APPLICATION OF SATELLITE REMOTE SENSING DATA FOR GEOLOGICAL MAPPING IN ANTARCTIC PENINSULA

Amin Beiranvand Pour, Mazlan Hashim

Geoscience and Digital Earth Centre (Geo-DEC), Research Institute for Sustainability and Environment (RISE),

Universiti Teknologi Malaysia (UTM), 81310 UTM Skudai, Johor Bahru, Malaysia
Email: beiranvand.amin80@gmail.com; mazlan.hashim@utm.my

KEY WORDS: Antarctic Peninsula (AP), Satellite remote sensing data, Geological mapping.

ABSTRACT

Remote sensing imagery is capable to provide a solution to overcome the difficulties associated with field mapping in the Antarctic. Recent generation of high resolution multi-platform satellite sensors with various spectra-spatial imagery in shortwave infrared to long wavelength thermal and radar regions of the electromagnetic spectrum could be investigated to extract geological information for Antarctic environments. The Antarctic Peninsula (AP) contains a variety of well-exposed lithologies and areas that have not been mapped. The different geological history and environmental conditions suggest that Antarctic Peninsula (AP) is one of the more likely places in Antarctica for significant base-metal deposits and possible associated gold and silver due to analogy with the Andes Mountain Range of South America. In this scientific research, the Antarctic Peninsula (AP) was selected to conduct satellite remote sensing investigations. Landsat-7 Thematic Mapper (TM), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Advanced Land Imager (ALI) data were used to extract the information in different regions of the electromagnetic spectrum. The improvised image processing algorithms and systematic GIS techniques were implemented to detect structural elements and geological features for producing detailed geological maps of the Antarctic Peninsula. The outcomes of the investigation demonstrated that new revisions of geological maps with high accuracy of the Antarctic Peninsula could be produced using recent remote sensing satellite data. The results could be extended to map coverage of non-investigated regions further east and validated previously inferred geological observations concerning other rocks and mineral deposits throughout the Antarctica.

1. INTRODUCTION

Antarctica remains a remote and logistically difficult region in which to conduct geological fieldwork, making the data collected there of significant value. This is predictable considering the size of the continent and the changing tectonic processes, environments and climates that it has experienced over geological era (Boger, 2011). Antarctica's geology is not identified in detail because of the extensive ice cover. Remote sensing imagery is capable to provide a solution to overcome the difficulties associated with field mapping in the Antarctic. Advanced optical and radar satellite imagery is the most applicable tool for mapping and identification of inaccessible and un-exposed regions in Antarctic. Remote sensing imagery has been used extensively for lithological mapping, structural analysis and mineral exploration in arid and semi-arid and tropical regions around the world (Pour and Hashim, 2011a, b, 2014 a,b, 2015 a,b). Consequently, an improved scientific research using remote sensing technology would be essential to provide new and more complete lithological and structural data to fill the numerous knowledge gaps on Antarctica's geology. The Antarctic Peninsula (AP) contains a variety of well-exposed lithologies and areas that have not been mapped directly providing an appropriate test of the use of optical and radar remote sensing data for lithological, structural and alteration mapping. There is good coverage of cloud and seasonal snow free over the Antarctic Peninsula (AP) providing a sound basis for remote sensing investigations. In this scientific research, the Antarctic Peninsula (AP) is selected to conduct geology and remote sensing investigations. The Antarctic Peninsula (AP) is the northernmost part of the continent of Antarctica, which is located approximately 650 miles of South America. The objectives of this study are (i) to delineate lithological units in exposed and un-exposed areas using advanced remote sensing data and developed image processing techniques for Antarctic Peninsula (AP) at regional scale, and (ii) to produce accurate geological structure and topographical maps for Antarctic Peninsula (AP) using remote sensing data and GIS techniques.

2. MATERIALS AND METHODS

2.1 Geology of the Antarctic

The Antarctic continent comprises three primary tectonic regions: (i) East Antarctica; (ii) West Antarctica; and (iii) the Transantarctic Mountains (Talarico and Kleinschmidt, 2009) (Fig.1). East Antarctica is thought to feature Precambrian continental lithosphere 35–45km thick, stable, coherent and topographically high, that held a central position in the Palaeozoic supercontinent of Gondwana as it did in the Mesoproterozoic supercontinent Rodinia. In contrast, West Antarctica is an amalgamation of low-lying, 20–35km thick, younger crustal blocks. The Transantarctic Mountains are approximately 2,500km long and 200km wide, dividing East Antarctica from West Antarctica with peaks that rise over 4 km above sea level. Crustal thickness estimates under the Transantarctic Mountains vary between 20 and 45km (Kanao et al., 2002; Bannister et al., 2003).

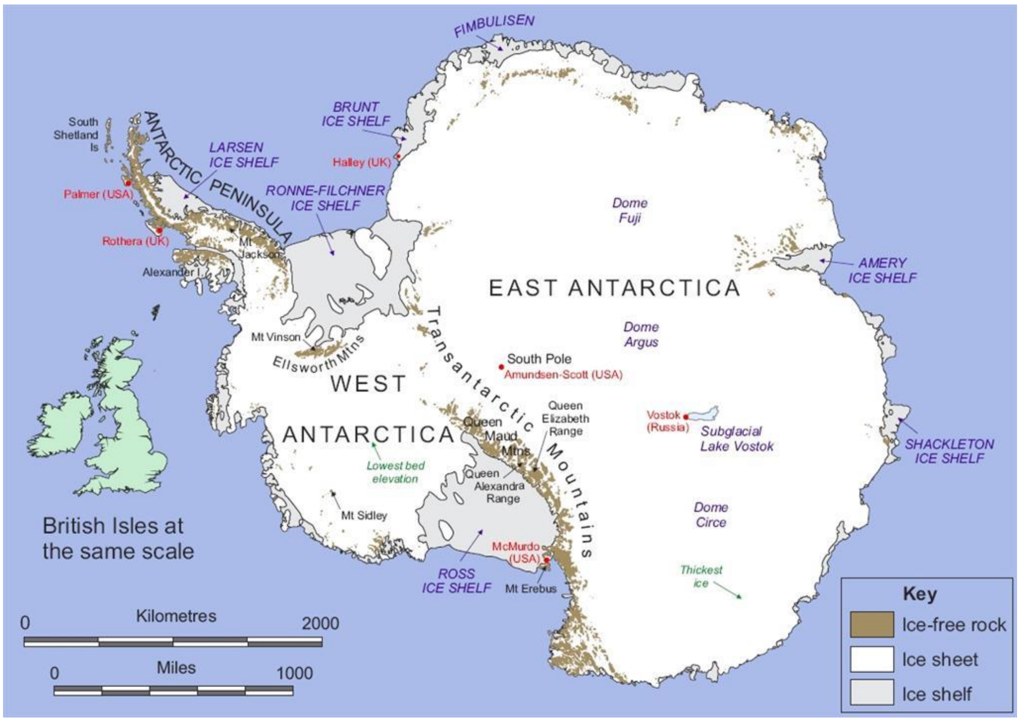

Figure 1. General geologic map of the Antarctic continent.

The Antarctic Peninsula (AP) is the most accessible region of West Antarctica, which occurred along the southeast Pacific continental margin (Yegorova et al., 2011). The AP consists of a number of large domains and is the largest tectonic block of West Antarctica (Fig. 2). The AP has been traditionally regarded as a magmatic arc formed along the palaeo-Pacific margin due to Gondwana breakup (Storey and Garret 1985). Recent geophysical and geological studies suggest that the AP is a composite magmatic arc comprising two or three separate terranes that were accreted and sutured along the Gondwana margin in the mid-Cretaceous. The two suspect terranes (the Western and Central Domains) have faulted contacts with continental Gondwana margin rocks (Eastern Domain), suggesting that any docking between the former domains and the Gondwana margin was probably dextral-oblique (Vaughan et al. 2002).

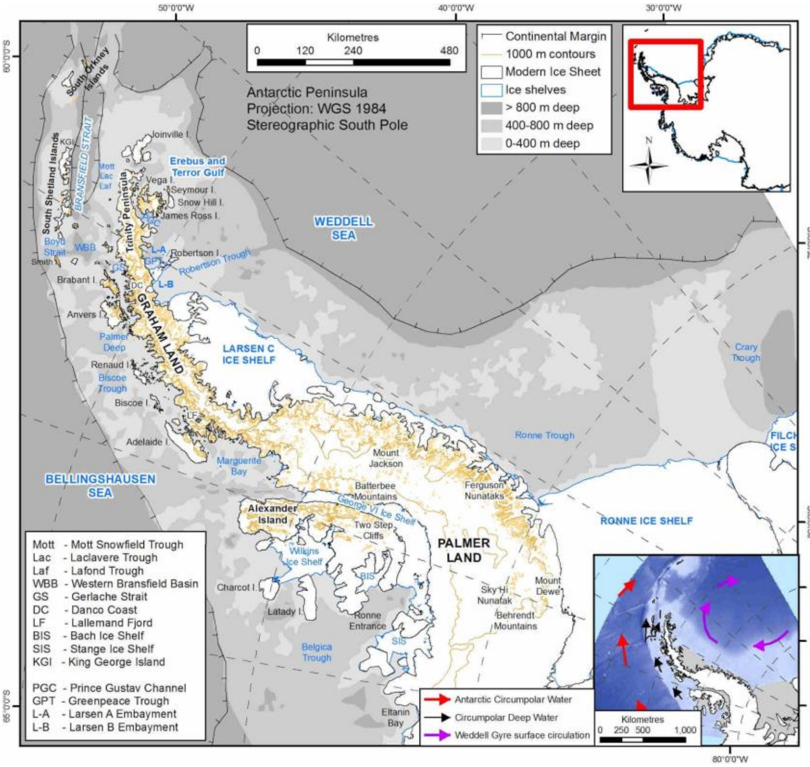

Figure 2. Geological map of the Antarctic Peninsula (AP).

2.2 Remote sensing satellite data

In this investigation, Landsat-7 Thematic Mapper (TM), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Advanced Land Imager (ALI) data was obtained from the U.S. Geological Survey's Earth Resources Observation System (EROS) Data Center (EDC). They were acquired on December to February during summer season with low cloud cover and more rock exposures for the Antarctic Peninsula (AP) and surrounding areas. The data were processed using the ENVI (Environment for Visualizing Images) version 5.2 and Arc GIS version 10.3 software packages.

2.3 Data analysis

Prior to spectral analysis of the satellite data an atmospheric correction model (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube, FLAASH) was applied to the datasets. Due to areas of snow, ice, sea and cloud in Antarctic environment, only convinced image processing tasks could be restricted to just areas of rock exposure (sunlit rock in the case of the reflective data) (Hall et al.1995). For the ASTER thermal emission data rock outcrop was discriminated using a mask produced by the threshold of band 12 of the ASTER L1B thermal radiance data. In the polar context, rock exposure is much warmer than surrounding snow, ice or sea as well as overlying cloud and is readily discriminated due to its high thermal radiance values. Spectral analysis of the calibrated VNIR/SWIR apparent surface reflectance and TIR emission data aimed to visualise and enhance the separation of the different spectral lithological classes manifested in the Landsat-7, ASTER and ALI images. This was initially undertaken using qualitative image processing procedures that included RGB (red, green, blue) composites in this study (Pour and Hashim, 2011a, b, 2014 a,b, 2015 a,b).

3. RESULTS AND DISCUSSION

Figure 3 shows merged RGB colour-composite of visible bands (1, 2 and 3) of Ladndsat TM at regional scale for West Antarctica. The RGB colour-composite reveals details about the glaciologic and geologic structures in the West Antarctica. Major geological and glaciological features are recognizable in the Ladndsat TM image such as mountain ranges and ice shelfs. The textural characteristic of mountain ranges particularly strong paralleling the flanks of the Transantarctic, Pensacola and Shackelton Mountains and extending deep into adjacent portions of the East Antarctic Plateau are distinguished in the south-western and western parts of the image. Ellsworth Mountain and associated Vinson Massif are appeared as curvilinear features with distinctive texture in the central north of West Antarctica. Ronne-Filchner Ice Shelf, Rose Ice Shelf and Larsen Ice Shelf demonstrated different textural patterns in comparison with Marie Byrd Land, Ellsworth Land, Palmer Land and Graham Land in West Antarctica and Antarctic Peninsula (AP) (Fig. 3).

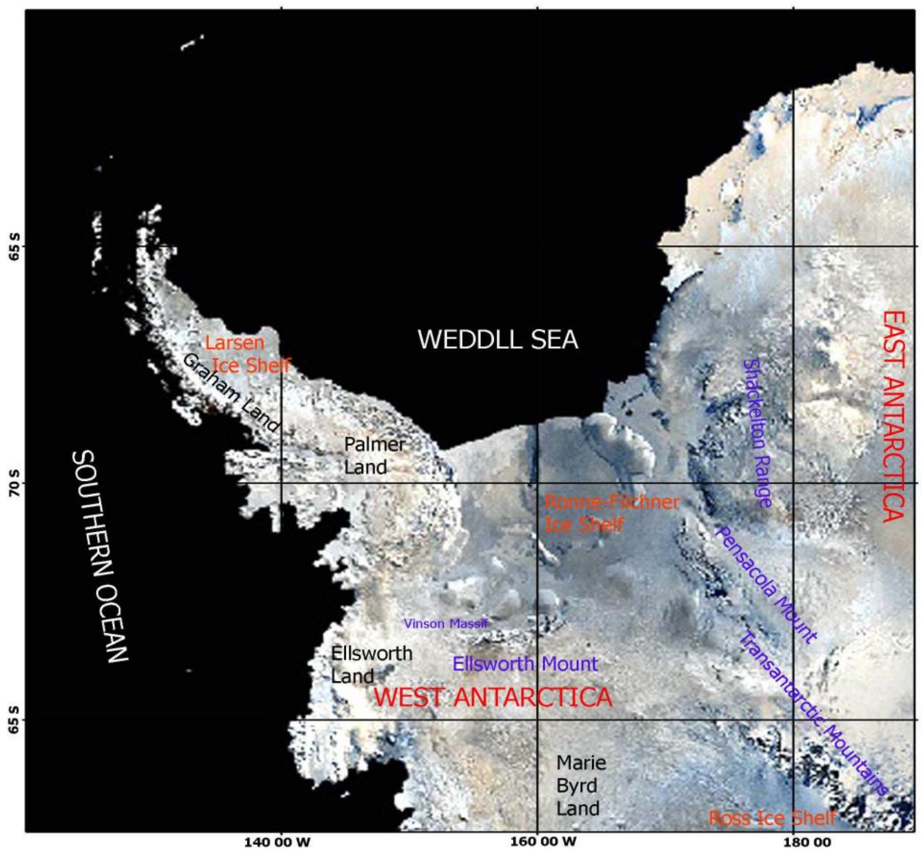

Figure 3. RGB colour combination of orthorectified Landsat 7 mosaic image of West Antarctica.

Figure 4 shows Antarctic Peninsula (AP) as merged RGB colour-composite of visible bands (1, 2 and 3) of Ladndsat TM at regional scale. Antarctic Peninsula has significant areas of exposed rock, varying surface slope and texture that are observable in Figure 4. The rocks of the Antarctic Peninsula in many ways resemble the Andes Mountains, which is dominated by volcanic and plutonic rocks. Different textural patterns are manifested associated with ice shelfs and rocky land background. Larsen Ice Shelf and other ice shelfs (George Vi and Wilkins) with smooth to semi-smooth feature are easily recognizable from rough pattern of rocky land background in the image. Palmer Land , Graham Land, Trinity Peninsula and several islands such as South Okrney Islands, South Shetland Islands, Anvers Island, Adelaide Island and Alexander Island have rocky background features (Fig.4). Most copper occurrences in Antarctica have been found in the Antarctic Peninsula and on islands off the coast of the Peninsula. The most promising copper occurrences are on islands off the west coast of the Peninsula and are associated with the youngest intrusions of the Andean belt. Economically promising deposits, if any are found in this region, would likely be of the type found in porphyritic igneous rock and may be associated with possible vein deposits. Veins containing a variety of metals are found throughout the Antarctic Peninsula. Extensive products of mineralization on King George Island, including pyrite, hydrothermally altered rock, and large veins have led some investigators to speculate that there maybe a porphyry-type copper deposit at depth on King George Island. The hydrothermally altered rocks containing mineralization are interpreted as representing the upper or near-surface portion of a large intrusive body. In addition, the pyrite contains anomalously high copper and cobalt values, suggesting that the intrusive body may be rich in copper. Others, however, do not find the evidence for an underlying porphyry copper deposit compelling, and they suggest that the observed minerals represent normal separation during solidification of an intrusive body of this sort. Other copper occurrences have been reported in the South Shetland Islands. Two localities on Livingston Island contain copper associated with igneous intrusive bodies. In one place, the copper minerals may represent the remains of a deeply eroded copper-molybdenum porphyry deposit. Vein and porphyry-type alteration and mineralization took place on a number of other islands and coastal locations throughout the region. Copper occurrences are found in about 30 places along the east coast of the Antarctic Peninsula. Low grade porphyry copper and vein deposits also are found in the southern part of the Peninsula. Three locations, in particular, contain porphyry copper mineralization. In view of the relative abundance of copper resources, there would appear to be little economic incentive to extract copper from Antarctica, given the added costs of operating in such an environment, unless it were an exceedingly rich and accessible deposit (Cox et al.,1980).

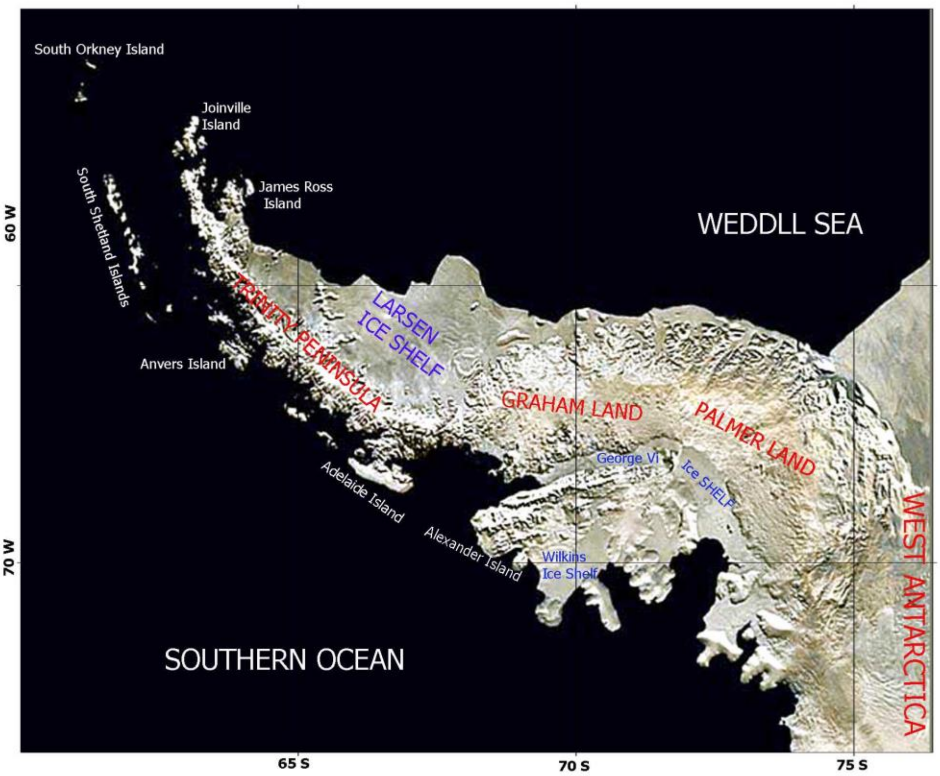

Figure 4. RGB colour combination of Landsat 7 mosaic image for Antarctic Peninsula (AP).

Figure 5 shows RGB colour composite of bands 12, 13 and 14 of ASTER for southern part of South Shetland Islands. Livinstone island, greenwhich island and southern part of King George island are observable in figure 5. Rock exposures are appeared as dark pixels. They are volcanic rocks and tectonically folded to broad syncline. NE-SW and NW-SE and NW-SE orientation could be seen associated with Andean intrusions. They are apparently controlled by regional NE-SW and NW-SE structures. It seems that there is DN value differences between basic (diorite) to acidic (granodiorite) in the main land of the islands. SWIR bands of ALI data were assigned to RGB colour composite in this study. Figure 6 shows RGB colour composite of bands 7, 8 and 9 of ALI data for southern part of South Shetland Islands. Rock exposures are manifested as purple pixels southern part of King George island and northern sector of Livinstone island and greenwhich island. It is seems that most of the detected pixels are hydrothermal alteration rocks, which has been documented by Cox et al. (1980). However, detected areas occupied very small sector of main land of the islands.

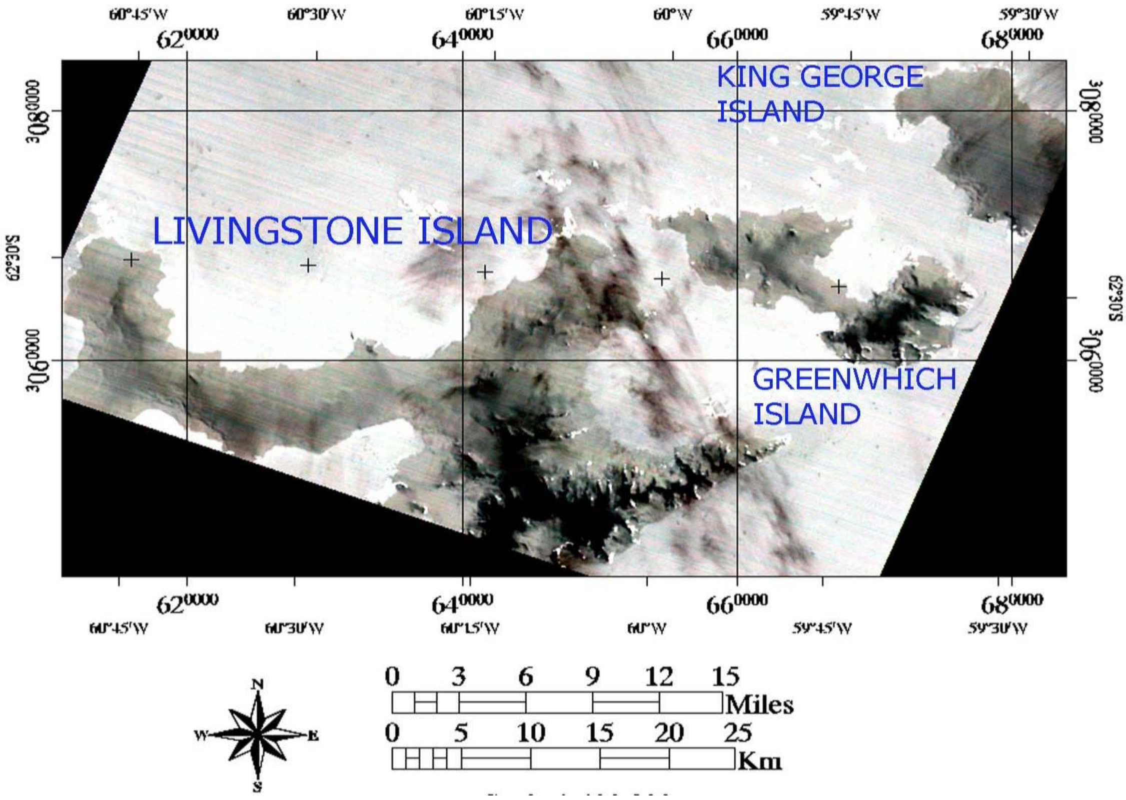

Figure 5. RGB colour composite of bands 12, 13 and 14 of ASTER for southern part of South Shetland Islands.

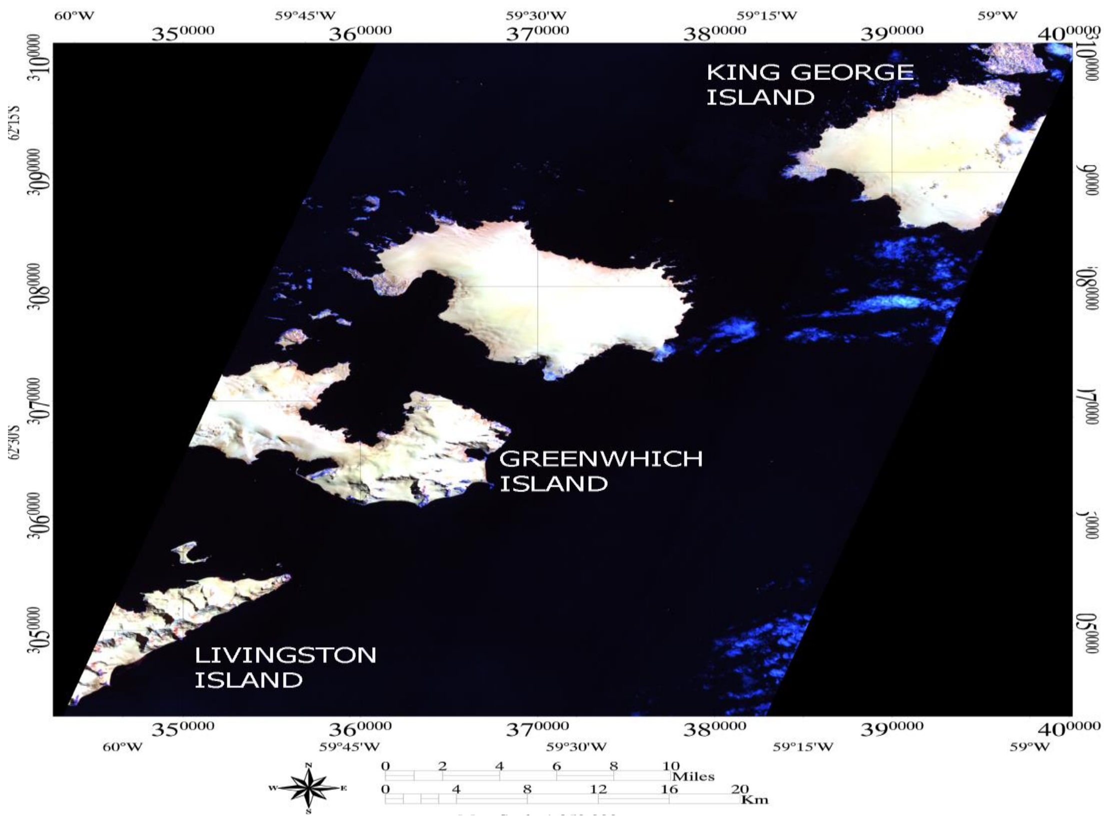

Figure 6. RGB colour composite of bands 7, 8 and 9 of ALI for southern part of South Shetland Islands.

4. CONCLUSIONS

Results of this investigation indicate that using satellite data for geological mapping could be a successful advanced technology in Antarctic environments. Novel model for geological mapping and mineral exploration in Antarctic using satellite remote sensing technology could be developed. Non-investigated and inaccessible regions in Antarctic can be mapped and identified using different bands of satellite remote sensing data with various spectra-spatial imagery in shortwave infrared to long wavelength thermal and radar regions of the electromagnetic spectrum.

ACKNOWDEGMENT

This study was conducted as a part of Yayasan Penyelidikan Antartika Sultan Mizan (YPASM) research grant (Vote no: R.J130000.7309.4B221), Sultan Mizan Antarctic Research Foundation, Malaysia. We are thankful to the Universiti Teknologi Malaysia for providing the facilities for this investigation.

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