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Latest Pleistocene and early Holocene surface exposure ages of glacial boulders in the Taiwanese high mountain range

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The high mountain range of Taiwan represents a unique isolated high altitude area at the junction of the Eurasian continent and the western Pacific Ocean with elevations up to 3952 m asl. It is presently unglaciated, but various glacial landforms and sediments mapped in three mountain massifs, the Nanhuta Shan, the Hsueh Shan and the Yushan, located in northern and central Taiwan, support the concept of repeated, multi-stage glaciations in these areas during the late Pleistocene and early Holocene. New results from surface exposure dating using in situ produced cosmogenic 10Be measured in samples taken from erratic and moraine boulders in Nanhuta Shan at altitudes between 3100 and 3500 m are presented here. The results confirm independently previously reported Optically Stimulated Luminescence (OSL) ages from glacial sediments in the same area and suggest an early Holocene glaciation, called the Nanhuta glacier advance with a minimum age of around 10 ka BP. The equilibrium line altitude (ELA) was calculated at 3510 m for that advance assuming an average uplift rate of 5 mm/a. The corresponding ELA depression was 440 m with respect to the present theoretical ELA. A correlation with the Younger Dryas period or early Holocene climate fluctuations is possible. Large scale erosional landforms indicate a much wider glacier extent during an earlier stage, which is not dated in Nanhuta Shan so far. Luminescence dating from near Hsueh Shan suggests an age of marine isotope stage (MIS) 4 for this stage. The present theoretical (virtual) equilibrium line altitude (ELAt) is estimated to be at about 3950 $\pm$ 100 m in Taiwan using the relationship of summer temperatures and annual total precipitation with a 30-year (1971-2000) database.