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Paleoenvironmental interpretation of paleosols

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Notes

Penrose Conference report

Paleoenvironmental interpretation of paleosols

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Fossil soils have been recognized for a long time. James Hutton as long ago as 1795 understood that major unconformities within Paleozoic rocks in southwestern Scotland were buried erosional landscapes. John Playfair, who popularized Hutton's views within a book published in 1802, added an example of a buried prehistoric forest along the coast of Lincolnshire. The term paleopedology was first introduced in 1927 by Boris Polynov for the study of such Quaternary paleosols. This kind of research has continued in soil science and Quaternary studies. In contrast, the study of older paleosols, now known back 3000 m.y., has been taken up by paleontologists, geochemists, sedimentologists, and economic geologists. A Penrose Conference in September 1987 attempted to reconcile these geological and pedological approaches. On the one hand, geologically trained researchers could use the expertise of soil scientists in interpreting their often altered and deformed paleosols. On the other hand, the fossil record of soils can be regarded as a long-term natural experiment in which the principal factors of soil formation have varied in ways that may reveal fundamental principles of soil formation.

The conference gathered 62 people, most from the United States but some from Argentina, Australia, Canada, England, Israel, South Africa, Switzerland, and West Germany, September 11–17, 1987, at Kah-nee-tah Lodge, on the Warm Springs Indian Reservation of central Oregon. Formal sessions were arranged so as to give equal time to Quaternary and pre-Quaternary studies of each of the main soil-forming factors: climate, organisms, topographic relief, parent material, and time.

Rose began the sessions by describing in detail how a variety of cryoturbation structures and sequences of clayskins within British interglacial paleosols could be related to waxing and waning of glacial climate. MacFadden followed by outlining a variety of climatic functions from his work on desert soils of the southwestern United States. Dormaar pointed

out problems with the use of soil organic matter as a paleoclimatic indicator. On the pre-Quaternary side, Wright introduced the shear abundance of paleosols with caliche as an indicator of dry climates and paleosols with pseudoanticlines as indicators of seasonality. Blodgett examined the long fossil record of Vertisols and talked about problems with their interpretation. Discussions later focused on the climatic interpretation of clayskins and difficulties introduced by diagenetic alteration of clays in paleosols. A pleasant surprise of this first morning was that there were more studies of climatically sensitive features of soils and more paleosols to which they could be applied than many of us had anticipated.

Hole discussed the role of organisms such as ants, squirrels, and fallen trees as earth movers. Pope outlined studies of soil and vegetation mapping and reconstruction after human interference in Belize and Greece. Retallack introduced three possible lines of evidence for former ecosystems of paleosols: fossils, trace fossils, and profile morphology. The first two methods were supported by R. Smith, who described the oldest (Late Permian) reptile burrows containing skeletons of their makers (*Diictodon*), and by Evanoff, who described differences between snail assemblages from Oligocene paleosols. Ensuing discussions explored the difficulty of using paleosol features other than root traces as a guide to former vegetation. Few robust biologic functions are known for modern soils. This is a conspicuous deficiency compared to understanding of other factors in soil formation.

Yaalon opened a session on the effects of topographic relief with examples of soil catenae from a variety of settings. Walker outlined some Australian examples. Follmer reviewed some concepts of slope models and the historic debate over midwestern clays variously regarded as gum-botils or accretion gleys. Fastovsky painted a pessimistic picture for reconstructing paleotopography from paleosols, because of complications from the diagenesis of organic matter and iron-bearing minerals. Andreis offered a perspective from sedimentary facies models, giving numerous examples of pre-Quaternary paleosols from South America. Discussion brought out clearly the extensive record of pre-Quaternary paleosols in sedimentary sequences of low-lying river basins and coastal plains, whereas the emphasis of many Quaternary soil studies is upland soils.

The parent material of a soil must be well characterized in order to make any sense of soil development. It has been disconcerting to find that

the parent material of many soils is not the rock beneath them, but air-borne dust that settled during their development. Muhs made this point with examples from southern California and the West Indies, as did Dixon with examples from the Colorado Rockies. Olson reviewed various deep weathering zones found beneath many midwestern soils. On the pre-Quaternary side, Holland developed an elegant model for relating parent material composition to the consumption of oxygen and carbon dioxide during weathering, and he used this to infer a weakly oxygenated Precambrian atmospheric composition from paleosols. Reinhardt demonstrated variation of paleosol types on different parent materials along a single mid-Cretaceous unconformity in the southeastern United States. Parent material provides both a geologic setting and a potential for soil development; discussion explored differences in terminology and viewpoint of geology and pedology.

Time is probably the best understood of the soil-forming factors. Birkeland summarized an impressive array of chronological functions for a variety of climatic and tectonic settings. Other such functions, based on the kind of mineralogical data that could be applied to paleosols, were introduced by Buol. Harden explained overall profile development indices. On the pre-Quaternary side, Kraus outlined how patterns of paleosol development in long alluvial sequences can be related to tectonic activity or paleoclimatic change. Patterson discussed problems with interpretation of age from paleomagnetic measurements of alluvial sediments. At the other end of the temporal spectrum, Valeton gave evidence that Indian bauxitic paleosols formed within only 7 m.y., rather than over many tens of millions of years as is commonly assumed. A wide range of rates of soil formation now are known, and old concerns continue about whether soil formation is stimulated by thresholds, limited by steady state, or constant with time.

A one-day excursion into Quaternary soils and sediments of the Willamette Valley was led by McDowell, with the help of Herb Huddleston of Oregon State University. Another trip, led by Retallack, examined mid-Tertiary paleosols and fossil localities at Camp Hancock and the Painted Hills in the high desert of north-central Oregon. It was a rare chance for hard-rock geologists to learn about such things as clayskins and for soil scientists to make sense out of indurated sedimentary rocks. A trip to view Holocene volcanic activity on McKenzie Pass allowed geologists to see paleosols in the making, and soil scientists to attempt to identify the soil on 2500-yr-old, blocky lava flows (Lithic Cryorthent).

A new wave of posters appeared each day. Discussion groups presented conclusions on the final day on such topics as defining "paleosol" (Zbinden and Shepherd), mapping and naming paleosols (Bettis), sedi-

mentation and pedogenesis (L. Smith), distinguishing stratigraphic and pedogenic layering (Guccione), observational methodologies (Creameens) and diagenesis of paleosols (Blodgett and Lander). Shlemon provided walking proof that there is a living to be made as a consulting paleopedologist. Consideration also was given to future meetings, newsletters, and journals.

The enthusiasm of the group for round-the-clock scientific discussion made this conference memorable. It proved possible for 62 people to have open discussions without acrimony or tedium. Discussions began with material presented but soon took on a life of their own. Those who style themselves paleopedologists are fond of regarding their work as pioneering. Certainly there have been few colleagues and little prior literature. The abstruseness of the subject is well conveyed, as Fastovsky aptly pointed out, by its claim to literary fame on page one of Vladimir Nabokov's novel *Lolita*. In contrast, however, this conference showed that, with a little borrowing of expertise from adjacent disciplines, paleopedology is starting to come of age. There is useful information on soil forming processes in paleosols, and paleoenvironments can be interpreted from paleosols.

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