# Plutonic rocks of the English Coast and northern Behrendt Mountains, eastern Ellsworth Land, Antarctica

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The previously unexplored English Coast (figure 1) was mapped in reconnaissance style by a seven-person U.S. Geological Survey party in December 1984 and January 1985. During that time, a visit to the northern Behrendt Mountains, about 150 kilometers east of the English Coast, was also made to complete mapping undertaken there during the 1977–1978 (Rowley et al. 1983) and 1965–1966 (Laudon et al. 1970) austral summers.

The geology and tectonic setting of the English Coast have been described by Rowley et al. (1991). Sedimentary rocks, Tertiary volcanic rocks, and fossil plants of the English Coast have been described by Laudon et al. (1987), O'Neill and Thomson (1985), and Gee (1989), respectively. This paper discusses plutonic rocks exposed in the English Coast and northern Behrendt Mountains.

Three small stocks of felsic plutonic rocks crop out in the English Coast. The southwest FitzGerald Bluffs and north FitzGerald Bluffs plutons are separated from each other by a 1-kilometer-wide quartzite roof pendant. The composite southwest FitzGerald Bluffs pluton consists of two phases: an older fine grained (<1 millimeter) sheared and hydrothermally altered granodiorite and a younger crosscutting slightly less mafic equigranular to porphyritic granite. A six-point rubidium-strontium whole-rock isochron derived from both plutonic phases and crosscutting aplite and porphyritic dikes yielded an age of 113.3±4 million years (Pankhurst and Rowley 1991). The north Fitzgerald Bluffs pluton consists of a single phase of equigranular to porphyritic rock that ranges between granodiorite and granite. A four-point rubidium-strontium isochron derived only from plutonic samples yielded an age of 128.3±5.3 million years (Pankhurst and Rowley 1991). The Mount Harry stock is composed of fresh fine- to medium-grained (1-5 millimeters) quartz monzonite exposed over an area of only 50-meter diameter. Rocks of the Mount Harry pluton vary texturally from a porphyritic interior to a chilled margin but have too small a range of rubidium-strontium ratios to be dated using that technique (Pankhurst and Rowley 1991). Unpublished paleomagnetic data (Kellogg personal communication) are most compatible with a Middle to Late Jurassic age for the Mount Harry stock.

A composite batholith of felsic rocks and a small gabbroic stock were mapped in the northern Behrendt Mountains. The composite Mount Caywood batholith is largely coarse-grained (>5 millimeter), equigranular to porphyritic granodiorite and quartz monzonite. It is locally crosscut by medium-grained, shallowly dipping sheets of biotite alaskite as much as 20 meters thick that contain abundant irregularly shaped masses of pegmatite and aplite. Pockets in these pegmatites contain doubly terminated smoky quartz crystals weighing as much as 4 kilograms. Rubidium-strontium whole-rock and mineral isochrons of 101±5 million years and 100±2 million years were determined from granodiorite at two localities within the Mount Caywood batholith (Halpern 1967). The Thomson Summit pluton, which has an exposed diameter of about 1 kilometer, consists entirely of strongly altered hornblende gabbro. It is one of the most mafic plutons known from eastern Ellsworth Land or the southern Antarctic Peninsula (Vennum and Rowley

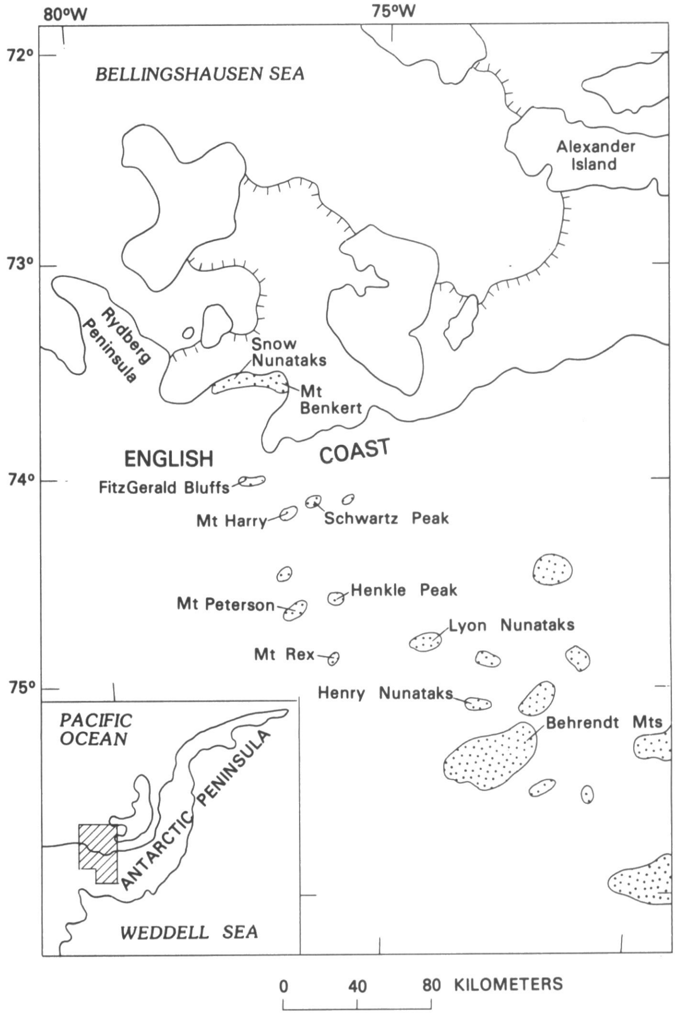


**Figure 1. Sketch map showing major geographic features of the English Coast. Hachures indicate edges of ice shelves. Stippled pattern indicates rock exposures that are surrounded by snow and ice. Figure is from Rowley, Kellogg, and Vennum (1985).**

1986). Although this pluton has not been isotopically dated, it is probably middle Cretaceous like the Mount Caywood batholith and most other plutons in this area (Pankhurst and Rowley 1991).

Geochemical data from the five plutons described above are listed in the table. Modes, norms, and additional trace-element and rare-earth element data may be obtained from Walter Vennum upon request. When plotted on a Harker silica-variation diagram, these analyses show decreases in aluminum oxide ($Al_2O_3$), ferric oxide ($Fe_2O_3$), ferrous oxide (FeO), calcium oxide (CaO), magnesium oxide (MgO), and manganese oxide (MnO) and slight increases in sodium oxide ($Na_2O$) and potassium oxide ($K_2O$) with increasing $SiO_2$. On ternary alkali – magnesium – (iron + manganese) and $K_2O$ – $Na_2O$ – CaO diagrams, these analyses follow a calc-alkaline differentiation trend. This suite of plutonic rocks makes the transition from diopside normative to corundum normative at approximately 67 percent silica ($SiO_2$). On a plot of parts per million niobium versus parts per million yttrium, all analyses fall in the volcanic-arc category (Pearce, Harris, and Tindle 1984), and on a spidergram of selected trace-element abundances normalized relative to ocean-ridge granite, the pattern produced by these analyses is virtually identical to Pearce et al. (1984) volcanic-arc granite pattern. A plot of weight percent CaO versus parts per million yttrium constructed from these analyses suggests that hornblende, apatite, and sphene are the major minerals effecting fractional crystallization of this suite of plutonic rocks (Lambert and Holland 1974). Figure 2 is a plot of rare-earth element abundances in analyzed samples from the English Coast and northern Behrendt Mountains. Geochemical behavior of the rare-earth elements in these analyzed samples is virtually identical to that described by Vennum and Rowley (1986) for plutonic rocks of the southern Antarctic Peninsula and by Saunders, Weaver, and Tarney (1982) for plutonic rocks of the northern Antarctic Peninsula.

Plutonic rocks described in this paper have similar geochemical, isotopic, and mineralogical characteristics as I-type granitoids from southeastern Australia and possess both typical calc-alkaline geochemical trends and a compositional range similar to the high alumina, calc-alkaline, basalt-andesite-rhyolite suite

**Geochemical data from plutonic rocks of the English Coast and northern Behrendt Mountains, eastern Ellsworth Land**

| Rock type[a] | Gb | Grd | Qm | Gr | Grd | Qm | Grd | Grd | Grd | Gr | Gr | Al | Ap | Ap |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample number | $Th520_b$ | $Ro515_h$ | $V201_l$ | $V202_j$ | $Ke213_c$ | $V201_m$ | V223 | $V219_a$ | $V200_a$ | $Dl8_g$ | $V202_a$ | $V219_b$ | $V200_b$ | $V202_f$ |
| Pluton[b] | T | SFB | H | NFB | SFB | H | C | C | NFB | SFB | NFB | C | NFB | SFB |
| Silica | 43.3 | 65.9 | 66.4 | 67.8 | 67.8 | 68.2 | 69.3 | 70.5 | 72.0 | 72.6 | 75.6 | 76.5 | 76.8 | 76.9 |
| Aluminum oxide | 19.7 | 15.5 | 15.4 | 15.0 | 16.0 | 15.0 | 14.8 | 14.2 | 14.0 | 14.3 | 13.0 | 13.2 | 12.3 | 12.8 |
| Ferric oxide | 4.29 | 2.05 | 2.04 | 2.07 | 1.60 | 1.59 | 0.95 | 0.89 | 1.38 | 0.82 | 0.44 | 0.37 | 0.42 | 0.24 |
| Ferrous oxide | 7.75 | 2.13 | 2.18 | 1.84 | 1.44 | 1.80 | 1.70 | 1.75 | 1.13 | 0.81 | 0.33 | 0.28 | 0.24 | 0.17 |
| Magnesium oxide | 6.63 | 1.77 | 1.50 | 1.43 | 1.06 | 1.20 | 0.81 | 0.85 | 0.69 | 0.54 | 0.24 | 0.11 | <0.10 | 0.10 |
| Calcium oxide | 13.1 | 4.32 | 3.79 | 3.97 | 4.04 | 3.21 | 2.99 | 2.75 | 2.71 | 2.23 | 1.25 | 1.03 | 0.70 | 0.48 |
| Sodium oxide | 1.75 | 3.29 | 3.64 | 3.38 | 3.71 | 3.33 | 2.89 | 2.72 | 3.43 | 3.42 | 3.39 | 3.64 | 3.28 | 3.83 |
| Potassium oxide | 0.45 | 3.05 | 2.81 | 2.94 | 2.74 | 3.65 | 4.45 | 4.54 | 3.05 | 4.22 | 4.44 | 4.48 | 4.70 | 4.63 |
| Titanium oxide | 0.84 | 0.59 | 0.55 | 0.52 | 0.47 | 0.51 | 0.29 | 0.29 | 0.38 | 0.25 | 0.13 | 0.06 | 0.10 | 0.07 |
| Phosphorus pentoxide | 0.26 | 0.16 | 0.16 | 0.16 | 0.13 | 0.13 | 0.14 | 0.13 | 0.11 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Manganese oxide | 0.21 | 0.08 | 0.08 | 0.07 | 0.06 | 0.09 | 0.06 | 0.06 | 0.07 | 0.03 | 0.03 | <0.02 | <0.02 | 0.03 |
| Structural water ($H_2O^+$) | 1.98 | 0.61 | 0.90 | 0.39 | 0.40 | 0.61 | 0.44 | 0.48 | 0.62 | 0.15 | 0.28 | 0.18 | 0.11 | 0.17 |
| Adsorbed water ($H_2O^-$) | 0.07 | 0.10 | 0.07 | 0.10 | 0.10 | 0.16 | 0.08 | 0.11 | 0.10 | 0.09 | 0.13 | 0.09 | 0.07 | 0.04 |
| Carbon dioxide | <0.01 | 0.02 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total | 100.3 | 99.6 | 99.5 | 99.7 | 99.6 | 99.5 | 98.9 | 99.3 | 99.7 | 99.5 | 99.3 | 100.0 | 98.9 | 99.5 |
| Barium | 120 | 640 | 720 | 780 | 920 | 790 | 880 | 910 | 770 | 720 | 560 | 21 | 330 | 130 |
| Niobium | <10 | 12 | 13 | 10 | 12 | 13 | <10 | <10 | 12 | 14 | 16 | 15 | 18 | 20 |
| Rubidium | <10 | 104 | 79 | 85 | 73 | 93 | 199 | 200 | 81 | 118 | 150 | 208 | 117 | 178 |
| Strontium | 685 | 355 | 345 | 380 | 475 | 330 | 380 | 340 | 323 | 255 | 130 | 59 | 60 | 26 |
| Yttrium | 17 | 17 | 17 | 24 | 10 | 17 | 24 | 16 | 21 | 15 | 14 | 21 | 34 | 10 |
| Zirconium | 45 | 175 | 180 | 174 | 250 | 180 | 115 | 110 | 210 | 120 | 75 | 55 | 100 | 50 |
| Σ14REE[c] | 48 | 124 | 126 | na[e] | 122 | 124 | na | 101 | 154 | 171 | 102 | 49 | 113 | 50 |
| $Ce_N/Yb_N$ | 1.9 | 6.9 | 6.0 | na | 8.4 | 6.4 | na | 3.8 | 6.4 | 7.8 | 5.0 | 0.9 | 2.0 | 2.9 |
| Eu/Eu[d] | 1.0 | 0.8 | 0.8 | na | 1.0 | 0.8 | na | 0.7 | 0.7 | 0.7 | 0.5 | 0.3 | 0.3 | 0.3 |

[a] Rock types: Al, alaskite; Ap, aplite; Gb, gabbro; Gr, granite; Grd, granodiorite; Qm, quartz monzonite. Rock names from Streckeisen (1976).
[b] Pluton name: C, Mount Caywood; NFB, north FitzGerald; SFB, southwest FitzGerald; H, Mount Harry; T, Thomson Summit.
[c] REE denotes rare-earth element.
[d] Rapid-rock major element analyses by methods described in U.S. Geological Survey bulletin 1144-A (Shapiro and Brannock 1962) and supplemented by atomic absorption. Trace elements determined by X-ray fluorescence; rare-earth elements by plasma emission spectrometry.
[e] na denotes not analyzed.

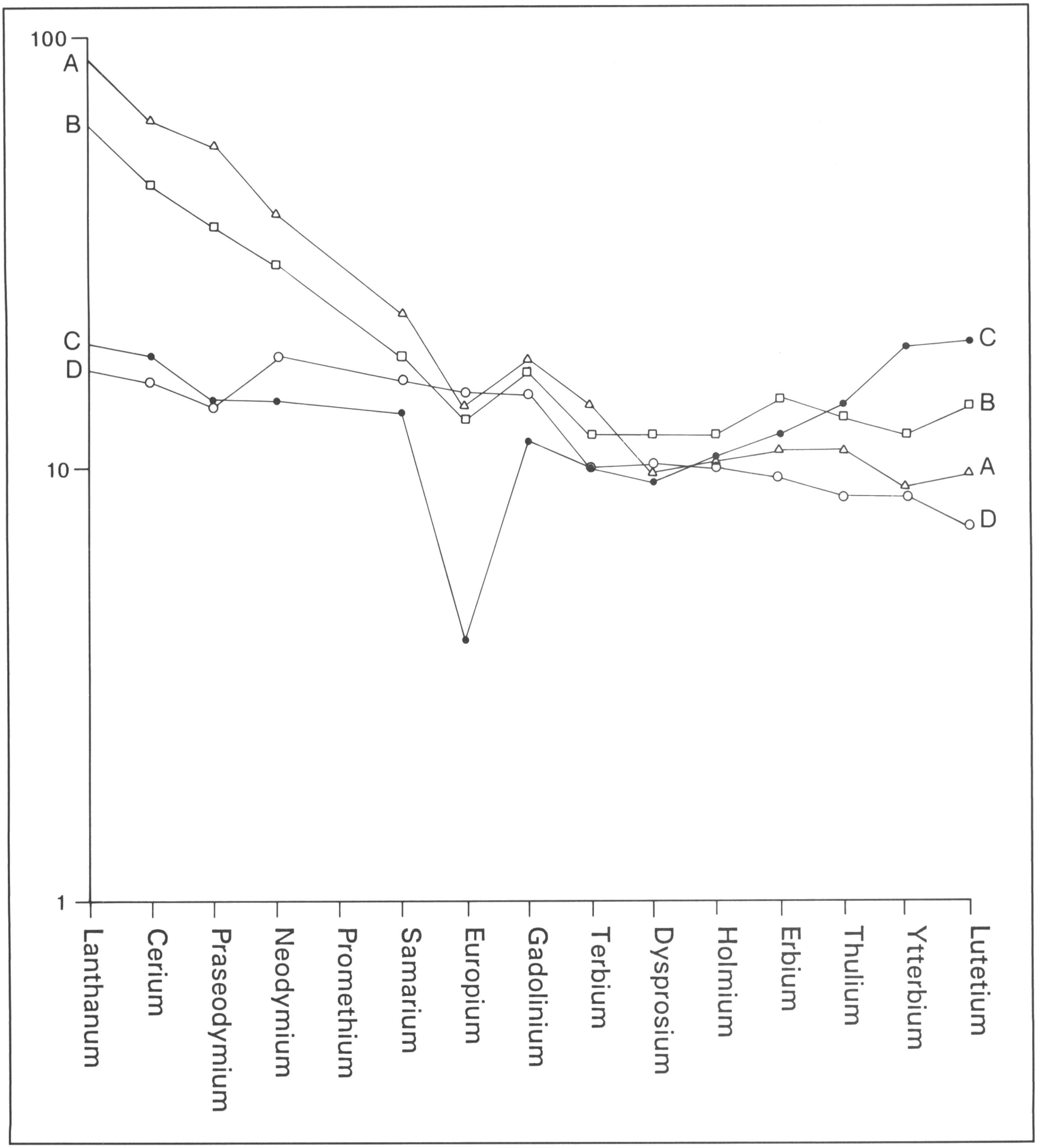


**Figure 2. Chondrite-normalized rare-earth element patterns of plutonic rocks from the English Coast and northern Behrendt Mountains. *A.* Average of 5 samples from the FitzGerald Bluffs plutonic complex (north FitzGerald Bluffs and southwest FitzGerald Bluffs plutons). *B.* Granodiorite ($V219_a$) from the Mount Caywood batholith. *C.* Alaskite ($V219_b$) from the Mount Caywood batholith. *D.* Gabbro ($Th520_b$) from the Thomson Summit pluton; normalizing values from Nakamura (1974).**

of continental margins. Their modal and normative compositions, petrography, geochemical parameters, isotopic ages and tectonic setting are identical to those previously described by Vennum and Rowley (1986) from the Lassiter Coast Intrusive Suite, which is exposed east and northeast of our study area in the eastern part of eastern Ellsworth Land and along the eastern edge of the southern Antarctic Peninsula. We conclude, therefore, that the plutonic rocks of the English Coast as well as the previously unstudied plutonic rocks of the northern Behrendt Mountains represent a southward and southwestward extension of the Lassiter Coast Intrusive Suite. We also conclude that the granitic rocks exposed throughout the entire southern Antarctic Peninsula and eastern Ellsworth Land represent a consanguineous suite of magmas formed in a magmatic arc that developed in response to subduction of the Pacific Ocean plate along the western edge of the southern Antarctic Peninsula.

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# Eocene terrestrial palynology of Seymour Island


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Terrestrial palynofloras preserved on Seymour Island reflect a shift to *Nothofagus*-dominated vegetation during the early Eocene in the northern Antarctic Peninsula region. In contrast, the preceding late Cretaceous and Paleocene palynofloras are dominated by podocarpaceous conifers, especially *Phyllocladidites mawsonii*, and *Nothofagidites* pollen are diverse but usually a minor part of the flora (Askin 1990). Conifers remain an important part of the Eocene vegetation; however, they are often a subdominant part of the palynoflora or match *Nothofagidites* pollen in abundance.

Eocene strata on Seymour Island are included in the La Meseta Formation, a complex array of deltaic marine, lenticular sandy sediments grouped into seven members (Telm 1 to 7, Sadler 1988). The basal part is probably upper Lower Eocene (Harwood 1988; Wrenn and Hart 1988; summarized in Askin et al. 1991), and the main part of the formation is Middle and Upper Eocene (e.g., Zinsmeister and Camacho 1982; Wrenn and Hart 1988). Current palynological research concentrates on terrestrial palynomorphs (spores and pollen from land plants) in about 500 samples from sections around the meseta. Marine dinoflagellate cyst assemblages from the middle and upper part of the formation were described by Wrenn and Hart (1988).

*Nothofagidites* pollen are particularly prominent in the lower part of the La Meseta Formation and include common *Nothofagidites matauraensis* (Couper) Hekel (*brassii* group) and *N. saraen-*