# Permian and Triassic paleosols and paleoenvironments of southern Victoria Land, Antarctica

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Our studies of paleosols as guides to Permian and Triassic paleoenvironments in southern Victoria Land were stimulated by earlier reports of fossil soils in rocks of the Beacon Supergroup (Pyne 1984; Gabites 1985; Barrett and Fitzgerald 1986; Cúneo et al. 1993; Woolfe et al. in press). We measured stratigraphic sections spanning the Permian-Triassic bound-

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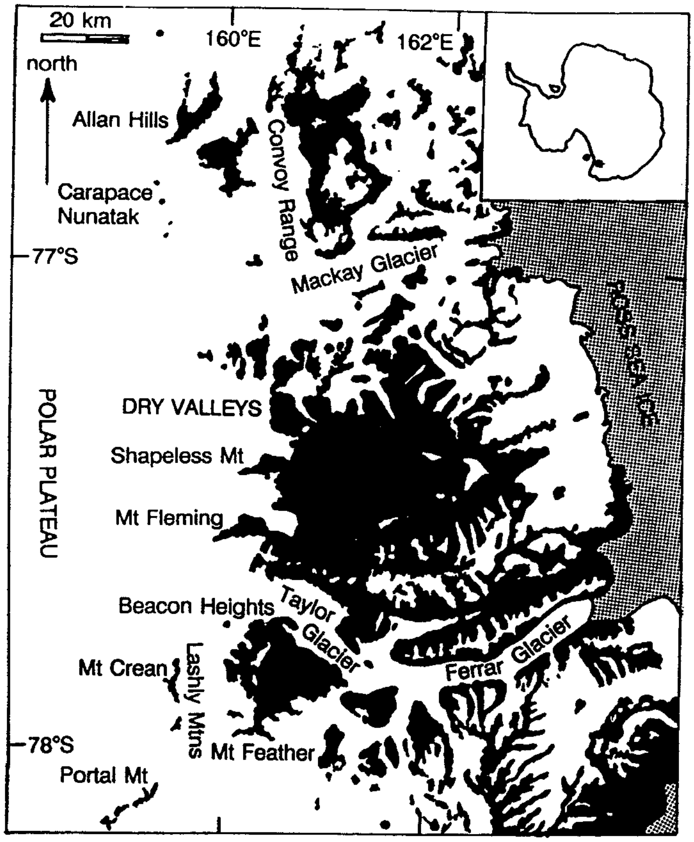

Figure 1. Rock and soil (black), and location of Allan Hills and Mount Crean in southern Victoria Land, Antarctica.

ary in the central Allan Hills (figures 1 and 2; 76°42.2'S 159°44.4'E) and on the southeast ridge of Mount Crean (figure 2; 77°52.4'S 159°32.0'E). Each paleosol type, or pedotype (of Retallack 1994), was characterized in detail. Because of the local shortage of place names, we named each pedotype from our own given names, with the exception of "Sandy" for sandstone profiles and "Dolores" because of our sorrow (Spanish *dolor*) over initially mistaking large nodules of these profiles for diabase (dolerite). The plotted development and the pedotype names (figure 2) show that we found 94 paleosols of 11 different pedotypes in a 292-meter (m) thickness of rock in the Allan Hills and 16 paleosols of four pedotypes in 145 meters at Mount Crean. This is not as many as can be found in clayey sequences of paleosols (Retallack 1983, 1991), but they are more abundant than fossil plant localities known from only four stratigraphic levels in the section measured at Mount Crean and eight levels in the Allan Hills.

The Permian Weller Coal Measures include many paleosols but a limited array of pedotypes. Susanne and Sandy pedotypes have root traces and much relict bedding and are either shaley (Susanne) or sandy (Sandy). Both preserve remains of horsetails (*Paracalamites australis*), and the type Sandy profile also has woody gymnosperm roots. Susanne and Sandy pedotypes probably supported lowland vegetation early in ecological succession to swamps represented by coals and underclays of the Evelyn pedotype. Clay partings, roof shales, and underclays of these coals have abundant leaves of *Glossopteris* and *Gangamopteris* (described by Plumstead 1962; Townrow 1967; Cúneo et al. 1993). The common deeply penetrating roots of *Vertebraria* beneath all the paleosols of the measured sections (figure 2; *see also* Cúneo et al. 1993) and associated permineralized trunks of *Dadoxylon allani* leave little doubt that these Permian swamps were forested by glossopterids. In waterlogged habitats, soils are isolated from regional climate by high water table, but such thick coals are indicative of humid climate and the big trees with growth rings are evidence for seasonal climate warmer than frigid (Taylor Taylor, and Cúneo 1992).

The Feather Conglomerate has few age-diagnostic fossils but is probably early to middle Triassic (Collinson 1990; Woolfe et al. in press). Its weakly developed paleosols include shaley profiles of the Susanne pedotype and bedded sandstone with fossil roots and *Skolithus* burrows of the Edwin pedotype. *Skolithus* is an ichnogenus of vertical sand-filled burrows, widely interpreted as dwellings of marine worms. In Antarctica, however, *Skolithus* is connected to chevron trails like those made by insects (Miller and Collinson 1994) and is found in fluvial deposits at least 2,000 kilometers from the sea (Fitzgerald and Barrett 1986). Comparable nonmarine *Skolithus*-bearing paleosols are known from Early Triassic fluvial sediments of the Sydney Basin, Australia (Retallack 1976). Dolores paleosols (paleosol 3 of Gabites 1985) are only a little thicker and more bioturbated and clayey than Susanne profiles, and their subsurface horizons include large green nodules. Also found in the middle Feather Conglomerate were angular blocks of permineralized peat comparable to those on Fremouw Peak, central Transantarctic Mountains (Taylor, Taylor, and Collinson 1989). These represent peaty paleosols, which we failed to find in place. Thick, clayey, moderately developed Gregory and John pedotypes show some reddish stain, but in all cases, the stain proved to be caused by thin surficial weathering. Nevertheless, these lowland soils were probably well-drained seasonally because they show well-developed soil cracks. Gregory profiles have columnar peds (figure 3*A*; number 1 of Gabites 1985). John paleosols (also described by Barrett and Fitzgerald 1986) have spectacular thick root traces and sand-filled cracks, as well as a thick subsurface horizon of clay accumulation (figure 3*B*). Neither of these paleosols is calcareous and so probably formed in a seasonally dry, humid climate of more than 1,000 millimeters of rainfall per year.

Paleosols of the middle to late Triassic Lashly Formation have white root traces of woody plants (Gabites 1985). Deciduous trees also are in evidence from fossil wood and a variety of fossil leaves dominated by *Dicroidium*, including fossils of petiolar abscission scars (Townrow 1967) and wood with pronounced growth rings (E.L. Taylor et al. 1990; T.N. Taylor et al. 1990). Weakly developed paleosols are here as well, including sandy profiles of the Michael pedotype (paleosol 4 of Gabites 1985) and shaly profiles of the Shaun pedotype (5 of Gabites 1985), these latter including horsetails (*Neocalamites*) in growth position. Horsetails were probably a conspicuous component of Triassic early successional vegetation, which included woody plants on sandy soils. Thicker paleosols of

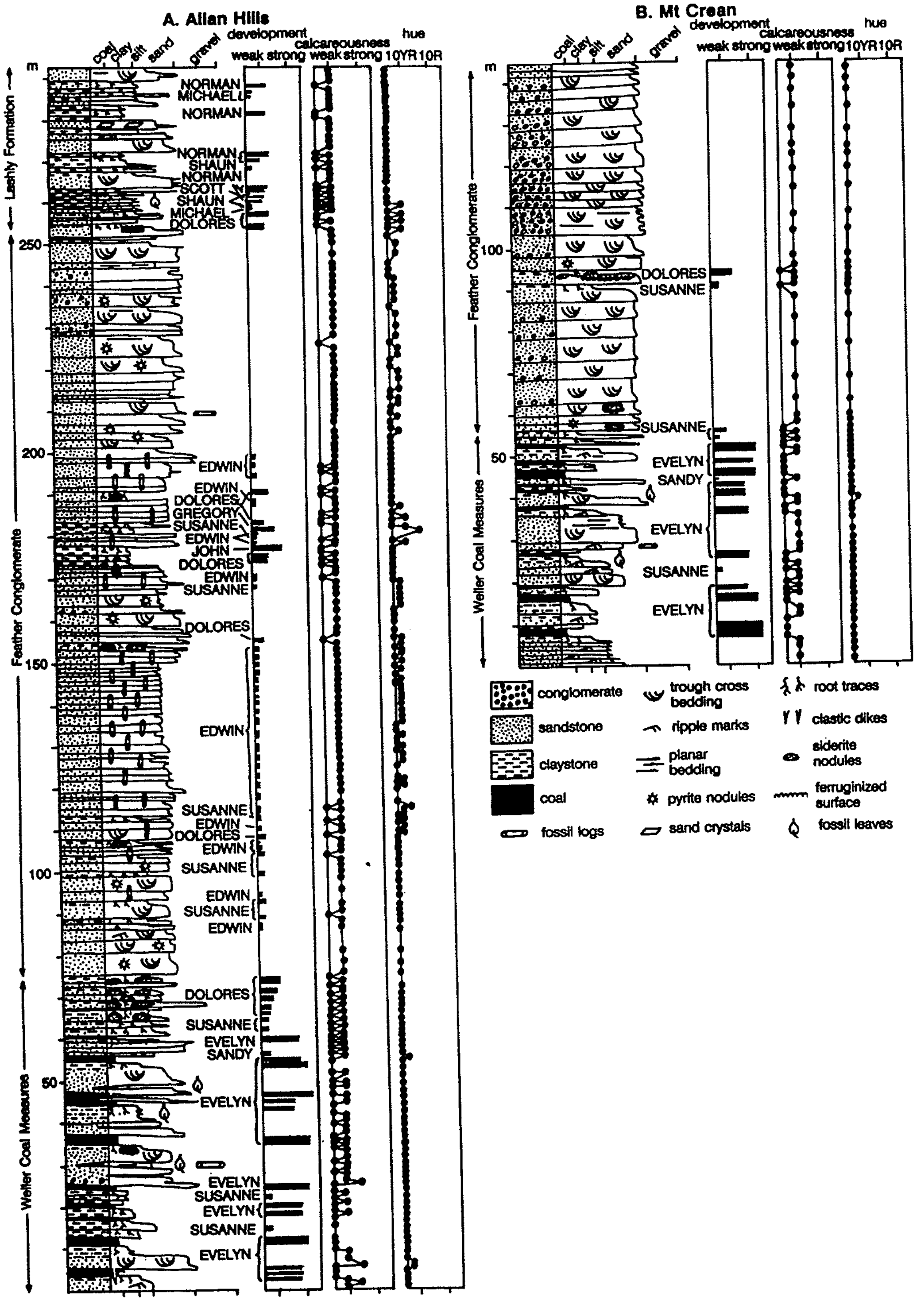

Figure 2. A measured section of paleosols in the central Allan Hills (*A*) and Mount Crean (*B*). Hue is from a Munsell color chart, and reaction with acid for calcareousness and degree of development are from scales of Retallack (1988). Names of paleosols are pedotypes (of Retallack 1994).

weak to moderate development which probably supported woodland vegetation include the Norman pedotype (6 of Gabites 1985) with locally prominent slickensides and surface undulation suggestive of incipient vertic structures (of Soil Survey Staff 1990) and the Scott pedotype (2 of Gabites 1985), with columnar peds like those of the less greenish hued and more silty Gregory pedotype. Carbonaceous paleosols (7 of Gabites 1985) and some coals were seen high in the Lashly Formation but were not reached by our measured section (figure 2*A*). Soils of the lower Lashly Formation were lowland profiles given their green color, but the vertic structures indicate a more severe dry season and drier climate overall than during deposition of the upper Feather Conglomerate. Their noncalcareous composition indicates a climate more humid than 1,000 millimeters of rainfall per year.

Much remains to be done to extract further paleoenvironmental information from these paleosols, by detailed petrographic and geochemical studies (comparable to those of Retallack 1983, 1991). Also of interest is the vexing question of the location and completeness of the Permian-Triassic boundary transition in these sections, which we intend to examine using paleobotany (with emphasis on glossopterid fructifications; see McLoughlin 1993, p. 253–264), palynology [increasing Kyle's (1977) sample coverage of the Weller-Feather Formation contact] and carbon isotopic studies (comparable to work of Morante et al. 1994) as has recently been done in the Sydney Basin of Australia (Retallack 1995). Our fieldwork to date, however, reveals that paleosols are indeed present in the Beacon Supergroup in sufficient variety and abundance to provide a useful supplement to sedimentological and paleontological reconstructions of the antarctic Permian and Triassic. Permian and Triassic paleosols of this former Gondwanan continental interior are more like those of southern Canada than arctic soils of today.

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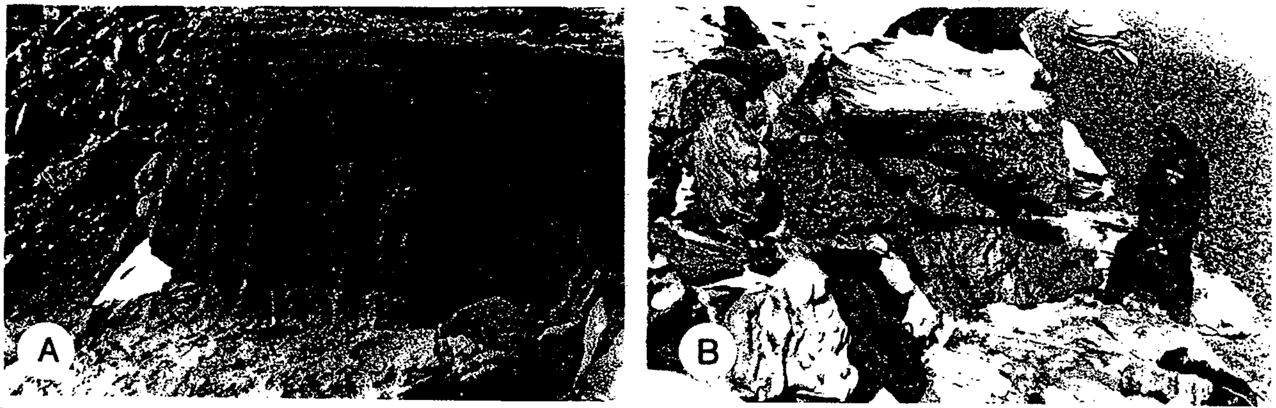

Figure 3. Paleosols of the upper Feather Conglomerate in the Allan Hills; *A*, columnar peds in type Gregory paleosol (184 meters in figure 2A), with hammer for scale; *B*, clayey subsurface horizon in type John paleosol (178 meters in figure 2A), with Evelyn Krull.

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