Twenty Fourth Indian Antarctic Expedition 2003-2005
Ministry of Earth Sciences, Technical Publication No. 22, pp 187-197

Geochemical Study of Weathered Gneiss Rock from Schirmacher Oasis, Antarctica

Baba Musta and Sanudin Hj. Tahir

Programme of Geology,
School of Science& Technology
Universiti Malaysia Sabah
88999, Kota Kinabalu, SABAH

ABSTRACT

Five weathered gneiss rock profiles from Schirmacher Oasis, Antarctica were collected in order to study the geochemical behaviour of weathered gneiss rock. The field observation and hand specimens of rocks show the chemical weathering occurred on the surface as indicated by thin layer formation with brownish colour. The petrographic study shows the rock forming minerals were altered to secondary minerals. All mafic minerals such as garnet, biotite and, chlorite altered to iron oxide, whereas feldspar has changed to sericite. The Scanning Electron Micrographs (SEM) shows the formation of iron oxide and sericite mostly at the edge and cleavages. The X-ray fluorescence analysis (XRF) show that the concentration of Al_2O_3 and Fe_2O_3 in weathered rocks is higher compared to the fresh rock. This indicates the increasing of the concentration with the weathering processes. In contrast, SiO_2 decreases due to the leaching processes. Most of the base element such as MgO, CaO, NaO are maintained or slightly increased with the weathering. However, K_2O is immediate decreased due to the decomposition of Kfeldspar. The abundance of TiO_2, K_2O and P_2O_5 is less than 1.00% in the fresh rock samples, but it also shows the concentration that is slightly increased in the weathered rocks.

Keywords : Gneiss, Chemical weathering, Major element.

INTRODUCTION

The study area is situated between 70°4.5'S to 70°46.5' S and 11°32.4' E to 11°32.5' E in Schirmacher Oasis, Antarctica **(Figure 1)**. The area is located between the polar ice continental in the south and ice self in the north. The morphology is dominated by hilly area, tilloid deposit, and melting lakes. The longer exposure to the glacier condition at higher elevations also could modify the landscape patterns (Sugden et al., 2005).

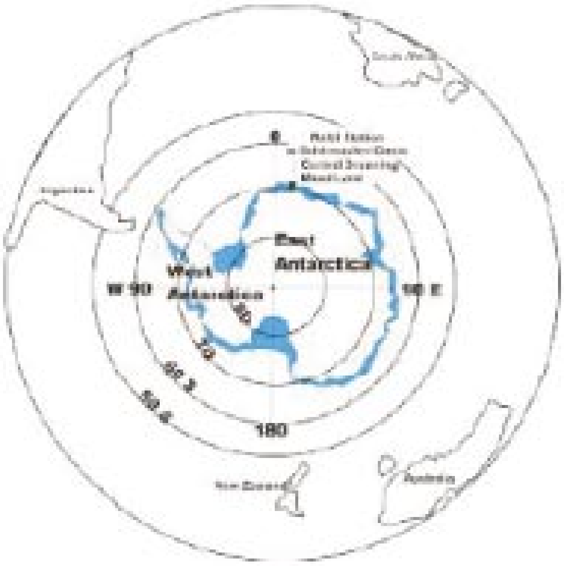

Fig. 1 : Map of the Antarctica showing the location of Maitri Station, in Schirmacher Oasis, East Antarctica, Antarctica

A **B**

Fig. 2 : The morphologic pattern of Schirmacher Oasis, showing (A) melting lakes in summer season and (B) the hilly area

The hilly area shows brownish colour and surrounded with tilloid deposit. The moraine is deposited in the lakes and lowland areas.

The objective of this research is to identify the distribution of gneiss rocks around Maitri Station. Secondly is to record the mineralogical changes and mineralogical development in the gneiss rock weathering profiles. Finally to analyse the concentration of major elements such as SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, NaO , TiO_2, K_2O MnO and P_2O_5 from selected weathering profiles of gneiss rocks.

MATERIALS AND METHODS

This research is incorporated of fieldwork and laboratory works. The purpose of fieldworks is to identify the distribution of rocks in the study area. In the field, measuring the characteristics of rock weathering are also conducting such as the colour, structure, and the relative hardness. The fieldwork also enabled sampling five weathered rocks for the laboratory analysis. Five profiles of weathered gneiss rock were also observed from outcrops. All the profiles exposed fresh rocks and the weathered materials. In laboratory, all fresh sample and weathered samples were analysed using X-Ray Fluorescence (XRF). X-ray fluorescence (XRF) technique was used to quantify the concentration of major elements. Major elements were analysed using fused disc. XRF technique uses Philips PW 1480 X-ray Digital Instrument and spectrometer is controlled by Digital Software X-44 Microcomputer. Scanning Electron Microscope (SEM) and petrographic study were performed for the identification of secondary minerals and the development of micro fabrics.

RESULT AND DISCUSSIONS

Geological background

The geology of Schirmacher Oasis, Antarctica mostly consists of gneiss rock and igneous intrusions **(Fig. 3)**. Geological Survey of India (1998) classified the gneisses rocks to quartzofelspathic augen gneiss (±garnet), Quartzofelspathic streaky gneiss, augen layers in quartzofelspathic gneiss, garnet rich biotite quartzofelspathic gneiss, quarz-garnet-sillimanit-perthit (±graphite) gneiss. Rao et al. (1995) divided the gneisses from Schirmacher oasis region into three types namely garnet-biotite gneiss, augen gneiss and leucogneiss. Petrographic analysis by D'Souza et al. (1995) showed that the typical assemblage of minerals in quatzofeldsphathic gneiss are quartz – K-Feldspar – plagioklast – biotite – hornblend. Whereas, biotite gneiss rocks consist of quartz – K Feldspar – plagioklast – garnet – biotite minerals. **(Fig. 4)** shows the hand specimen of gneiss rock from study area as indicated by augen textures **(Fig. 4A)** and lineations alignment of minerals **(Fig. 4B)**. Rb/Sr age data of the garnet biotite gneiss and leucogneiss indicate a Late Proterozoic age (Rao et al., 1995). Verma et al. (1987) determined the ages of quarzofelspathic gneisses in the range of Early Paleozoik – Late Proterozoic.

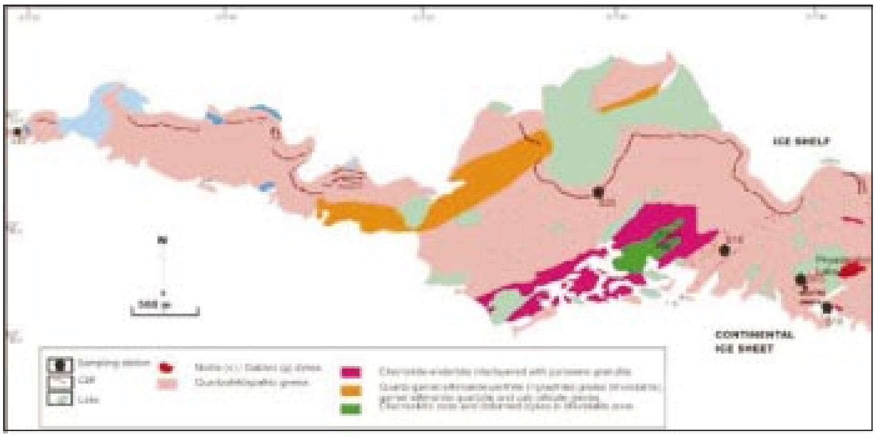

Fig. 3 : Map of the study area showing the rock distribution and the sampling station in Maitri, Schirmacher Oasis, Antarctica

A **B**

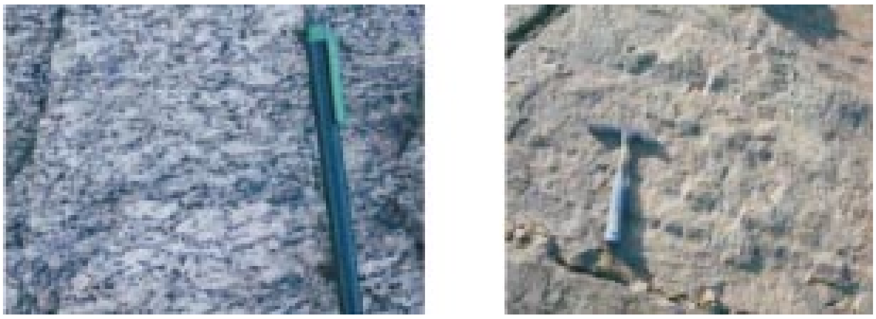

Fig. 4 : Hand specimen of gneiss rock shows the coarse grain and lineation alignment of feldspar, quartz, biotite and garnet

Field work observation

Field work observations were carried out around the Maitri Station, which is the permanent Indian Station in East Antarctica and also at the western part of Schimarcher Oasis. The location of field observation and sampling station are shown in (Fig. 1). In this area, as a polar region mechanical weathering is the primary process forms the landscape and topographic development. However, chemical processes and running water also play important roles in the rock breakdown and mineral decomposition **(Fig. 5)**. The highest temperature up to 10.3°C was recorded on 28 December 1991. Furthermore, data from the Indian Meteorological Department indicates that the area has a mean annual temperature in the summer season between -5°C to 5°C (Sharma, 1995). During the expedition in 2005, the

A **B** **C** **D**

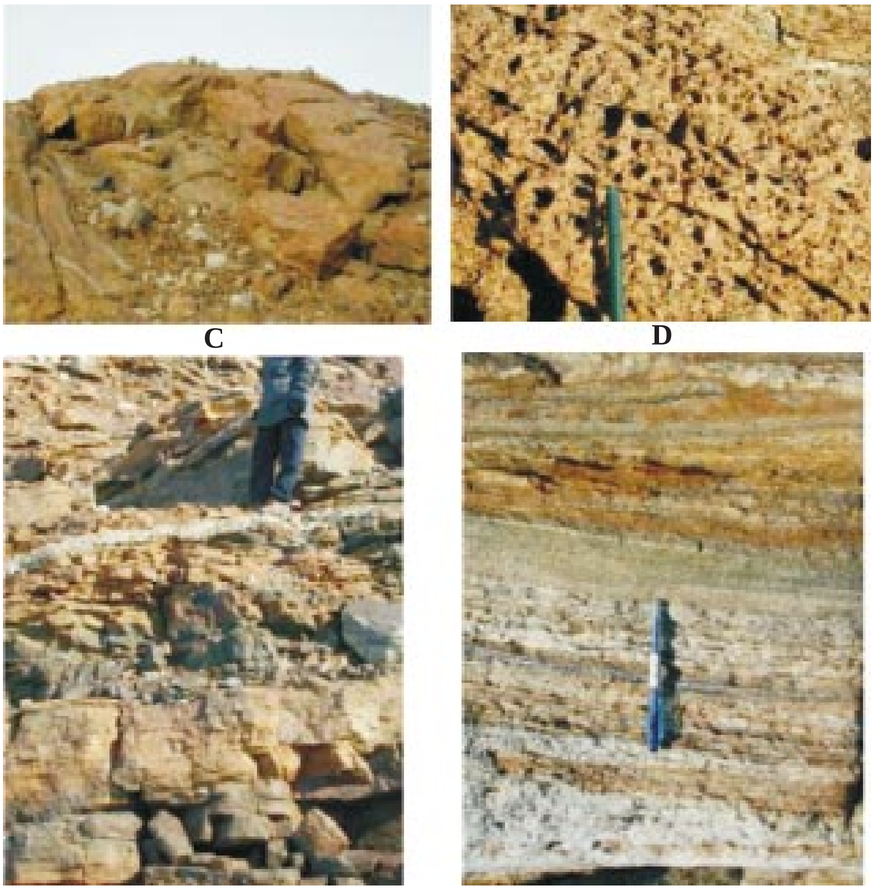

Fig. 5 : The panorama of weathering profile showing the chemical weathering of gneiss rocks (A & B). Minerals are segregated into bands and lineation. This features mostly contributed to the weathering processes minerals (C & D)

data from Indian Meteorological Department recorded that the temperature increased up to 5°C in the summer season (December–February). According to Carroll (1970) the speed of chemical reactions approximately doubles for each rise of 10°C. In this season the rock outcrops expose to the chemical weathering due to the melting of glacier. Rock vary in the mineralogy and structure, therefore the decomposed of rocks depends on the type of rocks. Gneiss rock has minerals which is low resistant and high resistant with the weathering processes therefore the rock showing varies of chemical decomposition. The variations of mineral decomposition from the field work observation are shown in **(Fig 5B)**.

The field observations show the oxidation processes is occurred mostly on the surface, joints, and edge of lineation **(Fig. 6)**. The typical weathering profiles of gneisses rock mostly consists of the moderately weathered or oxidized horizon, slightly weathered or little weathered chemically changes and fresh gneiss rock **(Fig. 7)**. The thickness of moderately weathered is varies from 1mm – 2mm, whereas the slightly weathered from 5mm – 10 mm.

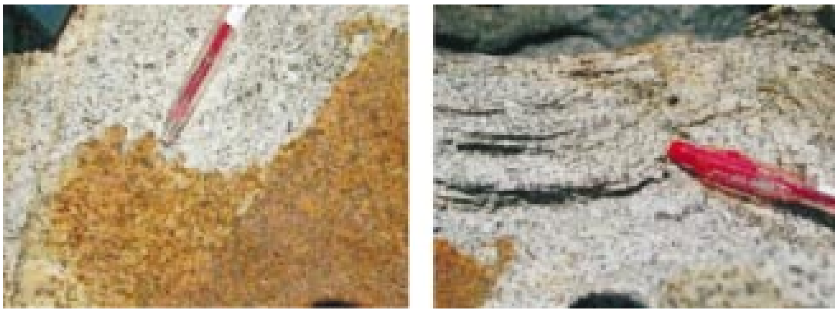

Fig. 6 : The oxidation process and ex-foliation on the gneiss rocks in Maitri Station East Amtarctoca

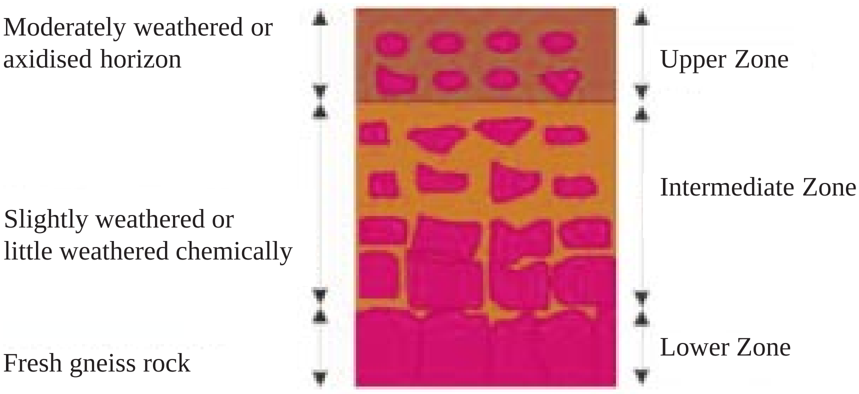

Fig. 7 : Schematic of typical weathering profile of gneiss rocks in Maitri Station, Antarctica

Petrography and mineralogy studies

Petrography and mineralogy study were carried out using polarizing microscope. Observations from the thin sections show the alteration of biotite into chlorite and iron oxide **(Fig. 8)**. This is due to the oxidation processes, which is an active chemical process when the rock exposed to the air. The much contains of biotite produced the most reddish of rock on

A **B**

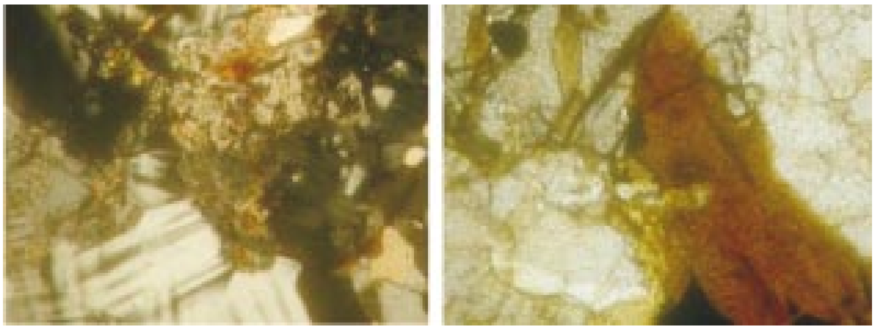

Fig. 8 : (A) Microphotograph of gneiss rock showing the alteration of biotite into iron oxide under plane polarized light (B) microphotograph under cross polarized light. The black dotted in the lower right hand side shows the formation of iron oxide

the surfaces. This is due to the oxidation and leaching of iron from the internal to the surface of the rock (Matsuoka, 1995).

Garnet as an index mineral is most common in gniesses rock. Garnet also contributed to the increasing of iron oxide in the weathered samples. The iron-magnesium garnet chemically weathered and produced iron oxide **(Fig. 9A)**. The microphotograph shows the formation of iron oxide at the edges of garnet crystal as indicated by the dark colour **(Fig. 9B)**.

Feldspar occurs in most metamorphic rocks. It is well defined by its cleavage characteristics, especially in the plagioclase feldspar (Mackenzie & Guilford, 1988) and perthite feldspar and this allows rapid penetration by water, enabling rapid alteration. Microphotograph shows phenocrysts

A **B**

Fig. 9 : Microphotograph of gneiss rock showing the alteration of garnet into iron oxide (A) under plane polarized light (B) under cross polarized light

A **B**

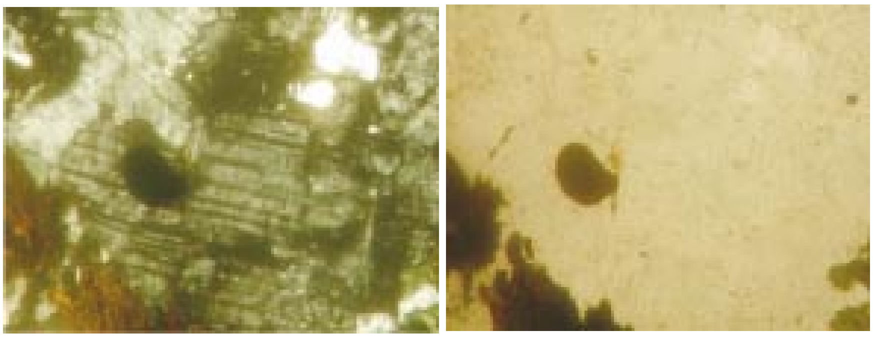

Fig. 10 : Microphotograph of gneiss rock showing (A) the alteration of feldspar into sericite under plane polarized light (B) the cleavage in feldspar provided space for the chemical reaction, photo under cross polarized light

of plagioclase. Very fine sericite at the edges of the crystals is a alteration products. **(Fig. 10)**. Normally, feldspar was altered to sericite before forming clay minerals.

Micro fabrics studies

Scanning electron microscope (SEM) was used in order to study the micro fabrics changes of weathered gneisses rock. The micro fabric of garnet are shown in **(Fig. 11)**. It is illustrated that most of the chemical reaction occurred in the edges as well as the micro fissures of garnet **(Fig. 11A)**. The alteration of garnet to form oxide minerals are clearly shown at the **(Fig. 11B)**.

A **B**

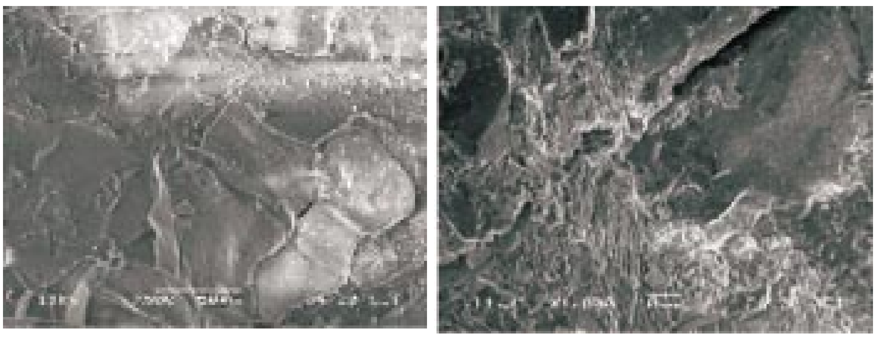

Fig. 11 : Scanning electron microphotographs showing the micro structure of garnet in weathered gneiss rocks (A) micro fabrics of garnet show the edges (B) decomposition of garnet to form iron oxide

Feldspar is among the abundances rock forming minerals is quartzofeldspathic gneiss rocks. The decomposition of feldspar due to the hydrolysis processes are shown in **Fig. 12**. Refer to the microphotographs, it is shown that the cleaveges of feldspar was attacked by water and form sericite minerals. The sericite then will decomposed further to form clay minerals such as kaolinite.

Fig. 12 : Scanning electron microphotographs showing the micro structure of feldspar in weathered gneiss rocks with resolution of (A) 500 X and (B) 1000 X

The chemical characteristics

The concentration of major elements in fresh gneiss rocks and weathered gneiss rocks as analysed using XRF is given in **Table 1**. The fresh gneiss rocks in the study area are composed of about :62.12%-77.67% SiO_2, 13.74%-16.84% Al_2O_3, 3.41%-9.32% Fe_2O_3, 1.15%-1.46% MgO, 2.50%-3.79% CaO, 2.48%-2.69% Na_2O, 2.17%-4.26% K_2O, 0.06%-0.11% MnO and below detection limit (bdl)-0.46% of P_2O_5. Refer to **Table 1**, in general, it is found that SiO_2 decreases as weathering increases. This is due to the leached of the elements from the silicate minerals during the chemical weathering. Most of the oxide base element such as MgO, CaO, NaO are maintained or slightly increased with the weathering process except K_2O which is immediately decreased due to the alteration of K-feldspar.

The low concentrations of MnO and P_2O_5 in all samples either because these elements were leached from the system during the weathering processes or their amount in the provenance rocks were originally low. This indicated that the less resistant feldspar minerals such as K-feldspar will decompose faster compared to the Ca-feldspar and Nafeldspar. The abundance of TiO_2 is less than 1.50% in the fresh rock samples, but it also shows the concentration that is slightly increased in the weathered rocks.

Table 1—The abundances of major elements in fresh gneiss rocks (F) and weathered gneiss rocks (W)

Major. E (%)	Gn3F	Gn3W	Gn10F	Gn10W	Gn16F	Gn16W	Gn23F	Gn23W	Gn25F	Gn25W
SiO_2	68.21	63.76	63.81	65.61	68.62	65.36	73.67	73.05	62.12	60.42
TiO_2	0.65	1.31	1.12	0.75	0.60	1.29	0.40	0.31	1.21	1.42
Al_2O3	13.74	15.22	16.64	17.26	13.75	15.19	10.84	14.64	16.84	16.74
Fe_2O_3	4.85	9.03	6.68	5.86	6.07	8.83	3.41	5.41	9.32	11.72
MnO	0.06	0.09	0.06	0.05	0.08	0.09	0.06	0.05	0.11	0.16
MgO	1.15	1.22	1.30	0.71	1.15	1.74	1.18	1.21	1.46	1.98
CaO	3.43	1.84	2.98	3.06	2.84	1.96	2.50	0.79	3.79	3.63
Na_2O	3.24	2.64	3.63	3.21	2.48	1.48	2.51	2.10	2.69	2.58
K_2O	4.26	3.64	3.00	2.87	4.10	2.66	5.41	1.97	2.17	0.87
P_2O_5	0.22	0.46	0.46	0.26	0.22	0.38	bdl	0.08	0.27	0.33
L.O.I	0.20	0.79	0.33	0.37	0.10	1.01	0.02	0.39	0.03	0.14
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* bdl : below detection limit

Based on the geochemical data, it is shown that the concentration of both Al_2O_3 and Fe_2O_3 increased with the weathering processes This is related to the formation of secondary minerals. The abundance of Fe_2O_3 is contributed by the development of iron oxides. Whereas, Al_2O_3 is the contribution of sericite minerals.

CONCLUSION

The geology of Schirmacher Oasis, Antarctica mostly consists of gneiss rock. The rock varies in the mineralogy and textures, therefore the decomposition is different among the type of mineral. The field observation and hand specimens of rocks show the chemical weathering occurred on the surface as indicated by thin layer formation with brownish colour.

The petrographic study shows the rock forming minerals were altered to secondary minerals. All mafic minerals were altered to iron oxide, whereas feldspar has changed to sericite. The Scanning Electron Micrographs (SEM) shows the formation of iron oxide and sericite mostly at the edge and cleavages of biotite and garnet.

The geochemical analysis demonstrated that the concentration of Al_2O_3 and Fe_2O_3 in weathered rocks is increased compared to the fresh rock. SiO_2 decreases due to the leaching processes. Most of the base element such as

MgO, CaO, NaO are maintained or slightly increased with the weathering. However, K_2O is immediate decreased due to the decomposition of K-feldspar. The abundance of TiO_2, K_2O and P_2O_5 is less than 1.00% in the fresh rock samples, but it also shows the concentration that is slightly increased in the weathered rocks.

ACKNOWLEDGEMENT

The authors would like to thanks the Academy Science of Malaysia (ASM) and Universiti Malaysia Sabah (UMS) for the financial support and arranged the scientific expedition to Antarctica. Thanks to National Centre of Antarctica and Ocean Research, Goa India for the support and cooperation. The XRF analysis was carried out at Geology Department, Faculty of Science and Technology, Universiti Kebangsaan Malaysia and SEM was conducted at Tropical Biology and Conservation Research Instutite, Universiti Malaysia Sabah.

REFERENCES

1. Carroll, D. 1970. *Rock Weathering*. Plenum Press, New York.
2. D'Saouza, M. J, Beg. M. J, Ravindra, R C, Haturvedi, A and Kaul, M. K. Geology of Skeids Area, Humboldt Maountains, Wohlthat Range Central Dronning Maud Land, East Antarctica. *Tenth Indian Expedition to Antarctica, Scientific Report*. No. 8: 107-136.
3. GSI, 1989. Geological Map of Schirmacher Oasis, East Antarctica. *Geological Survey of India,* Faridabad.
4. Mackenzie, W. S & Guilford, C. 1988. *Atlas of Rock-Forming Minerals in Thin Section*. Longman Scientific. London.
5. Matsuoka, N. 1995. Rock weathering processes and landform development in the SØr Rondane Mountains, Antarctica. *Geomorphology*, 12: 323-339
6. Rao, P. R, Ramana Rao, A. V, and Poornachandra Rao, G. V. S, 1995. Geological, Geochemical, Geochronological and Palaeomagnetic Studies on the Rocks from Parts of East Antarctica. *Tenth Indian Expedition to Antarctica, Scientific Report*. No. 8: 97-106.
7. Sharma, 1995. R.K. Report on Meteorological Programme During Summer Period of Tenth Indian Expedition to Antarctica. *Tenth Indian Expedition to Antarctica, Scientific Report*. No. 8: 55-70.
8. Sugden, D. E, Balco, G. Cowdery, S. G, Stone, J. O. and Sass III, L. C. 2005. Selective glacial erosion and weathering zones in the coastal maountains of Marie Bryd Land, Antarctica. *Geomorphology*, 67: 317-334.
9. Verma, S.K, Mittal, G. S. and Dayal, A. M. 1987. *Technical Publication No. 4. Department of Ocean Developmen*t, New Delhi: 43-54.

A Geochemical Evaluation of Metamorphic Rocks from Schirmacher Oasis East Antarctica: Implications of a MORB Source. Narasimman S. 1.Â Figure 1: Area of study and sample location, Schirmacher Oasis, east Antarctica. Figure 2: Normalization of concentrations of elements to those in the primitive mantle. J Geol Geophys, Vol. 10 Iss.Â These rock sequences include augen gneiss, biotite gneiss, pyroxene granulites, amphibolites, calc-silicates, dolorites, basalts, vein quartz, and pegmatites [9]. Hereby, the banded gneiss is the dominant rock type, where compositional variations in such rocks reflect the non-uniformity of the present metamorphic sequence, which has suffered superposed folding. Materials and methods. Geochronological and isotope-geochemical studies of KSDB rocks suggest the following sequence of events. The gneiss protoliths are estimated to be 2950-2850 Ma old; the emplacement of gabbro intrusions and the formation of ATPC granitoids took place 2835-2832 Ma ago. Pegmatites. Inset shows the tectonic division of the Kola subprovince. 14 - nepheline syenite intrusions, 15 - Caledonian nappes and Late Proterozoic sedimentary rocks, 16 - Early Proterozoic fold belts (Pe - Pechenga, Im-Var - Imandra-Varzuga, Lap - Lapland granulite), 17 - Late Archaean fold belts (01 - Olenegorsk, K-V - Kolmozero-Voronja), 18 - blocks of Archaean basement (Mur - Murmansk, Ko-Nor - Kola-Norwegian, Bel - Belomorian, Ter - Tersky, In - Inari, Ke - Keivy), 19 - sampling sites Gneisses The gneisses in the study area are medium grained, foliated, with bands of light and dark minerals. The light bands consist of felsic minerals, quartz and feldspars, while the dark bands are made up of mafic mineral, biotite. In hand specimen, the rock consists of quartz, feldspar and biotite.Â The minerals within the rocks are noted by their differences in colour. The proportion of the basalts to the host rock is seen to have varied in the study area. REE geochemistry of eclogites and associated rocks from Sauviat-sur-Vige, Massif Central franÃ§ais. Lithos 14, 263â€"74.CrossRef Google Scholar. Bernard-Griffiths, J., Peuchat, J. J., Cornichet, J., Ponce de Leon, M. I., & Gil Ibarguchi, J. I., 1985.Â Petrology and Geochemical Variations within the Tall Y Fan Intrusion: a Study of Element Mobility During Low-Grade Metamorphism with Implications for Petrotectonic and Modelling. Journal of Petrology 27, 1409â€"36.CrossRef Google Scholar. Meschede, M., 1986.Â Middle Jurassic within-plate granites in West Antarctica and their bearing on the break-up of Gondwanaland. Journal of the Geological Society, London 145, 959â€"1007.CrossRef Google Scholar. Stosch, H. G., & Lugmair, G. W., 1990. Keywords: Lakes of Antarctica, Geochemical studies, Geophysical studies, Review. Introduction In order to facilitate any future geochemical and geophysical study, it is important to collate and evaluate published literature on geochemistry and geophysics. So far, no significant detail review has been carried out on geochemical and geophysical studies in Antarctic lakes. Accordingly, an attempt has been made to provide an account of geochemical and geophysical studies exclusively carried out till date, in Antarctic lakes. The main objectives of the present paper are: (1) To prepare a bibliography of the geochemical and geophysical studies in Antarctic lakes. (2) To highlight the major contribution of different studies.