Calcium atmospheric transport recorded in the Moroccan calcretes: Sr isotope evidence

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Pedogenic carbonate accumulations (calcretes) are common in warm arid and semi-arid regions. Sr isotopic signatures are expected to provide insights into the sources of calcium to these secondary calcium carbonate deposits (Capo and Chadwick, 1993; Quade *et al.*, 1995; Chiquet *et al.*, 1998). Here, we use Sr isotopes to demonstrate the atmospheric origin of calcretes from the Atlantic moroccan coast.

The southwest moroccan coast is an ideal setting for this study, where the competing role of atmospheric fallout (Saharan dust or oceanic input) versus *in situ* bedrock weathering can be examined. In this region, calcretes are widespread on various lithologies: granites, volcano-detritic materials, alluvial deposits and old limestones.

Sampling and experimental methods

We studied surface pedogenic carbonates collected between 0 and 1 m in different soil profiles. Two latitudinal transects have been sampled in order to determine the geographical extension of the marine influence in calcretes: the first transect (10 km from sea-shore) is situated near Sidi Ifni, while the second extends 400 km inland from Agadir (Fig. 1). The studied samples consist of pulverulent to indurated (hardpan) facies. The range of altitude is between 50 to 300 m for Sidi Ifni and 50 to 1700 m for the Agadir transect.

Hand-picked calcite was dissolved in 1M acetic acid and separated from the residual silicates by centrifugation. Less than 500 ppb of Rb were leached from the residue by this method. Silicate bedrocks were processed using standard procedures. Isotopic ratios were measured on a Finnigan MAT 262 multi collector mass spectrometer.

Results and discussion

The Sidi Ifni bedrocks display a large range of $^{87}Sr/^{86}Sr$ values: respectively 0.7192 and 0.7319 for a granite and a granodiorite whole rocks, and 0.7175 for a plagioclase separate. The $^{87}Sr/^{86}Sr$ is also high (0.7160) in the volcanodetritic material, while the regional cambrian-ordovician limestone is much less radiogenic (0.7082). By contrast with these variable Sr isotopic signatures, all the calcretes from this coastal area show a restricted range from 0.7092 to 0.7097. Similar values are found on the Agadir transect from the coast to 150 km inland, up to an altitude of 1000 m (Fig. 1).

A slight increase in $^{87}Sr/^{86}Sr$ is noticed along the transect, while higher Sr concentrations are found in the calcretes closest to the ocean (300–600 compared to 100–200 ppm).

The isotopic compositions obtained in the samples collected on the Atlas region above 1200 m have different characteristics: in three calcretes developed on alluvial formations, lower $^{87}Sr/^{86}Sr$ (0.7084–0.7091) are found, whereas a much higher value (0.7120) is obtained at 1700 m near Tizi'n' Taghatine.

These results demonstrate that Sr is dominantly from allochtonous sources in these calcretes, as shown previously in several other regions of the world (Capo and Chadwick, 1993; Quade *et al.*, 1995; Chiquet *et al.*, 1998). Possible sources, compatible with the low $^{87}Sr/^{86}Sr$ ratios measured in these calcretes, include direct seasalt deposition or aeolian transport of calcium carbonate dust from remote limestone formations.

However, simple budget consideration seem to rule out that a direct marine input could be the major source of Ca and Sr, with a possible exception for the sites very close to the ocean.

On the other hand, calcium carbonate platforms on the exposed continental margins could have contributed a large amount of atmospheric dust with $^{87}Sr/^{86}Sr$ ratios close to that of present-day seawater, during glacial periods with sea level lower than present.

This hypothesis has been suggested previously by

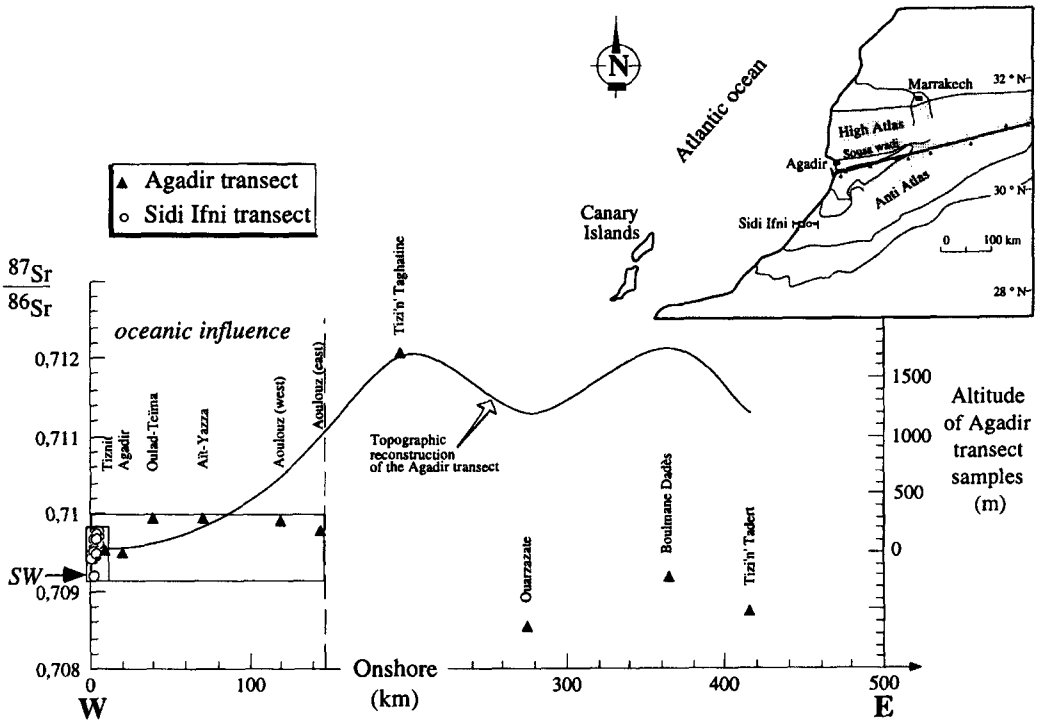

FIG. 1. Geographical position of the two transects sampled on the Moroccan Atlantic coast. Sr isotopic compositions of calcretes are reported *vs* seashore distance and altitude.

Rognon and Coudé-Gaussen (1996) to explain the origin of calcretes on the Canary Islands.

By contrast, more ancient continental limestones, possibly of Saharan origin, may have been the source of the lower $^{87}Sr/^{86}Sr$ found on the Atlas calcretes.

References

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