LAWSONITE PSEUDOMORPHS IN THE SCHISTS OF SYROS, GREECE

LINDSEY ABLE
Department of Geology, Smith College
Faculty sponsor: John B. Brady, Smith College

INTRODUCTION

Lawsonite, $CaAl_2Si_2O_7(OH)_2 \cdot H_2O$, is a common mineral in blueschist-facies metabasalts and metagreywackes and is considered to be an index mineral of high-pressure, low-temperature metamorphism (Comodi and Zanazzi, 1996). On the island of Syros, some outcrops of glaucophane schist, chlorite schist, and graphitic schist display prominent features 0.2 to 3.0 cm in size with a diamond-shaped cross-section that have been interpreted as pseudomorphs after porphyroblasts of lawsonite. These features serve as a testament to the previous high-pressure, low temperature blueschist mineral assemblages held by these rocks during the late Cretaceous (Bröcker and Enders, 1999), during which P-T conditions are believed to have varied between 12-20 kb and 450-500°C (Schliestedt et al, 1987). Lawsonite would have been stable under P-T conditions proposed for the Cretaceous event, but would have become unstable during the subsequent lower pressure Miocene greenschist event. It may have reacted during decompression to form other minerals, perhaps creating the some of the pseudomorphs now visible on Syros, as suggested by Sperry (2000).

The mineral assemblages of the lawsonite pseudomorphs on Syros vary, but typically include the components zoisite/clinozoiste + phengite + paragonite ± chlorite ± albite ± quartz ± calcite, and, rarely, remnant lawsonite. Occurrences of pseudomorphs after lawsonite have also been reported in other parts of the world, including Ile de Groix, France and the Sesia zone of the western Italian Alps, where the assemblages zoisite/clinozoisite + phengite/paragonite + chlorite + albite + quartz (Shelley and Bossiere, 1999) and zoisite/clinozoisite +paragonite + albite + calcite ± pumpellyite (Pognante, 1989), respectively, have been reported. Despite such reports, however, the reactions behind the formation of the lawsonite pseudomorphs have not been resolved, and in fact, there has been recent argument that the pseudomorphs of Groix might be after albite rather than lawsonite because the pseudomorphs in the locality have not been found to contain remnant lawsonite (Shelley and Bossiere, 1999).

This study, building on work of Arianne Sperry (2000), seeks to understand the formation of the lawsonite pseudomorphs on Syros through investigating the mineral assemblages of diverse rock types from the island containing pseudomorphs. This information can then be applied in constraining the P-T path of the rocks on Syros, and can perhaps be of use in understanding other localities in which lawsonite pseudomorphs are known to occur.

METHODS

Samples were collected from several locations across the island, although most sampling was concentrated in the north, which has the highest occurrence of pseudomorphs. (See Figure 1.) An effort was also made to sample from a variety of rock types containing pseudomorphs, including glaucophane schists, chlorite schists, and graphitic schists.

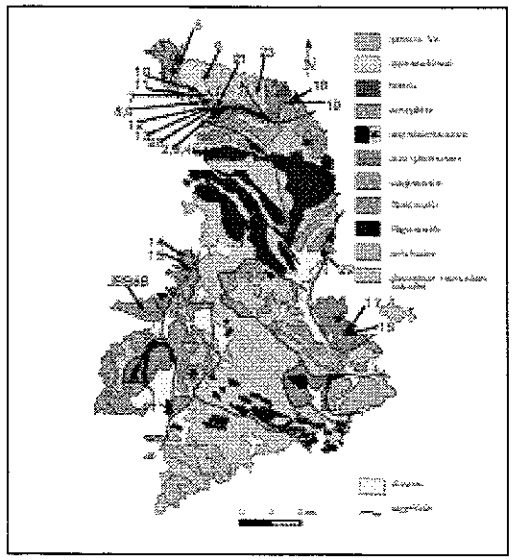


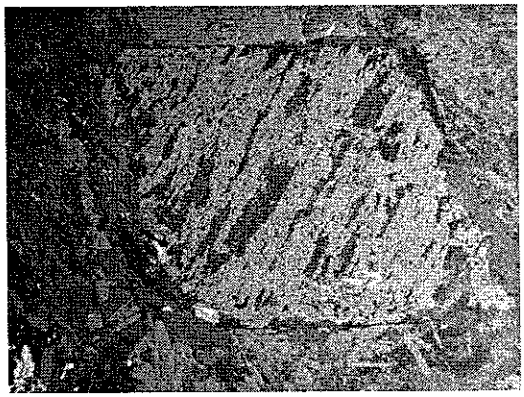
Figure 1. Geological map of Syros with sample locations indicated.

Mineral analyses and identifications were performed in thin section as well as by SEM/EDS. Modes for the pseudomorphs were also estimated using SEM/EDS through the use of backscatter electron imaging and the Area Meausurement capability of the Link ISIS software packagae.

DATA

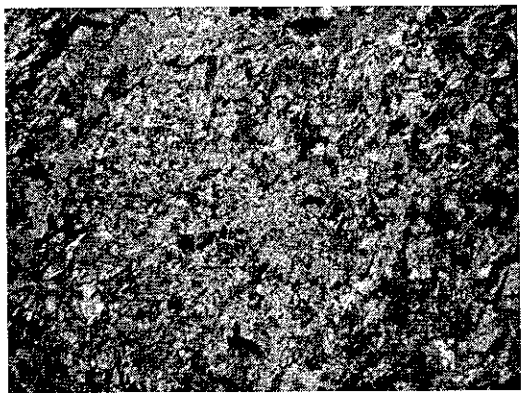
Data for six representative samples are presented here as examples of the types of pseudomorph-bearing rocks present on Syros.

Sample 13A



This pseudomorph in sample 13A, shown in backscatter, is distinctive because it displays alternating bands of zoisite and phengite/paragonite in a perfect diamond shape. The mica is mostly phengitic. Acessory minerals include titanite and apatite. The estimated mode of the pseudomorph is 64% zoisite, 35% phengite/paragonite and 1% titanite/apatite. The matrix of the rock is fine-grained glaucophane with patches of albite and actinolite.

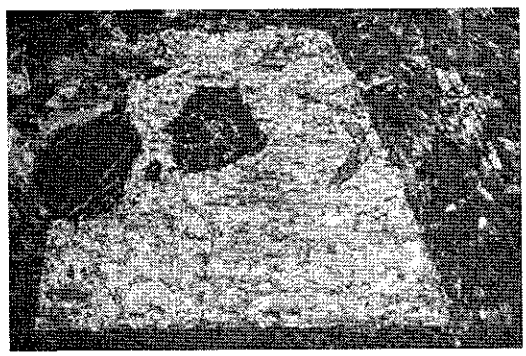
Sample 10A



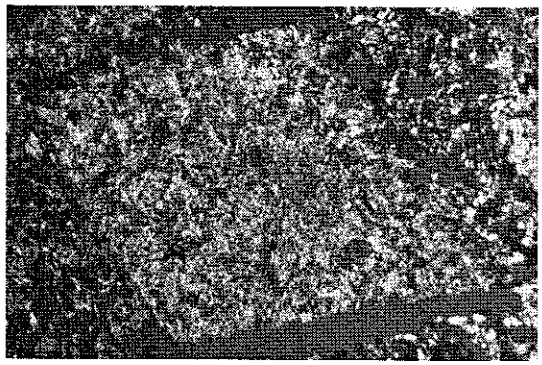
This pseudomorph in sample 10A, shown in polarized light, is highly disordered with indistinct boundaries between the pseudomorph and the surrounding matrix. The estimated mode of the pseudomorph is 53% phengite/paragonite, 33% clinozoisite/epidote, 13% albite, and 1% titanite. The epidote-group minerals display clinozoisite-rich cores and epidote-rich rims. The matrix of the rock is fine-grained glaucophane with omphacite, clinozoisite, chlorite, albite, actinolite, and apatite.

Sample 9C

This pseudomorph in sample 9C, shown in polarized light, is distinctive because it consists almost entirely of fine-grained white mica and contains no epidote-group minerals. The estimated mode of the pseudomorph is 91% phengite/paragonite, 8% calcite, and 1% titanite/rutile. The pseudomorph also contains large garnets that were overgrown by the lawsonite porphyroblast. The matrix of the rock consists primarily of euhedral fans of chlorite with crystals of phengite and garnet interspersed. Also present are large euhedral crystals of titanite and rutile and some scattered quartz.



Samples 12B and 6A



This pseudomorph in sample 12B, shown in polarized light, is a graphitic schist sample. It contains pseudomorphs with the mineral assemblage graphite, quartz, albite, chlorite, and phengite. There is no calcium present in the pseudomorph, and instead the pseudomorph is separated from the matrix by hollow area in which only a few remnants of calcite remain. This was a moderately weathered sample.

Sample 6A, a more representative graphitic schist sample, has an estimated mode of 42% quartz + albite + chlorite, 38% clinozoisite, 18% phengite/paragonite, and 4% titanite/apatite. The matrix of the rock contains calcite, quartz, glaucophane, phengite, albite, titanite and apatite. Graphite is present throughout.

Sample 5D

This pseudomorph, shown in polarized light, appeared green in outcrop. It has a distinctive chlorite-rich rim surrounding a second rim composed of almost entirely of pure phengite. Together, these two rims compose approximately 25% of the total area of the pseudomorph. The estimated mode of the center of this psuedomorph is 25% clinozoisite/calcite, 71% phengite/paragonite, and 4% titanite. The phengite in the center of the pseudomorph is intergrown with paragonite on a fine scale, contrasting sharply with the large phengite crystals of the rim. There is a calcite vein at the border of the pseudomorph, and many larger veins of calcite were noted in the outcrop. The epidote-group minerals display epidote-rich cores and clinozoisite-rich rims. The core of the pseudomorph contains some calcite. The matrix consists mostly of fine-grained glaucophane, which a few small grains of phengite, paragonite, and quartz dispersed throughout.

Sample JBB-8B

This pseudomorph, which occurs in a greenschist sample, was found to contain remnant lawsonite. Also present in the pseudomorph is zoisite, phengite, and a trace of plagioclase. Interestingly, the pseudomorph contains a few small anhedral garnets, approximately 100 micrometers in size, but no garnets could be found in the matrix. The estimated mode of the pseudomorph is 25% lawsonite, 35% zoisite, 38% phengite, and 2% garnet. Present as an accessory mineral is chalcopyrite rich in zinc. The matrix consists mostly of actinolite, with some chlorite, albite, and epidote, and a trace of phengite.

DISCUSSION

It is known that in most cases the migration of aluminum during metamorphism is small (Carmichael, 1969). Hence the preservation of the shapes of the lawsonite prophyroblasts in the rocks on Syros could be due to the limited diffusion of the aluminum component of the lawsonite during the lower pressure event. The pseudomorphs bearing the simplest mineral assemblage, such as sample 13A, reveal that lawsonite breaks down to zoisite, with the leftover aluminum and silicon going to phengite. In this

scenario, approximately two thirds of the aluminum can go to zoisite, and the rest must combine with potassium that has diffused into the pseudomorph from the matrix to form phengite (or, to a more limited degree, with sodium to form paragonite). In samples such as 10A, however, the proportion of phengite is greater than that of zoisite. Perhaps this is due to the migration of calcium out of the pseudomorph, possibly to be accommodated in actinolite, which is concentrated near the pseudomorph. In sample 12B, for example, no calcium even remains in the psuedomorph, and in samples such as 5D, the calcite veins surrounding the pseudomorphs, comprise the only calcium-bearing component of the matrix. In sample 9C, however, very little calcium is present either in the pseudomorph or in the matrix, and no calcium-bearing veins occur near the pseudomorph, so there is some question as to whether this pseudomorph is even after lawsonite.

In some samples, there is also the question of a potassium, or sometimes a sodium, source for the mica in the pseudomorph. For example, in sample 13A, the pseudomorph is high in phengitic mica, but there does not appear to be any phengite in the matrix of the rock outside of a few patches clustered around the psuedomorphs. If phengite is the potassium source for the pseudomorphs, it would seem that there should be some remaining phengite dispersed throughout the matrix of the rock. In sample 9C, there is a similar dilemma over sodium; the pseudomorphs contain substantial paragonite, yet a sodium source in the matrix is limited to the trace amount present in phengite.

Samples such as JBB-8B that contain remant lawsonite reveal some interesting aspects of the pseudeomophs. For example, the composition of the lawsonite from which the pseudomorphs formed can been ascertained, and has been found to be of nearly ideal composition, with only 0.5 weight percent substitution by ferric iron and 0.3 weight percent substitution by titanium for aluminum. However, in most of the pseudomophs, the epidote group minerals that have replaced lawsonite are clinozoisite and/or epidote, which have significant ferric iron content. Therefore, there must have been some migration of ferric iron into the pseudomorph from the matrix. Additionally, it is interesting that sample JBB-8B contains remnant lawsonite, yet is a greenschist, which by definition would have experienced a greater overprint than the rocks which retain blueschist assemblages. There is a significant difference between sample JBB-8B and the other samples, however. The matrix of sample JBB-8B consists primarily of actinolite and epidote, and hence, has a substantially higher calcium content than those samples in which lawsonite has undergone complete pseudomorphing. This may indicate that the preservation of remnant lawsonite may be due to bulk composition differences.

REFERENCES

Bröcker, M. and Enders, M., 1999. U-Pb zircon geochronology of unusual eclogite-facies rocks from Syros and Tinos (Cyclades, Greece). Geol. Mag., 136, 111-118.

Carmichale, D.M., 1969. On the mechanism of prograde metamorphic reactions in quartz-bearing pelitic rocks. Contributions to Mineralogy and Petrology, 10, 244-267.

Comodi, P. and Zanazzi, P.F. ,1996. Effects of temperature and pressure on the structure of lawsonite. American Mineralogist, 81, 833-841.

Schliestedt, M. and Matthews, A., 1987. Transformations of blueschist to green facies rocks as a consequence of fluid infiltration, Sifnos (Cyclades) Greece. Contributions to Mineralogy and Petrology, 97, 237-250.

Pognante, U., 1989. Tectonic implication of lawsonite formation in the Sesia zone (Western Alps). Tectonophysics, 162, 219-227.

Shelly, D. and Bossiere, G., 1999. Ile de Groix; retrogression and structural developments in an extensional regime. Journal of Structural Geology, 21, 1221-1455.

Sperry, A., 2000. Pseudomorphs after lawsonite as an indication of pressure-temperature evolution in blueschists from Syros, Greece *in* Mendleson, C.V., and Maciewicz, C. eds., Thirteenth Keck Research Symposium in Geology Proceedings.