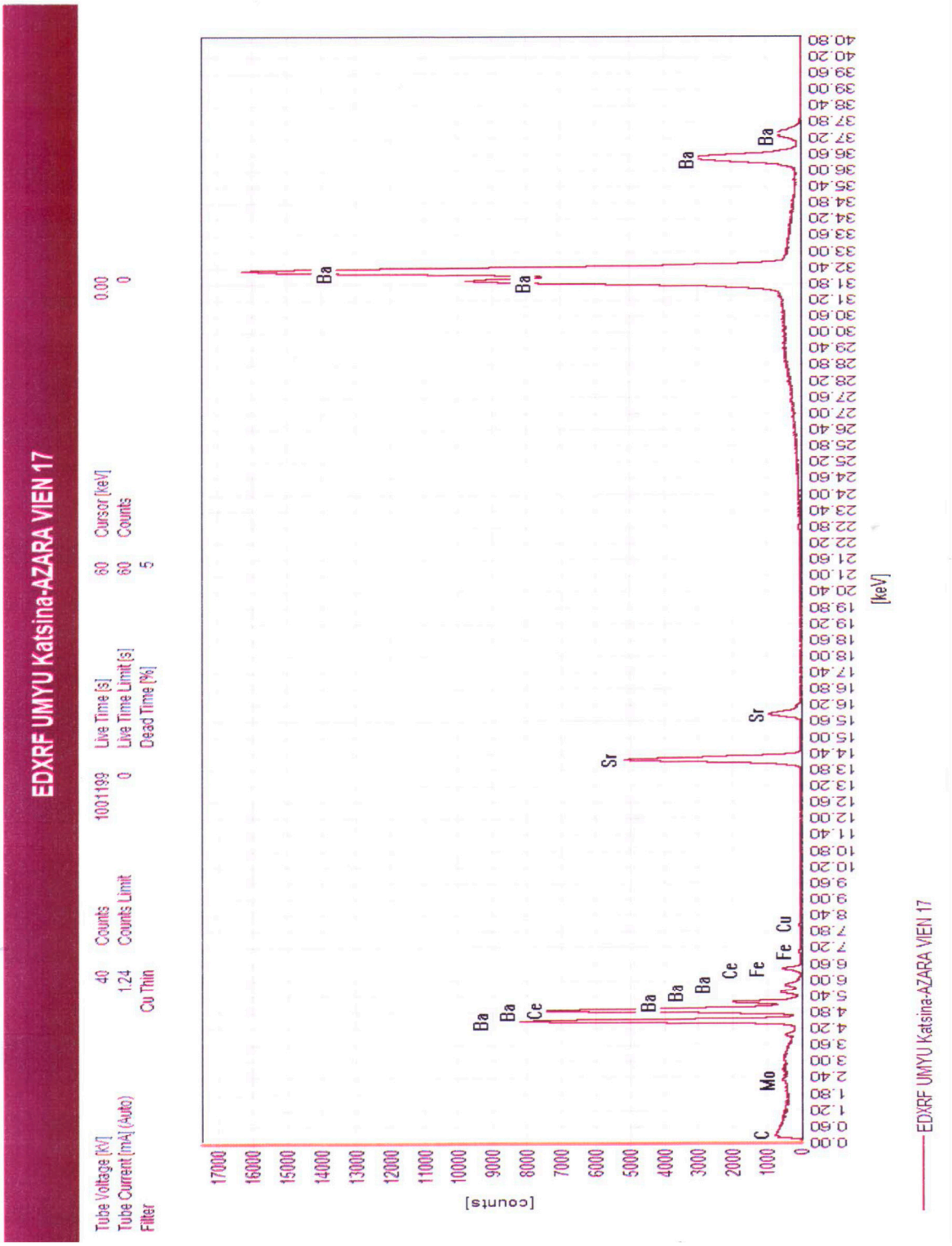

Figure S4. XRF spectra for barite samples from AZARA VEIN 17.

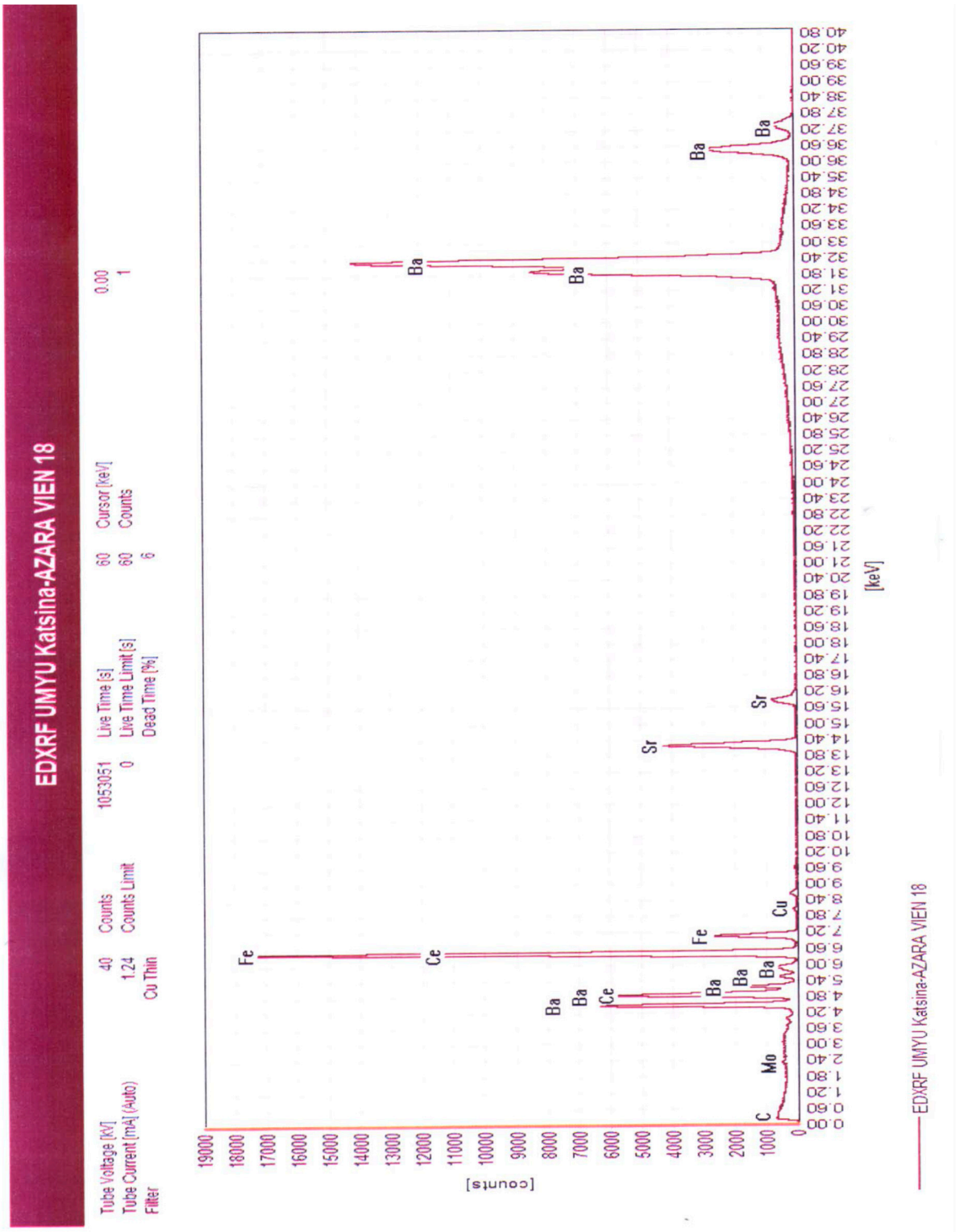

Figure S5. XRF spectra for barite samples from AZARA VEIN 18.

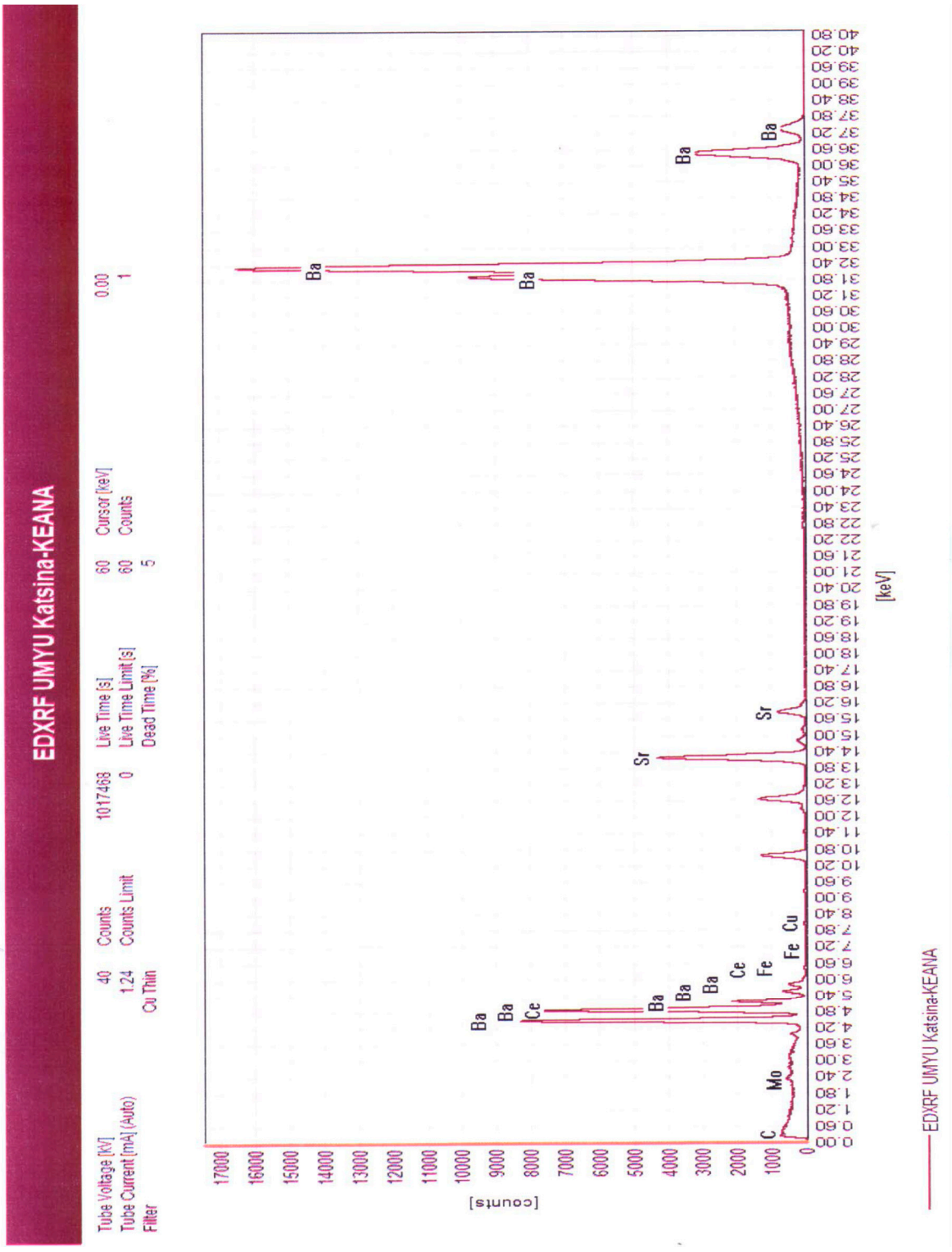

Figure S6. XRF spectra for barite samples from KEANA.

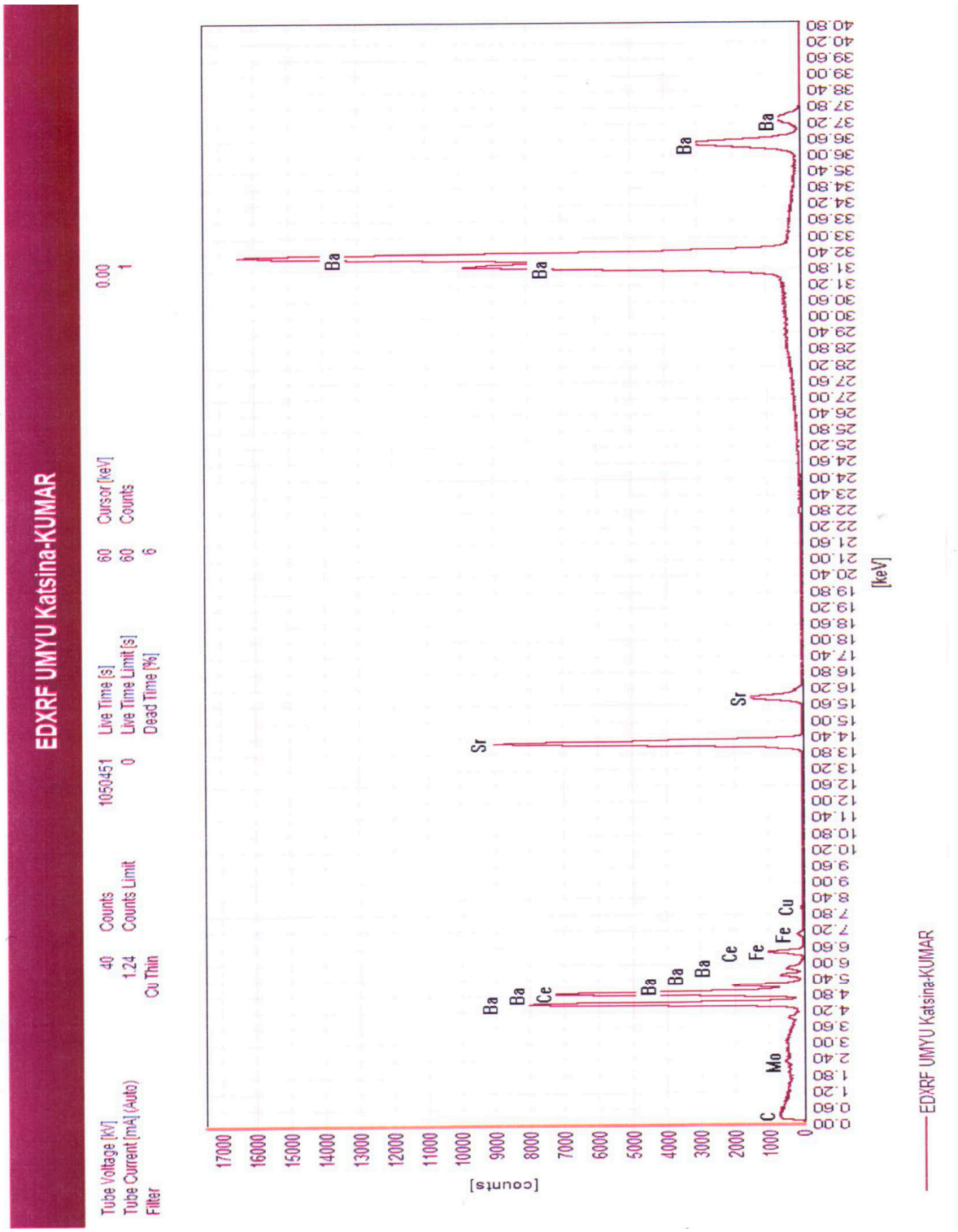

Figure S7. XRF spectra for barite samples from KUMAR.

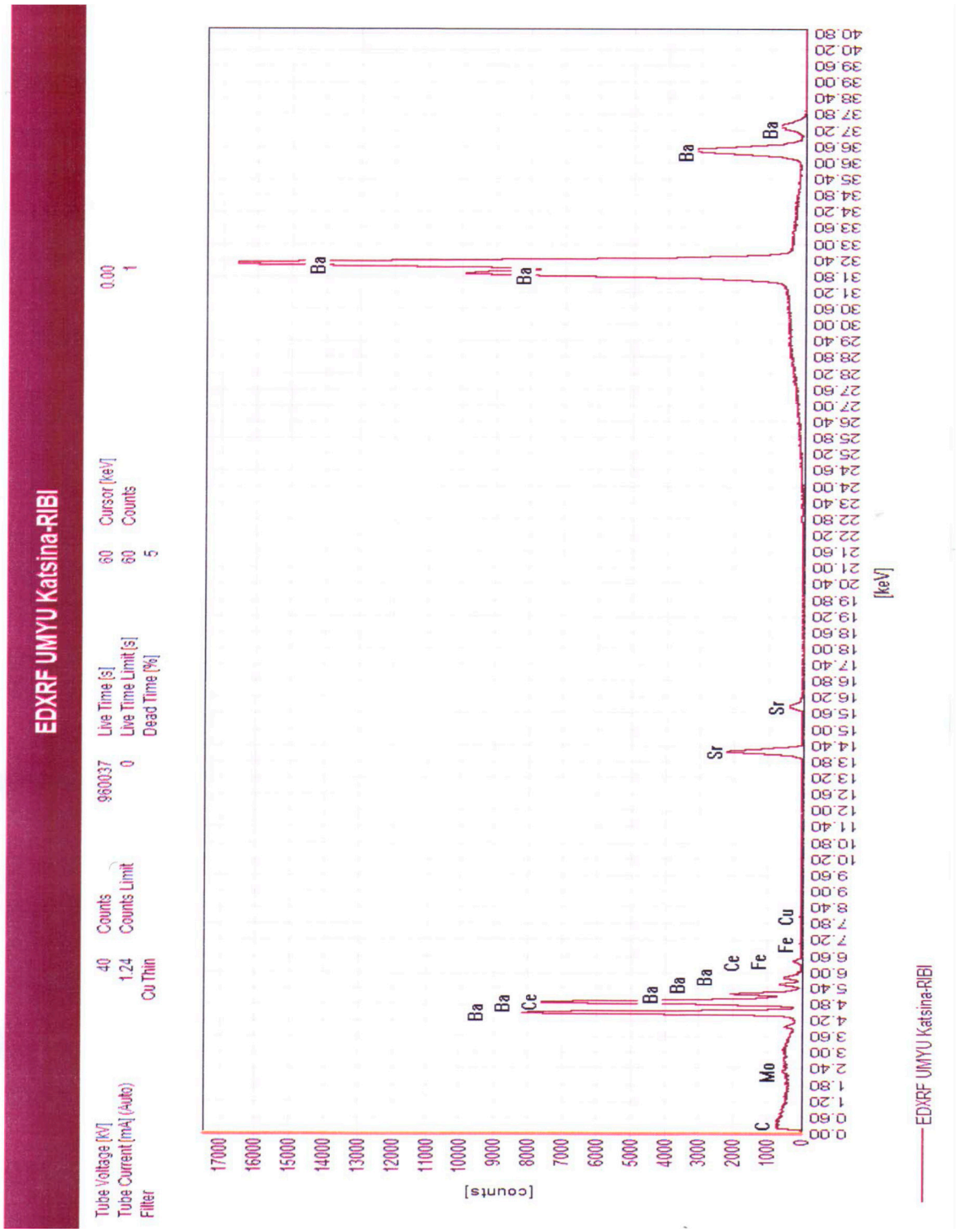

Figure S8. XRF spectra for barite samples from RIBI.

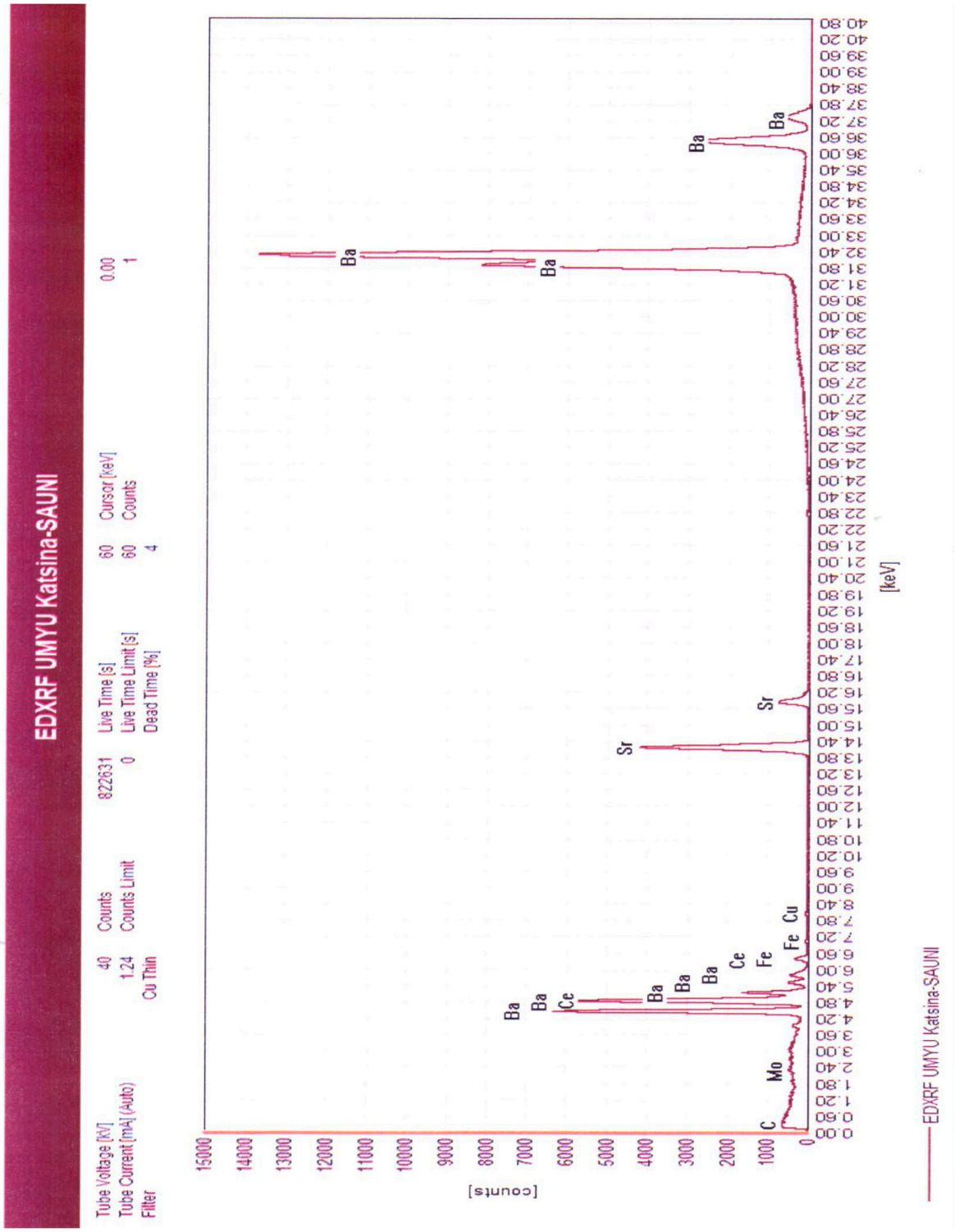

Figure S9. XRF spectra for barite samples from SAUNI.

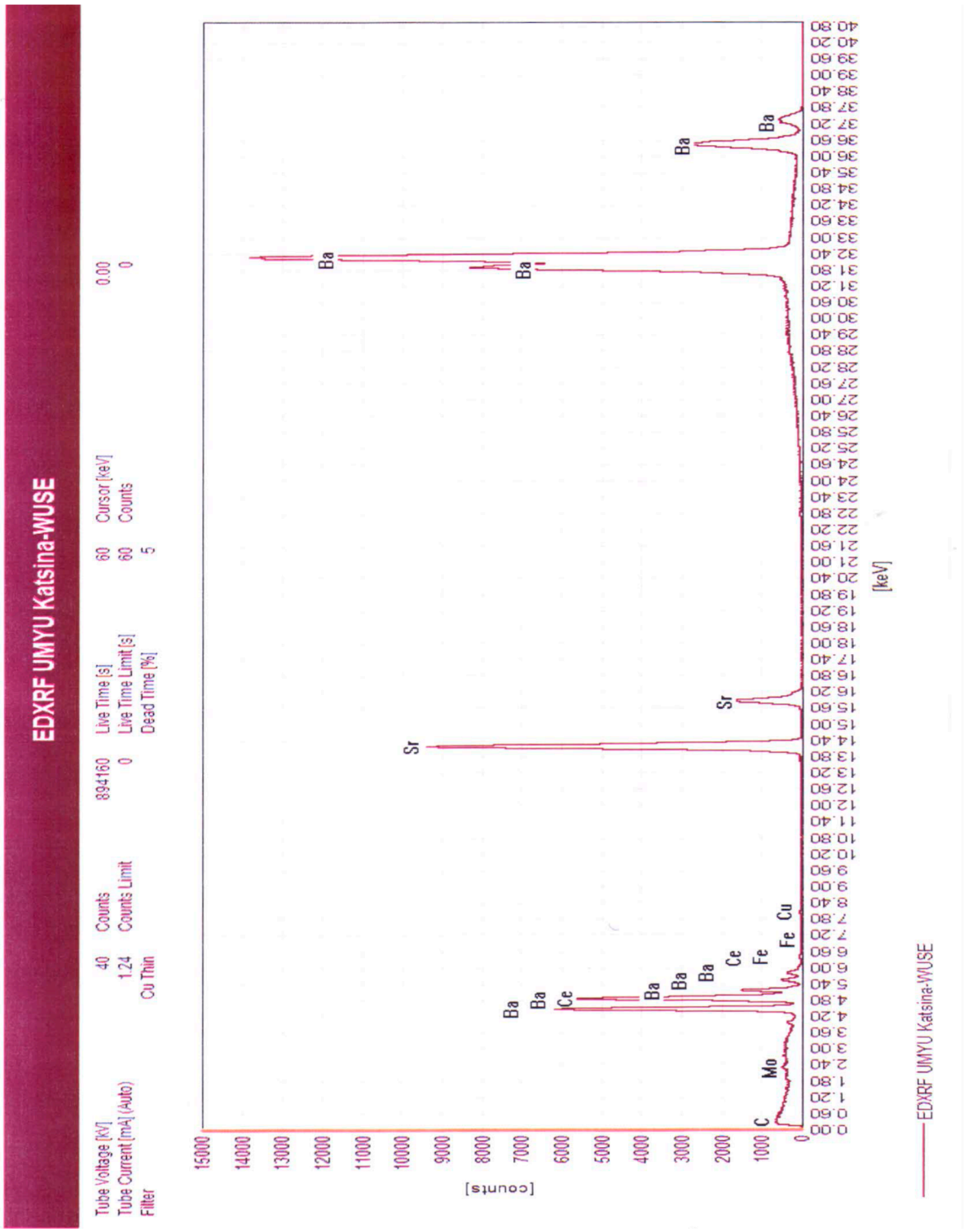

Figure S10. XRF spectra for barite samples from WUSE.

2. Laboratory procedure

2.1. Sample Collection

Different barite deposit sites were visited including, Nasarawa and Taraba State of Nigeria with representative samples collected from mining pits being worked by artisanal miners. Rocks exposure within the deposits were studied to understand the lithology of the deposits. Samples were collected across the veins and stored in sample bags with name tags.

Bulk barite samples were collected from the site under investigation. In the laboratory, these samples were washed with fresh water to remove any dust they may contain on their external surfaces. The cleaned samples were dried at a temperature of 50 °C in an oven for a week. Dry barite bulk samples were crushed with the clean hammer and then poured into a crushing machine to convert them to the required powder grade.

2.1. Sample Characterization

The samples were studied in the field as hand specimens and further characterized in the laboratory using different techniques like Scanning Electron Microscope and Energy Dispersive X-Ray (SEM-EDX) for the in-depth surface analysis of the samples using the EVO LS10 SEM-AMETER EDAX instrument. The FTIR (Fourier Transform Infrared) Analysis was determined by Perkin Elmer 1310 infrared spectrophotometer. The XRD (X-ray diffraction); The samples were crushed using an agate mortar and analyzed with powder X-ray diffraction for phase composition evaluation. The diffractometer was a microprocessor-controlled PANalytical X'Pert PRO MRD, Cu-K radiation, and a scan recording in the 2 θ angle range between 5 and 70°. The EDXRF data achievement using the M4 Tornado from Bruker was used to determine the chemical composition of rocks, minerals, sediments, and fluids. The X-ray radiation was engendered by a tube with rhodium target functioning with a maximum power of 30 watts. The polychromatic beam was focused by a poly-capillary lens, resulting in a spot size of 17 μm at 17.48 keV (molybdenum (Mo) Kα). For this work, the M4 Tornado was operated with two silicon drift detectors facing each other at 180 and 90◦ to the tube for oxides analysis [14–16]. Knowing the mineral samples and their location helped in the setting of the analysis; the spectra of the corresponding pixels of the EDXRF quantities were well-defined as mineral oxides for the mineral database. Furthermore, EDXRF spectra of selected areas were calculated based on the sum spectrum and quantify the element ratios for a quantitative chemical investigation using the Bruker fundamental parameter algorithm. SG was used to evaluate the physical, mineralogical, and chemical properties of the barite ores from the various locations. In testing for specific gravity (SG) an already prepared pycnometer bottle was weighed and filled to 1/3 its volume with the sample, reweighed. This is followed by weighing the pycnometer plus sample and water and finally by taking the weight of the pycnometer and water [17]. This procedure was carried out for all the samples. The specific gravity was calculated as shown in Equations (1a) and (1b).

$$True\ specific\ gravity = \frac{Weight\ of\ sample}{Weight\ of\ an\ equal\ volume\ of\ water} \quad (1a)$$

$$SG = \frac{(b-a)}{(b+d)-(a+c)} \quad (1b)$$

where: a = weight of empty pycnometer bottle; b = weight of pycnometer + sample 1/3 of the bottle capacity; c = weight of pycnometer + sample + water; d = weight of pycnometer + water.

Sample from Aloshi Nasarawa state was labeled as (NT) and Sample from Ibi, Taraba state was labeled as (TS); all other samples were labeled by the name of the location it was obtained from. The sample which was picked from the Port Harcourt drilling site labeled as (WS) was taken as the working standard.

Table S1. Mine site location in the Local Government Area.

Number	Sample Location	Local Government Area	State
1	Azara Vein 1	Awe	Nasarawa
2	Azara Vein 17	Awe	Nasarawa
3	Azara Vein 18	Awe	Nasarawa
4	Keana	Keana	Nasarawa
5	Ribi	Awe	Nasarawa

6	Kumar	Awe	Nasarawa
7	Sauni	Awe	Nasarawa
8	Wuse	Awe	Nasarawa
9	NS (Aloshi)	Keana	Nasarawa
10	TS (Ibi)	Ibi	Taraba
11	WS	Drilling Site	Rivers

Table S2. The physical appearance of the samples.

Number	Sample	Physical Appearance /Colour
1	Azara Vein 1	White
2	Azara Vein 17	Cream
3	Azara Vein 18	Light Brown
4	Keana	White
5	Ribi	White
6	Kumar	Ivory (Off White)
7	Sauni	White
8	Wuse	White
9	NS	Cream
10	TS	White
11	WS	Brown