First paleoenvironmental interpretation of a pre-Quaternary rock-varnish site, Davidson Canyon, southern Arizona

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ABSTRACT

Dark, manganese-rich rock varnish of probable Miocene age is exhumed in a road cut in the drainage of Davidson Canyon, southern Arizona. Its structure and inorganic chemistry is similar to modern arid and semiarid rock varnishes. The $\delta^{13}C$ content of organic matter in the varnish is consistent with a C_4 photosynthetic pathway for adjacent plants. Organic and inorganic chemical analyses of paleovarnishes can be used to interpret past subaerial environments.

INTRODUCTION

Rock varnish is a dark coating found on rocks in virtually every terrestrial weathering environment, from deserts to the high alpine, to point bars in humid-continental climates, even to soil peds in the Olympic Peninsula of Washington (Dorn and Oberlander, 1982). It is most common in arid and semiarid lands, in part because both the rock surfaces and the varnishes are most stable in arid nonacidic conditions. Quaternary varnish has a variable composition, from about 40% to 70% clay minerals, 10% to 40% manganese and iron oxides, and more than 30 minor and trace elements (Potter and Rossman, 1977, 1979; Dorn and Oberlander, 1982; Duerden et al., 1986); the manganese, and possibly the iron, is concentrated by bacteria (Dorn and Oberlander, 1981, 1982; Krumbein and Jens, 1981; Palmer et al., 1985). This study presents the first quantitative microchemical analyses of pre-Quaternary paleovarnish. These analyses are used to infer paleoenvironmental conditions associated with a Miocene paleosurface.

Fossil varnishes have been observed in Cenozoic, Mesozoic, and Precambrian geologic deposits. Paleovarnish from beneath a mudflow in Death Valley, California, has been radiocarbon dated to be about 11,000 yr B.P. by accelerator mass spectrometry, and it has a chemistry similar to adjacent subaerial varnishes (Dorn, 1988). Manganese-iron varnish has been observed in Triassic desert deposits of the Budleigh Salterton Pebble Beds (Green, 1985). Manganese-iron crusts have been found associated with a 2200 Ma paleosol that could be analogous to modern rock varnish (Retallack, 1986a, 1986b); it is possible that the Early Proterozoic microfossil *Eoastrion* spp. could have been involved in its development, because *Eoastrion* is similar in morphology to contemporary manganese-oxidizing budding bacteria (Barghoorn, 1977; Schopf et al., 1984) that are involved in the formation of modern varnish (Dorn and Oberlander, 1982).

Fossil rock varnishes are relatively rare. Preservation requires both mechanical and biogeochemical stability. The abrasion hardness of rock varnish is ≤4½ on Mohs scale (Dorn and Oberlander, 1982), and virtually any sustained mechanical abrasion will remove varnish. Because the manganese and iron in varnish are reduced and mobilized under acidic conditions, sustained low pH in vadose water will dissolve varnish. Preservation requires a low-energy depositional process for the material burying the varnish and nonacidic conditions after deposition.

STUDY SITE

Fresh samples of paleovarnish preserved on clasts of Miocene rubbly colluvium were collected from a steep roadcut on the interfluve between Davidson and Barrel canyons about 50 km southeast of Tucson (Fig. 1). The varnished colluvial layer (Fig. 2) mantles a buried paleosurface formed during Miocene erosion of the mid-Tertiary Pantano Formation, which is a local red-bed sequence of alluvial-fan, braidplain, and associated lacustrine deposits (Balcer, 1984). Intercalated volcanics have yielded late Oligocene K-Ar ages (n = 6) of 25–30 Ma (Dickinson and Shafiqullah, 1989). Prior to mid-Miocene time, Pantano strata were broken into multiple tilt blocks with dips of 20°–40° by extensional deformation associated with tectonic denudation of the nearby Catalina core complex. The colluvium that is coated with black varnish is a thin lag derived from conglomeratic Pantano beds.

The varnished colluvial horizon is overlain depositionally by gently dipping and weakly consolidated sandy gravel deposits whose pale gray to buff color contrasts strongly with the dark brown to red conglomeratic strata of the underlying Pantano Formation. The younger fluvial gravels onlapped a paleoslope developed by prior erosion of the more strongly deformed Pantano Formation (Fig. 2). The overlying gravels are laterally contiguous with the Neogene basin fill of Sonoita Valley to the south, and they are exposed where modern headward

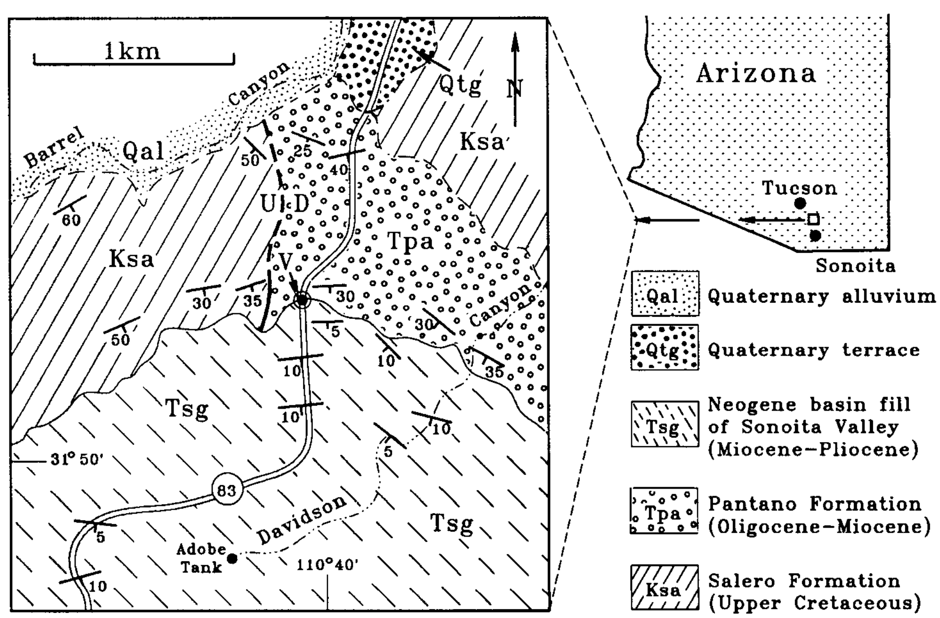

Figure 1. Geologic sketch map of area surrounding Miocene fossil varnish locality (V) along State Highway 83 in SE¼NW¼ sec. 27, T. 18 S., R. 16 E., Empire Ranch quadrangle, Pima County, Arizona. Modified after Finnell (1971). Alluvium shown only along wash floor of Barrel Canyon.