*American Mineralogist, Volume 60, pages 726–727, 1975*

# Penetration Twins in Synthetic Coesite

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**Abstract**

Two types of penetration twins were observed in coesite synthesized from amorphous silica, cristobalite, or quartz at 30 kbar and 600° to 1300°C, one with ($\bar{1}21$) and the other with ($\bar{2}33$) as the twin plane. Effects of added water and treatment temperature on twin growth were studied. Occurrence of twins may be attributed to preferential growth along the *c* axis of coesite.

## Introduction

In synthetic coesite, simple contact twins with (021) as the composition and twin plane are fairly common (Ramsdell, 1955; Sclar, Carrison, and Schwartz, 1962). Ramsdell also observed (100) twinning. Khitarov *et al* (1957) sketched cross-like intergrowths but without morphological evidence. Two new types of penetration twins in synthetic coesite are here described.

## Penetration Twins

The girdle-type high-pressure apparatus and experimental method used in this work have already been described (Naka *et al*, 1974a, b). The coesite was prepared from amorphous silica, cristobalite, or quartz at 30 kbar and 600° to 1300°C. Optical studies revealed two types of penetration twins (Fig. 1). The twin plane is ($\bar{1}21$) for one (Fig. 1A) and ($\bar{2}33$) for the other (Fig. 1B), as determined from coesite's axial ratio, $a:b:c = 0.58:1:0.58$. Under crossed nicols both types consist of two idiomorphic individuals of approximately equal size, each individual being elongated parallel to the *c* axis. Some of the crystals have (010) cleavage (Fig. 1B). Subconchoidal fractures were also observed perpendicular to the *c* axis, as shown by Sclar *et al* (1962). The optical orientation of coesite is $X = b$ and $Z \wedge c = 4°$-$6°$. The optical angle $2V_z$ was determined with a universal stage to be 66.5°.

Penetration twins occur more frequently in coesite prepared under anhydrous rather than hydrous con-

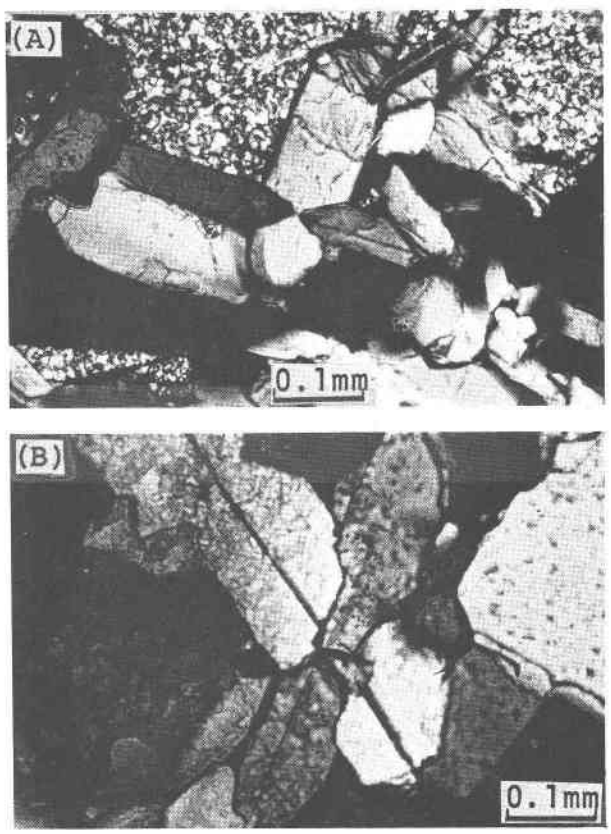


FIG. 1. Penetration twins of synthetic coesite under crossed nicols: (A) twinned coesite having twin plane ($\bar{1}21$). (B) twinned coesite having twin plane ($\bar{2}33$). (010) cleavage is also obvious. The starting material was cristobalite; growth conditions were $P = 30$ kbar, $T = 900°C$, $H_2O = 10$ wt percent. Heating durations of (A) and (B) were 1 and 12 hours, respectively.

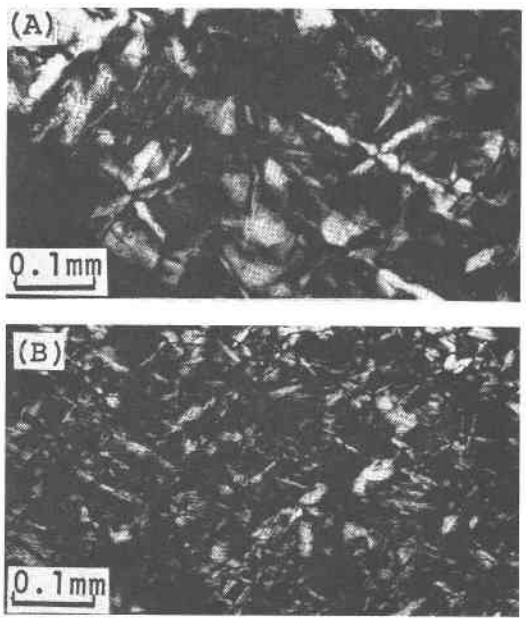


FIG. 2. Preferential growth of coesite with $c$ axis perpendicular to compression direction under crossed nicols: (A) growth of coesite in the plane perpendicular to compression direction. (B) growth of coesite in the plane parallel to compression direction. The starting material was amorphous silica. Growth conditions were $P$ = 30 kbars, $T$ = 600°C, $H_2O$ = 0 wt percent and $t$ = 3 hours.

ditions. In coesite prepared anhydrously from amorphous silica subjected to 30 kbar and 600°C for three hours, a great number of penetration twins developed, whereas in coesite prepared in the same way except for the addition of 16 wt percent water, penetration twins were no longer observed. Instead small single-crystal grains were obtained.

The growth of twins along the $c$ axis occurred preferentially perpendicular to the direction of compression (Fig. 2A). Growth was retarded parallel to the direction of compression (Fig. 2B). Such oriented growth of coesite seems partially due to the shearing stress inherent in the girdle-type apparatus (Naka, Ito, and Inagaki, 1972). The decrease in the growth of the twins in coesite prepared under hydrous condition is, therefore, probably explained by decreased shear stress in such hydrous compositions.

Furthermore, the growth of the twins is affected by treatment temperature. No twins were observed in coesite synthesized anhydrously from quartz at 30 kbar and 900°C for one hour. However, twins were observed in coesite prepared under the same conditions but at 1300°C.

The present experimental condition of synthesis is probably comparable to that of the formation of coesite inclusions in natural diamond. Therefore, there is some possibility of natural occurrence of the penetration twins. However, because of the very small grain-size of natural coesite, no reports on its morphology have been published.

## Acknowledgement

The authors wish to thank Dr. M. Inagaki who offered valuable criticism on the manuscript.

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*Manuscript received, September 10, 1974; accepted for publication, February 24, 1975.*