Neogene paleosols of the Sirius Group, Dominion Range, Antarctica

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The age and paleoclimate of fossils in the Sirius Group of the central Transantarctic Mountains have been controversial. Some see its fossil plants and diatoms as evidence of a major warming (5–10°C) and recession of the east antarctic ice some 3 million years ago (Webb and Harwood 1993). Others find more compelling evidence elsewhere for stability of east antarctic ice and warming of no more than 3°C and so regard the diatoms as surface contaminants (Burckle and Potter 1996) or the Sirius Group as geologically older than 3 million years (Kennett and Hodell 1996). Here we bring a new line of evidence to the dispute, that of fossil soils.

Our observations were confined to the Sirius Group exposed from Meyer Desert down to Oliver Bluff, where we recognize three distinctly different pedotypes (figures 1 and 2). The Siesta pedotype was named for its sunny aspect during our midnight rendezvous on a spur at the northeast edge of Oliver Bluff in the sequence of the lower Oliver Platform (85°6.8'S 166°43.2'E). This paleosol is the one noted 52 meters (m) above the base of unit 4 in section 5 of Webb et al. (1987). It overlies horizons yielding plant fossils from their unit 1/2 boundary to 4.5 m up into unit 4. The Siesta paleosol has a subsurface cemented zone (petrogypsic or By horizon) of fine-grained gypsum (figure 2C). The most weathered part of the profile (horizon Bw) is a little more clayey and ferruginized brownish red than the rest of the profile. The upper part of the profile has sparse drab-haloed root traces and irregular dikes of gray sand.

Peligro paleosols are named for exposures in the steep scarp in the central part of the Meyer Desert (85°11.4'S 166°47.1'W) and particularly the profile 16 m below the crest of the ridge (figures 1 and 2). The sequence on the upper Oliver Platform overlies a basement paleovalley at a high elevation (2,200 m) and, following the logic of a flight of postincisive terraces, is geologically older than the sequence (at 1,700 m) with the Siesta paleosol at Oliver Bluff (McKelvey et al. 1991). Peligro paleosols are similar to Siesta profiles but lack the gypsic horizon. Both Siesta and Peligro paleosols include dikes of gray sand in the reddish brown conglomerate of their Bw horizons. Viento paleosols are yellowish brown and thin. They are best represented by a profile 8 m below the crest of the ridge (figure 1).

Observations in petrographic thin sections confirm field impressions that these profiles are little weathered. Hypersthene grains persist unaltered in the paleosols from the parent Ferrar Dolerite. The profiles are unreactive to a dilute (10 percent) hydrochloric acid solution, but limestone clasts persist through the profile. Clay minerals determined by x-ray diffraction include mostly illite and chlorite, with only traces of smectite. Chemical analysis of the Siesta pedotype by AA

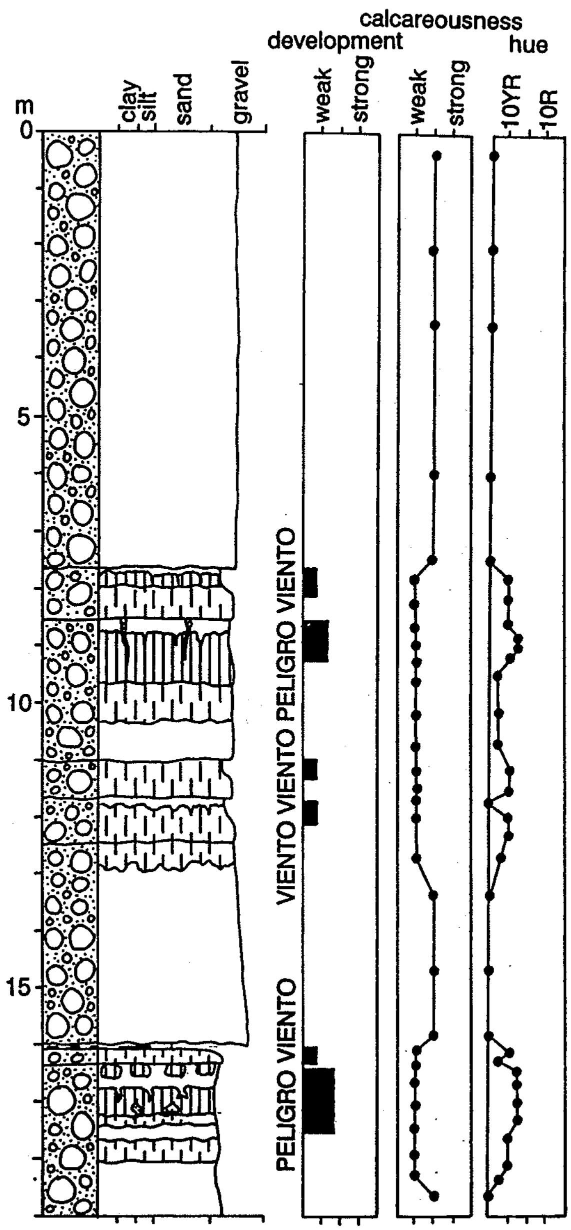

Figure 1. A measured section of paleosols down from the crest of the prominent scarp in central Meyer Desert, Dominion Range, Antarctica. Names are pedotypes, or field names, for recognizably different kinds of paleosols. Black boxes represent position of paleosols, their width corresponding to development. Scales of calcareousness are from relative reaction with dilute hydrochloric acid and hue is from a Munsell color chart. For key to lithological symbols, see figure 2.

This paper was published in the *U.S. Antarctic Journal* v. **30(5)**, p. 10-14.
Although this was the review issue for 1997, it was not published until 1999.

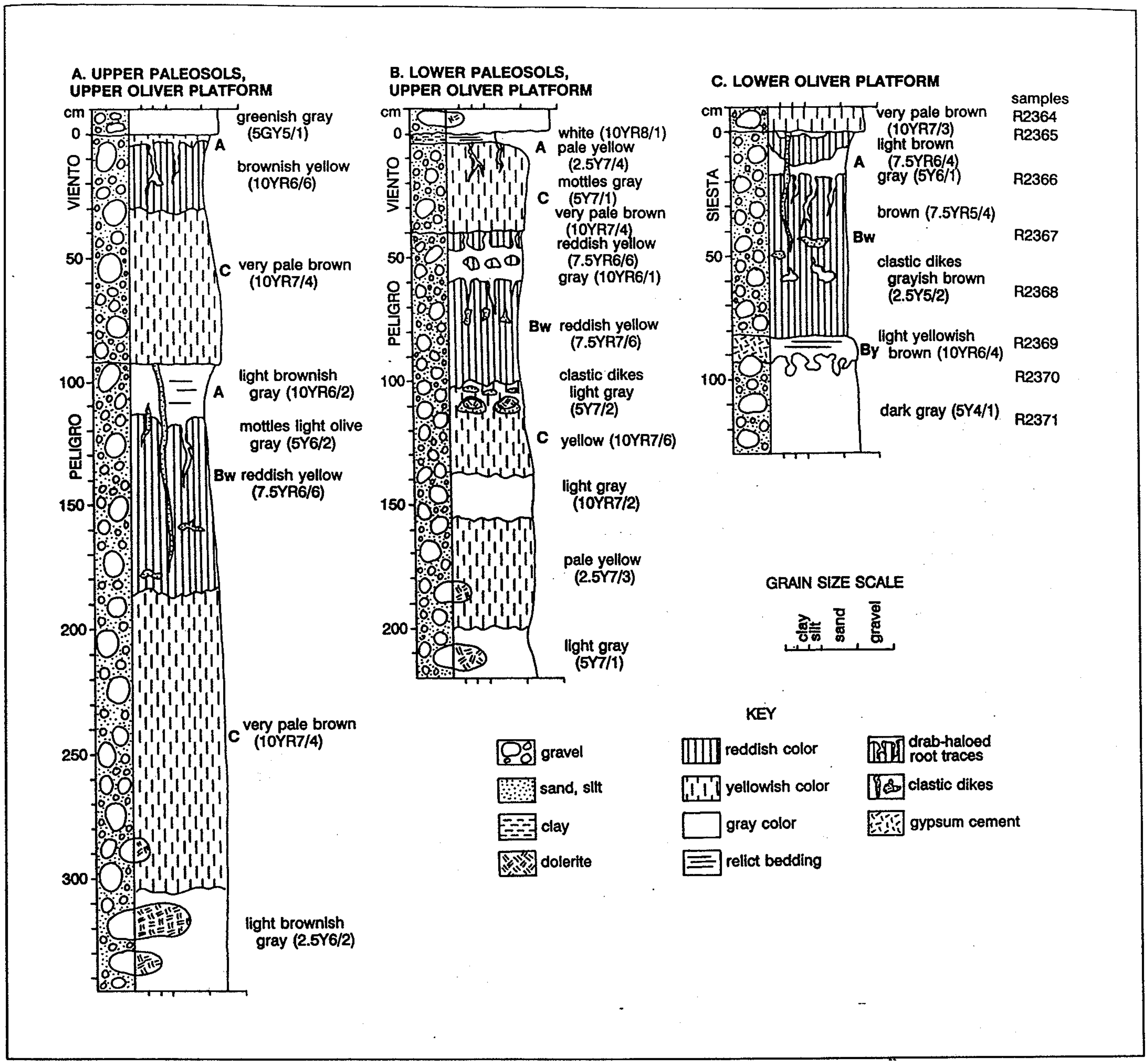

Figure 2. Detailed sections of recognized pedotypes in the Sirius Formation of the Dominion Range: (*A*, left) upper Viento and Peligro pedotypes from central ridge in Meyer Desert; (*B*, center) lower Viento and Peligro paleosols from central ridge in Meyer Desert; and (*C*, right), Siesta pedotype on spur east of Oliver Bluff.

shows evidence of only modest weathering (table 1). Indeed the degree of reddening, clay formation, and salt leaching is only about twice that in soils of the Dominion Range (Bockheim, Wilson, and Leide 1986). Viento, Peligro, and Siesta paleosols are comparable to xerous antarctic soils of progressively greater surface age (Campbell and Claridge 1987).

Comparison of the paleosols with modern soils (table 2) confirms their similarity with soils of the transition zone between polar desert and tundra (Bockheim and Ugolini 1990), as indicated by McKelvey et al. (1991). Comparable soils to Viento and Peligro paleosols support cushion plant-lichen communities including the woody plant *Salix arctica* on beach ridges of Truelove Lowland, Devon Island, Canadian Arctic, where mean annual temperature (MAT) is –16°C, mean annual precipitation (MAP) is 130 millimeters (mm), and a growing season of 69–99 days has temperatures of 1.3–13.6°C (Walker and Peters 1977). Such an assessment is compatible with recent interpretation of fossil *Nothofagus* from the Meyer Desert Formation as prostrate, dry tundra shrubs (figure 3; Francis and Hill 1996). Also comparable to the paleosols in depth and degree of weathering are soils of Enderby Land, Antarctica (MAT –11°C, MAP 600 mm; Bockheim and Ugolini

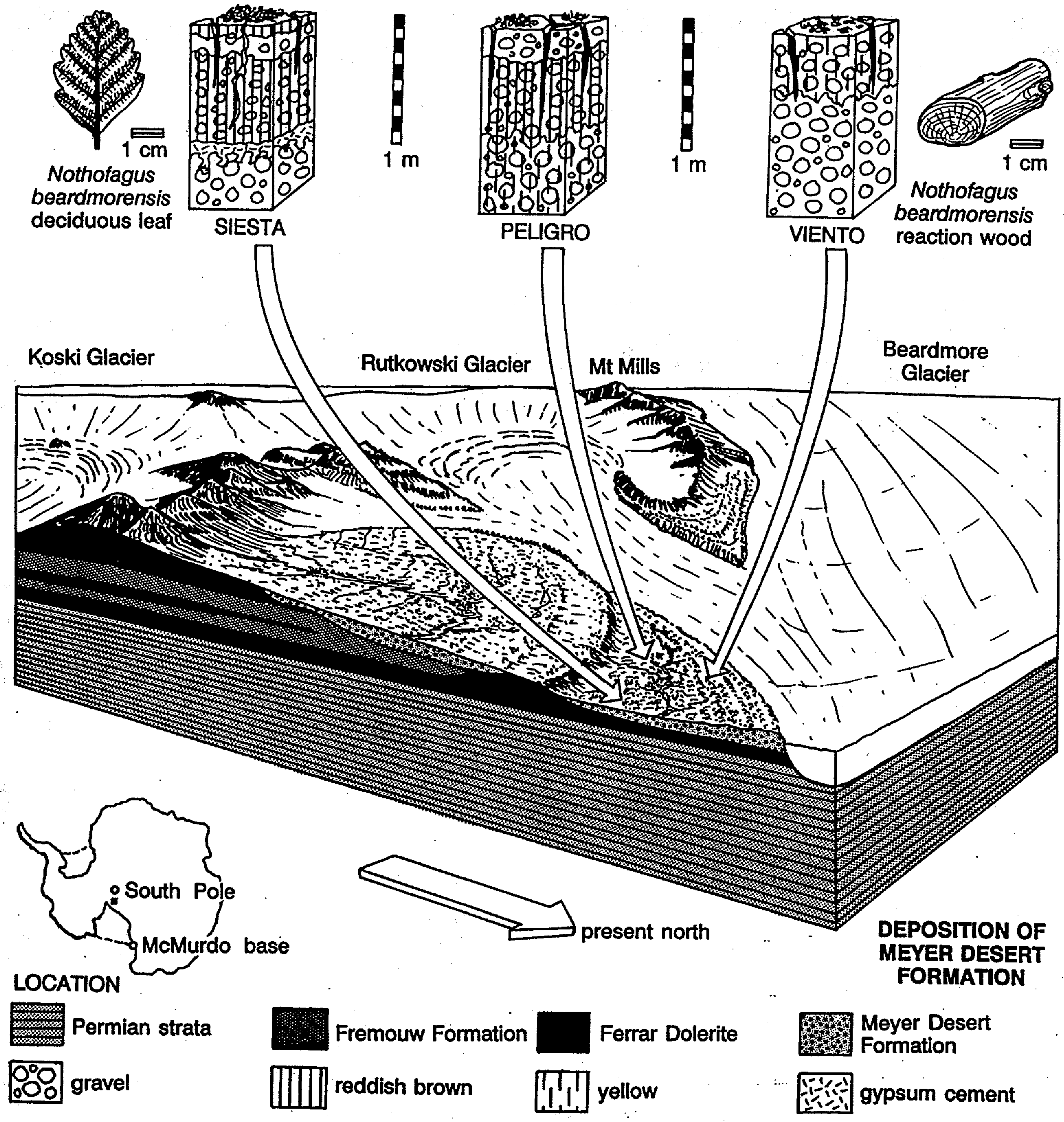

Figure 3. A reconstruction of soils and vegetation in Meyer Desert during deposition of the Sirius Group. Peligro and Viento pedotypes are presumed precursors in development toward the Siesta pedotype, but the type Peligro and Viento pedotypes are in the upper Oliver Platform. The South Pole is 500 kilometers south in the direction of the Beardmore Glacier.

Table 1. Major element (weight percent) and selected trace-element (barium, strontium, and zirconium in parts per million) composition and bulk density (in grams per cubic meter) of Siesta pedotype paleosol at Oliver Bluff, Dominion Range, Antarctica

Sample	Silica (SiO_2)	Titania (TiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Ferrous oxide (FeO)	Manganese oxide (MnO)	Magnesia (MgO)	Lime (CaO)	Soda (Na_2O)	Potash (K_2O)	Phosphorus oxide (P_2O_3)	Loss on ignition	Total	Barium	Strontium	Zirconium	Density
2364	59.58	0.48	11.53	3.55	1.35	0.09	2.80	6.24	2.06	1.98	0.07	7.97	97.87	448	172	143	2.24
2365	57.94	0.52	12.83	3.86	1.93	0.11	3.13	6.96	2.18	1.73	0.08	5.96	97.43	476	222	137	2.24
2366	59.96	0.48	11.59	3.30	1.48	0.09	2.72	6.36	2.08	1.75	0.10	7.41	97.50	465	203	141	2.12
2367	62.96	0.48	11.53	1.99	2.44	0.09	2.49	5.47	2.16	2.02	0.04	5.21	97.15	471	176	147	2.52
2368	63.45	0.47	11.40	1.74	2.61	0.08	2.23	5.24	2.18	1.83	0.05	5.51	97.09	479	173	153	2.50
2369	68.18	0.42	11.22	1.41	2.19	0.07	1.79	3.07	2.27	2.04	0.10	4.17	97.18	482	161	142	2.27
2370	61.45	0.56	13.46	2.09	3.60	0.11	3.56	5.10	2.12	1.53	0.09	4.33	98.40	456	44	10	2.44
2371	62.60	0.55	12.65	3.14	1.93	0.10	2.80	3.97	2.12	1.86	0.11	5.82	97.87	505	204	177	2.47

Table 2. Identification of paleosols of the Meyer Desert Formation in classification of modern soils

Pedotype	Campbell and Claridge (1987) stage	Bockheim and Ugolini (1990) soil	FAO (1974) World Map of Soils	U.S. taxonomy (Soil Survey Staff 1997; Bockheim 1997)
Viento	2 (20,000–100,000 years)	Red ahumisol	Gelic regosol	Cryorthent
Peligro	3 (390,000–340,000 years)	Subantarctic brown	Cambic arenosol	Cryochrept
Siesta	4 (800,000–920,000 years)	Subantarctic brown	Cambic arenosol	Gypsicryid

1990). The paleosols show much less podzolization, lessivage, or peat accumulation than found under conditions of subantarctic tundra or southern Chilean moorland or woodland, that have been suggested as paleoclimatic analogs for conditions during deposition of the Sirius Group (Mercer 1986). Paleosols of the Sirius Group in the Dominion Range are neither evidence for extreme warming and deglaciation nor for glaciers the same size as now but for an intermediate position of modestly, but significantly, warmer and wetter climates than present (figure 3). From this perspective, a Pliocene (3-million-year-old) age for *Nothofagus* leaves in the Sirius Formation is not especially anomalous.

We thank Scott Robinson and Shawn Norman for help with fieldwork. Work was funded by National Science Foundation grant OPP 93-15226.

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