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RIND, WEATHERING

Weathering rinds are zones of chemical alteration on the outer portions of rocks. In some, but not all cases, a distinct colour difference highlights this zone of intense CHEMICAL WEATHERING. Weathering rinds are important in geomorphology for their role in weathering processes, their role in the development weathering forms such as CASE HARDENING, and in their use in dating landforms. Obsidian-hydration rinds are a related phenomenon.

A weathering rind is not just a zone of chemical alteration at the outer edge of a clast; weathering rinds represent the redistribution of elements. Some rinds are dominated by an enrichment in iron, while others are depleted in such mobile cations as calcium and sodium. A variety of processes develop weathering rinds. Dissolution, for example, leaves void space in the rock and does not necessarily change the colour. Oxidation of iron, in contrast, leaves a band of discolouration. The appearance of the zone of discolouration varies by location and rock type. For instance, rinds can appear white on the upper slopes of Mauna Kea and appear orange on the lower slopes, all in a basalt lithology (Plate 96). Andesite in Japan can appear brown to pale grey (Matsukura *et al.* 1994), and sandstone

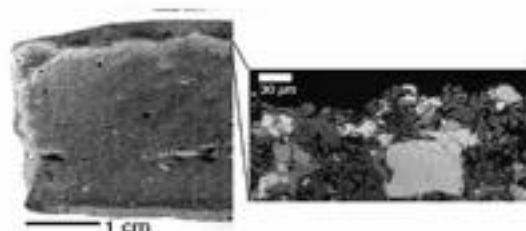


Plate 96 Weathering rind developed on a glacially polished basalt, Mauna Kea, Hawaii. This rind developed over a 16,000-year period. The left photograph shows an optical rind visible in a hand specimen. The right image shows an electron microscope (backscatter) image of a small section of the rind, illustrating three aspects of rind development. First, dissolution of minerals dominates rind formation, as exemplified by the pores (black areas). Second, the bright spots in the image are reprecipitated iron hydroxides, responsible for reddening. Third, rinds may not necessarily thicken over time. Often, they undergo erosion as pieces of weathered minerals progressively detach, that is if rinds are not protected by rock coatings

rinds in New Zealand can appear whitish (Knuepfer 1988).

Weathering rinds form on all three rock types: igneous (e.g. andesites, basalts, granitic), sedimentary (e.g. sandstones) and metamorphic (e.g. schists). Weathering rinds occur in a wide range of locations and in temperate, tropical, arctic and arid environments, for example, Hawaii (Jackson and Keller 1970), the coterminous United States (Colman and Pierce 1986), New Zealand (Chinn 1981), Japan (Matsukura *et al.* 1994) and northern Europe (Dixon *et al.* 2002). Weathering rinds are found in clasts at the surface and within the soil profile (Chinn 1981; Knuepfer 1988).

Weathering rinds are often used in geomorphology to estimate ages of landforms and landscape surfaces (Chinn 1981). This approach assumes that rinds begin to form soon after emplacement of the host rock, and that rinds grow thicker with time (Knuepfer 1988). Weathering rinds thus serve as a relative age indicator where thicker rinds occur on older landforms, and as a calibrated age indicator if accurate forms of age calibration are available in the study area. Prior to the use of cosmogenic nuclides

(see COSMOGENIC DATING), use of weathering rinds was prevalent in Quaternary research where moraines, outwash sheets and other landforms correlated climatic changes (Colman and Pierce 1986). The thickness of the discoloured zone of a number of clasts in a deposit is measured normal to the surface, usually with a caliper. Statistical methods differentiate groups of thicknesses among different deposits or surfaces.

Because weathering rinds are so often felt to be synonymous with discolouration, we stress that the study of weathering rinds should not be limited to the measurement of colour changes in hand samples for several reasons. First, a weathering rind can occur without any noticeable colour change. Second, colour change provides only one indication of weathering; microscope studies reveal that the zone of chemical weathering continues into the rock well underneath the zone of colour change. Third, although weathering rinds are not ROCK COATINGS, a single clast may exhibit both a weathering rind and a rock coating (Matsukura *et al.* 1994), a distinction not always recognized in the field. Fourth, where weathering rinds are not protected by rock coatings, weathered mineral fragments readily spill off.

Research into weathering rinds is expanding into exciting new dimensions. Physical and chemical characteristics of weathering rinds are being used to help discern geochemical weathering processes in a given region or area (Dixon *et al.* 2002). The use of cosmogenic nuclides as a dating method has made weathering rind analysis more important than ever. A key uncertainty in cosmogenic dating surrounds the prior exposure history of a possible sample. With each cosmogenic measurement costing about US\$2,000 in sample processing and analysis, weathering-rind measurements provide an inexpensive field check on the possibility that a particular sample might have a complex geomorphic history. In addition, *in situ* measurements of weathered minerals in rinds are providing new insight into quantitative rates of weathering; this method is being used, for example, to establish long-term rates of glass dissolution with the goal of understanding GEOMORPHOLOGICAL HAZARDS associated with nuclear waste storage (Gordon and Brady 2002).

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SEE ALSO: case hardening; chemical weathering; rock coating

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