# THE PETROGRAPHY OF THE BEACON SANDSTONE OF SOUTH VICTORIA LAND*

DUNCAN STEWART, JR., *Carleton College.*

## INTRODUCTION

Fifty-two sedimentary rock specimens of the Beacon Sandstone formation of South Victoria Land, Antarctica, have been examined petrographically. Gould, geologist of the Byrd Antarctic Expedition, 1928–30, collected 27 specimens in the Queen Maud Mountains. Fifteen duplicate specimens have been studied of those collected *in situ* in the Ferrar Glacier district by the National Antarctic Expedition, 1901–04. Ten duplicate specimens, mainly erratics from the Priestley Glacier moraine, Terra Nova Bay district, collected by the British Antarctic (*Terra Nova*) Expedition, 1910–13, have also been examined. Preliminary petrographical notes have been published by Prior (9) on five of the specimens collected by the National Antarctic Expedition.

## GENERAL STATEMENTS

The Beacon Sandstone formation derived its name from Beacon Heights named by Armitage of the National Antarctic Expedition.

The rocks of the formation vary from shaly types to sandstones containing approximately 99 per cent quartz—from arkoses with an average of 45 per cent feldspar to conglomerates containing pebbles of chert, volcanic material, diabase (?), and mica schist. This series rests upon a pre-Cambrian basement complex of igneous and metamorphic rocks. The lower members of the formation contain upper Devonian fish plates, and in the upper beds are found wood fragments, seams of low-grade coal, and fossil plants belonging to the *Glossopteris* flora. The widespread occurrence of cross-bedding and the presence of coal seams indicate a continental origin of a great part of the series. The upper strata are probably Permo-Carboniferous, with deposits of Triassic (?) age at the top. These sediments were intruded in late Mesozoic or early Tertiary by diabase sills of great thickness.

The Beacon formation extends from Adelie Land through King George V and South Victoria Lands, and into Marie Byrd Land. (See fig. 1). This widespread series of rocks is reported by Ferrar

* Part of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the University of Michigan.

This article is a preliminary paper on the geology and petrography of the Antarctic Continent which is in part complete and which will be published later in full.

(4) to be about 2,000 feet in thickness in the Ferrar Glacier region. Debenham (3) states that in the McMurdo Sound district the Beacon Sandstone is at least 3,000 feet in thickness. Priestley and Tilley (8) remark that the beds are 5,000 feet thick, and Gould (5) gives the thickness of the series in Mount Fridtjof Nansen as 7,000 feet, of which some 2,500 feet is composed of diabase intrusives.

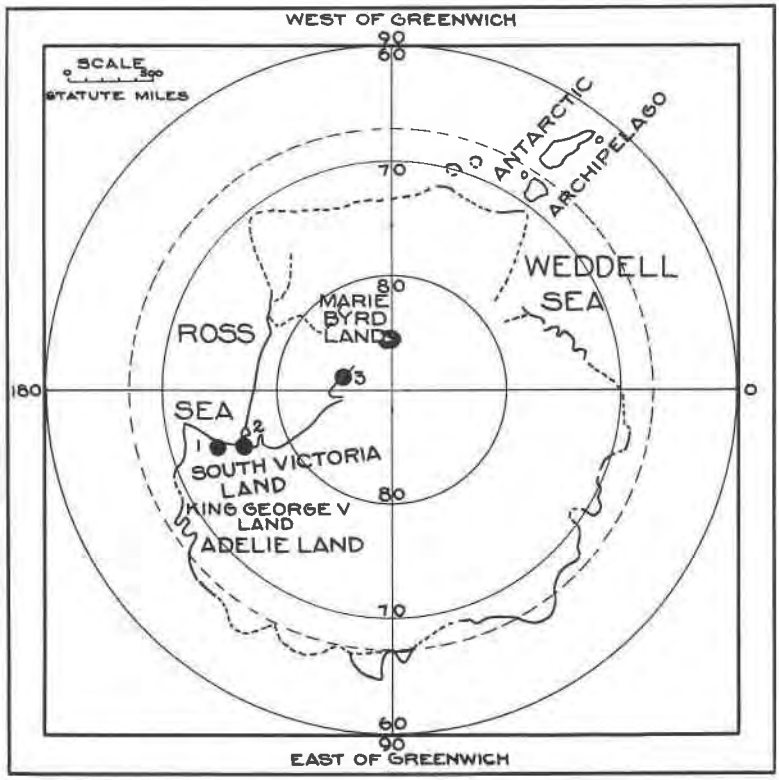


FIG. 1. Sketch map of Antarctica. (1) Terra Nova Bay district; (2) Ferrar Glacier district; (3) Mount Fridtjof Nansen district, Queen Maud Mountains, South Victoria Land.

The beds of the formation are practically horizontal, and occur in great fault-block mountains. According to Priestley and Tilley (8) the displacements of the beds are at least 5,000–6,000 feet.

## PETROGRAPHY

BRITISH ANTARCTIC TERRA NOVA SPECIMENS. Ten duplicate specimens of Beacon formation rocks, of which the majority are

TABLE 1. MINERALS IN THE ROCKS OF THE BEACON FORMATION COLLECTED MAINLY FROM THE PRIESTLEY GLACIER MORAINE, TERRA NOVA BAY DISTRICT

| Minerals | Specimens | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D88G | 1270 | 1718 | 1842 | 1865 | 1938 | A | B1 |
| Quartz | x | x | x | x | x | x | x | x |
| Orthoclase | | | x | x | x | x | | x |
| Microcline | | | x | | x | x | | x |
| Microperthite | | | x | | | | | x |
| Plagioclase | | x | x | | x | | x | x |
| Muscovite | x | | x | x | | | | x |
| Biotite | x | | x | x | x | | x | x |
| Chlorite | | | x | x | x | x | x | x |
| Glauconite (?) | | | | | x | | | |
| Apatite | x | x | x | x | x | x | x | x |
| Zircon | x | x | x | x | x | x | x | x |
| Tourmaline | x | | x | x | x | x | | x |
| Garnet | | x | x | | x | x | x | |
| Diopside | | x | | | | | | |
| Hornblende | x | x | x | | x | | | |
| Epidote | | | x | | | x | | |
| Calcite | | x | | x | x | x | | x |
| Natrolite | | | | | x | | | |
| Titanite | x | x | x | x | | x | x | x |
| Rutile | | | | | | | x | |
| Ilmenite | x | | x | x | x | x | | x |
| Leucoxene | x | x | x | x | x | x | | x |
| Magnetite | | x | x | x | x | x | | x |
| Pyrite | | x | | | x | | | |
| Hematite | x | | | | | | | |
| Limonite | | | x | x | x | x | | x |
| Chert | x | | x | x | | x | | x |
| Diabase (?) | | | x | | x | x | | |
| Volcanic fragments | | | | | x | x | | |
| Mica schist | | | | | | x | | |

D88G. Black sandstone
1270. Contact sandstone
1718. Yellow sandstone
1842. Coarse sandstone
1865. Impure coarse sandstone
1938. Impure coarse sandstone
A. Shale
B1. Impure coarse sandstone

erratics from the Priestley Glacier moraine in the Terra Nova Bay district, have been examined. Table 1 shows the mineral contents of eight of the rocks, and it is to be noted that there are a number of mineral species and rock pebbles recorded which are not present in the sandstones of the type area in the Ferrar Glacier region.

TABLE 2. MINERALS IN THE ROCKS OF THE BEACON FORMATION OF THE TYPE AREA (FERRAR GLACIER DISTRICT)

| Minerals | Specimens | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 630 | 638a | 638b | 639 | 641 | 642 | 643 | 644 | 663 | 673 | 677 | 678 | 679 | 682 | 683 |
| Quartz | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Orthoclase | x | | | | x | x | x | x | x | x | | ? | | x | x |
| Microcline | x | x | | | x | | | | x | x | | | | x | x |
| Plagioclase | x | x | | | x | ? | | ? | x | x | | x | | x | x |
| Muscovite | x | x | | x | x | x | x | | x | x | | | x | x | x |
| Biotite | | x | | x | x | | | x | x | x | | x | x | x | x |
| Chlorite | x | x | | | | x | x | x | x | x | | | | x | x |
| Apatite | x | x | | x | x | x | | x | x | x | x | x | x | x | x |
| Zircon | x | x | | x | x | x | x | x | x | x | x | x | x | x | x |
| Tourmaline | x | | | | x | x | x | x | | x | x | x | x | x | |
| Garnet | x | | | | | | | | | x | | x | x | | |
| Epidote | | | x | | | | | | | | | | | | x |
| Calcite | | | x | | | x | | | | | | | | | |
| Titanite | x | x | x | | | x | x | | x | x | | | | | x |
| Rutile | | | | | | x | x | | | | | | | | |
| Ilmenite | | | x | | | x | | | | x | | | | | |
| Leucoxene | x | x | x | x | x | x | x | x | x | x | | x | | | x |
| Magnetite | x | x | x | | x | | x | | x | x | | x | x | x | |
| Hematite | | x | | | | | | x | | | | | | x | |
| Limonite | x | x | x | | | | x | x | x | | x | x | x | | |
| Chert | | x | | | | | | | | | | | x | | x |

630. Arkose
638a. Conglomerate
638b. Siltstone
639. Sandstone
641. Coarse sandstone
642. Sandstone
643. Siltstone
644. Ferruginous sandstone
663. Fine-grained conglomerate
673. Quartzitic arkose pebble
677. Limonitic sandstone
678. Sandstone
679. Sandstone
682. Coarse sandstone
683. Sandstone

"Charred wood" remains are seen in specimens 1842, 1865, 1938, B, and C. In thin section the average grain size is 0.40 mm., and the particles, which are firmly cemented together, are subangular to rounded in outline. Microperthite, hornblende, glauconite (?), pyrite, and natrolite are present. Rutile grains are absent in the sandstones, whereas ilmenite, garnet, and dentated quartz are common. Diabase (?), chert, mica schist, and volcanic pebbles are noted, The quantitative measurements of the constituents of six of the sections were made with the improved Wentworth recording

TABLE 3. MINERALS IN THE ROCKS OF THE BEACON FORMATION OF MOUNT FRIDTJOF NANSEN

| Minerals | Specimens | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6a | 8a | 8b | 9a | 9c | 10 | 11b | 12b | 13 | 14b | 14c | 17a | 17b | 17c | 17d | 18a | 18b |
| Quartz | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Orthoclase | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Microcline | x | x | | | | x | | | x | | x | | | | x | x | |
| Placgiolase | x | x | x | x | x | x | x | | x | x | x | | x | x | x | x | |
| Muscovite | x | | | | x | | x | | x | | x | | | x | x | x | |
| Biotite | x | x | x | x | x | x | x | x | x | | x | x | | x | x | | x |
| Chlorite | x | x | x | x | x | x | x | | x | x | x | | x | x | x | x | x |
| Apatite | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Zircon | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| Tourmaline | | ? | ? | x | | ? | x | x | ? | x | x | | | | x | x | x |
| Garnet | x | x | x | x | x | x | x | x | x | x | x | | x | | x | x | x |
| Augite | | | | | | x | | | | | | x | | | | | |
| Epidote | | | | | | ? | | | | | | | x | | | | |
| Clinozoisite | | | | | | | | | | | | | | x | | | |
| Titanite | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Rutile | x | | | | x | x | x | x | x | x | x | | | | x | x | x |
| Ilmenite | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Leucoxene | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Magnetite | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Hematite | x | | x | | | x | | | | | | | x | x | | | |
| Limonite | x | | x | x | | x | x | | x | | | x | x | x | | | |

6a. Arkose
8a. Arkose
8b. Arkose
9a. Shaly arkose
9c. Micaceous arkose
10. Contact arkose
11b. Arkose
12b. Shaly arkose
13. Arkose
14b. Gray arkose
14c. "Spotted" arkose
17a. Contact quartzite
17b. Arkose with quartzitic arrangement of quartz
17c. Ferruginous micaceous arkose
17d. Arkose
18a. Arkose
18b. Slaty graywacke

micrometer. The quartz and feldspar percentages are variable, the quartz content in the thin sections varying from 40–97 per cent.

NATIONAL ANTARCTIC EXPEDITION SPECIMENS. Fifteen duplicate specimens of sedimentary rocks have been examined that were collected in Glacier Valley and Finger Mountain, Western Mountains, the Southwest arm of New Harbour Glacier, and the Inland Forts, South Victoria Land. Prior (9) (p. 134) has given preliminary reports on specimens 638*a*, 638*b*, 641, 642, and 679. Table 2 presents the mineralogy of the rocks. The average grain size of the particles

in thin section is 0.30 mm., and the grains which are practically all rounded or well-rounded, only a few of which are subangular, are in the majority of cases poorly cemented. Microperthite, hornblende, glauconite (?), pyrite, and natrolite are absent in these sections. Rutile as grains, ilmenite, and garnet occur sparingly, whereas dentated quartz and secondary quartz around well-rounded grains are common. Chert pebbles are rare. The percentages of the constituents of 10 of the sections were determined quantitatively, and

Chemical Analyses of Rocks from the Beacon Formation

| | 1 | 2 | 3* |
|---|---|---|---|
| $SiO_2$ | 78.54 | 76.01 | 67.34 |
| $Al_2O_3$ | 10.81 | 13.29 | 15.52 |
| $Fe_2O_3$ | 0.35 | 0.52 | 0.63 |
| FeO | 1.42 | 1.75 | 4.87 |
| MgO | 0.80 | 0.60 | 2.01 |
| CaO | 0.73 | 0.72 | 0.40 |
| $Na_2O$ | 3.32 | 3.33 | 1.59 |
| $K_2O$ | 2.08 | 2.63 | 3.44 |
| $H_2O$ | 0.95 | 0.25 | 2.93 |
| $H_2O-$ | 0.09 | 0.27 | 0.17 |
| $TiO_2$ | 0.65 | 0.31 | 0.89 |
| $P_2O_5$ | 0.15 | 0.37 | 0.15 |
| MnO | 0.06 | 0.01 | 0.04 |
| $CO_2$ | n.d. | 0.06 | n.d. |
| | 99.95 | 100.12 | 99.98 |

1. Arkose (specimen 6a). Mount Fridtjof Nansen. Analyst, Ellestad.

2. Arkose. Upper Glacier Depot, Beardmore Glacier. Analysts, Burrows and Walkom (1) (p. 207).

3. Micaceous arkose (specimen 9c). Mount Fridtjof Nansen. Analyst, Ellestad.

* Ellestad records a slight, black, insoluble residue, which is undoubtedly carbon.

seven of the 15 specimens contained an average of 99 per cent quartz.

Specimens Collected by Gould. Of the total 27 specimens of sedimentary rocks of the Beacon formation collected *in situ* by Gould, 17 were found in the eastern section of Mount Fridtjof Nansen, Queen Maud Mountains, and 10 were collected in the western slope of that mountain. Table 3 records the mineral contents of 17 of the rocks. The constituents of the rocks have an average grain size in thin section of 0.10 mm., in striking contrast to the grain sizes of the minerals in the specimens collected by the British expeditions. The grains vary in outline from angular to subangular, and are well-cemented. Microperthite, hornblende, glauconite (?),

pyrite, and natrolite are absent. Rutile grains and garnet are common, whereas rock pebbles, common in the *Terra Nova* specimens, are absent. Dentated quartz is rare. In fig. 2 are recorded the quantitative measurements of the constituents of seven Mount Fridtjof Nansen specimens all of which are sectioned both parallel and perpendicular to the bedding. The average feldspar content is 45 per

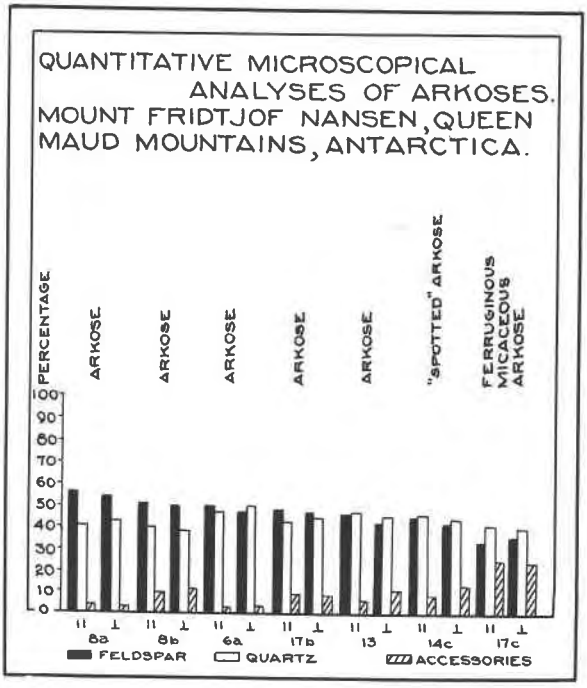


FIG. 2. Quantitative microscopical measurements of sections cut both parallel and perpendicular to the bedding. Gould collection, Mount Fridtjof Nansen, Queen Maud Mountains, Antarctica.

cent in contrast with the much lower feldspar content of the specimens collected by the National Antarctic and *Terra Nova* Expeditions.

## CHEMICAL ANALYSIS

Three chemical analyses of sedimentary rocks from the Beacon formation are recorded. Burrows and Walkom (1) (p. 207) have analyzed an arkose from Upper Glacier Depot, Beardmore Glacier, and Ellestad has analyzed an arkose and a micaceous arkose from Mount Fridtjof Nansen.

## Conclusions

The derivation of the material of these sedimentary rocks varied, as did the conditions under which deposition took place. The presence of garnet in practically all of the Mount Fridtjof Nansen slides is an indication that the derivation of the minerals of the sedimentary series was probably from metamorphic rocks, and considering the general mineral content the metamorphic series was acid in character—possibly, intruded by acid igneous types. The presence of such minerals as microperthite and microcline in the specimens collected by the *Terra Nova* Expedition suggests that the source of this material was in granitic rocks. Volcanic fragments, mica schist, chert, and diabase (?) pebbles point to sources varying somewhat from those of the Mount Fridtjof Nansen series. It is possible that the sandstones of the Ferrar Glacier region represent a northern phase of the Queen Maud sediments in that the feldspar content became less as the material was carried farther from the source. Highly feldspathic sandstones have been described by Mawson (1) from the area of the East Fork of Ferrar Glacier. They possibly represent a transition toward the typical arkoses of the Queen Maud Mountains.

It is suggested that the source of the material for the arkoses of the Mount Fridtjof Nansen district was in a great plateau to the south of this area. Undoubtedly, the source would have been in close proximity to the location of deposition, and considering the fact that the British found quite similar arkoses in the Beardmore Glacier district it is possible that the sediments were derived from a land mass to the south made up of acid metamorphic and igneous rocks.

## Résumé

The Beacon Sandstone formation, composed of great thicknesses of sandstones, arkoses, shales, and beds of low-grade coal, intruded by sills of diabase, rests upon a basement complex of pre-Cambrian age, and extends over a vast area including Adelie, King George V, South Victoria, and Marie Byrd Lands. Fifty-two specimens from the sedimentary strata, collected in South Victoria Land by three Antarctic expeditions, have been examined petrographically. Fine-grained arkoses are recorded from Mount Fridtjof Nansen, Queen Maud Mountains, which extends the known occurrence of the type many miles to the eastward of the Beardmore Glacier area studied by the British. The derivation of the

mineral constituents and the conditions of deposition varied. Two chemical analyses of rocks from the Beacon formation are added to the one already recorded.

## Acknowledgments

To Dr. Laurence M. Gould, geologist of the Byrd Antarctic Expedition, 1928–30, the author is under obligation for the opportunity to study his collection of specimens. Dr. W. Campbell Smith, Curator of the Department of Geology, British Museum of Natural History, very kindly supplied me with duplicate material from the Beacon Sandstone formation collected by the National Antarctic Expedition, 1901–04, and the British Antarctic *Terra Nova* Expedition, 1910–13. Professors William H. Hobbs and Walter F. Hunt, of the University of Michigan, have given most generous cooperation and support to this study.

## Bibliography

1. Benson, W. H., Chapman, F., Cohen, Miss F., Cotton, L. A., and others, Contributions to the paleontology and petrology of South Victoria Land: *British Antarctic Expedition*, 1907–09, vol. **2**, 1916.
2. David, T. W. E., and Priestley, R. E., Glaciology, physiography, stratigraphy, and tectonic geology of South Victoria Land: *British Antarctic Expedition*, 1907–09, Geology, vol. **1**, 1914.
3. Debenham, Frank, Rastall, R. H., and Priestley, R. E., The sedimentary rocks of South Victoria Land: British Antarctic "Terra Nova" Expedition, 1910, *Natural History Report, Geology*, vol. **1**, No. 4, pp. 101–130, 1921.
4. Ferrar, H. T., Geology—Field Geology: National Antarctic Expedition, 1901–1904, *Natural History*, vol. **1**, pp. 1–100, 1907.
5. Gould, L. M., Some geographical results of the Byrd Antarctic Expedition: *Geogr. Rev.*, vol. **XXI**, pp. 177–200, April, 1931.
6. Gould, L. W., Cold, 275 pp., *New York*, 1931.
7. Hunt, W. F., An improved Wentworth recording micrometer: *Am. Mineralogist*, vol. **9**, No. 9, pp. 190–193, 1924.
8. Priestley, R. E., and Tilley, C. E., Geological Problems of Antarctica: Problems of Polar Research, *Am. Geogr. Soc., Special Pub.* No. **7**, pp. 315–328, 1928.
9. Prior, G. T., Geology—Petrography: National Antarctic Expedition, 1901–1904, *Natural History*, vol. **1**, pp. 101–140, 1907.
10. Seward, A. C., Antarctic fossil plants: British Antarctic ("Terra Nova") Expedition, 1910, *Natural History Report, Geology*, vol. **1**, No. 1, pp. 1–49, 1914.
11. Stewart, Duncan, The petrography of some Antarctic rocks: *Am. Mineralogist*, vol. **19**, No. 4, pp. 150–160, 1934.
12. Taylor, Griffith, Antarctic Adventure and Research, 245 pp., *New York*, 1930.
13. Woodward, A. Smith, Fish-remains from the Upper Old Red Sandstone of Granite Harbour, Antarctica: British Antarctic ("Terra Nova") Expedition, 1910, *Natural History Report, Geology*, vol. **1**, No. 2, pp. 51–62, 1921.