



## 'Cool-spring' carbonate deposystems, Eastern Alps: controls on formation and mineralogy.

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With respect to their latitudinal and altitudinal range, 'cool'-spring associated limestones (SAL) are among the most widespread carbonate deposits on Earth. Aside of a review by Ford & Pedley (1996), however, no larger-scale perspective on controls over SAL deposition exists. Because of a common presence of SAL in the Eastern Alps, and because of a large range in altitude, geological substrates, and climate, the Alps are well-suited to better understand the formation of limestone-depositing spring. Our results indicate that presence and distribution of Eastern-Alpine SAL are mainly determined by rock substrate and tectonic structure, resulting in suited water chemistry, whereas 'climate' (mean annual temperature and precipitation, duration of snow cover) is of subsidiary influence only.

The question for the relation of SAL to environment was approached by parameterized inspection of all available, printed geological maps of the Eastern Alps (status 2008; total number of maps inspected: 168); data extracted from maps for a total of 290 SAL deposits were entered into a database. The geological parameter set was compared with long-term records of temperature, precipitation, and snow cover. In addition, many SAL deposits fossil and active were inspected in the field. Selected active SAL deposits were investigated, since 2004, by diverse physico-chemical and biological methods.

In the Eastern Alps, SAL are most common on substrata rich in marls (flysch) or fine-grained calcite (glacial lodgement till), and on substrata bearing sulfate evaporites (e. g. Triassic evaporites) and/or base metal sulfides in presence of carbonate minerals (e. g. calcareous phyllites of 'Bündnerschiefer' type). By combining high solubility (yielding Ca) with sulfate reduction (yielding bicarbonate), sulfate evaporites favour high-Ca/high-bicarbonate spring waters capable of limestone deposition. Oxidation of sulfide ores, present in (sub)economic deposits and/or as disseminated pyrite, strongly propels the formation of limestone spring. In glacial till, meteoric dissolution of glacigenic calcimicrite is furthered by sulfate reduction and/or by oxidation of disseminated clastic sulfides; in addition, abrasion powder of silicate minerals is hydrated; again, all these processes favour the formation of limestone-depositing spring.

Aside of low-magnesian calcite, the most common mineral of Eastern-Alpine SAL, several deposits both fossil and active were identified that consist of magnesian calcite and/or of aragonite. Over an altitude range from 190 m–2520 m a.s.l., no obvious correlation between abundance, size, and mineralogy of SAL versus altitude, mean annual temperature, and mean duration of snow cover is identified. All SAL, as identified so far, rich in aragonite and magnesian calcite are present at locations with a mean annual temperature of 5–10°C or less. At a spring with a Mg/Ca ratio close to that of present sea water, despite a concentration of bicarbonate and sulfate far below sea water, aragonite and magnesian calcite precipitate; this spring is situated on a shady slope with a mean annual temperature of 5–10°C. At other springs, located in similar climatic conditions, in waters of lower Mg/Ca ratio, fascicular-fibrous calcite (ffC) to magnesian calcite (ffMC) prevails; the lower limit of Mg/Ca ratio necessary for formation of ffC–ffMC, however, as yet is poorly defined. These data underscore that water chemistry, not climate, determines carbonate polymorphy and distribution of SAL deposits. Climate influences SAL deposition by indirect effects of minor impact.

Reference:

Ford, T. D., Pedley, H. M., 1996, A review of tufa and travertine deposits of the world. *Earth-Science Reviews*, 41, 117–175.