Vol 2, Issue 4, 2015 ISSN 2349-7041

Research Article

SUSTAINABLE MINING ACTIVITY IN THE NELLORE MICA BELT THROUGH EXPLORATION OF COLTAN DIPOSIT

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ABSTRACT

Coltan is a dull metallic ore found in major quantities in the Nellore mica belt and also found in eastern areas of the Congo possesses 80 percent of the world's coltan. Biswas (1935) [1] made an examination of the pegmatite and considered them to have magmatic origin in accordance with the Bowen's reaction principle. Ghosh visited the area in the field season 1932-1933 at the request of the Madras Government to investigate the behaviour of Nellore mica deposits at depth and the relationship between the country rocks and mica-bearing pegmatites (Fermor, 1935) [2]. He also described the occurrence of minerals such as beryl, coltan and samarskite in the pegmatites and minerals like garnet, kyanite and talc in the country rocks. The main objective of to determined from the spectrums obtained from SEM with EDS in the methodology of use, subjecting sample so collected though qualitative chemical analysis, C1 to C12 analysis of SEM with EDS.

Keywords: Coltan, Euxenite, SEM and EDS.

INTRODUCTION

The name "coltan" is a colloquial African name for the mineral with chemical composition $(Fe,Mn)(Nb,Ta)_2O_6$. As this mineral is a solid solution of columbite (the niobium end-member) and tantalite (the tantalum end-member), the name 'coltan' is coined by combining the first three letters of '*col*umbite' and '*tan*talite' of the columbite-tantalie series. Although this is a colloquial name vogue in Africa and popularized to some extent all over the world, it has been used in this report to refer not only columbite and tantalite, but also other niobium-tantalum minerals. The properties of refined coltan are a vital element in creating devices that store energy or capacitors, which are used in a vast array of small electronic devices, especially in mobile phones, laptop computers, pagers and other electronic devices.

The tantalum metal powder is mostly used in the production of tantalum capacitors in portable telephones, pagers, personal computers and automotive electronics. Because of a sudden demand for tantalum, the world's annual production of tantalum metal, which was around 215 tonnes in 1986, fluctuated between 1070 and 1430 tonnes during 2000 to 2008. The price of coltan, which was US$ 86,165/tonne on the average, rocketed to as high as US$ 591,000/tonne in 2000 but now fluctuate between US$ 73,100 and US$ 106,000 per tonne (U.S. Geological Survey, 2010). Apart from high demand, coltan has received wide publicity in the media in recent years because of its illegal mining in the Congo by the military forces of Rwanda, Uganda and Burundi, with the Rwandan army alone getting a profit of at least US$ 250 million in as little as 18 months from the sale of coltan between 2000 and 2001. In a bid to have control over these deposits, over 5.4 million people were massacred in the wars that took place since 1998 in Congo besides endangering the local gorilla species. Export of coltan from these African countries to European and American markets has been cited by experts to mainly sustain the civil wars in Africa. Tantalum-Niobium International Study Centre in Belgium, a country with traditionally close links to the Congo, has discouraged international companies from buying Congolese coltan on ethical grounds. The study area lies on a portion of Nellore district in Andhra Pradesh bounded by the Pennar River in the north, the Swarnamukhi River in the south, steeply-rising Velikonda hill ranges in the west and the Bay of Bengal in the East [3] (Fig 1).

Objective

To determine from the spectrums obtained from SEM with EDS.
To chemical analysis coltan related minerals in the study area.

Methodology

The chemical analysis of eight samples of euxenite containing tantalum, niobium and yttrium (C1-C8) and four samples of coltan (C-9 to C-12) containing tantalum and niobium from Parlapalli in Podalakur mandal as determined from the spectrums obtained from SEM with EDS.

Study area

The study area comprising about 5450 sq km in Sri Potti Sriramulu (SPS) Nellore district (generally called Nellore district) in Andhra Pradesh is essentially in between the north latitudes 13°57' and 14°30' and the east longitudes 79°18' and 80°12' in the Survey of India topographic maps 57 N, 57 O and 66 B on a scale 1:250,000 and 57 N/6-8, 10-12 & 14-16, 57 O/5 & 9 and 66 B/2-4 on a scale of 1:50,000. It borders the Bay of Bengal in the east, steeply-rising Velikonda hill ranges in the west, Pennar River in the north and Swarnamukhi River in the south.

RESULTS

Coltan Deposits of the Study Area

In order to locate coltan deposits, the work of Jagadiswara Rao (1965) who did extensive field work between 1960 and 1965 in connection with his Ph.D. work is found to be particularly useful. His field work revealed the existence of huge dumps of mine wastes in the vicinity of mica mines spread all over the study area, which contain a number of rare and exotic minerals including coltan in small amounts. Present field studies have, however, revealed the absence of any sizeable dumps of mine wastes in the vicinities of most mica mines.

This is attributed to the promulgation of rules on Mine Closure Plan and Progressive Mine Closure Plan by the Government of India in April 2003 which made most mine owners to close their abandoned mines with mine wastes in the dumps. As most of these abandoned mines filled up with mine wastes are water-inundated round the year, access to several rare and exotic minerals such as coltan in mine wastes, which were once served as natural museums of minerals for mineral collectors and academicians, is now completely lost. In a bid to locate coltan deposits, an intensive search of the entire study area, including remote areas and reserved forests has been made to collect hundreds of samples suspected to show characteristics comparable to those of coltan and some other samples of exotic or unusual nature. On subjecting the samples so collected through qualitative chemical analysis, determination of specific gravity, XRD and quantitative chemical analysis through spectrum obtained from SEM with EDS, almost all of them are found not to be coltan or related minerals containing niobium and tantalum

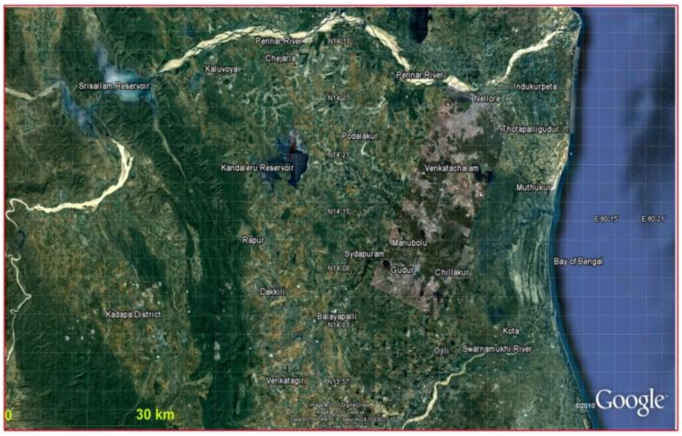


Fig 1: Satellate view of the study area showing also a portion of Kadapa (YSR) district in west of Andhra Pradesh

.After an intensive effort, a few samples of coltan and related minerals could be collected from an abandoned mica mine northeast of Parlapalli, Podalakur mandal (Fig 2, 3& 4). Figure 2 shows a specimen of coltan admixed with feldspar and mica in a pegmatite and Figure 3 shows a specimen of euxenite - an oxide of tantalum, niobium, yttrium and titanium. Figure 4 shows the satellite image captured on 27 May 2009 showing an abandoned mica mine northeast of Parlapalli village, where these minerals were collected. More samples could not be collected as most of the mine dumps were thrown into the mine to meet the government regulation of mine closure and entry could not be made in the mines as they are water-inundated round the year. Coltan is characterised by iron black colour, black streak, sub-metallic lustre and a specific gravity ranging from 5.5 to 6.5. Euxenite is characterised by blackish colour, greyish streak, sub-metallic lustre, conchoidal fracture and a specific gravity of 5.5. It glows red on heating in the blue flame generated by igniting butane with a professional torch lighter. Unlike coltan, euxenite contains large quantities of yttrium. One unusual thing with euxenite collected is that it contains around 2% silver (Figure 5). Confirmation by other methods of chemical analysis is however necessary. An XRD of the mineral proved that it is only amorphous.

Table 1 (a,b & c) shows the chemical analysis of eight samples of euxenite containing tantalum, niobium and yttrium (C1-C8) and four samples of coltan (C-9 to C-12) containing tantalum and niobium from Parlapalli in Podalakur mandal as determined from the spectrums obtained from SEM with EDS. Of the eight samples of euxenite, one sample has chloride and three samples have silver of around 2%. The atomic percent of tantalum to the sum of niobium and tantalum ranges from 21.7% to 75.0% with a mean of 45.3%. After recalculation of weight percentage of oxides of Nb_2O_5, Ta_2O_5, Y_2O_3, FeO and TiO_2 in each analysis to 100, the weight % of Nb_2O_5 is found to range from 14.05 to 42.80 with a mean of 30.27, Ta_2O_5 ranges from 18.01 to 69.70 with a mean of 47.14, Y_2O_3 ranges from 0 to 23.07 with a mean of 3.61, and FeO ranges from 0 to 13.50 with a mean of 7.23.

Fig 2: A picture of coltan admixed with feldspar and mica collected from the mine dump of abandoned mica northeast of parlapalli, podalakur Mandal.

Fig 3: A picture of euxenite - as oxide of tantalum, niobium, yttirium and titanium with around 2% silver collected from the mine dumps of an abandoned mica northeast of parlapalli, podalakur Mandal.

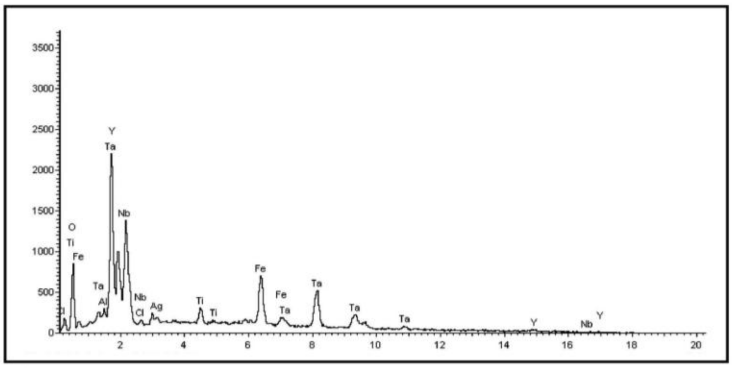
Fig 4: A Satellite image captured on 27 May 2009 showing an abandoned mica northeast of parlapalli village, where coltanm euxenite, titanomagnetite and ferrian ilmenite occur in the mine dumps and soils.

From a study of the coltan-bearing granitic pegmatites from SCHIST belt near Pedra Lavrada in northeastern Brazil [4], it can be known that coltan is a typical pegmatite mineral occurring in the intermediate zone in association with potash feldspar of heterogeneous complex zoned pegmatites, but not in homogenous pegmatites or in the wall zones or core zones of heterogeneous pegmatites (Fig 6 & 7). The picture of heterogeneous pegmatite at Pedra Lavrada in Figure 6 shows the contact between the core zone composed of quartz without any coltan in the foreground and intermediate zone composed of potash feldspar and coltan in the background. Because of the outcropping of pegmatite of intermediate zone, coltan could occur in outcrops in Brazil. Absence of coltan in the outcrops or their weathered mantles in the Nellore mica belt is attributed to the absence of any coltan-bearing outcrops of intermediate zone rocks of heterogeneous pegmatites anywhere in the study area.

Table 1a: Chemical Analysis of Coltan and Related Minerals in the Study Area as Determined from the Spectrums Obtained from SEM with EDS

Sample No.	C-1		C-2		C-3		C-4	
Elements	Weight%	Atomic %	Weight %	Atomic %	Weight %	Atomic %	Weight %	Atomic %
C	-	-	-	-	-	-	7.60	19.83
O	24.12	65.20	26.59	69.38	26.81	69.32	30.79	60.30
Cl	0.41	0.50	-	-	-	-	-	-
Ag	2.27	0.91	2.17	0.84	1.68	0.64	-	-
Ti	2.20	1.99	1.91	1.67	1.74	1.51	1.77	1.16
Al	0.49	0.79	0.00	0.00	0.28	0.43	0.00	0.00
Y	12.28	5.97	11.41	5.36	12.48	5.81	10.36	3.65
Nb	20.10	9.36	20.58	9.25	20.73	9.23	17.71	5.97
Ta	26.62	6.36	27.86	6.43	26.97	6.17	22.51	3.90
Fe	11.51	8.91	9.48	7.09	9.31	6.90	9.25	5.19
Total	100.00	99.99	100.00	100.02	100.00	100.01	99.99	100.00
TiO_2/Ti	2.11	6.0	1.86	5.6	1.68	5.0	2.01	5.8
Al_2O_3/Al	1.06	2.4	-	0.0	0.61	1.4	-	-
Y_2O_3/Y	17.92	17.9	16.92	18.0	18.34	19.3	17.92	18.4
Nb_2O_5/Nb	33.04	28.0	34.38	31.0	34.32	30.7	34.52	30.0
Ta_2O_5/Ta	37.35	19.1	39.72	21.6	38.11	20.5	37.44	19.6
FeO/Fe	8.51	26.7	7.12	23.8	6.93	23.0	8.11	26.1
Total	99.99	100.1	100.00	100.0	100.00	100.0	100.00	100.0

C-1 to C-3: Euxenite in an abandoned mica mine northeast of Parlapalli, Podalakur Mandal
C4: Euxenite at the same locality without silver and chloride



Spectrum processing:
Peak possibly omitted: 5.890 keV
Processing option: All elements analyzed (Normalised)
Number of iterations = 4
Standard :
O SiO2 1-Jun-1999 12:00 AM
Al Al2O3 1-Jun-1999 12:00 AM
Cl KCl 1-Jun-1999 12:00 AM
Ti Ti 1-Jun-1999 12:00 AM
Fe Fe 1-Jun-1999 12:00 AM
Y Y 1-Jun-1999 12:00 AM
Nb Nb 1-Jun-1999 12:00 AM
Ag Ag 1-Jun-1999 12:00 AM
Ta Ta 1-Jun-1999 12:00 AM

Element	Weight %	Atomic %	Atomic %	Oxides	Weight %
O K	24.12	65.2			
Al K	0.49	0.79	2.4	Al_2O_3	1.06
Cl K	0.41	0.5			
Ti K	2.2	1.99	6	TiO_2	2.11
Fe K	11.51	8.91	26.7	FeO	8.51
Y L	12.28	5.97	17.9	Y_2O_3	17.92
Nb L	20.1	9.36	28	Nb2O5	33.04
Ag L	2.27	0.91			
Ta M	26.62	6.36	19.1	Ta2O5	37.35
Totals	100	99.99	100.1		99.99

Fig 5: Chemical analysis of euxenite as computed from the spectrum obtained from SEM with EDS.

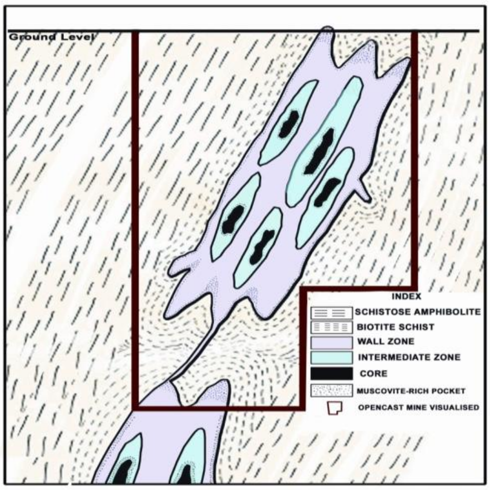


Fig 6: Zoned psegmatite showing wall zone

Fig 7: Picture of heterogenous pegmatite exposed near Pedra Lavrada in northeasern Brazil showing the contact between the core zone composed of quartz in the foreground and intermediate zone composed of potash feldspar and economically extractable coltan in the background (Baumgartner *et al.*,2006).

Table 1b: Chemical Analysis of Coltan and Related Minerals in the Study Area as Determined from the Spectrums Obtained from SEM with EDS (Continued)

Sample No.	C-5		C-6		C-7		C-8	
Elements	**Weight %**	**Atomic %**	**Weight %**	**Atomic %**	**Weight %**	**Atomic %**	**Weight %**	**Atomic %**
C	-	-	-	-	-	-	8.15	14.93
O	32.37	74.44	35.09	77.39	37.71	78.75	47.52	65.34
Si	-	-	2.25	2.82	3.32	3.96	11.45	8.97
Ti	1.91	1.47	0.00	0.00	0.00	0.00	1.44	0.66
Al	0.00	0.00	0.00	0.00	0.00	0.00	3.32	2.71
Y	11.51	4.76	14.97	5.94	12.27	4.61	7.13	1.76
Nb	19.71	7.80	24.59	9.34	23.17	8.33	9.16	2.17
Ta	24.60	5.00	23.11	4.51	23.52	4.34	4.90	0.60
Fe	9.90	6.52	-	-	-	-	6.04	2.38
Ca	-	-	-	-	-	-	0.88	0.48
Total	100.00	99.99	100.01	100.00	99.99	99.99	99.99	100.00
SiO_2/Si	-	-	2.84	12.5	4.38	18.6	23.39	45.5
TiO_2/Ti	1.97	5.8	-	-	-	-	2.29	3.3
Al_2O_3/Al	-	-	-	-	-	0.0	11.98	13.7
Y_2O_3/Y	18.09	18.6	22.42	26.3	19.24	21.7	17.29	8.9
Nb_2O_5/Nb	34.89	30.5	41.48	41.3	40.92	39.2	25.02	11.0
Ta_2O_5/Ta	37.17	19.6	33.27	19.9	35.46	20.4	11.43	3.0
FeO/Fe	7.88	25.5	-	-	-	-	7.42	12.1
CaO/Ca	-	-	-	-	-	-	1.18	2.4
Total	**100.00**	**100.0**	**100.00**	**100.0**	**100.00**	**100.0**	**100.00**	**100.0**

C-5: Euxenite at the same locality without silver
C-6 to C-8: Euxenite at the same locality admixed with silicates

Table 1c: Chemical Analysis of Coltan and Related Minerals in the Study Area as Determined from the Spectrums Obtained from SEM with EDS (Continued)

Sample No.	C-9		C-10		C-11		C-12	
Elements	Weight %	Atomic %	Weight %	Atomic %	Weight %	Atomic %	Weight %	Atomic %
C	5.65	11.23	-	-	5.02	9.14	-	-
O	45.55	67.92	47.15	75.69	50.63	69.12	52.04	75.13
Si	10.68	9.08	11.59	10.60	14.52	11.29	15.75	12.95
Ti	1.22	0.61	1.31	0.70	0.76	0.35	0.82	0.40
Al	2.75	2.43	2.97	2.83	4.80	3.88	5.17	4.43
Nb	4.87	1.25	5.34	1.48	2.26	0.53	2.47	0.62
Ta	21.94	2.89	23.72	3.37	13.13	1.59	14.21	1.81
Fe	1.80	0.77	1.93	0.89	4.83	1.89	5.17	2.14
Ca	3.61	2.15	3.91	2.50	3.24	1.76	3.49	2.01
Na	1.16	1.21	1.26	1.41	-	-	-	-
K	0.75	0.46	0.81	0.53	0.80	0.45	0.87	0.51
Total	99.98	100.00	99.99	100.00	99.99	100.00	99.99	100.00
SiO_2/Si	20.17	43.5	19.79	43.6	31.14	51.9	31.22	52.1
TiO_2/Ti	1.80	2.9	1.74	2.9	1.27	1.6	1.27	1.6
Al_2O_3/Al	9.18	11.7	8.96	11.6	18.19	17.8	18.11	17.8
Nb_2O_5/Nb	12.30	6.0	12.19	6.1	6.48	2.4	6.55	2.5
Ta_2O_5/Ta	47.30	13.9	46.23	13.9	32.14	7.3	32.16	7.3
FeO/Fe	2.04	3.7	4.01	3.7	6.23	8.7	6.16	8.6
CaO/Ca	4.46	10.3	4.37	10.3	4.54	8.1	4.53	8.1
Na_2O/Na	2.76	5.8	2.71	5.8	0.00	0.0	0.00	0.0
K_2O/K	1.60	2.2	1.56	2.2	1.93	2.1	1.94	2.1
Total	100.00	100.0	100.00	100.0	100.00	100.0	100.00	100.0

C-9 to C-12: Coltan at the same locality admixed with silicate minerals

Thanks to the efforts of the geochemists from Imperial College of Science and Technology in London and the British Geological Survey, geochemical drainage studies involving panned-concentrate drainage sampling along stream networks could be taken up in Africa on a large scale in the middle of the 20th century by a labour-intensive technology involving local semi-literate people as barefoot scientists. This has resulted in the discovery of several economic deposits, including coltan in several parts of Africa. Once the demand for coltan grew, the African military forces engaged large number of labours to dig large craters in streambeds to collect coltan-bearing alluvium at depth. Through sloshing water and mud around in large washtubs, coltan settled in the bottom owing to its heavy weight could be recovered.

Geochemical drainage studies involving panned-concentrate drainage sampling along stream networks have been carried out in Marupur Reserved Forest (RF) in Podalakur mandal and in Rajupalem area in Sydapuram mandal (Fig 8 & 9). At both these places, ilmenite rather than coltan was found. The significance of the occurrence of ilmenite has been discussed in Section 22. It is concluded from these studies that coltan-bearing rocks do not occur in the catchments of these two stream networks.

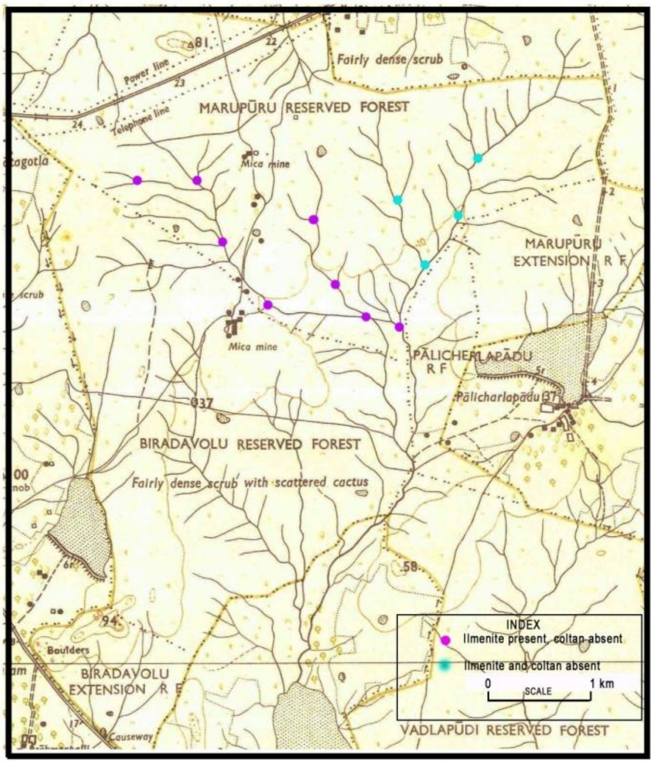


Fig 8: Drainage surveys for the occurrence of coltan and ilmenite in Marupur Reserved Forest (RF), Podalakur Mandal.

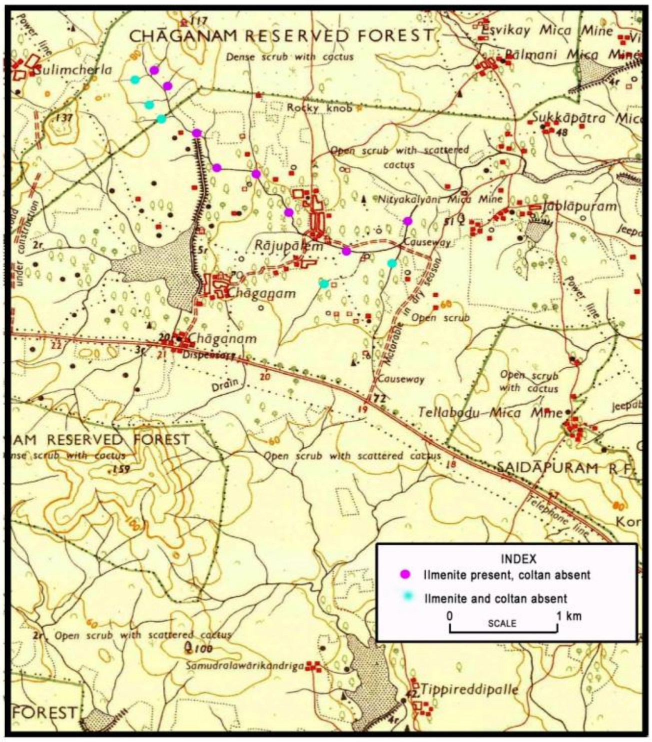


Fig 9: Drainage surveys for the occurrence of coltan and ilmenite at Rajupalem, Sydapuram Mandal.

As coltan is a heavy resistant mineral, its presence in sizeable amounts in the surface rocks and their weathered mantle of the Nellore mica belt should lead to the accumulation of heavy minerals in the coastal sand deposits east of the mica belt in Nellore district. The detailed work carried out by the AMD on the heavy mineral sand deposits of Andhra Pradesh has been summarised by Ravi *et al* (2001) [5]. Based on these studies the 982-km long coast of Andhra Pradesh has been divided into 352-km long northern segment, 328-km long central segment and 302-km long southern segment covering Prakasam and Nellore districts. The average Total Heavy Minerals (THM) in these coastal sands ranges from 25 to 10% in the northern segment, 15 to 10% in the central segment and 12 to 3% in the southern segment. Amphibole, ilmenite, magnetite, garnet and rutile are the dominant heavy minerals. But, no coltan has been reported. Thus, the work of the AMD also supports the contention that the surface rocks and their weathered mantles in the study area are devoid of coltan.

DISCUSSION

Although coltan is absent in the surface rocks and their weathered mantles, it can occur in sizeable amounts in the intermediate zone of the numerous heterogeneous pegmatites occurring at depth. Figure 7 is an idealised cross-section of a heterogeneous pegmatite showing its normal mode of occurrence in the study area. The intermediate zone where coltan can be accumulated is found at some depth below the surface, but not near the surface. As the entire underground mining taken up in the mica belt was highly selective, aimed at extracting economic sheet mica only, very little coltan could be extracted. The little coltan that was extracted was thrown out as waste in the mine dumps, which are now used to fill up the abandoned mines under the mine closure plan. The only way the entire coltan occurring in the intermediate zone of the hundreds of heterogeneous pegmatites in the study area could be extracted completely is by replacing the present mode of selective underground mining for mica with opencast mining that allows for extraction of all the available economic minerals in pegmatites such as mica, quartz, feldspar, beryl and coltan.

The works of Odikadze (1958) [6] and Baumgartner *et al* (2006) [4] have indicated that there is a strong geochemical affinity between beryl and coltan in pegmatite. It would be worthwhile to make special efforts for prospecting for coltan in beryl-bearing pegmatites. The principal mica mine, where beryl is known to occur in fairly large amounts is the L.N. mica mine near Chaganam. Recent studies have indicated the occurrence of large-sized beryl crystals in a shallow opencast mine of Ani Minerals mine at Chaganam. Further studies are required at this place to locate the possible occurrence of coltan.

CONCLUSION

It is known from the past experience that coltan and other rare minerals could be collected by intensive search of mine dumps around operating or abandoned mines. Now such a search is not possible because most such mine dumps were used by the mine owners to fill up the abandoned mines and unproductive prospecting pits as a way out to fulfil the rules promulgated by the Government of India in 2003 to implement "Mine Closure Plans" and "Progressive Mine Closure Plans". Similar intensive search along the innumerable upland streams and geochemical drainage studies involving panned-concentrate drainage sampling along two stream networks have also not revealed the occurrence of any coltan, indicating that the intermediate zone pegmatites which carry coltan are not exposed at all anywhere in the study area. The only way sizeable deposits of coltan could be extracted consists in replacing the hitherto practiced underground method of selective mining for mica by the opencast method of mining where the entire pegmatite is mined. By this, all useful minerals, including coltan could be segregated and recovered. The policy decision of the Government in including coltan and other non-radioactive materials such as beryl as Prescribed Substances for exclusive development by the AMD is responsible for the local mining industry in the study area showing little interest in their exploration and production. As coltan, beryl and rare earth elements, minerals are not radioactive minerals, International Atomic Energy Agency (IAEA) does not impose any restrictions on their sale. The only way to boost up the exploration and exploitation of coltan, beryl and other rare earth elements, minerals in the study area consists in removing them from the list of prescribed minerals under the exclusive control of the AMD and allow mine owners to mine and market them as per the market prices.

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