

Heavy-Mineral Analyses of Five Samples: Addendum to Sand Resource Evaluation on Virginia's Outer Continental Shelf Coastal Plain – Final Technical Report

C.R. Berquist, Jr.

Previous work supported by the U.S. Minerals Management Service showed sporadic occurrence of heavy minerals in sand offshore of the Virginia coast (Berquist and others, 1990). Iluka Resources, Ltd. has been mining zircon and ilmenite, principally, in Dinwiddie and Sussex counties, Virginia, and has expressed an interest in beach nourishment sands (Adam Karst, personal communication). Potential development of oil, gas, and offshore wind farms with their bottom infrastructure (pipelines, cables) is on the horizon. We elected to take large-volume samples during our August 2011 cruise to analyze for heavy-mineral content. This addendum report provides the results of that analysis.

We contracted a 47-foot sport fishing boat, the *Matador* out of Virginia Beach. This vessel did not have winch capability to allow us to use a large-volume sediment sampling device (such as a Smith-McIntyre). Once on station, we made multiple casts with a clamshell sampler to acquire about a half of a 5-gallon paint bucket. Rather than anchor, we collected surficial material over a few hundred feet of drift. We collected three bulk samples in this manner.

Virginia Institute of Marine Science contracted with the city of Virginia Beach to examine potential beach nourishment sand in the vicinity of the southern end of the Chesapeake Bay Bridge Tunnel. From the vibracores taken during the summer of 2011, we acquired an additional two bulk samples that showed occurrences of heavy minerals.

At laboratory space provided by the Virginia Institute of Marine Science (VIMS), these large volume (2 to 4 gallon) samples were dried, weighed, and wet-sieved to remove oversize clasts (greater than 10-mesh or 2 mm) and mud fractions (silt and clay, less than 230-mesh or .0625 mm). The oversized and sand fractions were dried and weighed, and the mud fraction was calculated by subtraction of retained sediment from the original weight.

The sand fraction of each sample was processed through a three-turn Humphrey Spiral (Figure 2.) to acquire a heavy-mineral concentrate. Approximately 200 grams of concentrate from each sample was sent to Actlabs (Activation Laboratories, Ontario, Canada) for detailed analysis. Actlabs further concentrated each sample by removing all quartz using a heavy-liquid with a specific gravity of 2.89. The weights of the sink and float fractions were used to back-calculate a “true” mineral abundance by weight in the

original sample. It should be noted that some heavy minerals were lost during processing due to damaged seals on the spiral. As a result, the “true” mineral abundance is conservative and should be treated as a minimum value.

The locations of the samples are found in Appendix I. The laboratory report for each sample is found in Appendix II. Specific questions about the analytic procedures, sampling techniques and geologic framework of the study area may be directed to the author. He may be contacted at: rick.berquist@dmme.virginia.gov or by phone at 757-221-2448.

Although total heavy mineral abundance is low for all samples, it is important to note the presence of monazite, particularly in the vibracores. Within the heavy mineral fraction, zircon ranges from 4.76% to 5.73% for three samples, and ilmenite is above 50% in one sample. Analysis of surface grab samples is an inexpensive but limited approach to determining economic potential for offshore sands. When funding is available, a study that focuses on several offshore target areas and relies on vibracores would better characterize the possibility for economic hard minerals offshore.

I would like to acknowledge Woody Hobbs and Steve Kuehl (VIMS) for providing laboratory space and the Department of Geology (W&M) for space to store and operate the Humphrey Spiral. Scott Hardaway, Donna Milligan and (VIMS) allowed access to and assisted sampling of vibracores. Dennis Feeney and Lee Bristow assisted in sample processing.

References

Berquist, C.R., Jr., Fischler, C.T., Calliari, L.J., Dydak, S.M., Ozalpasan, H., and Skrabal, S.A., 1990, Heavy mineral concentrations in sediments of the Virginia inner continental shelf, in Berquist, C.R., Jr., [ed.], Heavy-mineral studies - Virginia inner continental shelf, Virginia Division of Mineral Resources Publication 103, p. 31-94.



Figure 1. Three-turn Humphrey Spiral: Heavy mineral concentrate is collected in the bucket to the right.

Appendix I

Location of Samples

We used a Humminbird 1198c Sidescan Sonar for navigation and determining bottom sediment type. At each sample station, we recorded a “snapshot” of bottom imagery, chart, location, and other navigation information. VIMS cores came from the south end and on either side of the Chesapeake Bay Bridge Tunnel.

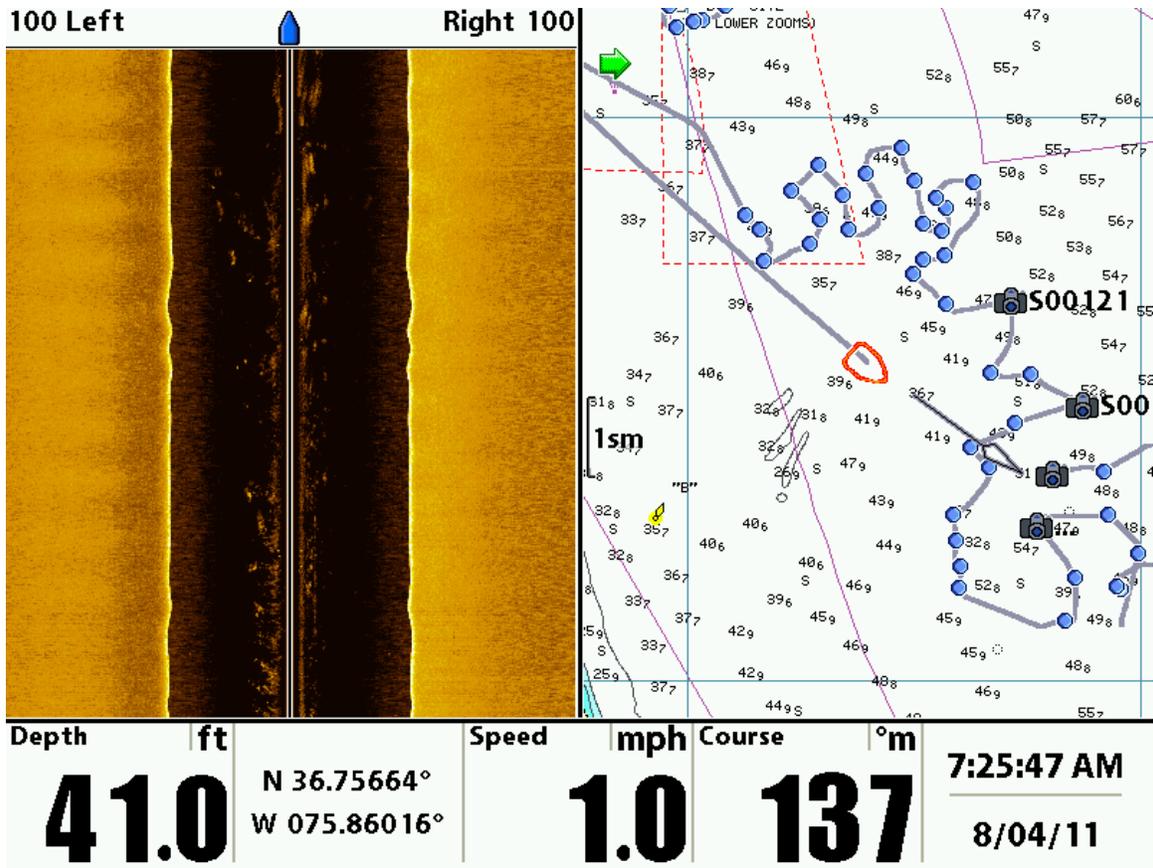


Figure 2. Humminbird imagery (sandy bottom) and location for sample S0153-154 at beginning of drift.

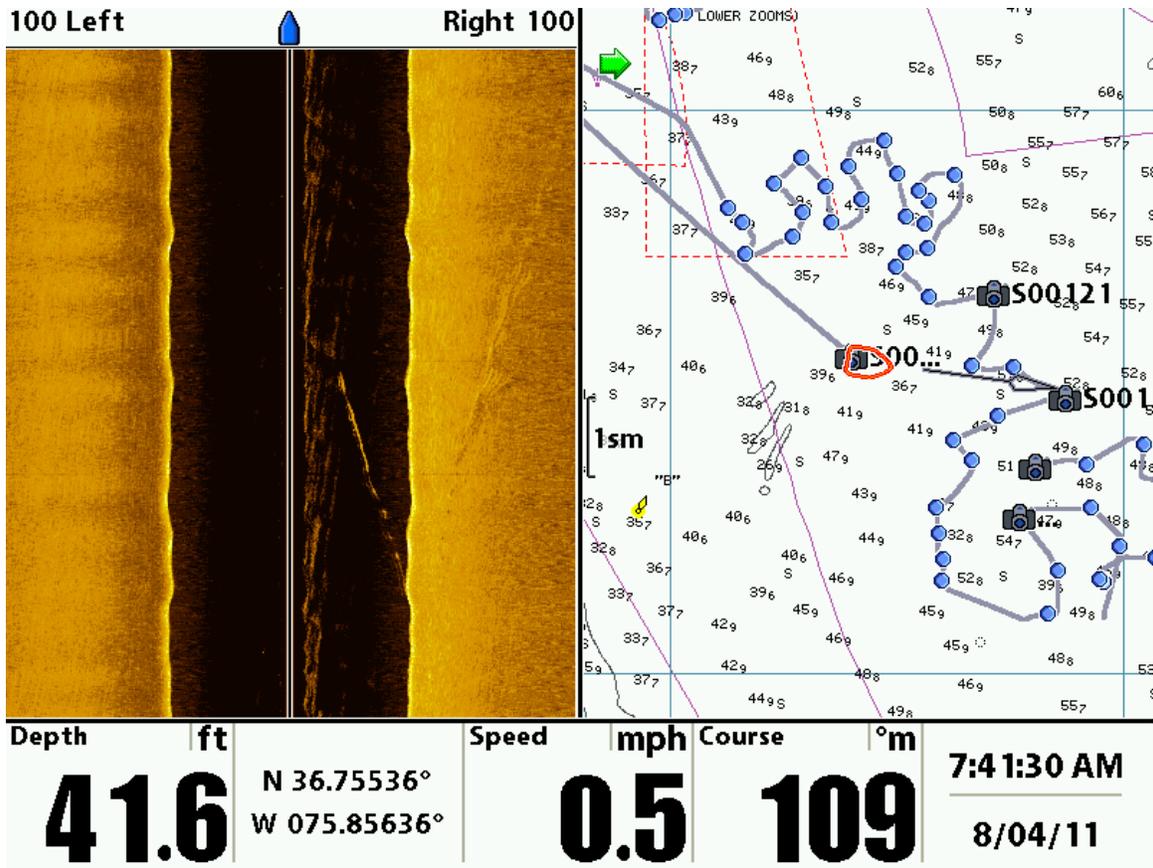


Figure 3. Humminbird imagery (sandy bottom) and location for sample S0153-154 at end of drift.

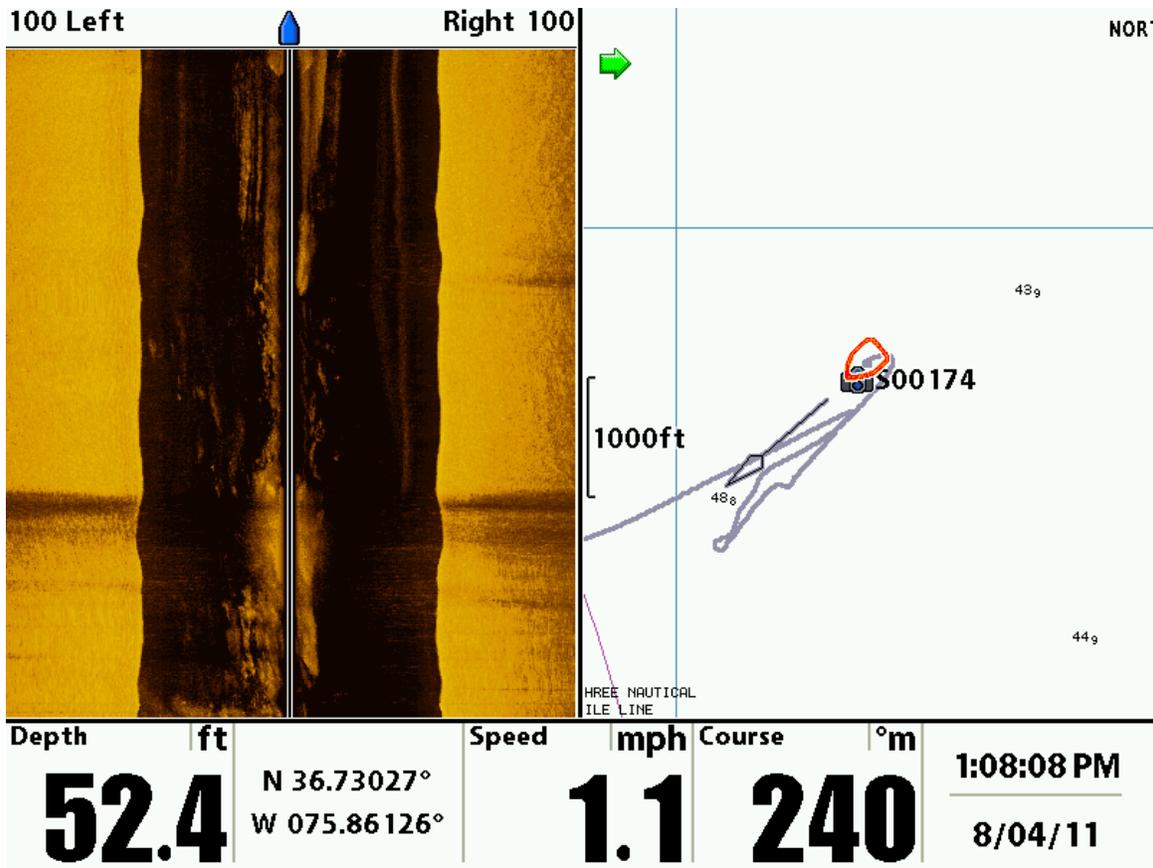


Figure 4. Humminbird imagery (sandy bottom) and location for sample S0175 with negligible drift.

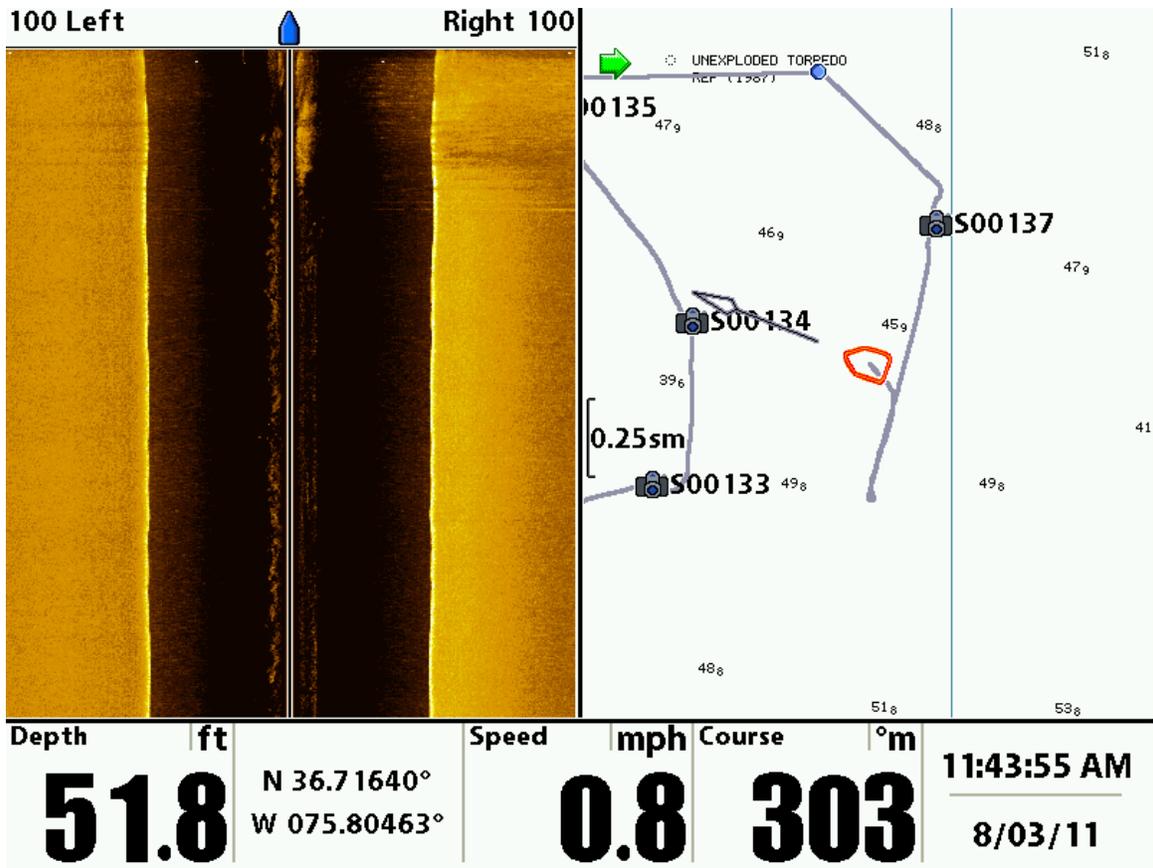


Figure 5. Humminbird imagery (sandy bottom) and location for sample S038-139 at beginning of drift.

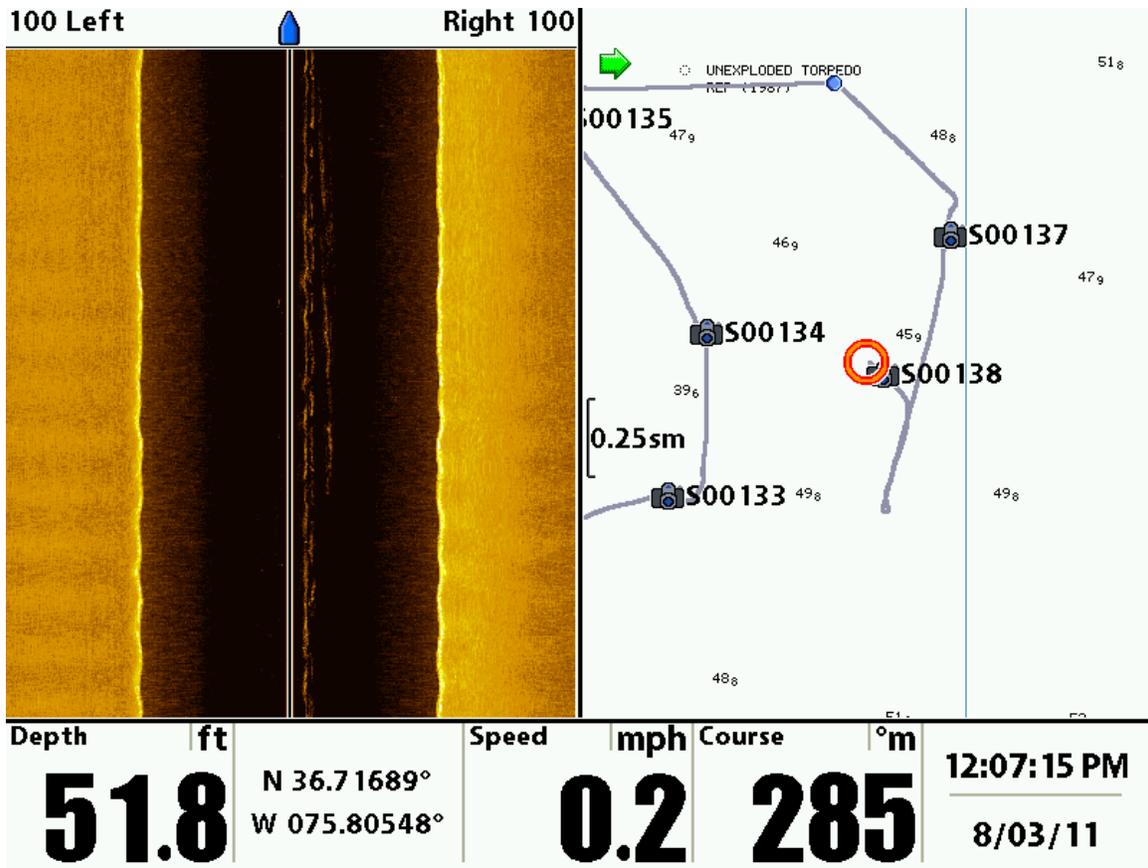


Figure 6. Humminbird imagery (sandy bottom) and location for sample S0138-139 at end of drift.

Sample ID	Location Latitude/ Longitude	DGMR Repository Number	Approximate heavy mineral abundance
S0153-154	37.75664 -75.86016	R-10414	0.27%
S0175	37.73027 -75.86126	R-10415	0.24%
S0138-139	37.71640 -75.80463	R-10416	0.14%
VIMS Core 18	36.92530 -76.11958	R-10412	0.70%
VIMS Core 40	36.92590 -76.13666	R-10413	0.48%

Table 1. General information for samples. For samples taken during drift, the location is for the beginning of sampling.

Appendix II

Report of Analyses from Actlabs

We contracted with Activation Laboratories, Ltd. (Actlabs) for geochemical and point-count analysis of heavy-mineral concentrates. The “4E Exploration Package” provided elemental composition for the samples, noted as “Report: A11-12126 (i)”. Modal oxide composition was calculated by two methods, Direct Assay X-Ray Fluorescence and the proprietary Mineral Liberation Analyzer (MLA). MLA is basically a point-count of individual grains with a Field Emission Scanning Electron Microscope. Both methods are compared for oxide composition and agree quite closely.

Reviewers of the report asked for a clarification of “pseudorutile” and an explanation is provided by Actlabs (C. Hamilton, personal communication): “Pseudorutile is a bona-fide intermediate oxidized ilmenite phase in which $1/3^{\text{rd}}$ of Fe has been leached out of the ilmenite and all remaining Fe is oxidized to Fe³⁺. As such, whereas primary ilmenite has the empirical formula FeTiO₃, (or 3[FeTiO₃], to give the balanced equation), pseudorutile is Fe³⁺Ti₃O₉ (with 60 % TiO₂). Like maghemite, when in water, the ferric iron stays around, but as soon as leaching continues it rapidly becomes leached-pseudorutile with increasing TiO₂ and with continuous leaching it changes to Fe-rich leucoxene and ‘purer’ or more TiO₂-rich leucoxenes. The reference to this process is a paper by Mucke, A. & Bhadra-Chaudhuri, J.N. (1991), titled ‘The continuous alteration of ilmenite through pseudorutile to leucoxene.’ (Ore Geology Reviews, 6, 25-44.)”

The Modal Analysis shows results for seven samples. The process for extracting heavy minerals involves splitting the flow of water and sediment at the bottom of the spiral; the “light” mineral fraction (quartz, calcite) would be caught in one bucket, the “concentrate” (heavy minerals and some quartz) would be caught in another bucket. For each sample, we would adjust the position of the splitter to insure concentrating as much of the heavy mineral fraction as possible. As a check on our procedure, we re-spiraled the concentrate for two samples, R-10412 and R-10413. The “-A” sample is the concentrate of the first concentrate, the “-B” is the light fraction of the first concentrate. Note in the Modal Analysis that a greater amount of “heavier” heavy minerals (ilmenite, pseudorutile, leucoxene, zircon) is found in the -A sample, and a greater amount of lighter heavy minerals (tourmaline, epidote, amphibole) are found in the -B sample.

Report: A11-12126 (i)
 Report Date: 11/23/2011

Final Report
Activation Laboratories

Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Ba	Sr	Y	Sc	Zr	Be	V
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01		0.01	2	2	1	1	2	1	5
R10412A	19.95	8.7	28.27	0.961	2.05	3.48	0.28	0.2	31.7	0.13	-0.58	95.14	62	146	133	43	25010	< 1	562
R10412B	31.74	17.89	17.55	0.498	4.58	8.03	0.61	0.37	14.3	0.14	1.33	97.04	95	314	71	55	5425	< 1	454
R10413A	11.65	7.16	31.27	1.108	0.8	2.57	0.13	0.1	39.45	0.15	-0.49	93.88	48	142	140	43	26300	< 1	615
R10413B	21.18	15.31	25.14	0.859	1.79	5.22	0.32	0.2	26.05	0.13	0.7	96.91	64	227	85	54	14420	< 1	531
R10414	28.21	14.72	24.06	0.769	4.4	7.09	0.48	0.31	18.54	0.12	0.29	98.98	61	204	108	60	7201	< 1	478
R10415	22.38	12.47	27.73	0.93	3.27	4.92	0.34	0.22	25.12	0.14	-0.54	96.97	46	132	115	51	13220	< 1	521
R10416	22.29	12.22	27.54	0.926	3.24	4.88	0.34	0.22	24.79	0.13	-0.13	96.44	46	130	116	51	12930	< 1	515

Analysis method is Fusion-ICP for all species

MODAL ANALYSIS

Mineral	R10412A	R10412B	R10413A	R10413B	R10414	R10415	R10416
Ilmenite	37.36	11.44	50.84	32.07	23.70	34.11	32.73
Pseudorutile	4.07	0.20	5.00	3.01	1.52	2.10	3.44
Leucoxene_LPSR*	8.62	1.98	8.20	5.58	6.20	7.17	5.77
Leucoxene_Fe	1.93	2.13	2.20	3.70	1.56	1.90	1.27
Leucoxene_siliceous	0.40	0.42	0.41	0.54	0.30	0.41	0.46
Rutile	3.05	3.85	3.38	3.99	2.16	1.36	2.34
Titanite	0.25	0.01	0.00	0.00	0.49	0.89	0.07
Fe_oxides	0.03	0.63	0.08	0.30	2.48	1.65	1.95
Goethite	0.00	0.12	0.00	0.25	0.05	0.37	0.58
Cr-Zn-Mg_Spinels	0.26	0.00	0.04	0.01	0.15	0.40	0.12
Zircon	5.73	2.05	5.01	2.98	2.93	4.76	2.74
Monazite	0.09	0.01	0.18	0.13	0.00	0.03	0.24
Apatite	0.02	0.01	0.00	0.01	0.00	0.01	0.01
Goyazite_REE	0.18	0.00	0.09	0.14	0.01	0.00	0.00
Allanite	0.02	0.07	0.02	0.03	0.11	0.22	0.07
Tourmaline	2.93	4.59	1.09	1.81	6.69	5.45	3.87
Garnet	1.15	0.77	0.21	0.49	4.33	4.04	4.45
Amphibole	10.79	30.84	4.11	11.52	20.81	18.90	19.25
Epidote	8.51	19.82	8.88	14.77	11.75	6.06	8.67
Pyroxenes	1.11	3.56	0.50	0.78	4.10	3.53	2.32
Staurolite	3.68	5.48	3.12	7.50	3.82	2.62	4.43
Andalusite/Ky/Sill	4.54	8.65	2.87	6.94	4.63	1.61	3.56
Quartz	4.23	2.16	1.02	1.60	1.14	0.83	0.77
Feldspar	0.58	0.56	0.20	0.26	0.33	0.52	0.23
Corundum	0.00	0.00	0.00	0.00	0.35	0.31	0.04
Chlorite	0.18	0.32	0.21	0.11	0.16	0.42	0.33
Mica	0.14	0.15	0.08	0.25	0.19	0.15	0.20
Clay	0.13	0.18	0.09	0.32	0.06	0.05	0.09
Pyrite	0.00	0.01	2.20	0.91	0.00	0.12	0.01
Total	100.00						

Combined_Ti_Mineral	55.7	20.0	70.0	48.9	35.9	47.9	46.1
Ilmenite/PSR Ratio	4.3	5.8	6.2	5.8	3.8	4.8	5.7
Total Heavy Silicates	32.7	73.7	20.8	43.8	56.1	42.2	46.6

Colour to emphasize differences

Notes

LPSR = abbreviation for leached pseudorutile

Zn-spinels dominant, followed by spinel & trace chromite

XRD Required to positively identify polymorph

Ilmenite/PSR Ratio Proxy for degree of alteration of ilmenite