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Rock spiraea (*Petrophytum caespitosum*) from the Grand Canyon – habitat and growth rings

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Introduction

Shrubs, dwarf shrubs and herbs have a large potential for dendrochronological research in cold and arid regions, where trees are not the dominant form of vegetation cover. The presence of annual growth rings in plants in these environments is significant for climatic, ecological and geomorphologic applications in cliff-face, alpine and other "extra-arboreal" regions of study. Many studies on the analysis of dwarf-shrub data have been yielded from the Arctic and high mountain environments. *Salicaceae* collected north of the Polar Circle are widely used in various studies (Woodcock & Bardley 1994, Zaltan & Gajewski 2006, Owczarek 2009), although the analysis of their anatomy is very difficult due to several factors, such as very narrow growth rings (0.001 – 0.1 mm), common discountinuous rings, missing rings and scars connected with animal grazing. The effect of periglacial processes (e.g. debris flows, creep) on the formation of growth rings as measured by tension wood analysis and identification of injuries in small dwarf shrubs (*Salix polaris* (Wahlenb.) and *Salix reticulata* (L.)), have been investigated only in the Svalbard archipelago (Owczarek 2010). Analyses of dwarf shrubs in the high mountain areas in USA have been carried out on the eastern side of the Sierra Nevada range in California. The growth form of plants occupying rock glaciers and high elevation talus/scree slopes on the arid eastern slope of this range is often a low shrub or cushion plant form (Major & Taylor 1988). Several species, e.g. *Linanthus pungens* (Torr.), sampled in this region for dendrochronological potential have been found to be long lived (up to 150 years) and to have climatically sensitive, cross-dateable annual growth rings in their persistent woody taproot (Franklin, unpublished data). East of the Sierra Nevada range, on the Colorado Plateau, the small prostrate dwarf shrub *Petrophytum caespitosum* (Nutt.) can be found. It inhabits the desert scrub community found on the upper walls of the Grand Canyon of the Colorado River. The aim of this paper is to present the habitat, ecology and wood anatomy of this shrub.

Study area

Samples of *Petrophytum caespitosum* (Nutt.) were collected on the northern edge of the Grand Canyon (the Colorado Plateau, Arizona) in the Kaibab National Forest (Fig. 1, Fig. 2) between 2,100 and 2,250 m a.s.l. The Colorado Plateau is a region of the mountainous western United States characterized by reddish layers of alternating sandstone, limestone, shale and siltstone laid down by transgressing and regressing seas during the Paleozoic Era (Crampton 1985). These layers are exposed most obviously in the walls of the Grand Canyon of the Colorado River in northern Arizona. The depth of the Grand Canyon can reach almost 2 km.

Because of the vast vertical distance covered by the canyon walls, the vegetation of the Grand Canyon falls into several different biotic communities that are influenced not only by elevation but by climate, geomorphology and geology. Immediately adjacent to the Colorado River a riparian community of willow (*Salix spp*.) exists. Above the riparian corridor, a community of desertscrub thrives with species similar to many western US deserts such as creosote (*Larrea tridentate*), rabbitbrush (*Chrysothamnus spp.*) and big sagebrush (*Artemesia spp*.). Above the desertscrub community the Pinyon-Juniper woodland extends up to approximately 1,900 m a.s.l..

From 2,000 – 2,500 m a.s.l. Ponderosa Pine is found along with some species of oak, locust and mahogany (Fig. 2). At the upper reaches of the northern rim of the canyon (2,500 m.a.s.l.), spruce, Douglas-Fir and White Fir and Aspen can be found (McDougall 1947).
Annual rainfall for the Colorado Plateau has a bimodal pattern with peaks in rainfall in late summer (August) and late winter. The driest months occur in early summer (May/June) (Mock 1996, Spence 2001).

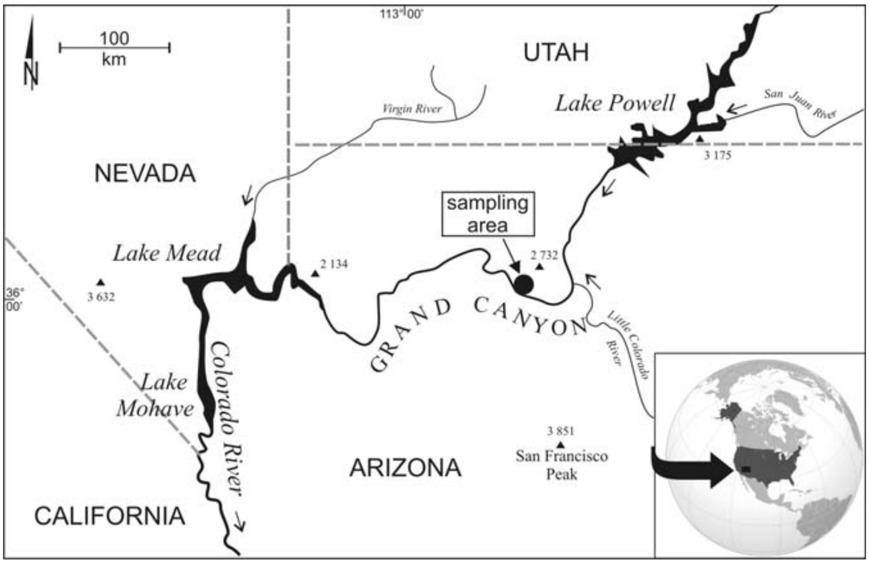

Figure 1: Location of the study area.

Figure 2: Upper part of the North Rim (Kaibab Plateau) with the sampling area on the elevation 2,200 m a.s.l. In the vicinity are visible Ponderosa Pine trees.

Methods

The samples of *P. caespitosum* were collected in May 2009. Complete individuals of *P. caespitosum,* including their root and branch systems, were collected and each individual was documented by digital images. The samples were sectioned with a GSL 1 sledge microtome, with 15 – 20 µm cross-sections taken from 2 to 4 different locations along the length of each individual. Microtome sections were prepared from the whole diameter of selected segments. The samples were drying after staining with 1% solutions of Safranin and Astrablue and dehydration. The microscopic observations were carried out using a light microscope with objective magnifications 10, 20 and 40. Digital images of the micro-sections were taken for tree-ring analysis and measurements. Wood anatomical structures such as growth ring width were measured along two to three radii using OSM 3.65 and PAST4 software.

Plant characteristics

General description

Petrophytum caespitosum (Nutt.) is a dwarf shrub commonly known as rock spiraea, rockmat or Rocky Mountain rockmat, and belongs to the family *Rosaceae*. The species grows elsewhere on limestone and igneous outcrops from desert scrub to the subalpine zone (1,700–3,100 m a.s.l), typically on the sunny edges of rock cliffs in south-western United States and northern Mexico. An isolated occurrence is also known in Washington and northwestern Oregon (northwestern US) (Hitchcock et al. 1961, Sterlin 1966, Heil & Kane 2005). The plant is common on the upper regions of the Grand Canyon walls. This part of the Grand Canyon is formed from the Kaibab limestone. Often the plant hangs downwards from the rock wall and forms “hanging gardens” (Fig. 3A) held in place by stout roots growing in wet rock cracks. This growth form is associated with the presence of water in bedding planes within the rock strata (Welsh 1989). The plant occurs as mats on the edges of rock surface as well (Fig. 3B). The lance-shaped leaves, 8-10 mm long, are grayish green and form rosettes. The stems and branch system are 1 – 3 cm in diameter and grow in horizontally spreading mats (Fig. 4AB). This prostrate shrub grows 10 – 20 cm high (without the flower spike). Mats at the research site were found to reach 1.3 m in diameter. The whitish flowers form small spike-like clusters located on a single upright stem approximately 2-3 cm tall (Fig. 4A).

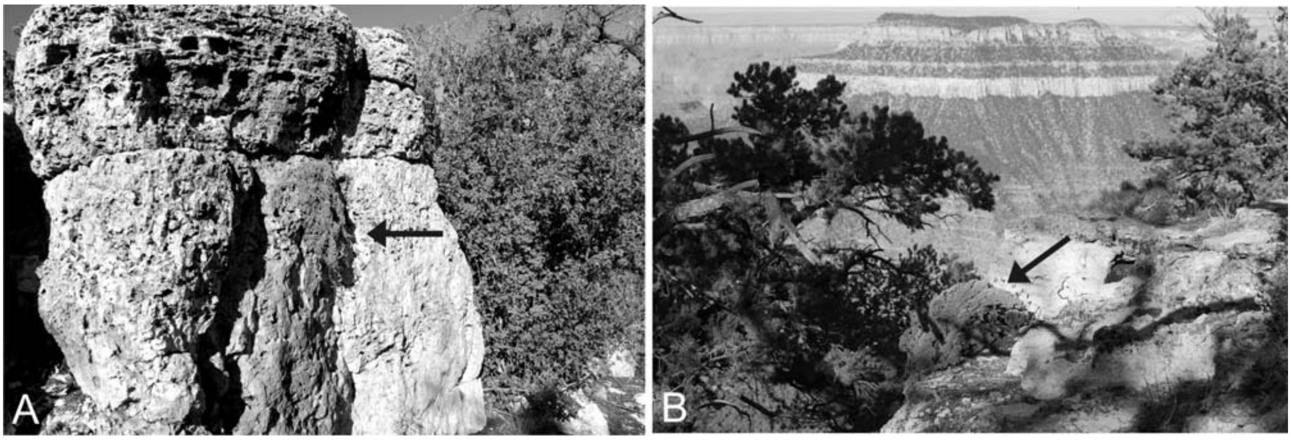

Figure 3: P. caespitosum attached to cracks in the upper part of the Kaibab limestone formation. (A) – typical growth form - “hanging gardens”, (B) – the plant often forms dense mat on the cliff edge.

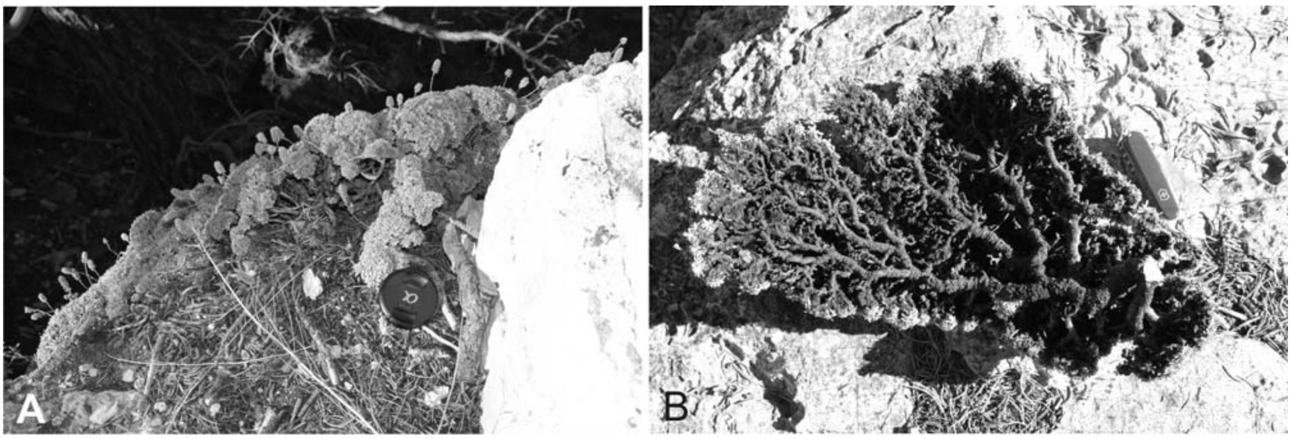

Figure 4: The individual of P. caespitosum. (A) – the stem 2.6 cm in diameter, visible small flowers on a single upright stems, (B) – the branch system.

Wood anatomy

The microscopic analysis of the samples collected indicates that this species has clear visible growth rings which range from relatively wide, 0.3 mm in width, to extremely narrow rings less than 0.1 mm in width (Fig. 5AB). Discontinuous rings are very common in this species (Fig. 5B). The border between annual rings is marked by one row of radially flattened thick-walled fibres (Fig. 5C). This species is diffuse to semi-ring porous. The size of vessels is differential with diameters from 30-50 µm (near pith) to 80-150 µm (Fig. 5A). Wide rays composed of relatively large cells are typical for similar plant species growing in rock crevices (Schweingruber & Poschold 2005). The rays often reach 500 µm in width and diameters of cells vary from 10 to 50 µm (Fig. 5C).

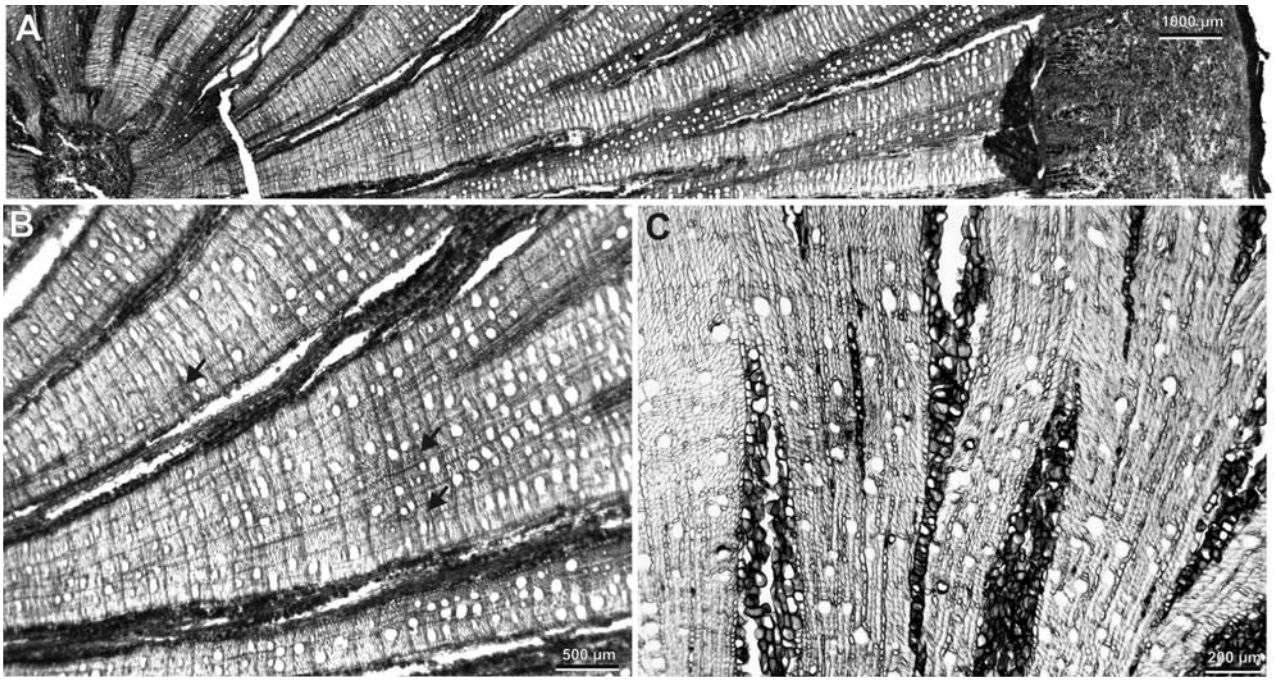

Figure 5: Examples of wood anatomy features of Petrophytum caespitosum (A) cross-section of the individual, note large bark and system of wide rays, (B) growth rings, arrows indicate discontinuous rings, (C) growth rings marked by one row of thick-walled fibres, note rays composed of large cells.

Final remarks

The most important question for dendrochronological analysis is: are the growth rings in *P. caespitosum* annual in nature? Growth-ring boundaries are distinctly visible in the samples we analysed and a maximum of 86 rings were counted. Although precipitation values are low, a bimodal pattern of rainfall is noted at the Grand Canyon with peaks in precipitation during August and March. These two peaks of rainfall may cause the development of two growth rings during one year. Analysis and research on this species should be continued in the future to solve this question (as to the annual nature of growth rings in *P. Caespitosum*) because chronologies of long-lived woody shrubs from extra-arboreal regions (where trees are absent or rare). Complement the existing tree ring chronologies can also yield climatic, ecological and geomorphological information for a greater spatial extent than tree-ring chronologies alone. This species especially demontrates its excellent potential for the use in dendrogeomorphological analysis, if the determination of correct ages of *P. caespitosum* can be achieved. Rock falls are a common geomorphic phenomena on the Colorado Plateau. The establishment age of a plant enables the determination of the minimum age of rock fall events in the past, the rate of rock wall retreat and will allow potential risk areas to be identified.

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