# MONITORING OF RARE EARTH POTENTIAL AREAS USING REMOTE SENSING

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**Abstract.** Rare Earth element is collection of 17 chemical elements in the periodic table, especially the 15 lanthanides plus scandium and yttrium. Rare earth element in Indonesia is obtained from monazite or associated minerals which is waste of tin ore sand mining. Monazite is composed of several elements of the rare earth, uranium, and thorium for nuclear reactors. Rare earth element can be processed into electronic components such as liquid crystal display (LCD), magnet, automotive components, and high-tech space shuttle. Rare earth element can be detected by remote sensing data. Remote sensing data in the form of optical data, Synthetic Aperture Radar (SAR), microwave, and lidar. In this research is used remote sensing data based on satellite, namely ALOS PALSAR,Landsat, X SAR, and Shuttle Radar Topographic Mission (SRTM). Rare earth element exploitation activities affect to regional development. This research study area is in Bangka island. The parameters used for rare earth detection are height model, density, gravity, hydrothermal alteration, land cover, and magnetic fields. The results is the potential of rare earth element mining area. The accuracy of rare earth potential area is more than 3σ (90%). Monitoring of Rare Earth Potential Areas using Remote Sensing will take effective in time and low cost.

**Keywords:** rare earth element, remote sensing, regional spatial plan, Bangka island

## 1. Introduction

Spreading mineral in Indonesia uneven suitable geological conditions along the span of the archipelago. The development of the science of geology has given an overview of how the occurrence of minerals and various factors that control it. Geologic parameters are known, then the spread of the mineral can be estimated. Because it requires knowledge of the geological conditions covering the entire Indonesia territory. Through geological mapping, both remote sensing and field survey, Indonesia had geological map covering the entire territory of Indonesia. Based on geological map of the experts can arrange various theories or hypotheses in mineral detection, for mineral formation associated with variety of geological processes.

Currently the development of remote sensing has been increased with a marked development of various mapping technology. Remote sensing using five main data types, namely optical data, Synthetic Aperture Radar (SAR), microwave, lidar, and sonar. Optical data has advantages in accordance with the conditions, True but not free cloud effect. While the SAR data, microwave, and sonar has an advantage in cloud-free conditions effects but require special expertise for data processing. This data can be used for the field of geology and mining utilization of energy and minerals. Application of remote sensing in Indonesia's geological and mining also has regulatory Law No. 4 of 2009 on mineral and coal and Kepmentamben no 1519.K / 20 / MPE / 1999 (KESDM 1999 dan KESDM 2009).

Rare earth element is collection of 17 chemical elements in the periodic table, especially the 15 lanthanides plus scandium and yttrium (Boesche 2015). Due to the characteristics of its geochemical. Rare earth found in highly dispersed condition, but these element are relatively abundant amounts in

the earth's crust (Boesche 2015a). The rare earth element can not be found in the form of free elements in earth crust (Boesche 2015b).In general, rare earth is found in the form of complex compounds phosphates and carbonates that should be separated first from complex compound (Boesche 2016). Here are some examples of rare earth element mineral found in nature (Mariano A N and Mariano A 2012).

a. Bastnaesit (CeFCO3), is cerium fluoro-carbonate containing 60-70% rare earth element oxides such as Lanthanum and Neodymium. Mineral bastnaesit is source of main rare earth element in the world. Bastnaesit founded in Carbonate rock, dolomite breccia, pegmatite and amphibole skarn (Taylor and Mc Cafferty 2014).
b. Monazite ((Ce, La, Y, Th) PO3), rare earth element phosphate compounds containing 50-70% Rare Earth Oxides. Mineral monazite taken from weight sand which is product of other heavy element compounds. Monazite contains higher thorium, so that the mineral is radioactive. The Thorium emits ionizing radiation. Monazite certain amounts classified as Technologically Enhanced Naturally Occuring Radioactive Material (TENORM) ie radioactive material nature due to human activity or process technology increased potential exposure when compared to the initial state, handling TENORM must comply with the limits of radiation exposure as follows: Exposure of workers 20 mSv / th or 10 USV / h and the public exposure of 1 mSv /year (Thompson 1988).
c. Xenotime (YPO4), phosphate-containing compound yttrium 54-65% rare earth including erbium, cerium and thorium. Xenotipe mineral also found in heavy mineral sands such as pegmatite and the molten rock (igneous rocks) (Turner et al. 2014).
d. Zircon, is zirconium silicate that is found therein thorium, and cerium yttrium (Turner 2015).

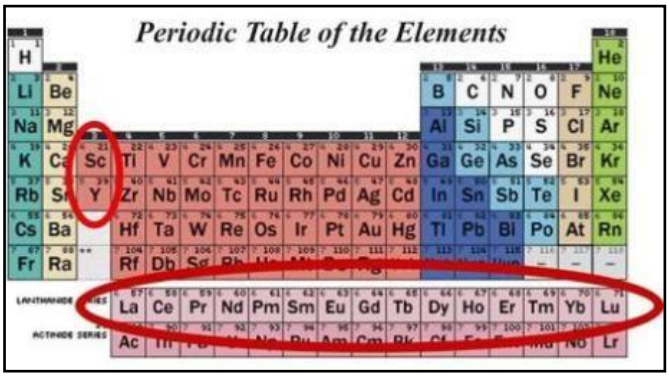


**Figure 1**. Periodic Table of the Element

Rare Earth Element is actually not rare as implied in its name. For example, thulium and lutetium are two types of rare earth element is the most abundant (Mielke2014). They have an abundance of surface average is nearly 200 times greater than the abundance of gold on the surface (Swayze 2013). However, this metal is very difficult to mine, because they are rarely found in concentrations high enough to be extracted economically. While cerium, yttrium, lanthanum, and neodymium, they have an average abundance similar to industrial element such as chromium, nickel, zinc, molybdenum, tungsten and tin (Olsonand Hedlund1981). But nonetheless they are rarely found in sufficient concentrations to be extracted (Vander Meer et al. 2012). Rare earth element and alloys are used in many devices such as computer memory, DVDs, rechargeable batteries, cell phones, catalytic converters, magnets, fluorescent lights, and much more. Over the past 20 years, there has been explosion in demand that require rare earth element (Olson 1954). 20 years ago, very few people use mobile phones, but today that number has increased to more than 7 billion use mobile phones and computers. When this has been growing almost as fast as mobile phones.


**Figure 2.** sample of rare earth element

Many Rechargeable batteries are made with rare earth compounds. Demand for battery driven by demand for portable electronic devices such as portable computers and cameras. A number of rare earth compounds are also located in battery used as power on any electric vehicle and hybrid electric vehicles. Rare earth element can also be used as catalyst, phosphorus, and compounds polishing (Olson and Wallace 1956). It is used for air pollution control and display lights on electronic devices. All of these products are expected to experience increased demand. Some other elements may supplant the use of rare earth element, but the substitute elements is usually ineffective and expensive (Randolph et al. 2008).One way to detect rare earth potential is using the association premises Tin ore and Copper. In this study focused on the potential association with tin ore. One area that has been done for tin ore mining is Bangka island.

Bangka Island is located next to the East coast of South Sumatra, bordering the South China Sea in the north, Belitung Island in the east and Java sea in south is 1° 20'-3° 7' South latitude and 105°-107° East Longitude extends from Northwest to the Southeast along the ± 180 km. The island consists of swamp, hills, and hilltops are dense forests, while there are mangrove swamp areas. Bangka island is not so different from the swamp on the island of Sumatra, while the beaches privileges compared with other regions is sloping beaches of white sandy expanse decorated with granite.

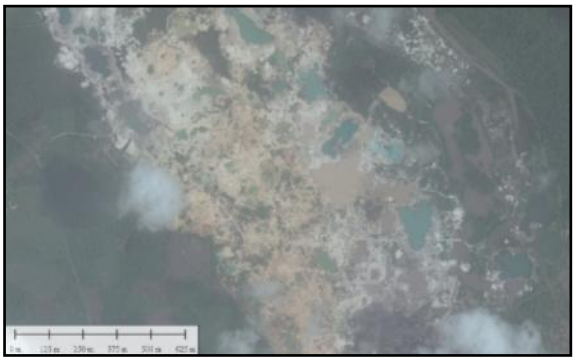

**Figure 3**. one of the tin ore mining land and its mining lake in Bangka island

This study aims to identify the rare earth potential using remote sensing data. This research study area is Bangka island. Figure 4 is the research flowchart.

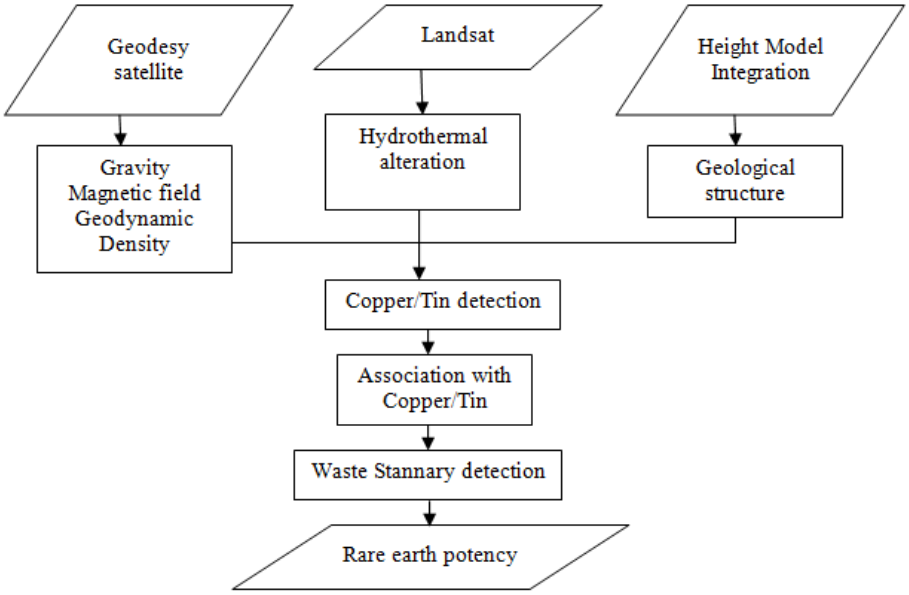


**Figure 4**. research flow chart

## 2. Method

Geologic parameters used in potential copper detection are as follows.

a. Before mining: structure and geological formations (dip and strike), geomorphology, earth gravity, magnetic field, density, geodynamics, land cover (object based classification), height models.
b. Open pit mining: structure and geological formations (dip and strike), geomorphology (band ratio, filtering, threshold, index), hydrothermal alteration, land cover (object based classification), height models.

Geological structure use dip and strike method automatically, there are five alternative methods to do dip and strike, which are three points, plane contact, strike from map, retrace, and parallel contact.

Geomorphological analysis used is spectral form of interpretation and optical data to the mining area. There are several methods for identification of geological conditions and mining, including Prost method (identification of mine site), Segal (alteration zones, potential of ferrous metals, mineral hydroxil, iron ore), Abrams (hydrothermal alteration of iron oxide, clay, mines category C ), Kaufmann (mineral hydroxyl), Chica-Olma (metallic and non metallic minerals, clay, mines category C, iron ore), and others.

Analysis of earth gravity, magnetic fields, and geodynamic using the approach of physical geodesy. Analysis in plate tectonics and deformation detection (north-south and west-east) the study area. The density of tin ore can be detected by microwave (geodesy) satellite data. Tin ore density value lies at around ρ = 7500 kg / m3 and Specific Gravity (S-G = 8.9). This condition applies to the S-G = ρsubstance / ρH2O where ρH2O 4 ° C of 1000 kg / $m^3$ (Seigel, 1995a).

## 3. Result and Discussion

In this study, more focused on the tin ore which has special association to the special minerals around it. Tin ore has association or closeness with sand, graphite and rare earth. The association with tin ore, rare earth element can also be detected in association with copper potential.

Copper or cuprum in the periodic table that has the symbol Cu and atomic number 29. Copper is not so abundant in nature and is found in free form or in the form of a compound. The most important copper ore is pyrite or chalcopyrite (CuFeS2), copper glance or chalcolite (Cu2S), cuprite (Cu2O), malaconite (CuO) and malachite (Cu 2 (OH) 2CO3), while the free element found in Northern Michigan, United States. In small amounts of copper found in some plant species, particularly birds feathers feathery light and in the blood of animals such as shrimp and scallops. The proximity of the

nearest copper minerals. Copper have association with tin ore. Tin ore or Stannum in the periodic table that has the symbol Sn and atomic number 50 (Freeden et al. 2010 and Seigel 1995a).

Copper➔Argentum (silver)➔Aurum (gold) ➔tin ore➔rare earth element➔uranium

Tin ore ➔ Graphite ➔ Sand ➔ Rare earth element

The value of rare earth element can be detected by the reflectance values of the object (Clark et al. 2007). These results are less accurate when compared to density detection. The reflectance values can be useful in copper and tin ore detection. Both element are the association of the rare earth elements.

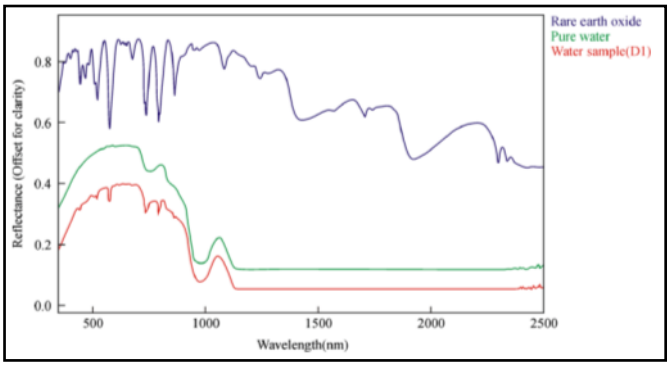


**Figure 5**. Reflectance of pure water, rare earth oxide, and leachate containing maximum concentration of rare earth element

Minerals used in human life is not all there is in Indonesia. It is estimated that only 30% or 30 kinds of major minerals found in Indonesia. These minerals are gold, silver, copper, rare earth, nickel, tin ore, lead, aluminum, iron, manganese, Chromite, iodine, salts, various industrial minerals (asbestos, bentonite, zeolite, sulfur, phosphate, limestone etc.), precious stones, including diamonds, and building materials. Rare earths is still unknown in Indonesia, as well as uranium, until now has not provided detailed data about it (Freeden et al. 2010).

Some minerals have become mainstay of the mining sector in Indonesia. Production and reserves are also quite large. Tin ore, for example, produces about 15% of world production, while reserves of approximately 8% of world reserves. Nickel reserves reach 15% of world reserves, but production has only reached 10% of world production.

Rare earth mapping is done by the tin ore detection. Tin ore mining land can be detected by Landsat imagery. The location of tin ore mining land can be detected by the VIDN method (differencing two or more NDVI values) (Julien Y and Sobrino J A 2011). NDVI created using Landsat imagery in 1990 and 2005. Then both NDVI do differential in order to obtain VIDN value that indicates the tin ore mining land.

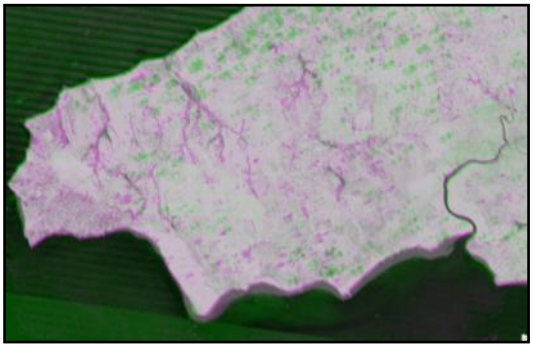

**Figure 6**. differential of NDVI 1990-2005

Tin ore mining land in Bangka island includes the old mining so that it does not require the latest data. If the identification of these mining land compared with Landsat imagery data (2015), then the location of tin ore mining land are still clearly visible.

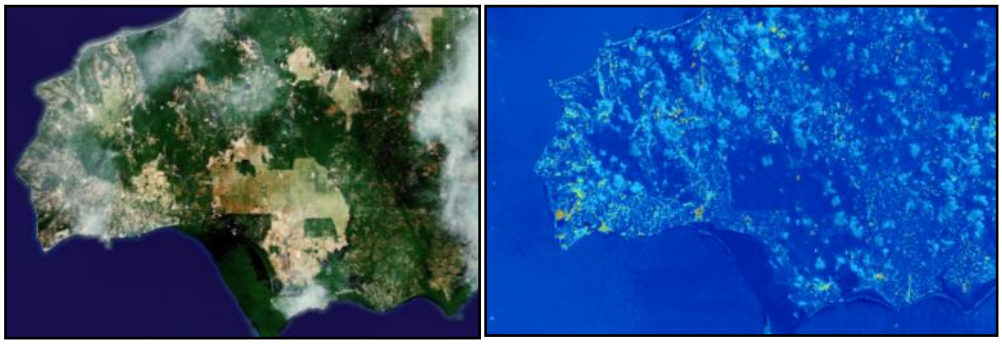

**Figure 7**. tin ore mining land in Landsat 2015 and its NDVI ((in yellow to orange)

Other geologic parameters that can be used for detection of tin ore potential is height model. This parameter can be made by integration of ALOS PALSAR with X-SAR, SRTM, and satellite altimetry.

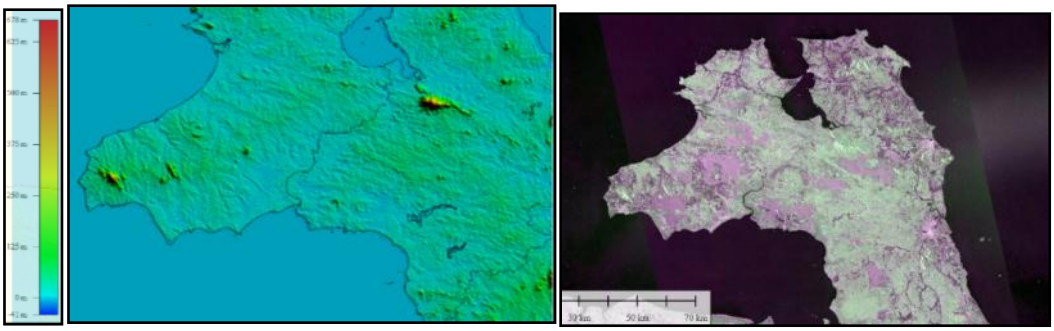

**Figure 8**. Height model integration (left) and ALOS Palsar (right)

Other geologic parameters used are gravity and geodynamics extracted from geodesy satellite (Grace, GOCE, Champ, and Swarm).

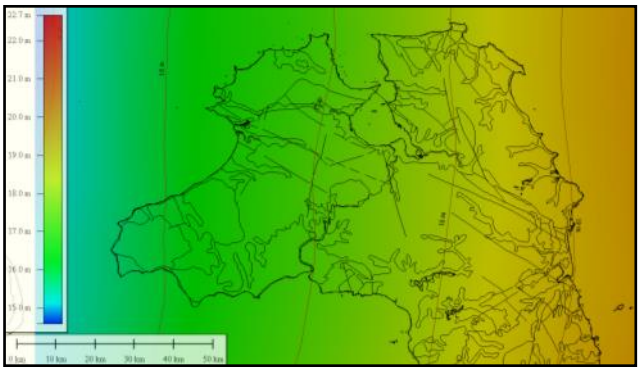

**Figure 9**. gravity and geodynamics

Geological structure can be extracted by dip and strike method. Height model integration is used for these geological structures detection.

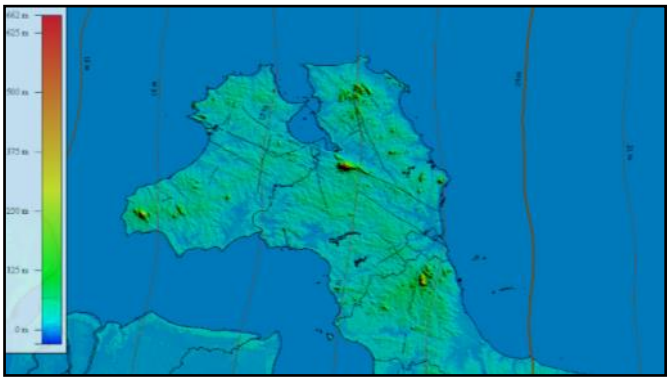

**Figure 10**. geological structure from height model integration

Then all the geological parameters need correlated each others. The result is tin ore potential. The results of rare earth element potential is known after associated with tin ore potential and waste stannary has been detected.

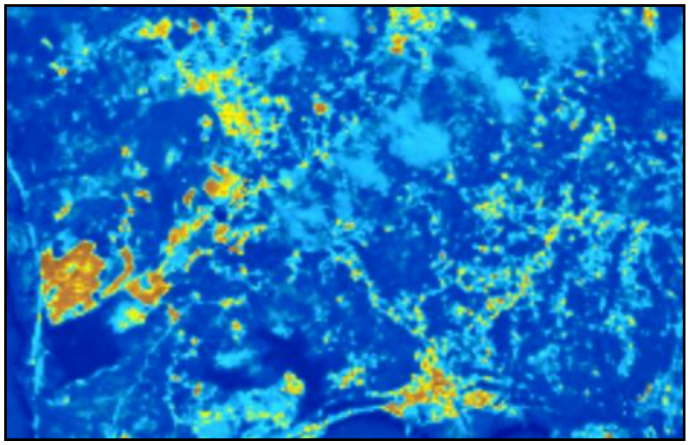

**Figure 11**. tin ore mining land and its rare earth potential (yellow to orange)

The accuracy of rare earth potential area is more than 3σ (90%). Monitoring of rare earth potential areas using remote sensing will take effective in time and low cost.

## 4. Conclusion

In this study it can be concluded that the remote sensing data can be used to identify potential rare earth. The potential of rare earth can be detected by the association to the potential of tin ore and copper potential association. Bangka Island is one area that has rare earth potential in Indonesia.

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## References

Boesche N K 2015 *Detection of Rare Earth Elements and Rare Earth Oxides with Hyperspectral Spectroscopy Near field and Spaceborne Investigations in Preparation of the EnMAP Mission* Mathematisch-Naturwissenschaftlichen Fakultät Der Universität Potsdam.

Boesche N K, Rogass C, Lubitz C, Brell M, Herrmann S, Mielke C and Kaufmann H 2015a Hyperspectral REE (Rare Earth Element) Mapping of Outcrops-Applications for Neodymium Detection*RemoteSensing***7** 5160-5186

Boesche NK, Rogass C, Mielke C, Herrmann S, Körting F K, Papenfuß Aand Altenberger U 2015b*Hyperspectral Rare Earth Element Mapping of three Outcrops at the Fen Complex, Norway: Calcitic, Dolomitic, and Ankeritic Carbonatites. In Rare Earths Industry* Technological, Economic, and Environmental Implications (1 edition) Elsevier

Boesche N K, Mielke C, Segl K,Chabrillat S, Rogass C, Thomson D, Lundeen S, Brell M and Guanter L 2016*Simulated EnMAP Satellite Data for Mountain Pass, USA*

Clark R N et al 2007 *USGS Digital Spectral Library splib06a, US Geology Survey, Denver*.

Freeden W, Nashed M Z and Sonar T 2010 *Handbook of Geomathemathic* Springer

Julien Y and Sobrino J A 2011 Temporal analysis of NDVI and LST parameters to detect changes in the Iberian land cover between 1981 and 2001 *Int J Remote Sensing***32** 2057–2068

KESDM 1999 *Kepmentamben no 1519.K/20/MPE/1999* Kementerian ESDM Jakarta

KESDM 2009 *UU Minerba No.4 tahun 2009* Kementerian ESDM Jakarta

Mariano A N and Mariano A 2012 Rare earth mining and exploration in North America*Elements***8** 369-376

Mielke C, Boesche N K, Rogass C, Kaufmann H, Gauert C and de Wit M 2014 Spaceborne Mine Waste Mineralogy Monitoring in South Africa, Applications for Modern Push-Broom Missions: Hyperion/OLI and EnMAP/Sentinel-2 *Remote Sensing***6** 6790–6816

Olson JC and Hedlund DC1981 Alkalic rocks and resources of thorium and associated elements in the Powderhorn district, Gunnison County, Colorado *U.S. Geological Survey Professional Paper* 1049-C 34p

Olson JC, Shawe D R, Pray L C and Sharp W N 1954 Rare-earth deposits of the Mountain Pass district, San Bernardino County, California*U.S. Geological Survey Professional Paper* 261 75p

Olson J C and Wallace S R 1956 Thorium and rare-earth minerals in Powderhorn district, Gunnison County, Colorado*U.S.Geological Survey Bulletin* 1027-O p 693-723

Randolph K et al 2008 Hyperspectral remote sensing of cyanobacteria in turbid productive water using optically active pigments, chlorophyll a and phycocyanin *Remote Sensing Environment***112(11)**4009–4019

Seigel 1995a *guide to high precision land gravimeter surveys*Scintrex Limited 222 Snidercroft Road Concord, Ontario, Canada

Swayze G A, Pearson N, Wilson S, Benzel W M, Clark R, Hoefen T M, Van Gosen B, Adams M and Reitman J 2013 Spectrally distinguishing between REE-bearing minerals based on differences in their crystal field f-f transition absorptions *In Geological Society of America Abstracts with Programs***45** 278

Taylor C D and Mc Cafferty A E 2014 Characterization of REE-Bearing Minerals and Synthetic Materials Using High Resolution Ultraviolet to Near-Infrared Reflectance Spectroscopy *In AGU Fall Meeting Abstracts***1** 4299

Thompson T B 1988 Geology and uranium-thorium mineral deposits of the Bokan Mountain granite complex, southeastern Alaska *Ore Geology Reviews***3**193-210

Turner D J, Rivard B and Groat L A 2014 Visible and short-wave infrared reflectance spectroscopy of REE fluorocarbonates *American Mineralogist***99** 1335-1346

Turner D J 2015 *Reflectance spectroscopy and imaging spectroscopy of rare earth element-bearing mineral and rock samples* Unpublished Ph.D Thesis University of British Columbia, Vancouver, Canada 310p

Vander Meer F D, van der Werff H M A, van Ruitenbeek F J A, Hecker C A, Bakker W H, Noomen M F and Woldai T 2012 Multi and hyperspectral geologic remote sensing: A review *International Journal of Applied Earth Observation and Geoinformation***14(1)** 112–128

# REMOTE SENSING AND GIS APPLICATIONS IN: PRECISION AGRICULTURE