

# CALCITE NEEDLES IN SYROS MARBLES

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## INTRODUCTION

The rocks on the Greek island of Syros are part of a suite of high pressure metamorphic rocks which outcrop all across the Cyclades. There is a complex metamorphic history recorded in the rocks here, including a Cretaceous or Eocene high-pressure blueschist event and a Miocene, extension-related greenschist overprint. The Island of Syros is mostly composed of schists, which alternate with north-dipping pure and "impure" marbles, and some smaller outcrops of breccia and metagabbro [Dixon and Ridley 1987]. Calcite in the marbles here shows a needle-like texture. Needles are generally sub-vertical, sub-perpendicular to the marble foliation (see Figures 1 and 2) and range in length from 1 cm to 6cm. The origin of these needles, the significance of their alignment with respect to local structures and understanding why these needles might be oriented sub-perpendicular to the foliation make up the bulk of this study.

## OBSERVATIONS

The structural data collected about the needles focuses on three types of structures: i) within boudins or clasts (Figure 3), ii) surrounding boudins or clasts (Figure 4) or iii) in folded layers (Figure 5). In the first setting (within boudins or clasts in a marble matrix), the calcite needles exhibit one of two behaviors. Either the needles appear to be parallel to each other within the clast and parallel to the needles in surrounding clasts (6 times out of 10 documented cases; Figure 3) or the needles are not uniformly oriented. In this second situation (4 cases out of 10) the needles were either parallel within the clast but not parallel to surrounding calcite needles (3 cases) or were fanned within the boudin (1 case). The needles in both scenarios are most often sub-vertical and sub-perpendicular to surrounding foliation and the long axis of the boudin. In cases where the clast shape records a sense of shear, the calcite needles remain parallel to each other and do not appear deformed by the shear. There are two documented cases in two different parts of the island where the calcite needles within the clast are bent to some degree.

In the second setting (when calcite needles were found in a layer wrapping around boudinaged layers or clasts of another rock type), the needles occur in two distinct ways. Either the calcite needles fan around the boudin, remaining sub-perpendicular to the shell of the boudin (in seven cases out of 8; Figure 4) or the needles remain perpendicular to the local foliation and then lie flat on the top of the boudin (one case). In some cases the needles wrap completely around an isolated clast or boudin (parallel to local foliation), and in others, the needles fan around the boudin but then return to perpendicular to local foliation at the pinched out ends of the boudin.

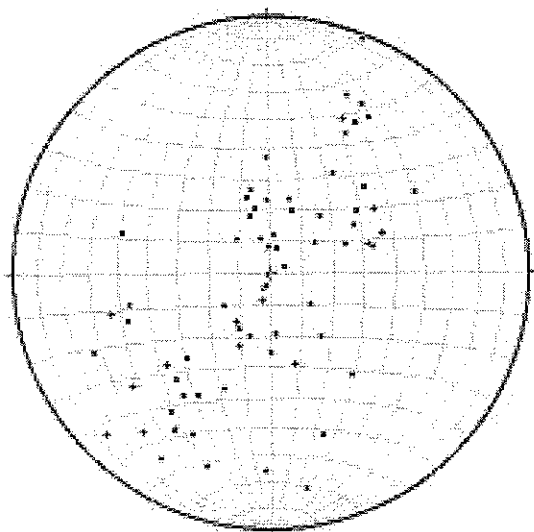


Figure 1. Calcite needle orientation across Syros.

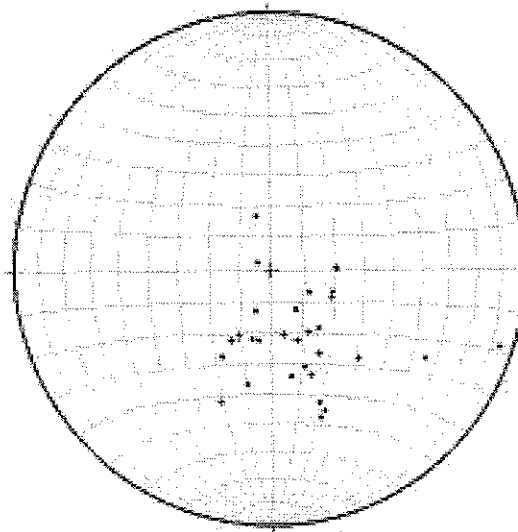


Figure 2. Poles to foliation across Syros.

Schliestedt et al, 1987. Transformation of Blueschist to Greenschist Facies Rocks as a Consequence of Fluid Infiltration Sifnos (Cyclades), Greece.

The third documented setting illustrates the calcite needle orientation in relation to folded layers across the island. In seven out of eight outcrop-scale isoclinal folds where calcite needles were present, needles are perpendicular to the fold axial plane. In these cases, the needles also are sub-perpendicular to the local foliation. In the one different case, the innermost layer of a 3 inch wave length isoclinal fold, the calcite needles fanned slightly around the fold hinge (Figure 5).

There is one site, on the northwest shore of the island, where the needles behave very differently from everywhere else on the island. A large (6 foot x 5 foot) pod of thick (3 inch long) calcite needles sits within a highly folded section of green and blueschist rocks. The needles are much larger than elsewhere on the island and they are bent and swirled without regard to any obvious structures. There is no preferred needle orientation across the pod.

## PETROGRAPHY

Petrographic observations of calcite needles show that the needles are generally composed of a number of individual calcite crystals. Calcite crystals are generally also elongate, or needle-shaped and show a strong preferred orientation (see Figure 6). Their long axes range in length from 1 to 3mm, and these crystal long axes generally parallel the mesoscopically-visible needles. In one case, calcite c-axes parallel the long axis of the needles. But in other samples, no clear relation between calcite crystallography and the needles exists. The relation between calcite crystallography, visible needles and regional rod structures and fabrics will be the focus of future work.

## DISCUSSION

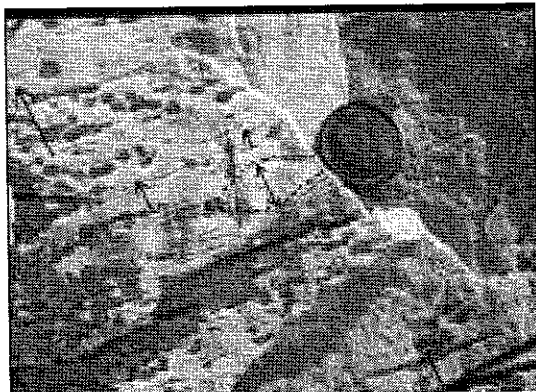
One of the essential questions to be answered here is: are these calcite needles pseudomorphs of calcite after aragonite, as some have suggested. There are three pieces of evidence that indicate that these structures are, in fact, relicts of the high pressure mineral aragonite. First, marbles and mafic rocks on Syros experienced metamorphism at the facies transitional between blueschist and eclogite. These marbles experienced the temperature/pressure conditions needed to transform calcite into aragonite (1.7-2.0 GPa and 500-600 degrees according to Hacker and Kirby, 1993). Secondly, a long, needle-like habit is not common for calcite, which normally exhibits a rhombohedral form (Deer, Howie, and Zussman, 1992). Aragonite on the other hand is described in the literature as columnar and needle-like – both words which describe the structures present across Syros. The third argument is that at other sites across the world where calcite shows a similar needle-like habit in similar subduction and exhumation settings, workers have made the same interpretation. For example, Coleman and Lee (1962) describe calcite pseudomorphs after aragonite in the Franciscan formation, a metamorphic belt which has often been compared to the Cycladic one.

The tectonic significance of the orientations and preservation of these pseudomorphs after aragonite is unclear. Because aragonite should revert to calcite during the transition from blueschist to greenschist facies (the exhumation event widely recorded by rocks on Syros), the preservation of pseudomorph needles suggests that these marbles did not recrystallize significantly during exhumation. They therefore preserve textures associated with the blueschist facies metamorphism (the earlier subduction event). Why did aragonite needles grow and remain in a sub-vertical orientation, sub-perpendicular to foliation during this earlier event? Does this fabric represent a single episode of late growth, or the product of continuous recrystallization during blueschist facies deformation and metamorphism? These questions are the focus of our ongoing work.

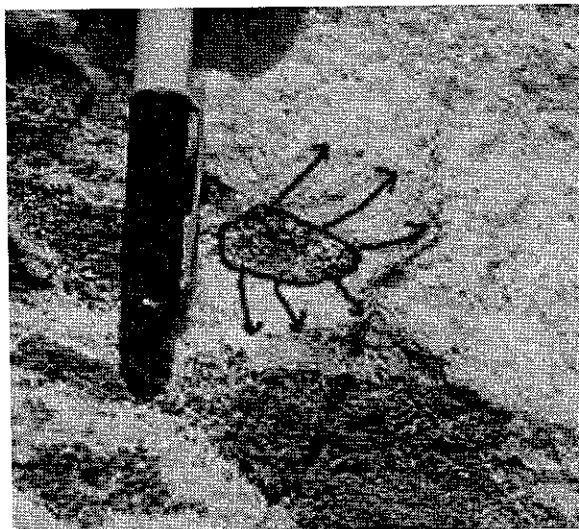
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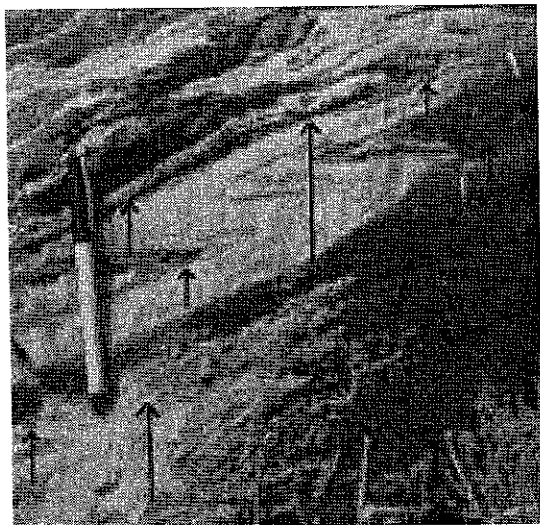
Hacker, B. and Kirby, S.H. (1993) High-Pressure deformation of calcite marble and its transformation to aragonite under non-hydrostatic conditions: *Journal of Structural Geology*, v. 15, No 9/10, pp. 1207-1222.



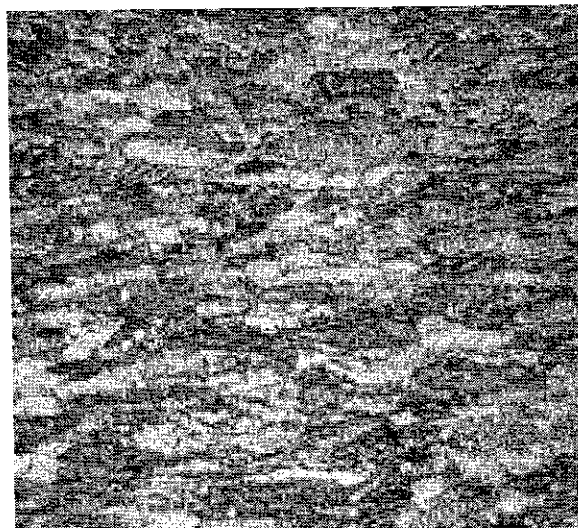
**Figure 3.** A clast of pure calcite needles in a marble matrix. The needles in the boudin are parallel to the surrounding matrix needles, which are sub-perpendicular to foliation. Lens cap for scale.



**Figure 4.** Two centimeter garnet boudin surrounded by calcite needles which fan completely around the structure. Pen for scale.



**Figure 5.** An isoclinal folded impure marble layer. The calcite needles sweep across the fold and remain sub-perpendicular to foliation. Pen for scale.



**Figure 6.** Photomicrograph of the calcite needle preferred orientation. Scale 5mm across.