



Morphological analysis of waterfall cliff face by terrestrial laser scanning

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A waterfall highlights the locus of active erosion in bedrock rivers around mountainous and plateau areas. Mechanism of bedrock erosion at a waterfall has been studied for some cases, but there remain uncertainties in erosional processes with regard to detailed form of rocks composing a waterfall. In this study the details of cliff forms around a waterfall is examined using a terrestrial laser scanner in relation to processes occurring in the cliff at and around the waterfall. The study site is Kegon Falls in Japan, having a 97-m high vertical drop of surface water with outflows of underground water at the lower portion of the cliff. Since the cliff is vertical to overhanging, a DEM is created against a vertical plane, and longitudinal and transverse profiles extracted from the DEM are investigated. Stability analysis of the waterfall cliff indicates that the igneous rock composing the cliff is strong enough to keep its current overhanging shape, and catastrophic collapse of whole of the waterfall face seems to hardly occur. Indeed, the upper cliff face is being gradually eroded by gravitational collapses of blocks bounded by joints, which may occur once in decades. The most recent large collapse of the upper cliff occurred in 1986, which caused recession of the waterfall for approximately 10 m, whereas smaller collapses of the cliff seem to have occurred more frequently. The erosion by surface water sets the position of horizontal depression of the cliff top, while underground outflow plays a prior role in undercutting the upper cliff base. Although the outflows of underground water coming from an upstream lake may not freeze much due to its moderate temperature, freeze-thaw process frequently occurs on cliff surfaces around the waterfall due to sprays mostly from the surface water (and partly from the underground water outflow) in winter to spring seasons. The jointed rocks thus seem to be gradually weakened to cause rock-falls, particularly at the middle portion of the cliff where sprays are frequently supplied. The load and tractive force by surface water flow, whose discharge becomes approximately 100 t/s at maximum flooding, may support faster removal of rock blocks behind the water drop. Abrasion may rarely occur because the surface water is coming from an upstream lake (Lake Chuzenji), which traps most sediment supplied from the upstream catchment. With a rapid drop of surface water without any sediment, cavitation is another possible erosional process operating on the lip of the waterfall.