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Environmental significance of vesicular sediment structure in arid regions

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Vesicular structure is a frequent and widely spread phenomenon in surficial fine-grained sediments in arid environments. It typically affects the upper few millimetres to decimetres of sediment and consists of isolated, spherical to ovoid pores, some 100 to 1000 micrometres in diameter, which give the sediment a foamy appearance. The vesicular layer has, together with an often genetically associated stone pavement cover, major control functions for dust trapping as well as dust mobilisation, water infiltration, soil moisture and surface runoff, as well as ecological site characteristics.

Accordingly, there are numerous but often contradictory hypotheses about vesicular structure formation. Most of them are based on individual experiments with settings that were never consistent and overarching but rather focused on one sediment or environmental variable and its relative influence on vesicle formation. We present highlights of extensive laboratory experiments where physical and chemical sediment properties as well as environmental variables such as wetting technique, wetting amount, surface cover type or drying temperature were changed systematically over the entire range of published characteristics of vesicular layers. A series of measures of vesicle features, derived from digitised sediment sections, forms the base for quantitative sample comparison. Furthermore, the experimental results are related to natural analogues from severe regions throughout a climatic gradient from the hyper-arid part of Baja California, Mexico, to the sub-humid southern Sevier Basin, USA.

Based on the results, the plausibility of published vesicle formation hypotheses is discussed and a genetic model is formulated. Vesicles are no transient feature but rather evolve exponentially and become stabilised. They form due to surface puddling and a wetting front which advances downward, thereby elevating the gas pressure within the sediment matrix. Translocation of clay and calcium carbonate support stabilisation. An increasing sand content leads to larger and rounder vesicles, whereas calcium carbonate content has the opposite effect. The amount of dissolved ions does not considerably influence vesicle formation. Under a clast cover vesicles were not formed at all, which has consequences for the published genetic coupling of stone pavement and vesicular layer. Vesicular structures can be connected to environmental parameters which allows one to use fossilised formations as palaeo-environment proxy in sediment archives.