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Deep thermal disturbances related to the sub-surface groundwater flow (Western Alps, France)

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In mountain area, the bedrock of the valley side is affected by a thickness of decompressed rock in subsurface (decompressed zone). Groundwater flowing in this zone disrupts the depth geothermal gradients. The evolution of thermal gradients under the decompressed zone depends of groundwater temperature changes into the decompressed zone. In this study, the phenomenon is studied from data acquired in exploration drilling prior to the construction of the France – Italy transalpine tunnel (High Speed Line project between Lyon and Turin). The study area is located in the Vanoise siliceous series between Modane and Avrieux (Western Alps, France). Of 31 boreholes, we selected 14 wells showing a natural thermal disturbance (not due to the drilling) linked to the groundwater flow in decompressed zone. The drill holes have a length between 200 and 1380m and well logs were carried out (gamma log, acoustic log, temperature log, flowmeter log). The rocks are constituted mainly by quartzite with high thermal conductivity or by schist and gneiss with low thermal conductivity. The decompressed zone concerns the quartzite with thicknesses ranging from 50m to 750m where groundwater flow imposes a constant temperature throughout the rock thickness. In the very low permeability rocks under the decompressed zone, the thermal gradient shows variations with depth. These variations suggest a water temperature change in the decompressed zone probably due to a paleoclimate event. We used the derived of the equation describing the propagation of a temperature in a 1D semi-infinite, in response to a sudden temperature disturbance at the boundary of the medium, to estimate the age and the amplitude of temperature change in the decompressed zone. The medium under the decompressed zone is supposed to be initially in a steady state and only conductive. Numerical tests assess that the 1D model is applicable in the slope context. The results obtained from 13 wells data show a few warming degrees (1 to 4°K) of the decompressed zone occurring about two to four centuries BP. The latest high altitude drilling shows about two degrees cooling of the decompressed zone two centuries ago. The groundwater temperature warming can be due to a type of recharge change with a reduction of the snowmelt contribution or it can be provided by an increase of atmospheric and rainfall temperature. The observed cooling in the latest drilling can be interpreted as a groundwater flow change caused by the permafrost melting. The temperature change occurs during the end of Little Ice Age.