doi: 10.13679/j.advps.2018.2.00144 June 2018 Vol. 29 No. 2: 144-149

Preliminary investigation of rubidium distribution in the Grove Mountains area, East Antarctica

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Received 31 October 2017; accepted 28 March 2018

Abstract We analyzed rock samples from the Grove Mountains in Antarctica to determine the distribution of rubidium (Rb) in that location. We collected samples from the Black Nunataks, Melvoldt Nunataks, Mason Peaks, Zakharoff Ridge, Mount Harding, and the northern Gale Escarpment. Geochemical analysis indicated that in some samples the amount of Rb was higher than 300 ppm. This suggests that rocks from the Grove Mountains are rich in Rb. Based on field observations and previous research, we speculate that mica and potash feldspar from moyite, granite gneiss, and felsic pegmatite are the primary carrier minerals of Rb. However, further research is necessary to confirm this speculation.

Keywords **Rb distribution, carrier minerals, Grove Mountains, East Antarctica**

Citation: Li Y, Huang F X. Preliminary investigation of rubidium distribution in the Grove Mountains area, East Antarctica. Adv Polar Sci, 2018, 29 (2): 144-149, doi:10.13679/j.advps.2018.2.00144

1 Introduction

Rare metals, rare earth metals, and rare dissipated metals are the functional and structural materials described in the Chinese "Twelfth Five-Year Plan" as a means to initiate and develop strategic emerging industries in China (Sun et al. 2013). Rubidium (Rb) is a metal used widely in military, science, and technological applications. The unique physical properties of Rb make it non-substitutable in many applications. Previously, Rb was used primarily in electronic components, catalysts, special forms of glass, and medicine. Now, however, it is gaining wider use in highly technical fields, such as thermal ion research, magnetohydrodynamic power generation, laser conversion of electric energy, and ion propulsion rocketry (Liu et al., 2015; Sun et al., 2013).

Previous research has shown that small deposits of Rb exist on all seven continents. Rb deposits are mainly found in Canada, United States, Zimbabwe, Namibia, Brazil, Mozambique, Russia, Germany, Portugal, France, Jordan, and Australia. However, there has been little research on the distribution of Rb in Antarctica. Supported by the Chinese Polar Environmental Comprehensive Investigation and Assessment Programs (known simply as the China Polar Program), we previously conducted a geochemical survey on the Grove Mountains area in Antarctica. We found Rb-rich rocks in the Grove Mountains and around the Zhongshan Station in the Larsemann Hills (Li et al., 2017a, 2017b). The Rb content in some samples was up to 0.1%, suggesting the area maybe contain large Rb deposit. Because of the results of our previous study, we conducted a systematic sample analysis of the southeastern Grove Mountains area. This was done to investigate the distribution of Rb in the Grove Mountains. Our investigation of Rb deposits did not consider methods for the development of this resource, or any environmental protections that would be necessary before exploitation of the resource could begin.

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2 Geographical location and geology of the Grove Mountains

The Grove Mountains are located on the right bank of the Lambert Rift in East Antarctica, between 72°20′–73°10′S and 73°50′–75°40′E. The Grove Mountains are part of the nunataks of the east Antarctic ice sheet, which are one of the most important geological features of the Prydz Belt. The Grove Mountains are an area in Antarctica where geological research has been conducted mainly by Chinese scientists (Liu et al., 2013; Liu et al., 2002).

The outcrops of high-grade metamorphic rocks in the Grove Mountains are primarily felsic orthogneiss, but also include small amounts of mafic granulite, paragneiss, and calcsilicate rock. The emplacement age of the protoliths of mafic granulite and orthogneiss is approximately 920–910 Ma, which was during the Grenville Orogenic period. The age of the zircon overgrowth is approximately 549—529 Ma, which indicates that the terrane in the Prydz Belt is a typical Pan-African metamorphic terrane (Wang et al., 2016a, 2016b; Liu et al., 2013, 2007; Mikhalsky et al., 2001). The protoliths of paragneiss and calcsilicate rocks may be Mesoproterozoic sedimentary rocks. These rocks together form the pre-Pan-African basement of the Grove Mountains (Liu et al., 2013, 2006, 2003; Yu et al., 2002a, 2002b). Because of Pan-African metamorphic events, synorogenic or late orogenic granite, and the late orogenic granitic and granodioritic aplitic dyke, felsic pegmatites are widely distributed in this region (Liu et al., 2007; Liu et al., 2002).

Field observations and structural elements measurements revealed that the Grove Mountains underwent three periods of deformation. These deformations were northeast to southwest thrust in the earlier period (D1), northeast to southwest decoupling in the lower angle in the middle period (D2), and north-northeast semi-graben uplift of normal faults in the late period (D3) (Figure 1, Hu et al., 2008).

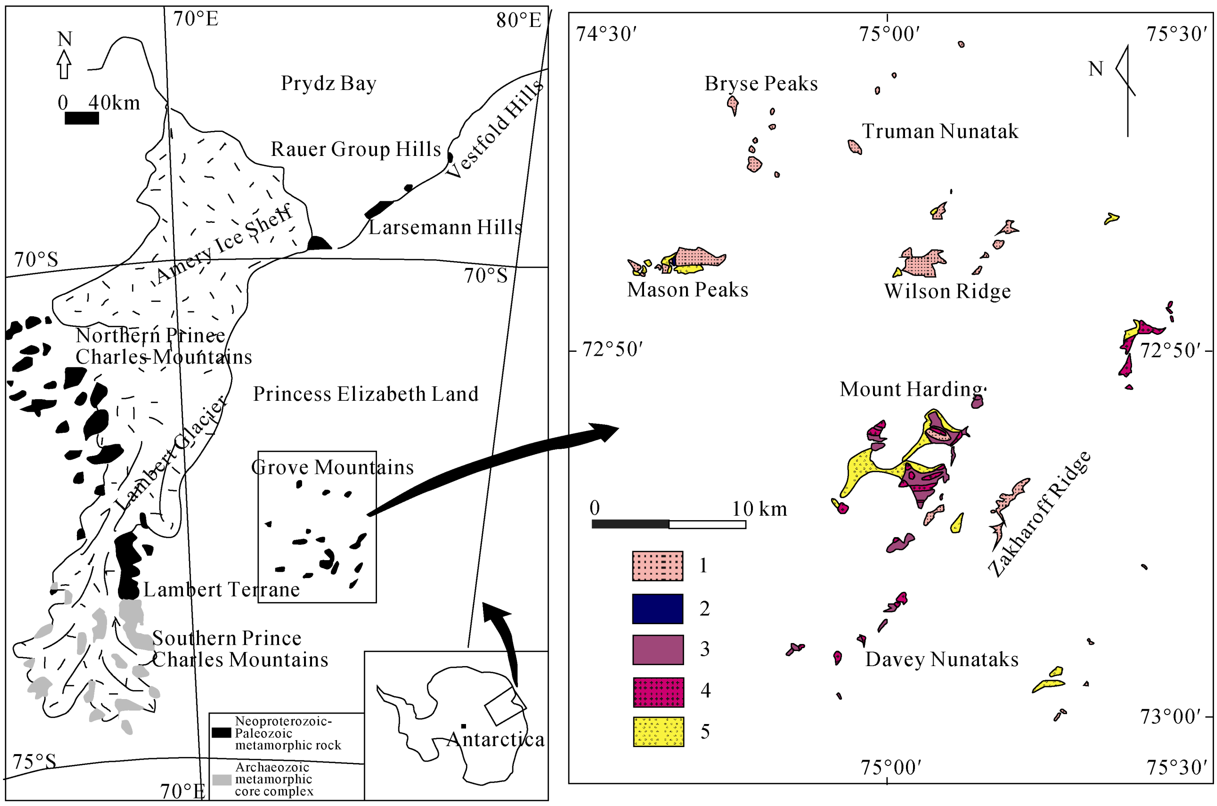

Figure 1 Geological sketch map of the Grove Mountains in East Antarctica (after Liu et al. (2009), Yu et al. (2002a, 2002b)). [XL1]1, Orthogneiss; 2, Mafic granulite; 3, Charnockite; 4, Granite; 5, Moraine.

3 Sample collection and test analysis

Samples were collected from the seventh Antarctic Grove Mountains Expedition (Figure 2). As allowed by the permitting conditions, we performed systematic sampling (mainly point sampling) on outcrops of the Grove Mountains (Figure 3). However, due to cold weather and other unforeseen difficulties, sampling work could not be done in some areas of the mountains. Sample tests were conducted in the Shandong Bureau Testing Center of the China Metallurgical Geology Bureau.

To perform our analysis we used an electronic balance (YQ008), ICE3500 atomic absorption spectrophotometer (YQ003), X Series2 inductively coupled plasma-mass spectrometer (YQ006), and IRIS Intrepid II XSP plasma emission spectrometer (YQ031). Our testing protocol followed the fourth edition of the "Rock Mineral Analysis", published in 2011. Test data are shown in Table 1.

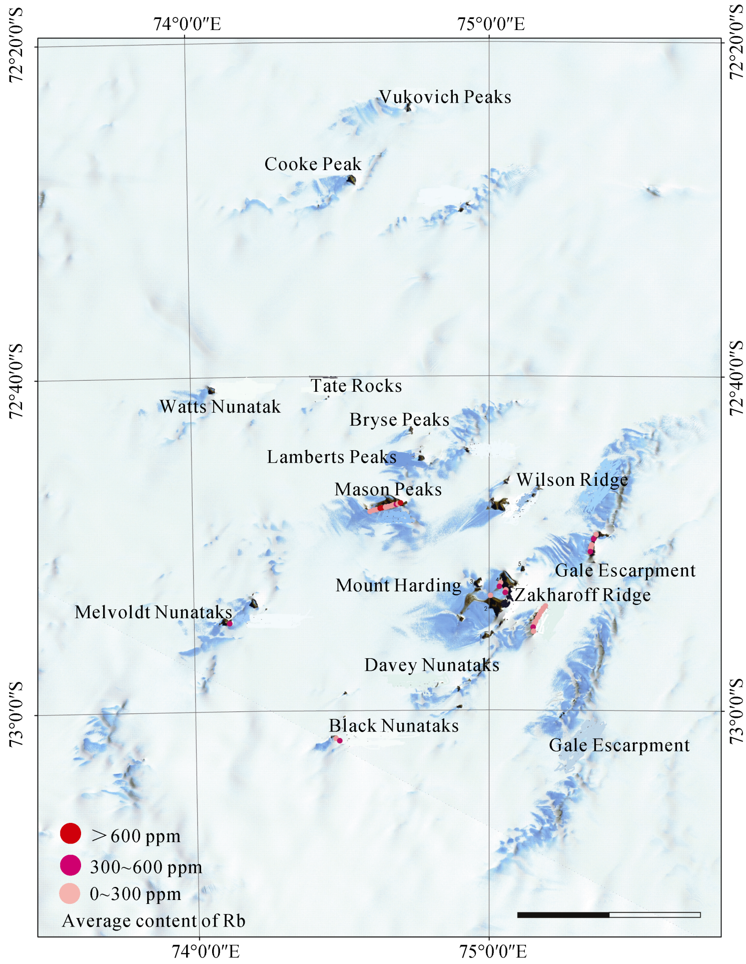

Figure 2 Sample location map of the Grove Mountains in East Antarctica.

Figure 3 Photographs of samples taken from the Grove Mountains in East Antarctica. Samples are: **a**, granulite; **b**, pegmatite; **c**, granitic gneiss; **d**, moyite. Notes: bio–biotite; ilm–ilmenite; Kfs–K-feldspar; pl–plagioclase; pyr–pyroxene; q–quartz.

Table 1 Rubidium content of samples from the Grove Mountains in East Antarctica

Sample	Content of Rb /ppm	Average content of Rb/ppm	Latitude/S	Longitude/E	Altitude /m	Location	lithology
G01	304	208.48	73°01′03″	74°30′02″	1945	Black Nunataks	moyite
G02	195		73°01′03″	74°30′02″	1945	Black Nunataks	pegmatite
G04	61.9		73°01′03″	74°30′02″	1945	Black Nunataks	granitic gneiss
G05	204		73°01′03″	74°30′02″	1945	Black Nunataks	pegmatite
G06	196		73°01′03″	74°30′02″	1945	Black Nunataks	diorite
G07	290		73°01′03″	74°30′02″	1945	Black Nunataks	granitic gneiss
G08	956	418.60	73°02′10″	74°31′27″	1990	Black Nunataks	granulite
G10	109		73°02′10″	74°31′27″	1990	Black Nunataks	granitic gneiss
G11	360		73°02′10″	74°31′27″	1990	Black Nunataks	moyite
G12	277		73°02′10″	74°31′27″	1990	Black Nunataks	granitic gneiss
G13	391		73°02′10″	74°31′27″	1990	Black Nunataks	mafic granulite
G16	267	331.63	72°53′51″	74°14′57″		Melvoldt Nunataks	granitic gneiss
G17	306		72°53′51″	74°14′57″		Melvoldt Nunataks	granitic gneiss
G18	209		72°53′51″	74°14′57″		Melvoldt Nunataks	gneiss
G20	331		72°53′51″	74°14′57″		Melvoldt Nunataks	pegmatite
G21	424		72°53′51″	74°14′57″		Melvoldt Nunataks	granitic gneiss
G22	103		72°53′51″	74°14′57″		Melvoldt Nunataks	pegmatite
G23	556		72°53′51″	74°14′57″		Melvoldt Nunataks	gneiss
G24	457		72°53′51″	74°14′57″		Melvoldt Nunataks	granitic gneiss
G25	123	249.00	72°47′46″	74°40′52″	1816	Mason Peaks	gneiss
G26	296		72°47′46″	74°40′52″	1817	Mason Peaks	pegmatite
G27	261		72°47′46″	74°40′52″	1818	Mason Peaks	granitic gneiss
G28	279		72°47′46″	74°40′52″	1819	Mason Peaks	pegmatite
G29	286		72°47′46″	74°40′52″	1820	Mason Peaks	monzonite granite
G30	262	262	72°47′45″	74°41′02″	1811	Mason Peaks	monzonite granite
G31	293	293	72°47′45″	74°41′07″	1818	Mason Peaks	monzonite granite
G32	715	715	72°47′44″	74°41′10″	1812	Mason Peaks	pegmatite
G33	1255	1255	72°47′42″	74°41′23″	1813	Mason Peaks	gneiss
G34	150	150	72°47′42″	74°41′23″	1813	Mason Peaks	gneiss
G35	63.8	159.40	72°47′42″	74°41′34″	1817	Mason Peaks	gneiss
G36	72.5		72°47′42″	74°41′34″	1817	Mason Peaks	gneiss
G37	197		72°47′42″	74°41′34″	1817	Mason Peaks	gneiss
G38	79.7		72°47′42″	74°41′34″	1817	Mason Peaks	gneiss
G39	384		72°47′42″	74°41′34″	1817	Mason Peaks	gneiss
G40	166	166	72°47′43″	74°41′42″	1821	Mason Peaks	gneiss
G41	192	192	72°47′45″	74°42′00″	1811	Mason Peaks	pegmatite
G42	438	331.00	72°47′44″	74°41′53″	1807	Mason Peaks	granitic gneiss
G43	224		72°47′44″	74°41′53″	1807	Mason Peaks	pegmatite
G46	19.9	62.45	72°47′47″	74°40′53″	1817	Mason Peaks	quartzite
G48	105		72°47′47″	74°40′53″	1817	Mason Peaks	pegmatite
G49	753	753	72°47′39″	74°41′20″	1835	Mason Peaks	moyite

Continued

Sample	Content of Rb /ppm	Average content of Rb/ppm	Latitude/S	Longitude/E	Altitude /m	Location	lithology
G51	215	215	72°54′39″	75°09′18″	2194	Zakharoff Ridge	pegmatite
G52	154		72°54′43″	75°09′16″	2220	Zakharoff Ridge	pegmatite
G53	217	185.33	72°54′43″	75°09′16″	2213	Zakharoff Ridge	granitic gneiss
G54	185		72°54′43″	75°09′16″	2213	Zakharoff Ridge	gneiss
G55	180	180	72°54′47″	75°09′21″	2216	Zakharoff Ridge	granite
G56	188	188	72°54′49″	75°09′27″	2187	Zakharoff Ridge	gneiss
G57	222	222	72°54′53″	75°09′34″	2700	Zakharoff Ridge	monzonite granite
G58	206		72°54′39″	75°09′18″	2194	Zakharoff Ridge	monzonite granite
G59	290	241.33	72°54′39″	75°09′18″	2194	Zakharoff Ridge	pegmatite
G60	228		72°54′39″	75°09′18″	2194	Zakharoff Ridge	pegmatite
G62	237	237	72°56′06″	75°09′08″	2226	Zakharoff Ridge	granite
G63	481	481	72°56′06″	75°09′08″		Zakharoff Ridge	gneiss
G64	111	111	72°55′14″	75°09′12″	2192	Zakharoff Ridge	moyite
G64a	449		72°49′26″	75°22′20″	1997	Gale Escarpment	moyite
G65	125	201.60	72°49′26″	75°22′20″	1997	Gale Escarpment	gneiss
G66	30.8		72°49′26″	75°22′20″	1997	Gale Escarpment	granitic gneiss
G67	382	375.50	72°49′29″	75°22′19″	1996	Gale Escarpment	granitic gneiss
G68	369		72°49′29″	75°22′19″	1996	Gale Escarpment	granitic gneiss
G69	18.2	18.2	72°49′34″	75°22′13″	1957	Gale Escarpment	ilmenite
G71	4.78	7.84	72°49′36″	75°21′40″	1962	Gale Escarpment	gneiss
G72	10.9		72°49′36″	75°21′40″	1962	Gale Escarpment	monzonite granite
G73a	428	420.00	72°49′38″	75°21′20″	1997	Gale Escarpment	pegmatite
G74	412		72°49′38″	75°21′20″	1997	Gale Escarpment	pegmatite
G75	308		72°51′47″	75°02′57″	1874	Mount Harding	monzonite granite
G76	281	258.58	72°51′47″	75°02′57″	1874	Mount Harding	granitic gneiss
G77	414		72°51′47″	75°02′57″	1874	Mount Harding	granitic gneiss
G77b	31.3		72°51′47″	75°02′57″	1874	Mount Harding	gneiss
G78	552	552	72°51′48″	75°02′54″	1883	Mount Harding	pegmatite
G79	119	119	72°51′50″	75°02′39″	1880	Mount Harding	gneiss
G80	540	540	72°51′52″	75°02′31″	1870	Mount Harding	pegmatite
G81	269	259.00	72°53′24″	75°02′16″	1904	Mount Harding	granitic gneiss
G82	249		72°53′24″	75°02′16″	1904	Mount Harding	pegmatite

4 Results and discussion

There are 64 independent nunataks in the 320 km^2 of blue ice surface in the Grove Mountains. They are made up of five distinct islands of nunataks, distributed from the northeast to southwest. The nunataks illustrate the ridge and longitudinal valley geomorphology of the area. The relative height between the nunataks and the blue ice surface varies from 10 to 80 m. Because of the rising and scraping effects of ice cover movement from the southeast to the northwest, the snow-ice line is relatively high on the southeast side of the nunataks. Conversely, the northwest side of the nunataks usually show near-vertical fracture collapse.

Most of our samples came from the Black Nunataks, Melvoldt Nunataks, Mason Peaks, Zakharoff Ridge, Mount Harding, and the northern Gale Escarpment. We assumed that the average Rb content of samples from a particular location indicated the Rb content in that location. Figure 2 shows that every nunatak from which we had samples showed local Rb enrichment (Rb content up to 0.03%). This clearly suggests that rubidium is rich in this area of Antarctica.

Table 1 shows that the samples in this research were primarily granite, granitic gneiss, granitic pegmatite, mafic granulite, and diorite. Twenty-four of our samples contained Rb content above 0.03%. The samples with high Rb content were mainly granitic gneiss and pegmatite, but some samples were moyite and mafic granulite (Figure 2). There is no independent Rb mineral found in nature. Rb is usually found in K-rich silicate and chloride minerals in isomorphic forms, such as K-feldspar, muscovite, biotite, lepidolite, pollucite, and carnallite (Liu et al. 2015; Song et al. 2015). We used a Niton XL3t-500s Goldd analyzer on our rock samples in the field, and we found that the main carrier minerals of Rb were mica and K-feldspar. These minerals are often found with Rb. Further research, however, is needed to confirm this relationship.

5 Conclusions

We come to the conclusions below on basis of rubidium distribution in the Grove Mountains area, East Antarctica:

(1) Rubidium is relatively rich in the Grove Mountains, and the Rb content is very high in some locations.

(2) We found that Rb in the Grove Mountains was highest in moyite, granitic gneiss, and felsic pegmatite. Additionally, mica and K-feldspar may be the main carrier minerals of Rb. Further research, though, is needed to confirm this.

Acknowledgments This study was funded by the Chinese Polar Environmental Comprehensive Investigation and Assessment Programs (Grant nos. CHINARE2016-02-05 and CHINARE2016-02-02). Our field investigation was supported by the Chinese Arctic and Antarctic Administration and Polar Research Institute of China. We wish to thank the seventh Grove Expedition team members for their help in the field sample collection process.

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