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Noble Metal Contents in the Placer Sands of Manavalakurichi, Tamil Nadu

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Abstract: *Beach placer minerals of garnet (2) magnetite (1), ilmenite (2), zircon (1), rutile (13) and monazite (14) are analyzed to estimate their major and trace elements compositions and their noble elements concentrations using High resolution X-ray energy diffusive micro-analyzer in the Department Metallurgical Engineering and Material Science Laboratory of Indian Institute of Technology. The very low abundances each and every trace-elements were magnified to per cent levels and determined. The analyses were made in nano-material scale. The analyses show that rutile is relatively enriched in PGE, Ag and Au 16.7 followed by ilmenite 5.9, monazite 5.7, Zircon 5, magnetite 4.3 and garnet 4.3%. The lower estimation determined may range in the order of 10^{-3} (167-43ppm) to 10^{-5}(1.67-0.04ppm). Rutile has high concentration of Pb and U also. The high concentration of PGE, HREE, Pb and U in all these major placer sands, indicate that they might have been derived from same mantle source.*

Keywords: *Garnet, Ilmenite, Rutile, Zircon, Monazite, Beach Placers sands, PGE, Au, Manavalakurchi.*

1. INTRODUCTION

Verma [1] reported to the Government of Tamil Nadu on conservation and economic potential of ilmenite and other placer sands that concentrated along the coasts of Tamil Nadu, India. He collected ilmenite sands from Manavalakurichi in Tamil Nadu and Neendakarai in Kerala. Using fire-assay technique, he estimated Pt contents in ilmenite in these areas are 200 ppm and Au contents are 60 ppm in Tamil Nadu and 40 ppm in Neendakarai. This is fabulous discovery of noble metals in placer sands. Knowing this fact, Thiru V. Gopal then State Geologist, Department of Geology and Mining wanted to install a fire-assay unit under United Nations Mineral Development Project and sent a chemist to train abroad to learn this technique. Unfortunately, the work was stopped due to over exposure of heat from the installed unit.

During exploration of granite dimension stone for cutting and polishing industrial units in Thirunelveli District, Tamil Nadu in 1992, the author visited Viravanallur village situated 5 km east of Ambasamudram where half a dozen people were engaged grinding and panning for gold. They informed the author that they were getting gold an average of ½ g/t or 0.5 ppm per tonne from lake sediments nearby. Gold occurs mainly in the form of fine granules and sulphides like pyrite, pyrrhotite, chalcophyrite and other accessory minerals formed under anaerobic environment in the lake sediments. Similar is true for the sediments occurring in the drainage channels of goldschmidt's. The beach placer sands occur in huge volumes along the coastlines of India. Therefore, an attempt was made to estimate weight per cent of noble metals, Pb and U in garnet, magnetite, ilmenite, rutile, zircon and monazite placer sands.

2. METHODLOGY

SEM images were taken individual placer sands and their major elements, trace elements like LREE. HREE, Y, Sc Platinum Group of Elements (PGE), Ag, Au, Pb and U were determined using Electron diffusive X-ray analyses in the laboratory of Department of Metallurgical Engineering and Material Science, Indian Institute of Technology, Madras. Optimum sieved size fractions of sand grains can be measured by using SEM images and their scales. The chemical elements determined by weight per cent on nano-material scale were converted into their oxides. Several types of chemical variation diagrams were constructed to interpret geochemistry and source of heavy mineral placer sands. Rittmann's norm [2] (weight per cent) were calculated.

3. GEOCHEMISTRY

SEM images show that the placer sand grains are slightly subrounded by mechanical transportation and their subhedral forms by retaining their original euhedral forms. The EDAX spot chemical and trace elemental compositions of individual grain solely represents site compositions the mineral and widely vary from site to site in nano-material scale. The chemical analyzes of all these placer sands indicate that they were subjected to oxidation and dissolution in seawater (**Fig** 1 and **2**).

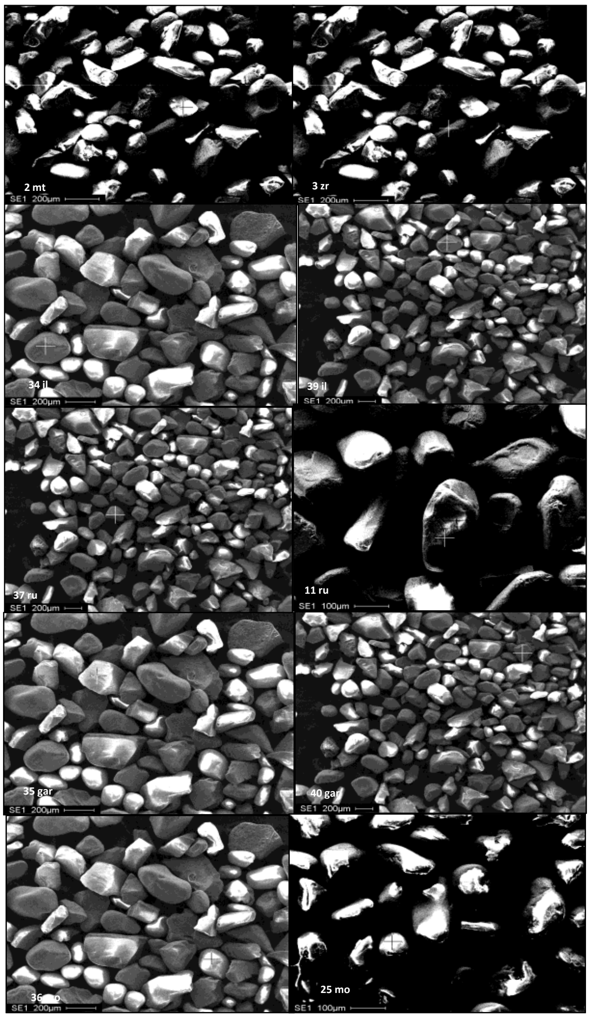

Fig2: *SEM images of phosphate rich monazite sands*

Table 1: *The EDAX chemical and noble metal concentrations in garnet, magnetite, ilmenite, zircon and rutile*

	Gae35	Gar40	mt	*il*	il	zr	ru	ru	ru	ru	ru	ru	ru	ru	ru	ru	ru	ru	ru
SiO2	44.14	42.50	5.71	*22.71*	1.25	6.15	2.25	4.04	16.88	1.10	0.16	10.08	1.61	0.75	1.23	3.23	1.00	0.24	1.42
Al2O3	24.99	24.46	2.19	*5.45*	2.14	0.38	1.07	2.24	10.30	1.86	0.92	7.71	1.35	2.13	3.59	2.95	1.38	1.39	1.54
FeO	17.11	20.00	62.10	*11.86*	26.46	1.72	1.76	3.51	11.48	1.16	0.58	3.63	0.32	0.66	1.41	1.08	0.38	0.79	0.22
MnO	0.00	0.00	0.71	*0.23*	0.11	0.18	0.42	0.45	0.27	0.20	0.35	0.27	0.00	0.36	0.42	0.34	0.18	0.35	0.00
MgO	8.58	9.29	1.31	*1.09*	2.92	0.00	0.79	0.14	1.08	1.09	0.60	1.65	0.93	1.68	1.77	1.96	0.82	0.89	1.05
CaO	1.88	1.18	1.34	*0.34*	0.63	0.00	0.68	0.68	0.07	0.72	0.70	0.67	0.00	0.65	0.76	0.60	0.46	0.54	0.03
Na2O	0.00	0.49	0.97	*0.88*	0.84	0.12	1.01	0.19	0.00	1.18	0.56	1.24	1.18	1.68	1.70	1.73	0.80	1.13	1.04
K2O	0.37	0.12	0.35	*0.00*	0.61	0.00	0.62	0.78	0.00	0.48	0.53	0.47	0.00	0.59	0.49	0.50	0.24	0.60	0.00
TiO2	0.55	0.61	1.54	*20.96*	43.19	0.37	74.26	74.19	24.74	75.67	80.62	58.68	82.24	73.62	68.68	75.17	60.63	76.78	81.69
P2O5	0.36	0.00	1.22	*6.41*	2.30	4.29	2.30	0.68	5.10	1.97	1.20	1.93	0.94	1.92	1.76	2.06	0.93	1.64	0.63
ZrO2	0.20	0.00	2.70	*15.67*	2.54	75.19	2.00	0.89	16.72	2.93	2.00	2.05	3.43	2.59	1.97	0.67	12.24	2.56	3.33
HfO2	0.15	0.14	1.86	*1.34*	1.30	1.64	1.15	0.87	0.33	0.66	1.02	0.82	0.00	1.29	1.21	0.76	0.59	1.16	0.00
Ree	1.68	1.21	18.01	*13.07*	15.72	9.96	11.69	11.34	13.04	10.98	10.75	10.82	8.00	12.09	15.01	8.95	20.35	11.92	9.04
	100.00	100.00	100.00	*100.00*	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.01	100.00	100.00	100.00	100.00	100.00	100.00
Ru	0.51	0.23	0.52	*0.11*	1.06	0	0.11	1.23	0.84	0	0.69	1.14	1.11	0	1.14	1.16	0.96	0.99	0
Rh	0.57	0.19	0.51	*0.13*	1.01	0	0.13	1.07	0.89	0	0.51	0.95	0.92	0.15	0.85	0.86	0.69	0.87	0.26
Pd	0.44	0	0.47	*0.22*	0.97	0	0.22	1.01	1.18	0	0.65	0.97	0.84	0.06	0.85	0.81	0.88	1.07	0
Ag	0.43	0.27	0.54	*0.3*	0.64	0	0.3	0.77	0.71	0	0.6	0.79	0.55	0	0.74	0.77	0.64	0.74	0
Os	1.24	0.45	1.24	*0.64*	1.17	1.37	0.61	1.52	0.9	0.33	0.23	0.98	0.67	0.27	0.27	1.56	0.43	1.16	0.29
Ir	0.83	0	1.48	*0.71*	0.63	1.38	0.71	1.06	1.32	0.11	0.27	0.87	0.52	0.15	0.15	1.06	0.66	0.98	0.21
Pt	0.93	0.6	1.56	*0.55*	0.9	1.32	0.55	0.99	1.45	0.2	0.39	0.81	0.59	0.24	0.24	1.29	0.45	1.09	0.68
Au	1.23	0.56	1.55	*0.4*	0.53	0.97	0.4	0.6	1.23	0.37	0.31	0.94	0.47	0.25	0.25	0.86	0.77	1	0.46
Pb	0.91	0	1.38	*0.54*	1.23	1.34	0.54	1.23	2.55	0.47	0.54	0.84	0.58	0.5	0.5	0.82	1.4	0.77	0.78
U	1.84	0	2.3	*1.49*	0	5.67	1.49	0	1.11	2.15	1.34	2.39	1.82	2.26	2.26	2.07	6.87	2.84	3.15

The optimum size fraction of garnet and magnetite is 200µm. Ilmenite it is 400x200µm. Rutile it is 400x200µm. Platelets and prisms of monazite 400x100 x 50µm. The minimum size fraction retained in the sieved fraction is 50x50 µm.

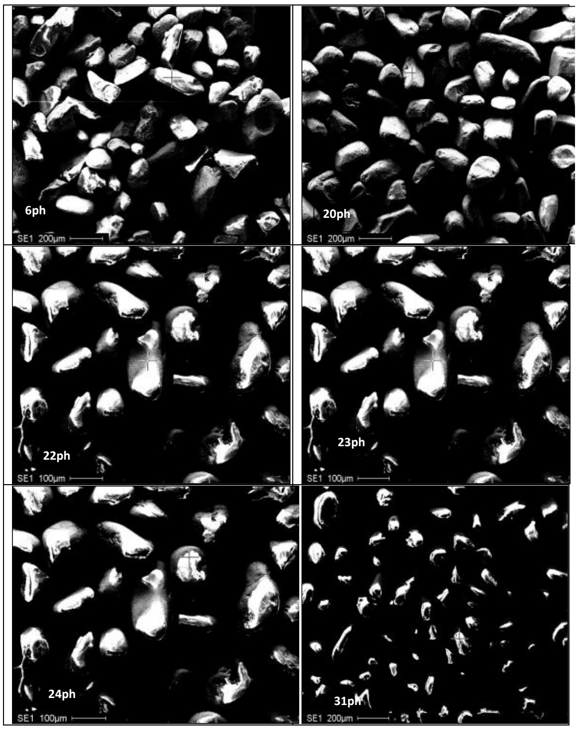

Fig 2: *SEM images of Phosphate rich monazites slightly subrounded and subhedral forms.*

Table 2: *The EDAX chemical composition and noble metal concentration in monazite*

Monzi	mo	mo	mo	mo	mo	mo	mo	mo	mo	mo	mo	mo	mo	mo
SiO2	9.97	7.89	37.74	5.06	5.30	4.97	8.15	4.93	7.03	5.02	5.18	10.37	6.88	7.39
Al2O3	1.99	3.91	0.29	1.31	0.51	0.00	1.61	0.00	1.31	3.95	1.26	8.82	1.06	1.63
FeO	2.76	3.25	0.48	1.48	0.87	0.00	1.51	0.82	1.65	1.53	1.11	6.76	1.76	1.78
MnO	1.42	0.00	0.13	1.12	1.16	0.00	0.93	0.00	0.59	0.58	1.44	1.51	1.05	1.11
MgO	0.00	2.09	0.00	0.00	0.95	0.72	1.10	0.00	0.00	0.00	1.52	0.55	0.79	0.00
CaO	3.18	2.97	0.00	2.24	3.69	1.37	4.33	1.29	2.17	2.02	2.77	2.64	2.82	2.90
Na2O	2.19	1.19	0.55	0.00	1.21	6.85	2.62	0.97	1.73	1.17	2.51	0.41	2.56	0.00
K2O	1.71	0.00	0.00	0.00	0.62	0.00	0.39	0.00	0.48	0.12	0.77	0.80	0.47	0.35
TiO2	3.38	0.63	0.00	0.52	0.91	0.00	0.67	0.58	0.83	1.61	1.44	1.91	0.37	0.48
P2O5	50.90	51.21	46.21	65.60	60.04	68.14	59.60	62.84	57.00	58.70	58.59	45.18	58.13	61.59
ZrO2	11.22	7.61	13.76	11.51	13.23	7.37	8.60	15.06	13.82	11.20	9.29	8.48	12.96	11.93
HfO2	0.50	0.25	0.13	0.00	0.00	0.00	0.16	0.07	0.11	0.00	0.16	0.13	0.10	0.00
Ree	10.77	18.99	0.71	11.16	11.51	10.59	10.33	13.45	13.28	14.11	13.95	12.44	11.04	10.84
	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Ru	0.26	0.26	0.26	0.51	0.00	0.58	0.15	0.64	0.08	0.18	0.99	0.53	0.62	0.65
Rh	0.00	0.16	0.16	0.25	0.00	0.55	0.26	0.44	0.10	0.27	0.42	0.49	0.23	0.42
Pd	0.35	0.24	0.24	0.19	0.00	0.23	0.00	0.22	0.05	0.12	0.71	0.37	0.50	0.34
Ag	2.37	2.27	2.27	5.19	3.25	6.85	2.08	3.81	1.12	2.71	4.31	1.20	4.70	5.03
Os	0.39	0.39	0.00	0.36	0.00	0.39	0.00	0.21	0.15	0.00	0.90	0.45	0.68	0.21
Ir	0.20	0.20	0.18	0.60	0.00	0.49	0.00	0.44	0.63	0.00	0.77	0.23	0.74	0.53
Pt	0.35	0.35	0.00	0.20	0.00	0.00	0.66	0.80	0.59	0.00	0.44	0.56	0.71	0.61
Au	0.62	0.62	0.00	0.00	0.00	0.32	0.42	0.43	0.59	0.00	0.96	0.30	0.68	0.38
Pb	0.78	0.78	0.39	0.72	0.58	0.65	1.12	0.94	1.20	0.39	0.96	0.78	1.41	0.77
U	3.15	3.15	3.33	3.42	4.42	3.38	5.27	4.81	2.78	2.56	4.37	3.20	4.80	3.48
PGE	4.54	4.49	3.11	7.30	3.25	9.41	3.57	6.99	3.31	3.28	9.50	4.13	8.86	8.17

All these placer sands including monazites were severely affected by physical and chemical weathering processes on outer surfaces of mineral grains and impoverishments of metal ions are commonly seen (Table 1 and 2). Studying surface-morphology of these crystals with pits, tunneling, crevices and corrosive outline, it is possible to know dissolution effects of these mineral grains. Garnet sand has significant proportions of MgO content and S35 has almandine:pyrope 47: 34 and S40 has 50:32. The garnets are quartz normative. Significant amount REE particularly HREE were concentrated in garnets including, Y, Dy, Zr, Hf, Pb and U. Magnetite is enriched with HREE, Y, Dy, Zr, Hf, Pb and U. In addition to these elements considerable amount of PGE, Ag, Au Pb and U elements are found. It is under saturated in silica and nepheline normative (Table 3). Ilmenite is nepheline normative. They are enriched with PGE, noble metals and zirconium. The lower normative concentration ilmenite is compensated by entry of monazite and zircon molecules. The low TiO_2 in rutile [3] is compensated by entry notable quantities of other major oxides. About 13 analyses of rutile were made (Table 1). The maximum concentration of TiO_2 reaches up to 82.24%. The lowest concentration of TiO_2 24.74% might be due to bulk estimation of rutile rich sands. They have significant enrichment of ZrO_2, HfO_2, HPGE, Pb and U however, no significant variation in trace element concentration is observed in these minerals. Zircon is highly oxidized and converted into baddeleyite [4] which is enriched with (Table 1) HPGE, Pb and U. Significant enrichment P_2O_5 and REE constituents are present in zircon. LREE are distinctly absent in zircon. Monazite is Ce and La phosphate. Considerable amount Y enters as xenotime YPO_4. Some monazites are P_2O_5 enriched.

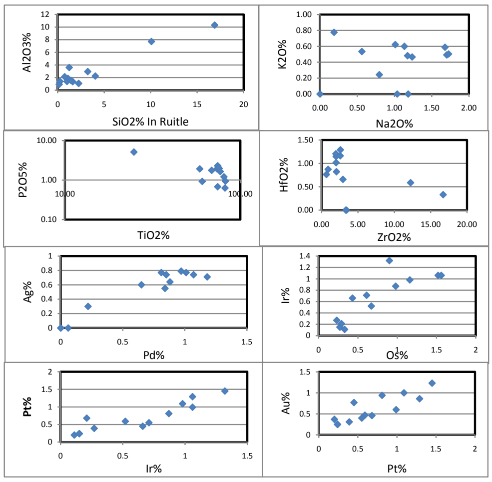

Fig 3: *The Chemical variation diagrams for rutile*

A high concentration of ZrO_2, HfO_2, REE, HPGE, Pb and U is seen in monazite. Phosphate enriched monazites with entry of Y, Al, Si with excessive P are seen.

The binary variation diagrams of rutile Al_2O_3 vs SiO_2, K_2O vs Na_2O, HfO_2 vs ZrO_2, Ag vs Pd, Ir vs Os, Pt vs Ir and Au vs Pt show linear positive trends while P_2O_5 vs TiO_2 shows a negative trend of correlation in rutile (**Fig. 3**). On the other hand, monazites have similar trends of variation including positive trends of Al_2O_3 vs SiO_2, Na_2O vs CaO and U vs Pb in monazite (**Fig: 4**). The negative correlations are found P_2O_5 vs TiO_2 and HfO_2 vs ZrO_2 The mean values of PGE, Ag, Au, Pb and U are also plotted at the end of Fig:4. The mean values of PGE alone excluding Pb and U are given in the Table 6.

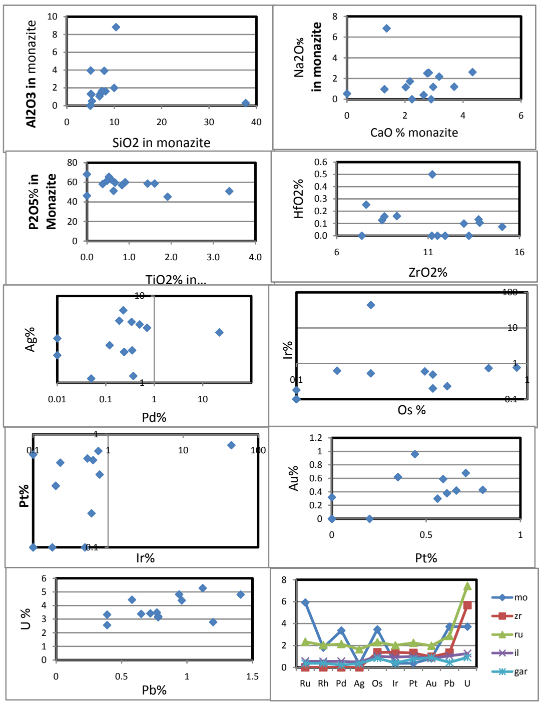

Fig 4: *The chemical variation diagrams of monazite*

The Rittmann's norms of garnet, magnetite, ilmenite and zircon (Table3) significant enrichments of monazites ions are found in all these minerals. Notable zircon ions are present in magnetite, ilmenite and garnet. All these minerals were corroded and oxidized. Rutile shows that entry of zircon ranges between 2 and 16%. All rutiles are monazite bearing from 0.5 to 8% (Table 4). Their rutile contents vary between 44 and 88%. They are nepheline normative. Rarely quartz 2% is found rutile it has only 40% of rutile.

Table 3: *Rittmann's norm for garnet, magnetite, ilmenite and zircon*

	35	40	2	1	5	3
mo			3.29	13.44	3.62	8.63
ap	0.73			0.78	1.3	
zr	0.33	0.11	20.04	19.84	14.19	89.21
ru				5.23	6.37	
il	0.78	0.9	2.78	30.47	65.6	0.72
mt	1.39	1.69	64.89	0	0	0.14
alkf	2.23	4.95		11.33		
ne			8.56		8.69	0.86
sil	8.03	8.26	0.44	9.14	0.22	0.43
al	50.14	47.36				
py	31.68	34.44				
qz	4.68	2.36		9.77		
Total	100	100	100	100	100	100

Garnet (35, 40), magnetite (2), Ilmenite (1, 5) Zircon (3)

mo-monazite, ap-apatite, zr-zircon, ru-rutile, il-ilmenite, ns-sodium silicate, ne-nepheline, alkf-alkali feldspar, sil-sillimanite, qz-quartz

Table 4: *Rittmann's norms for rutile*

	4	7	9	10	11	12	13	14	15	16	17	18	19
mo	3.58	0.49	8.19	3.12	2.76	3.03	2.05	3.06	2.62	3.36	2.10	2.67	1.42
ap	1.63	1.55		1.64		1.44		1.45	1.62	1.38	1.05	1.26	
zr	10.74	1.80	15.70	4.21	3.41	3.18	4.41	4.13	3.39	1.38	16.44	4.21	4.27
ru	68.48	76.53	40.44	81.12	88.14	65.96	86.00	78.96	76.79	79.60	73.41	82.81	86.88
il	7.78	9.65	16.04										
ns	2.88			1.25	1.30		1.42	2.75		0.99	0.48	2.67	0.32
ne	4.90			8.66	4.39		6.14	9.64	15.03	13.29	6.53	6.36	7.11
alkf		7.28				14.86							
sil		2.70	17.24			11.52			0.54				
qz			2.39										
	100	100	100	100	100	100	100	100	100	100	100	100	100

mo-monazite, ap-apatite, zr-zircon, ru-rutile, il-ilmenite, ns-sodium silicate, ne-nepheline, alkf-alkali feldspar, sil-sillimanite, qz-quartz

Monazites enriched with phosphate ions (Fig.2) have monazite from 56 to 69% and the rest of ths portions are compensated by zircon, apatite ilmenite and phosphates. Similarly for phosphate ions saturated monazites have 62-75% of monazite (Table 5).

Table 5: *Rittmann's norm of monazite*

Phmo	20	21	22	23	24	25	31	32	8	26	27	28	29	30
mo	61.23	64.83	60.67	55.52	55.80	69.49	59.23	60.50	74.90	75.08	61.76	74.11	77.20	69.43
ap	3.97	3.57	5.55	1.99	6.60	1.92	4.33	4.41	4.92	3.48	4.47	3.05	3.85	4.00
zr	27.17	10.40	11.10	6.15	8.11	12.53	11.54	10.35		11.75	20.47	9.47	8.11	7.79
ru											4.12			
il	0.84	0.82	3.35		0.94	0.81	0.58	0.58	1.77	1.09		2.53	1.82	2.40
mt	0.21	0.20	0.10		0.19		0.38	0.29	0.98	0.11	0.35		0.10	0.50
ne	2.19								17.42		7.41			4.80
ns											1.41	0.21		
alp	3.76	2.85	0.96		3.39		2.12	3.45		2.83		8.00	2.43	
nak3p			3.54	14.92	6.69	2.12	6.25	0.48		4.79		2.63	6.48	
si3p			6.12	5.70	9.71	5.56	8.08	8.72		0.87				
Sil														11.09
p	0.63	17.33	8.61	15.73	8.58	7.58	7.50	11.22						
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

This feature indicates that monazite was subjected to extensive corrosion in seawater and removal of metallic ions. The oxidation of monazite and conversion of zircon into baddeleyite [4] may also be another cause.

The order of decreasing concentration of PGE, Ag, Au ions in various placer minerals as follows: rutile (16.7), ilmenite (5.9) monazite (5.7), zircon (5.0), magnetite (4.3) and garnet (4.3%). The study reveals (Table 6) that almost all the major placer sands have potential resource for PGE. Au. Ag and other REE, Pb and U elements and these minerals appear to be co-genetic..

Table 6: *PGE Concentrations in garnet, magnetite, ilmenite, rutile and monazite*

	gar	mt	il	ru	zr	mo
Ru	0.37	0.52	0.56	2.34		5.93
Rh	0.38	0.51	0.55	2.04		1.81
Pd	0.22	0.47	0.55	2.14		3.37
Ag	0.35	0.54	0.49	1.65		0.3
Os	0.85	0.64	1.02	2.31	1.37	3.47
Ir	0.42	0.71	0.94	2.02	1.38	0.38
Pt	0.77	0.55	1.00	2.24	1.32	0.38
Au	0.90	0.40	0.83	1.98	0.97	0.82
Pb	0.46	0.54	1.05	2.88	1.34	3.72
U	0.92	1.49	1.26	7.44	5.67	3.72
PGE	4.26	4.34	5.94	16.72	5.04	5.71

PGE excluding Pb and U

Garnet which occurs in a larger volume in placer sands (198 M.T) 49 have significant amount of PGE, Ag and Au. Next to garnet ilmenite (179 M.T) is present 44 followed by rutile (8 M.T) 2, zircon 10.2 M.T 2.5 and monazite (3.2 M.T) 0.8%. in heavy mineral concentrate of Tamil Nadu [5]

4. DISCUSSION

PGE, Au and Ag are generally concentrated in peridotite in the mantle, and ophiolite, ocean-floor effusive, MORB, basalt, kimberlite, phoscorite, and carbonatite magmas [6-15]. The higher concentration of PGE, Au and Ag particularly in Fe-Ti bearing minerals has notable significance that they might have been derived from mantle source [16]. Again, except monazite (Ce, La)PO_4 they have similar enrichment of HREE, Zr, Hf, Y. Au, Ag, PGE, Pb and U. There are not enough evidences that they have been derived from khondalite-charnockite complexes on land as many of geologists presumed [17, 18, 19, 20] by mechanical disintegration and transportation for long distances from on land to sea. Some parts of khondalite-charnockite series have mineral accessories of garnet, sillimanite, magnetite, ilmenite, rutile, zircon and monazite. But no geochemical studies on PGE, Au and Ag on these minerals are available from these crustal rocks. The higher concentrations of heavy elements in placer sands particularly HREE and HE that their provenance might have been different from other than granitic rocks. The study reveals that high concentrations of PGE, Au and HE are often found in the rocks derived from mantle source.

Table 7: *The distributions of LREE, HREE and other HE contents in magnetite, ilmenite, rutile, zircon and monazite*

	LREE	HREE	HE
gar	1.30	5.80	2.66
mt	2.49	6.87	5.79
il	5.96	0.62	6.08
ru	4.41	1.28	7.11
zr	0	2.29	69.62
mo	18.02	1.03	9.92

LREE: La, Ce, Nd ;HREE: Eu, Dy, Yb, Lu; HE: Zr, Hf, Pb, U, Y

Gar-garnet, mt-magnetite, il-ilmenite, ru-rutile, zr-zircon, mo-monazite

The distribution average concentration of HREE and HE exceeds over LREE in all these minerals except for monazite composed of (La, Ce, Y)PO_4 in which Ce is the major element. Therefore, trace elements concentrations of other minerals are taken into account. HREE and HE enriched rocks and mineral have particular significance for the present study (Table 7).

Table 8: *The constants in various placer sands in depleted mantle of MORB*

	K/U ,	Y/Yb,	Zr/Hf,	La/Ce,	Nd/U	Ce/Nd,	Ce/Pb,	Ce/P
gar	0.09,	0.17,	0.19,	0.47	0.17	1.85,	0.65	9.08
mt	0.10,	3.03,	1.27	1.32	0.32	1.04	0.55	1.90
il	0.32	0.03	1.71	2.72	0.30	2.31	1.09	1.44
ru	0.11	2.47	3.48	4.58	0.05	6.28	1.12	1.41
zr		4.02	1.72					
mo	0.03	8.18	15.02	0.09	0.02	2.27	14.99	1.45

Gar-garnet, mt-magnetite, il-ilmenite, ru-rutile, zr-zircon, mo-monazite

The lower constants of K/U, Y/Yb, Zr/Hf, La/Ce, Nd/U, Ce/Nd, Ce/Pb, Ce/P than in the rocks of depleted mantle of MORB (Table 8) in these placer minerals does not give any idea since the compositions of these placer sands do not represent the composition of their host rocks of depleted mantle source of MORB [9]. On the other hand, it is quite possible that they might have been derived from un-depleted siderophilitic rocks such as phoscorite-carbonatite complex, peridotite, kimberlite or ophiolite complexes emplaced on the earth-surface [7, 12, 13, 14]. According to Salters and Sreacke [9] the evolution of PGE, Au and REE is derived by series of stages of differentiations from Lu element (HREE) which intern derived from CaO enriched source of peridotite, kimberlite, phoscorite and carbonatite magmas. After emplacements of these magmatic rocks in the crust they were subjected to mechanical disintegration, liberation and transportation to sea, where heavy minerals were subjected to surface corrosion [21, 22, 23] in seawater producing scars, pits, tunnels and crevices for quite long duration get altered and oxidized with increasing HREE, HE oxides, and phosphates.

5. CONCLUSIONS

Though, it appears to be that all these individual placer sands have very high concentrations of HPGE, Au, Pb, U and other HE elements in their nano-material scale, this may be quite possible and can be treated as upper limits of concentrations. The analytical error might have been take place due to very low concentrations of these elements magnified by the analytical programs specially used for the determinations major-elemental compositions. The occurrences of huge volumes of replenishable placer sands are important resources to India. The analyses and determinations are acceptable by presence up to the order of 10^{-3} (167-43ppm) and some elements can be present even just below the order of 10^{-5} (1.67-0.04ppm) considering their associated valuable poly-metallic components. Therefore, suitable analytical and extraction processes should be evolved. Initially, the residue obtained from the manufacture of synthetic rutile from placer sands of rutile and ilmenite are to be studied for extraction of PGE, Au and Ag.

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List Item -1 Two plates SEM images of placer sands

List Item - 2 Binary variation diagrams Fig3 & Fig 4

List Item – 3 33 EDAX analyses and Rittmnn's norms

List Item - 4 Average concentration of PGE

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