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Comparison of PIXE Technique with Chemical Analysis and NAA -Geo chemistry of High Grade Metamorphic Charnockite Rocks

A.V.S.Satyanarayana[1*].*Mokka Jagannadha Rao*[2].*Kemburu Chandra Mouli*[1]. *Byreddy Seetarami Reddy*[3]

[1]Department of Engineering Physics, Andhra University, Visakhapatnam-530003, AP, India.
[2] Department of Geology, Andhra University, Visakhapatnam-530003, AP, India.
[3] Department of Nuclear Physics, Andhra University, Visakhapatnam-530003, AP, India.

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Abstract: The investigation describes the results obtained by PIXE analysis-Geochemistry of high grade metamorphic rocks and comparison with the previous chemical analysis and neutron activation analysis results. The performances of PIXE technique through geochemical analysis of metamorphic charnockite rocks at various levels of elements have been discussed. The reasons at advantages and drawbacks of PIXE as 3MeV methodology with Si (Li) detector and matrix composition of metamorphic geological materials are tried to explain. The experimental uncertainties like incident proton energy, production cross sections, X- ray fluorescence, brumstralung, detector efficiency, matrix effects and limit of detection, resolution at light elements, medium elements and REEs are studied with respect to the well-established Chemical analysis and NAA results of charnockites.

Keywords: PIXE analysis, Geochemistry, Metamorphic rocks, Comparison, Chemical analysis and NAA, Experimental uncertainties.

1 Introduction

Particle induced x-ray emission PIXE [1], is a powerful non-destructive elemental analysis technique now applied routinely by geologists and others to support answer questions of provenience, dating and authenticity. Quantum theory states that orbiting electrons of an atom must occupy discrete energy levels in order to be stable. Bombardment with ions of sufficient energy (usually MeV protons) produced by an ion accelerator, will cause inner shell ionization of atoms in a specimen. Outer shell electrons drop down to replace inner shell vacancies, however only certain transitions are allowed X-rays of a characteristic energy of the element are emitted. An energy dispersive detector is used to record and measure these x-rays and the intensities are then converted to elemental concentrations.

The nuclear science has been in the forefront of the development in various fields, including in the science of nuclear chemistry. This resulted in many applications of nuclear instruments NAA, PIGE, PIXE, XRF, EPMA, AAS and others. PIXE is one of such analytical techniques gained popularity and applicability of the PIXE technique, especially in geochemistry [2] has been gaining importance in recent times. When we observe the related scientific literature a number of researchers from earth sciences have established its applicability in the analysis of materials from geological sciences, these include rocks, minerals and ores etc. PIXE is giving results of geological materials for their major, minor, trace and REE concentrations.

It has been an argument that some of the elements present in geological material by using PIXE analysis are purely determined or could not be determined at all, due to various reasons including the matrix. It is felt that a systematic investigation needs to be designed and implemented to understand the limitation of PIXE in certain elements. It is believed that the accuracy of problematic elements, especially from high grade rock can be improved and the conditions of PIXE can be standardized for various elements under different combinations. The reasons behind the poor performance of Proton Induced X-ray Emission in case of certain elements have been established [3].

The PIXE spectrum of the matrix Charnockite samples G1 to G7 collected from the interior of the hill recorded by Si (Li) detector (table-1). The concentrations in ppm of these continuous ranges of elements in each sample were

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[*] Corresponding author e-mail: savs.viit@gmail.com

determined using the GUPIX software [4]. These concentrations are presented with errors in table-1 by using the analysis of PIXE spectrum. The results of PIXE spectrum of Charnockite samples are reviewed by using previous analytical techniques. With the comparison of previous analytical studies [5] [6] [7] [8] (table-2) there is a need to be discussed the elements in Charnockite composition.

2 Experimental Details

The experiments were carried out with a 3MV accelerator at the Institute of Physics of Bhubaneswar, India. For the measurements, 3MeV protons deflected by a 60° analyzing magnet was used. The energy calibration of the accelerator has already been arranged. Samples were placed at the centre of a scattering chamber at an angle of 45° with respect to the proton beam. The X-rays are detected with a Si(Li) detector, which has an area of about 80 mm2 and a resolution of 160 eV at 5.9 keV and is located about 15 mm away from the target, outside the vacuum. The detector is coupled to an amplifier and a computer controlled and is mounted at 90° with respect to the proton beam. The X-rays pass through a Be window. The output of the Si (Li) detection is completed to data acquisition system which records the X-ray spectrum. The spectrum of each sample is recorded for a sufficiently long time so as to ensure good statistics.

To assure the reliability of experimental system and other parameters, in the same experimental conditions, the PIXE spectrum is recorded with NIST certified reference material and the relative concentrations of different elements are estimated using GUPIX software package. The relative concentrations of different elements, thus obtained in the present experiment for the above standard samples are compared with the certified concentrations supplied by NIST.

The Guelph PIXE (GUPIX) software package [4] is used to analyze the spectra utilizing a standard Marquardt non-linear least square fitting procedure. Using this GUPIX software package the X-ray intensities of different elements are converted into the respective concentrations using a standardized technique involving fundamental parameters, pre-determined instrument constants and input parameters such as solid angle, charge collected etc. Comparing the concentrations of Yttrium obtained in the present work with the known concentration of Yttrium added to the sample, the reliability of the input parameters is checked.

3 Results and Discussion

(Table-1, Table-2 Locations)

In this study, PIXE spectrums of the geological metamorphic rock samples G1 to G7 collected from the interior of the charnockite hill recorded by Si (Li) detector. The ppm concentrations of various elements in each sample were determined using the GUPIX software, are presented with errors in table-1. Another attempt is made to compare the results of charnockite samples from the same area using previous chemical and NAA analysis [6] [9] table-2 for PIXE experimental factors evaluation. It is observed that the results obtained by PIXE are comparable except few elements with previous chemical and NAA analysis which are already published data. With respect to certain elements, the reasons behind the low performance of PIXE at various levels of elements in case of matrix composition of geological materials have been tried to explain.

3.1 Low Z Elements.

In charnockite metamorphic composition the elements are started from Li and Li, Be, F, Na, Mg, Al, Si and P are detected by using previous chemical analysis. But not detected in this case PIXE as 3 MeV, the disadvantage is that they do not interact very strongly with lighter elements, so this could impose a limitation on the elements detectable by X-ray techniques. PIXE with 3 MeV unable to detect the low Z elements present in Charnockites due to detector limits. For light elements, the problem is mainly due to absorption of the low energy X-ray by detector Si (Li) windows. X-rays below or near the sodium cannot be seen because they are absorbed in either the detector window atmosphere or through any filter used. A possible disadvantage to running in this configuration is that low energy X-rays from lighter elements attenuated in air. For light elements, the problem is mainly due to absorption of the low energy X-ray by detector Si (Li) windows and the tails of the heavier major elements peaks.

The element Li, no X-ray and Be with X-ray energy Kα= 0.108 keV are not detected even though these elements previously reported in chemical analysis of Charnockites. Similarly the elements F with X-ray energy Kα=0.677 keV and Na (Kα=1.040keV) to P (Kα=2.010 keV) not detected in present investigation due to above detector limits, but these elements analysed by previous analytical methods. Atcually the analysis is started from element S (Kα=2.309) but not present in Charnockite composition. The spectrum in above started from peak of Cl because Kα= 2.622 keV, because detector limits starts from Cl element. From the element Cl onwards, all the elements within the detector limits, and all are detected in above spectrum of Chanockite sample.

The sensitive volume ranges from order of 10 mm in diameter, and order of 5 inch thickness depending on the derived application. The smaller diameter detectors provide better energy resolution of elements at low X-ray energies, and the thicker detectors have higher detection efficiency at energies of the X-rays above about 20 keV. The X-ray enters the cryostat through a thin beryllium window to reach the detector. The beryllium windows of detectors are

Table1: Present analytical results of all matrix charnockite samples in ppm(PIXE).

S.NO	Element	G1	G2	G3	G4	G5	G6	G7
1	Cl	394.1±16.5	399.6±17.1	379±16.5	403.5±19.5	546.9±23.5	383.7±16.7	462.6±20.6
2	K	4080±28.2	4187±25.1	4148±26.1	4246±29.3	6699±40.2	5458±27.1	5393±33.4
3	Ca	2229±25.9	2281±22.8	2637±25.6	2754±28.1	4120±23.5	2544±26.2	3091±32.1
4	Ti	1394±11.6	1271±9.3	1109±9.3	13.67±11.3	1590±13.8	1044±9.1	1510±12.4
5	V	17.92±4.8	23.69±4.1	7.85±4.0	BDL	37.78±6.0	10.79±4.0	11.55±12.4
6	Cr	16.63±2.3	38.53±2.1	15.16±2.1	16.93±2.5	17.71±3.1	9.118±2.1	14.13±2.6
7	Mn	18.62 ±3.9	34.71±3.7	34.31±3.7	33.68±4.1	47.43±5.3	27.36±3.5	27.03±4.5
8	Fe	5200±20.3	6575±21.0	5649±19.8	5838±22.2	7325±26.4	4905±17.7	6238±23.1
9	Ni	10.96±3.7	11.43±3.7	10.06±3.39	8.94±3.92	28.29±5.02	10.11±3.1644	16.5±4.3692
10	Cu	BDL	BDL	6.1±2.7	BDL	BDL	BDL	8.717±3.47
11	Zn	9.147±3.3	18.21±3.5	14.23±3.0	14.41±3.5	11.96. ±4.6	24.73±2.9	4.29±2.0
12	Se	6.3±65±2.5	BDL	BDL	0.9499±1.7	BDL	BDL	BDL
13	Br	4±2.2	12.17±2.93	11.82±2.85	13.47±6.2	10.32±4.031	8.61±2.455	9.08±3.503
14	Rb	48.87±6.0	42.08±6.1	62.73±6.0	34.71±6.2	56.14 ±7.9	34.58±5.3	52.46±7.1
15	Sr	38.5±5.4	28.6±4.6	44.61±4.9	27.65±5.2	38.02±6.5	33.91±4.9	35.53±6.1
16	Y	BDL	12.64±4.5	BDL	18.13±5.0	BDL	BDL	BDL
17	Zr	95.91±9.8	20.86±6.0	23.6±6.1	63.7±8.7	11.44±7.0	12.16±5.0	77.82±9.3
18	Nb	7.035±3.1	9.812±3.9	BDL	6.09±3.29	BDL	BDL	BDL.
19	Mo	BDL	24.34±6.3	BDL	10.84±4.04	BDL	BDL	BDL
20	Ru	BDL	BDL	BDL	BDL	BDL	9.977±3.59	BDL
21	Ag	BDL	12.36±9.0	BDL	BDL	BDL	BDL	BDL
22	Pb	32.93±15.6	38.35±17.3	17.68±7.7	28.82±11.2	41.58±14.48	BDL	24.49±12.5

typically 8-25.4 pm thick. The thickness of the window sets the lower energy limit for photons that can be detected by the detector. The X-ray of the order of 2 keV energies of low Z elements can be measured using the above window thickness. Recently in place of beryllium foils very thin (of the order of 0.5 p) films of polycarbonate have been used which can withstand high pressure, and is resistant to environmental degradation. With these windows low atomic number elements like carbon (0.282 keV K X-rays) has been measured.

From this investigation of Charnockite matrix composition, the knowledge of X-ray production cross sections for light elements are required for quantitative analysis by PIXE using fundamental parameter method. There is a simplest accepted universal expression of ionization cross-section for proton induced X-ray emission. The K and L shell ionization cross-sections as a function of incident proton energy and target atoms in the charnockite composition. In this, the K-shell X-ray production cross section should measure for low-Z elements in the composition, are comparable bombarded by incident slow protons with energies [10]. All these results have importance for fundamental physics considerations as well as for low-energy PIXE (probably < 1MeV protons not 3 MeV) [11], and in general, for application in which thick targets need to be used. The application of these energies has certain advantages has been explained by [12] [13], especially when analyzing light elements because the bremsstrahlung background in the spectra is much lower within this proton energy region.

We have measure K X-ray production cross sections for elements using protons with energies between 1-3 MeV and conclude that the successful modification for PIXE especially for quantitative analysis of light elements which are present in the Charnockite composition. Finally we note that we have to improve the experimental cross section for PIXE analysis at low proton energies with Si (Li) detector [14] for light element determination or with the availability of ultra LE-Ge detectors low-Z elemental detection [15].

3.2 Medium Z elements

From the above analysis medium Z elements of Charnockite metamorphic rocks stated from Cl, Ca, K to Zr. Atomic number Z=17 to Z=40, out of medium Z elements some of elements are not exactly traced out by PIXE due to following reasons, these are detected correctly by both chemical analysis and NAA methods. Therefore, PIXE once again fails to detect exact value of ppm of major elements like K and Ca in Charnockite composition. The K and Ca escape peaks in Si (Li) detector interfere with X-ray lines of N, Mg, Al, Si, P and K, Ca summing peaks could interfere with X-ray lines of Ti, V, Mn, Fe, Ni, Co and Cu

Table 2: Previous Analytical results of all matrix charnockite samples in ppm(Chemical and NAA Analysis).
(in ppm; instrument: Yvon Z-3 Quartz Prism Spectrograph, chemical analysis). (* previous Neutron activation analysis)

Element	Atomic Number (Z)	Present PIXE Analysis, average of 7 samples	Previous Chemical analysis of pyroxene granulites from charnockitic rocks, Visakhapatnam [8]	Previous, Chemical analysis of allanite from Air Port Hill charnockite, Visakhapatnam [6]
Li	3	ND	18.08ppm	-
Be	4	ND	-	<4ppm
F	9	ND	0.400ppm	-
Na	11	ND	Na_2O=1.591(Wt%)	-
Mg	12	ND	MgO=4.022(Wt%)	MgO=1.18(Wt%)
Al	13	ND	Al_2O_3=18.137(Wt%)	Al_2O_3==14.79(Wt%)
Si	14	ND	SiO_2=50.345(Wt%)	SiO_2=31.24(Wt%)
P	15	ND	P_2O_5=0.213(Wt%)	-
Cl	17	424.2±18.62ppm	0.130ppm	-
K	19	4887.28±29.91ppm	K_2O=0.428(Wt%)	-
Ca	20	2808±26.31ppm	CaO=11.376(Wt%)	CaO=11.01(Wt%)
Sc	21	ND	23ppm	150ppm
Ti	22	1133.09±10.97ppm	TiO_2=1.314(Wt%)	TiO_2=1.62(Wt%)
V	23	18.26±5.88ppm	240ppm	V_2O_3=0.09(Wt%)
Cr	24	18.31±2.4ppm	180ppm	70ppm
Mn	25	31.934±4.1ppm	MnO=0.089(Wt%)	MnO=0.28(Wt%)
Fe	26	5961.42±21.5ppm	Fe_2O_3=1.123(Wt%) FeO =10.649(Wt%)	Fe_2O_3=5.10(Wt%) FeO=8.49 (Wt %)
Co	27	ND	74ppm	150ppm
Ni	28	13.755±3.89ppm	170ppm	66ppm
Cu	29	7.40±3.08ppm	262ppm	150ppm
Zn	30	13.85±3.25ppm	80ppm	140ppm
Ga	31	ND	36ppm	30ppm
Ge	32	ND	-	80ppm
Se	34	3.65±2.1ppm	-	-
Br	35	9.92±3.45ppm	-	-
Rb	37	47.36±6.37ppm	66.52ppm	-
Sr	38	35.26±5.37ppm	325ppm	480ppm
Y	39	15.385±4.75ppm	-	*Y_2O_3= 0.15 (Wt%)
Zr	40	43.64±7.41ppm	78ppm	*ZrO_2=0.15(Wt%)
Nb	41	7.6±3.43ppm	-	900ppm
Mo	42	17.59±5.17ppm	-	60ppm
Ru	44	9.97±3.59ppm	-	-
Ag	47	12.36±9.0ppm	-	-
Sn	50	ND	-	*SnO_2=0.03(Wt%)
Ba	56	ND	338.40ppm	-
Hf	72	ND	3.23ppm	-
Ta	73	ND	0.69ppm	-
W	74	ND	-	<40ppm
Au	79	ND	-	10ppm
Pb	82	30.64±13.13ppm	-	*PbO=0.04(Wt%)
Th	90	ND	7.07ppm	*ThO_2= 0.50(Wt%)
U	92	ND	2.83ppm	*U_3O_8=0.01 (Wt%)
REE	57 to71	ND	-	*$(Ce,La,Nd)_2O_3$= 23.29(Wt%)

in Charnockite composition [16]. By present PIXE analysis, the concentration value of Cr in Charnockite samples is low ppm, like V, in this case also obtained the same result by PIXE analysis. In this case variation is due to the matrix of non-resolution of peaks between Mn Kβ and Fe Kα overlapped present.

The concentration of error due to Ti-Kα and Fe-Kα have closely 4.5 keV energy X-rays (4.509 and 4.647 keV) and also Ti-Ba have same X-ray energies (4.469 and 4.509 keV). So PIXE not given proper concentration value in case of major elements like Ti due to above overlapping peaks. PIXE also could not perform well in the determination of Fe also, because the overlapped of Co-Kα and Fe- Kβ causes the inability of proper detection. Non determination by PIXE of Coin Charnockites is due to mainly two reasons; 1) Co- Kα and Fe- Kβ and 2) Ni Kα and Co Kβ from the interferences of above two peaks trace of cobalt not detected. In this case also Fe is the major component so that the X-ray emitted from this element in the composition will dominate the energy spectrum. The above reason is due to the interference of Cu peak with Zn peak in case of Charnockites samples from Figures 1 to 7 [17].

In this analysis, PIXE is not given good result when compared with Chemical analysis and due to Ni Kα with Co Kβ. The concentration of Zn element in samples of Charnockites by PIXE analysis, the value is low ppm range but the result obtained by Chemical analysis. So the variation of above value with Chemical analysis due to the above Cu and Zn peaks overlapped in spectrums of Charnockites obtained by PIXE analysis. In this case of Sr, the Sr Kα and Rb Kβ and also with Y Kα X-rays overlapped corrections due to error value. The concentration values of Rb obtained by PIXE are low ppm. The difference is nearly low ppm range and this is due to the overlapped peaks of Y Kα and Rb Kβ, Sr Kα and R Kβ in the analysis of spectrum of the peaks of Charnockites. From these analyses PIXE analysis is very poor in the detection of Zr and resolution of peaks with Nb. The poor results obtained in PIXE analysis of element Zr also in the Charnockites as concentration value of element in Charnockite composition and it is due to small matrix effect of Zr and Mo.

Tin 3.444 3.663 keV (L X-rays) are similar to the potassium K X-rays. Therefore Tin is not detected in charnockite composition by PIXE analysis. Barium 4.466 4.828 22 keV (L X-rays) since K X-rays limited in case of PIXE and for L X- rays, similar to titanium 4.512 4.933 (K X-rays). Therefore Ba is present charnockite composition but not detected in PIXE analysis due to above reason. Cerium have 4.839 5.262 keV (L X –rays), these L X- ray energies are same as titanium 4.9339 (K X- rays), Vanadium 4.953 5.428 keV (L X –rays). Therefore cerium is not presented in PIXE spectrum and overlapped with either titanium or vanadium. Similarly Au L- X-rays, 9.713 11.443 keV, Germanium 9.886 10.982 31 keV L- X-rays, Ga Gallium 9.251 10.267 keV L- X-rays have similar characteristic X-rays, Au, Ge and Ga are not detected in PIXE but these are already presented in Charnockites in the form of traces by another previous techniques.

The most important consequences of PIXE `with 3 MeV spectra in the above Charnockite composition is the intense peaks due to major elements like Fe and Ti. A geological sample can produce some tens of pile-up peaks in its spectrum due to major concentration. Pile-up continua and pile-up peaks will accompany these and hence it increases the detection limits for trace elements by increasing the backgrounds. Electronic pile-up rejection and on-demand beam deflection are mandatory in order to minimise the pile-up continuum, and the software used to fit the spectrum should be able to model at least first and second order pile-up [18].

3.3 Halogens

It is an important element in Charnockites in Visakhapatnam and these are halogen rich minerals. PIXE is a very suitable technique in the determination of gaseous phase elements like Cl. Its value is minor ppm which is the similar result obtained by previous analysis. But chemical analysis is also able to detect the Cl element directly. Br is also a trace element in halogen rich minerals of Charnockites. PIXE is very suitable in the detection of Br and Cl but not F present in the composition due to X- ray energy limitation. The gaseous elements given information about rock formation and the traces of Br identified by the PIXE are in the range low ppm and Br is not detected by chemical analysis.

Since element fluorine detected previously by Chemical analysis, but it is not possible due to the low X-rays and detector limits at 3 MeV incident proton energy. Similarly halogen element iodine is due to the, range present in charnockite or igneous rocks in the range of ppb and the element Sc have same chacteristic X- ray energy and also resolution problem with Fe and Ti major elements in charnockite spectrum.

3.4 Thorium and Uranium

Th and U not detected by using PIXE analysis. Because of Uranium contain 98.440 keV, 111.303 keV (k-X-rays), 13.614 keV 17.220 keV (L-X-rays) 3.171 keV 3.336 keV (M-X-rays) and Thorium contain 93.351 keV 105.605 keV (k-X-rays), 12.968 keV 16.202 keV (L-X-rays) 2.996 keV 3.149 keV (M-X-rays)The X- ray energy from PIXE experiment should only lies 1-20 keV detected in case of PIXE detection but K-X-rays more energy, therefore detection is not possible through K-X rays. But the atomic number of Th and U > 83, according to PIXE theory, M X-rays are limited to PIXE technique because for M-X-rays, atomic number validity is 72<Z<83. Finally L X-rays energies of Th and U are similar K X-rays energies of Br 13.292 keV, Rb 13.396 keV, Sr 15.835 keV, Mo 17.480 keV. Therefore, due to above reason U and Th not detected in charnockite composition by PIXE spectrum analysis. Since these are detected by NAA analysis due to reasonable cross sections.

The frequently encountered pileup of the iron K lines, for example, interfere with the K X-ray peaks of rubidium and strontium and the L X-ray peaks of lead and uranium, while the triple pile-up obscures the spectral region containing the K lines of Ru, Rh, and Pd region. The LD values for different elements reflect the general characteristics of the PIXE spectra (background dominated at lower energies by the bremsstrahlung of the secondary electrons, as well as by X- and gamma-ray scattering at higher energies), and the experimental conditions (detection efficiency and attenuation in absorbents for a specific counting set-up, sample matrix and thickness, pile-up effects).

The problem of adjacent peak interferences [19] can also be serious for PIXE Charnockite composition analysis. Rubidium and strontium commonly occur in rock samples and their K alpha lines interfere with the thorium and uranium L alpha lines. This increases the uncertainty in the thorium and uranium concentration estimates. When rubidium and strontium are present in the charnockite composition with concentrations greater than 10 to 15 times the thorium or uranium concentrations in previous charnockite analyses, then the L alpha peaks are completely obscured and other L series lines for thorium or uranium have to be used to obtain a concentration estimate.

3.5 Rare Earth Elements

The REE are also very important but not detected by using PIXE analysis. However for REE elements, the LOD are markedly poorer. Determination of REE in Charnockite [20] geological samples is a very important subject but hard to tackle because in this PIXE, the L X-rays energies of REE elements from 4-9 keV strongly overlap with K X-rays energies of light elements in Charnockite matrix composition (Spectrums 1-7). The quantification of REE by PIXE with 3 MeV becomes very difficult and inaccurate as a result of the needed complex spectrum deconvolution. In fact, in this work context of REE in geological sample's composition; L X-ray used and concluded that PIXE with 3 MeV is limited for REE.

Rare earth elements (REE) have very high thermal neutron cross sections and NAA is usually the first choice for the determination of REEs in a trace elements analysis. This is particularly the case for the REE s [21] High energy protons 20–25 MeV are useful for detection of trace elements in rare earth region due to their high K X-ray ionisation cross-section. The Dysporsium (Dy) Ka peaks are clearly visible in the spectrum. The Holmium Ka and Kb peaks seen in the figure are due to the Holmium nuclei produced due to (p, n) reaction at these energies [22-25].

3.6 High Z Elements

The element Pb is an important element in rock formation, which is determined by PIXE and its value low ppm range and in the investigation of Pb, PIXE not given good results. So in PIXE analysis traces of Mo not exactly found due to corrections of interferences with Nb but its value by chemical analysis also given very low traces due to matrix effect of Nb. The traces of Ru found by using PIXE like Ag in Charnockites. It is a precious metal previously not detected in Charnockite, in this PIXE also not trace out exactly because in ppm levels and most of above series samples are at BDL. So PIXE is not suitable to measure the concentration of precious metal like Ag. The traces of Ag investigated also in the Chemical analysis.

The K X-rays of high Z elements like Hf, Ta, and W, have less energy characteristic X-rays and absorbed by detector window. The Hf L-X-Ray energies (keV) 7.899, 9.023, M-X-ray energies (keV) 1.646 1.700, Ta L-X-Ray energies (keV) 8.146 9.343 M-X-ray energies (keV), 1.712 1.770, W L-X-Ray energies (keV) 8.398 9.672 M-X-ray energies (keV) 1.775 1.838 and Co K-X-ray energy 7.649 (keV), Ni K-X-ray energy 8.267 (keV), Cu K-X-ray energy 8.046, 8.904 (keV), Zn K-X-ray energy 9.570 (keV), Ga K-X-ray energy 9.251, (keV) from the above discussion M X-ray energies of Hf, Ta, W are low not detected by PIXE and L-X-ray energies are nearly equal to K-X- ray energies of Co, Ni, Cu, Zn, Ga and Ge. Gallium 9.251 10.267 (K X-rays) 1.098 1.125 (L X-rays) Germanium 9.886 10.982(K X-rays) 1.188 1.218 (L X-rays). Therefore Hf, Ta, W and other rare earth elements not presented in the PIXE spectrum of Charnockite composition in this PIXE at 3MeV methodology.

4 Conclusions

PIXE with 3 MeV unable to detect the low Z elements present in Charnockites due to detector limits. For light elements, the problem is mainly due to absorption of the low energy X-ray by detector Si (Li) windows. The beryllium windows of detectors are typically 8-25.4 pm thick. The thickness of the window sets the lower energy limit for photons that can be detected by the detector. The X-ray of the order of 2 keV energies of low Z elements can be measured using the above window thickness. The elements are started from Li and Li, Be, F, Na, Mg, Al, Si and P are detected by using previous chemical analysis. But not detected in this case PIXE as 3 MeV,and X-rays energies lies below 2 KeV elements were not detected.

At middle Z elements, the K and Ca escape peaks in Si (Li) detector interfere with X-ray lines of N, Mg, Al, Si, P and K, Ca summing peaks could interfere with X-ray lines of Ti, V, Mn, Fe, Ni, Co and Cu in Charnockite composition. . In this case alsoTi and Fe is the major components so that the X-ray emitted from this element in the composition will dominate the energy spectrum. A geological sample can produce some tens of pile-up peaks in its spectrum due to major concentration. Pile-up continua and pile-up peaks will accompany these and hence it increases the detection limits for trace elements by increasing the backgrounds. Due to the above reason, the concentrations not not exactly equal to the previous chemical and NAA analyses.

PIXE at halogens is very suitable in the detection of Br and Cl but not F present in the composition due to X- ray energy limitation. The gaseous elements given information about rock formation and the traces of Br identified by the PIXE are in the range low ppm. Similarly halogen element iodine is due to the, range present in charnockite or igneous rocks in the range of ppb but PIXE range iisin order of ppm.

PIXE at Uranium and Thorium, the problem of adjacent peak interferences can also be serious for PIXE Charnockite composition analysis. Rubidium and strontium commonly occur in rock samples and their K alpha lines interfere with the thorium and uranium L alpha lines. This increases the uncertainty in the thorium and uranium concentration estimates.

PIXE at REE, determination in Charnockite in geological samples is a very important subject but hard to tackle because in this PIXE, the L X-rays energies of REE elements from 4-9 keV strongly overlap with K X-rays energies of light elements in Charnockite matrix composition.

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