A SIMPLE PROCEDURE TO SEPARATE NATURAL FROM SYNTHETIC AMETHYST ON THE BASIS OF TWINNING

By Robert Crowningshield, Cornelius Hurlbut, and C. W. Fryer

Dr. Karl Schmetzer recently showed how near-flawless to flawless natural amethyst could be separated from synthetic amethyst on the basis of the presence of Brazil twinning in the natural stones. Whereas Dr. Schmetzer's procedure required a special apparatus, the authors have determined that a standard gemological polariscope is more than adequate to make the separation in most cases. Although some synthetic amethyst does show evidence of twinning, in the synthetic stones examined thus far it has taken a form that is distinctly different from the Brazil twinning seen in most natural amethysts. The presence of certain inclusions as well as the nature of the color zoning seen in natural versus synthetic amethysts is of primary use in making a separation. However, where there are no inclusions or color zoning, the presence of Brazil twinning in the natural amethyst will usually make the distinction.

ABOUT THE AUTHORS

Mr. Crowningshield is a director of the GIA Gem Trade Laboratory in New York City; Dr. Hurlbut is professor emeritus of mineralogy at Harvard University, Cambridge, Massachusetts; and Mr. Fryer is chief gemologist in the Research Department of the Gemological Institute of America, Santa Monica, California.

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Since 1970, when synthetic amethyst first became available commercially, it has created problems in identification for gemologists. Although inclusions have proved reliable in distinguishing synthetic from natural in most "flawed" amethysts, until recently no test was available to separate the flawless or near-flawless stones that represent the bulk of the fine faceted stones on the market (figure 1). As a result, otherwise ethical jewelers and suppliers everywhere may have unwittingly sold thousands of synthetic amethysts that were represented to them as natural. In 1985, however, Dr. Karl Schmetzer described a procedure by which a distinction can be made (see also Schmetzer, 1986). Subsequently, the authors adopted Dr. Schmetzer's procedure for use with standard gemological equipment. This test alone is not always unequivocal but, when used in conjunction with other observations, such as color zoning, it presents an excellent method for the separation of most near-flawless synthetic and natural amethyst.

The procedure described by Dr. Schmetzer is based on the fact that most natural amethysts are repeatedly twinned on the Brazil law, while synthetic amethysts are usually grown as single crystals (Schneider and Droschel, 1983; Lind et al., 1983). In polarized light, a twinned stone will exhibit varying degrees of interruption in the spectral rings, while an untwinned stone will show undisturbed rings of spectral colors. While Dr. Schmetzer's description suggested that a special apparatus was required, we have found that a polariscope or standard polarizing microscope is adequate to observe the diagnostic twinning. To confirm the accuracy of our method, we examined more than 1100 natural and 200 synthetic amethysts. In this article, we describe how to apply these simpler procedures.

First, however, it is well to review twinning in amethyst as well as why synthetic quartz was made in the first place. Other tests useful in distinguishing natural from synthetic amethyst are also discussed briefly.

Figure 1. One of the major problems facing gemologists today is the separation of natural from synthetic amethyst, as illustrated by the 9.40-ct natural oval cut and the 5.48-ct synthetic emerald cut shown here. Photo © Tino Hammid.

TWINNING IN AMETHYST

The fact that almost all natural amethyst is twinned according to the Brazil law has been known for at least 150 years. The optical structure of amethyst was first described by Sir David Brewster in 1821 (Frondel, 1962), and was correctly interpreted as due to the polysynthetic twinning of right- and left-hand quartz. In the course of the 19th century, further descriptions were given by many other workers. A brief summary of these and later works is found in *Dana's System of Mineralogy* (Frondel, 1962): "Amethyst virtually always shows polysynthetic twinning on the Brazil law. Untwinned crystals have been noted. The twin lamellae, a fraction of a millimeter thick, are remarkably uniform and are arranged parallel to the terminal r or r and z faces. The lamellae are alternately right- and left-handed. They may give rise to sets of delicate striations, or to open polygonal markings on the rhombohedral faces, and cause a rippled, or fingerprint appearance on the fracture surfaces. The twinning can be studied in etched sections or, more conveniently, by optical means."

The last sentence of the above quotation, if applied to the study of gemstones, might better have been written: "The twinning can be studied in etched sections or more conveniently *and less destructively* by optical means." For etching is done with hydrofluoric acid, a harsh treatment of a gem. The twin lamellae are, however, made readily apparent by the process (figure 2).

Gemologists are familiar with the term *poly-*

synthetic twinning in connection with the repeated twinning of corundum and some feldspars. In the term *polysynthetic,* "synthetic" is not to be confused with its use meaning "man-made," but rather carries the classical meaning of "put together;" while "poly-" is a combining form meaning "many." Thus, the term *polysynthetic* conveys the meaning of "many thin crystals (lamellae) put together."

Quartz is optically active; that is, if polarized light moves parallel to the optic axis, the plane of polarization is rotated. The rotation is to the right, conventionally clockwise, in right-hand crystals and to the left in left-hand crystals. The shorter the wavelength, the greater is the rotation; violet light is thus rotated more than red light. As stated in the above quotation from *Dana's System of Mineralogy,* Brazil twinning results in alternating lamellae most commonly under faces of the major rhombohedron, r, the large triangular faces that terminate the quartz crystal. Figure 3 is a drawing of a section perpendicular to the optic axis that shows twinning under the major rhombohedron with the right-hand portions of the quartz shown in white and the left-hand portions of the quartz shown in black. If slices of quartz represented by this drawing were observed between crossed polarizers, they would take on the appearance seen in figure 4. One would see narrow parallel bands of alternating colors and shadow under the major rhombohedrons and broad swaths of color under the minor rhombohedrons.

With light moving parallel to the optic axis through the twinned areas, the rotation of polarization is alternately right and left. Because the lamellae are not of exactly the same thickness, the net rotation is always greater in one sense than the other, resulting in different colors for the right-hand and left-hand regions. The lamellae are thus striated and sharply defined, whereas the untwinned areas are of a single color. Twinning may be confined to isolated triangular areas, but frequently in amethyst it will be evidenced by straight lines crossing the stone. There may be only one set of parallel lines, or there may be two or three sets making angles of 60° or 120° with one another (again, see figure 4). These latter result from the meeting of the twinned areas under two or three of the rhombohedron faces.

In the authors' experience, untwinned crystals (as noted in the *Dana's* quotation above) are very rare. Although some natural untwinned faceted amethysts have been observed, they were probably cut from the area completely under the minor rhombohedron.

THE HISTORICAL DEVELOPMENT OF SYNTHETIC AMETHYST

Before World War II, Brazil was able to supply the world with the rock crystal necessary to make the oscillators used to control radio frequency. Since the oscillator must be free of twinning, the first step in manufacture was to inspect the raw crystals for Brazil twinning. This was done in an immersion tank, using a giant polariscope with polarizers one foot square. The hand-held quartz crystal was turned until the optic axis was parallel to the direction of light through the polariscope and the Brazil twinning, if present, was observed. Many crystals with twinning throughout were discarded, others with little or no twinning were passed on to the next operation, cutting.

During the war, however the demand for Brazilian quartz skyrocketed. In the United States alone, thousands of tons of quartz crystals were used in the manufacture of over 50 million small oscillator plates cut at precise crystallographic angles. In 1944, because quartz was high on the critical list of minerals, the U.S. Signal Corps initiated a quartz synthesis program. Private industry also became involved. Although success was not achieved until after the war, by 1950 hydrothermally grown synthetic quartz was in mass production. Now untwinned quartz crystals grown on untwinned seed plates supply the material for oscillators in radios, watches, clocks, radio-frequency filters, and other apparatus where frequency control of electrical circuits must be precise.

The successful synthesis of colorless quartz pointed the way to the manufacture (by the irradiation of iron-bearing synthetic quartz) of colored quartz (Balitsky, 1980). But with citrine and amethyst so abundant and relatively inexpensive, there would seem to be no incentive to synthesize these materials. Since about 1970, however, both have been made commercially in the Soviet Union and, later, in Japan. To date, most synthetic production is untwinned, single-crystal material.

DETECTION OF BRAZIL TWINNING WITH THE POLARISCOPE

It is to Dr. Karl Schmetzer, of the University of Heidelberg, West Germany, that credit must be

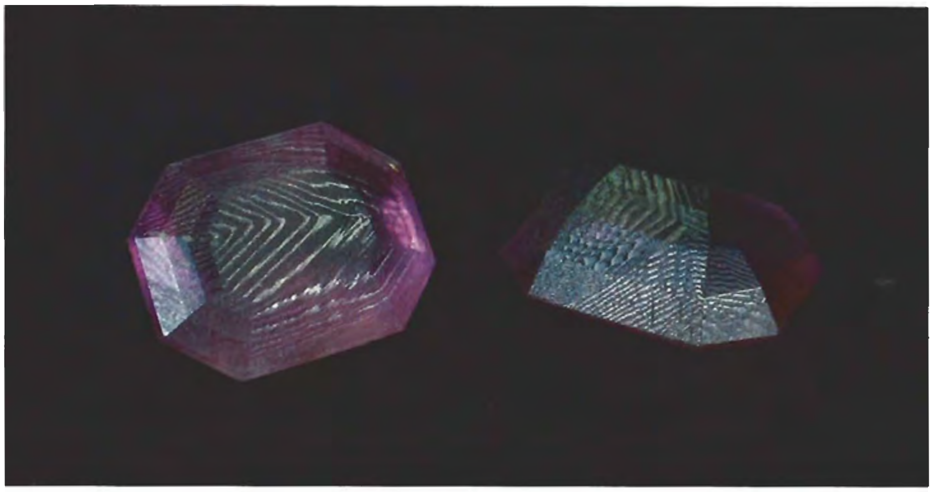


Figure 2. Etching an amethyst with hydrofluoric acid clearly reveals the presence of Brazil twinning in these two 18-ct stones. The test is, however, highly destructive and therefore not practical for gemologists. Photo by Shane McClure.

given for first promoting (1985) the optical test to differentiate flawless or near-flawless synthetic from natural amethyst. However, there is the implication by Schmetzer that to observe the twinning, one must use an "improved sample holder" with a horizontal immersion microscope. We have found that twinning can be equally well observed using a vertical polarizing microscope, but even more easily by simply using a standard gemological polariscope with the stone held in ordinary stone tweezers or even in one's fingers.

In adapting Schmetzer's procedure to the open polariscope, we have used several items that are readily available. Many times, the twinning effect can be seen without immersion. However, when immersion is necessary, a number of items are useful. Since amethysts tend to be relatively larger than more costly stones, we have found small flared colorless glass votive candle holders, about two inches (5 cm) high and two inches in diameter, to be good immersion cells. They are also sold as oyster cocktail condiment holders for restaurant use. One is shown with a polariscope in figure 5. Various immersion liquids may be used, but the closer the refractive index of the liquid is to that of quartz, the better. However, water usually provides relatively good results.

To observe twinning in amethyst, the stone must be turned so that its optic axis is parallel to

Figure 3. This idealized illustration shows left-hand (black) and right-hand (white) portions of a twinned amethyst. Adapted from Schlössin and Lang, 1965.

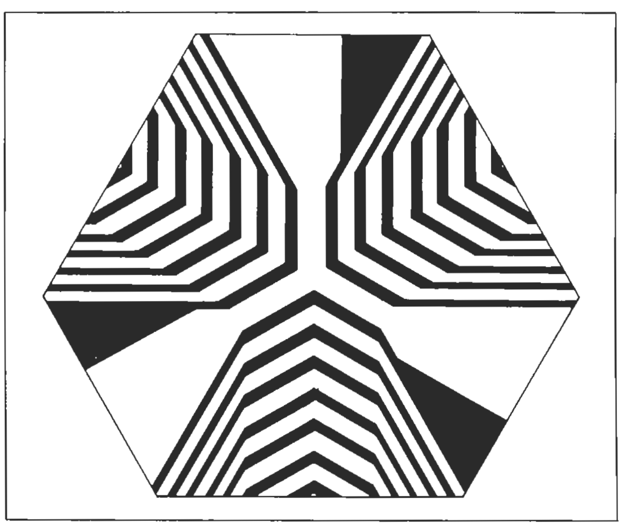


Figure 4. The twinning evident in this natural amethyst closely resembles the idealized drawing shown in figure 3. Note the narrow bands of color under the major rhombohedrons and the broad swaths of color under the minor rhombohedrons. Magnified 15×; photomicrograph by Robert Kane.

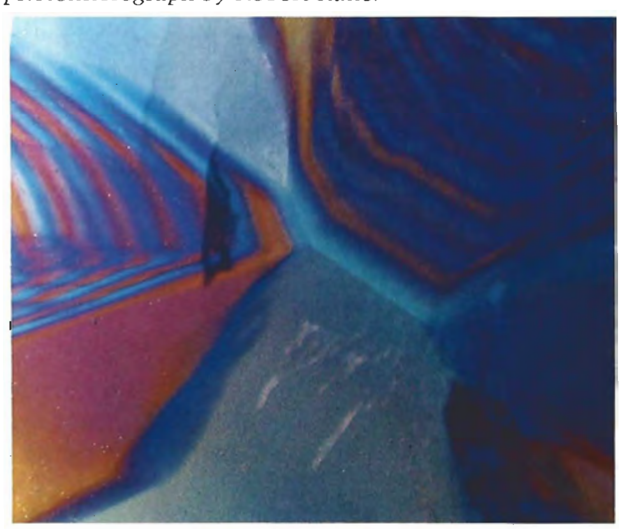


Figure 5. A simple polariscope and immersion cell are sufficient to identify Brazil twinning in near-flawless to flawless natural amethyst. Photo by David Hargett.

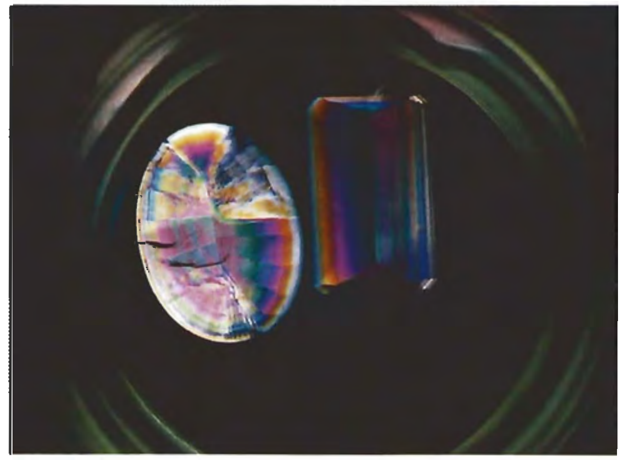


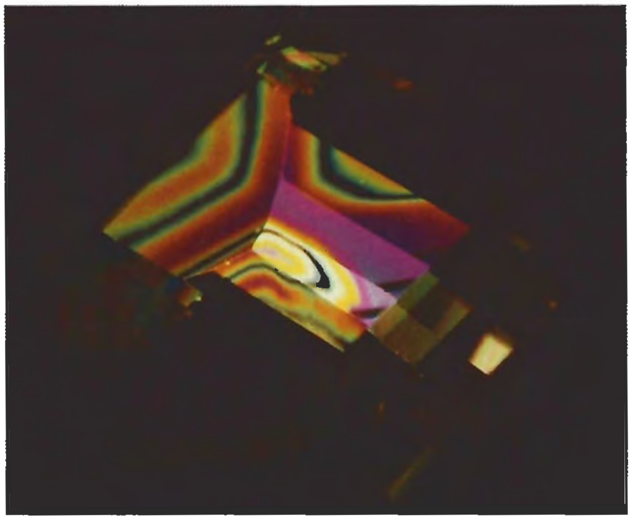
Figure 6. The difference between the twinned natural (oval) and the untwinned synthetic (emerald cut) amethyst is clearly seen looking in the optic axis direction of each under crossed polarizers. Photo by David Hargett.

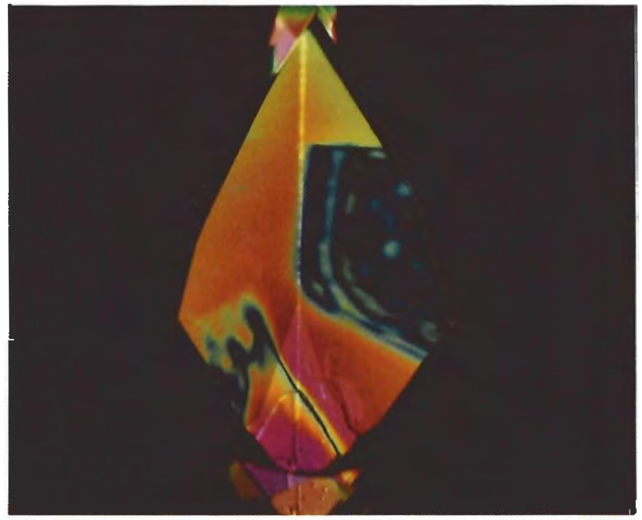
the line of sight through the polariscope or microscope, which must have crossed Polaroids, that is, the dark position. The basic problem is thus one of crystallographic orientation. Cut amethysts usually are not oriented except for maximum weight retention, or best color, so that finding the optic axis direction is a challenge. This is the reason Dr. Schmetzer felt a special holder was necessary. Only rarely is a stone cut with the table perpendicular to the optic axis. Nevertheless, such is the case with the two stones in figure 6. The oval is a natural amethyst showing twinning, whereas the emerald cut shows the untwinned effect of a synthetic stone. The photograph was taken "dry," that is, the stones were not immersed.

Rarely in practice will the test yield such conclusive and dramatic results as easily—and without immersion. For one thing, the optic axis of the stone being tested may coincide with the point of a fancy shape or the girdle of any stone, making it difficult to maneuver with the tweezers to find the right direction. Another problem, more serious, is that if a natural stone has been cut so that it lies entirely under the minor rhombohedron, it will not exhibit twinning. Sometimes only a small area of the stone encompasses an area under the major rhombohedron, but the diagnostic twinning effect, although minimal, is still conclusive. As quoted from Dana above, there have also been reported rare untwinned natural amethyst crystals. These could not be detected by the Schmetzer test alone. Of course, mounted stones offer another problem. If the optic axis direction is obscured by the setting, they cannot be tested without unmounting. Herein lie the shortcomings of the test.

Figure 7 shows the twinning seen with the polariscope in a variety of natural stones. Equally good results can be obtained with a polarizing microscope (figure 8). In contrast, figure 9 illustrates three untwinned synthetic stones. The natural stone shown in figure 10 had to be maneuvered quite a bit, as it apparently was cut from material predominantly under the minor rhombohedron. However, even a tiny area of fine parallel colors shows the presence of twinning, and thus given our present knowledge proves natural origin.

Some synthetic amethysts, notably from Japan, do exhibit twinning (Balakirev et al., 1975). However, our observations thus far indicate that the twinning in these synthetics has a distinctly different appearance from that of natural amethyst. The twinning in the synthetics appears as





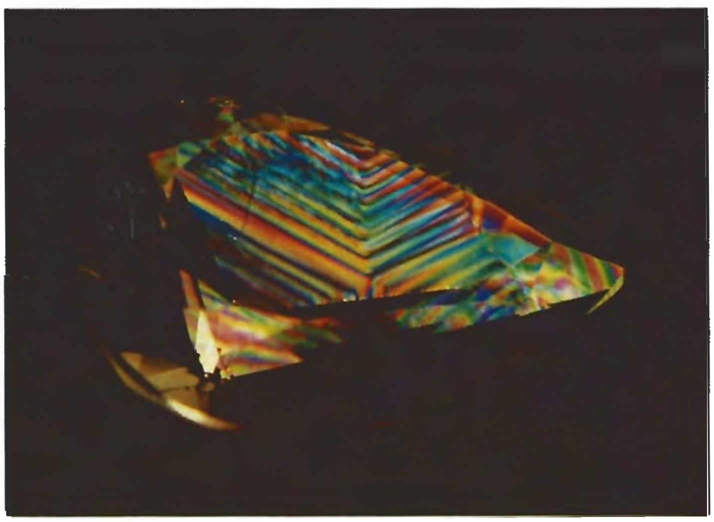
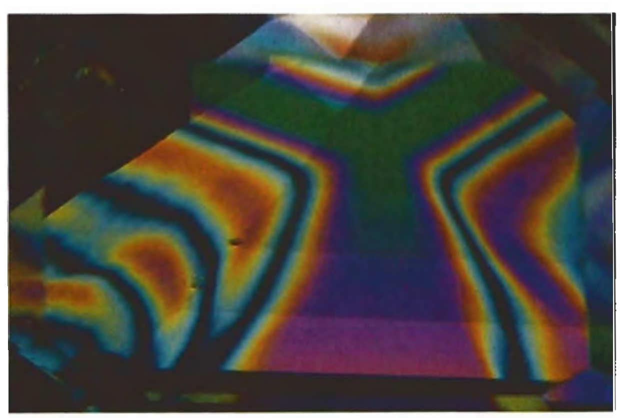


Figure 7. As these three examples of natural amethyst viewed through a polariscope indicate, the Brazil twinning may vary somewhat from one stone to the next. Often the stone will have to be maneuvered with the tweezers or in one's fingers to see the twinning clearly. While immersion may be helpful, these photos were all taken with the stones dry. Photos by Shane McClure.

irregular-shaped, small arrowhead-shaped, or flame-like areas (figure 11). Such stones will have definite zones of yellow or dark purple that coincide with these flame-like or irregular-shaped twinned areas (figure 12). Even in very small areas, however, the acute included angle of the twinning in the synthetics can be distinguished from the 60° or 120° angles characteristic of Brazil law twinning in natural amethyst.

Citrine that has been produced by heating natural amethyst will behave in the polariscope in the same manner as natural amethyst. Bi-colored quartz, sometimes called "ametrine" or amethyst/citrine (figure 13), usually behaves differently. Koivula (1980) noted that Brazil twinning is present in the amethyst zones, whereas the citrine zones are untwinned (figure 14). Thus, ame-

Figure 8. Twinning in natural amethyst can also be identified using a polarizing microscope with crossed polarizers. Magnified 6×; photomicrograph by John Koivula.



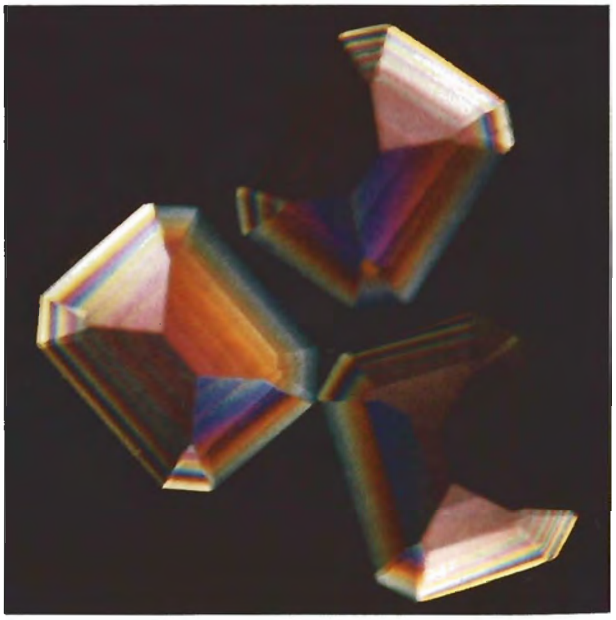


Figure 9. These untwinned synthetic amethysts provide a striking contrast to their twinned natural counterparts when viewed with the polariscope. Note the broad color bands that are characteristic of untwinned single-crystal material. Photo by David Hargett.

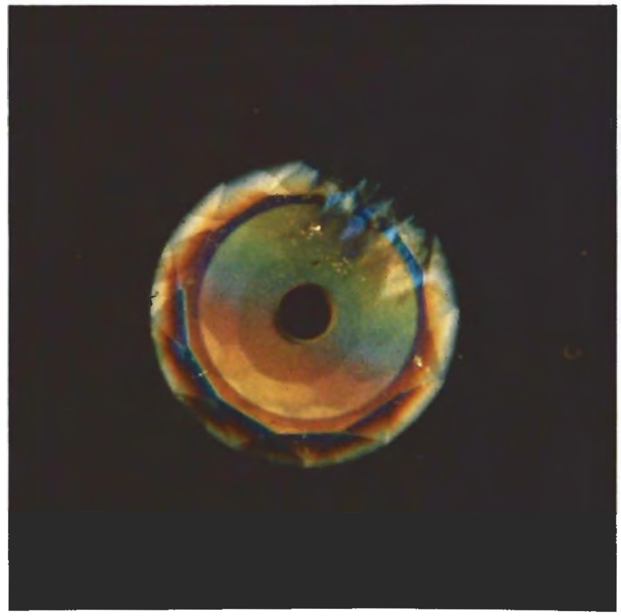


Figure 10. Even a small area of twinning, as shown here in rock crystal quartz, indicates natural origin. Photo by David Hargett.

thyst/citrine and citrine with twinning present can be identified as natural by this method.

OTHER EVIDENCE OF NATURAL VS. SYNTHETIC AMETHYST

Since some natural amethyst may be untwinned, one should consider evidence other than the absence of twinning before calling a stone "synthetic." The presence of recognizable inclusions, such as those described by Gübelin and Koivula (1986), proves natural origin. At one time, "fingerprint" inclusions were regarded as proof of natural origin. This is no longer the case since some synthetic crystals may also have liquid-filled "fingerprint" inclusions (figure 15), especially near the surface of the crystal. The presence of spicules, or

Figure 11. In the synthetic amethyst manufactured in Japan, a form of twinning appears as small irregular-shaped, arrowhead-shaped, or flame-like areas that are very different from the twinning seen in natural amethyst. Magnified 6×; photomicrograph by John Koivula.

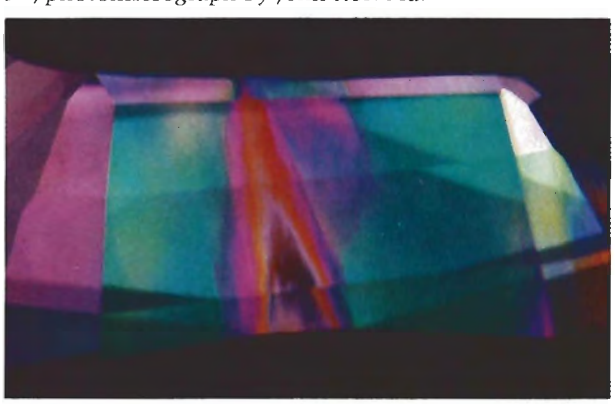
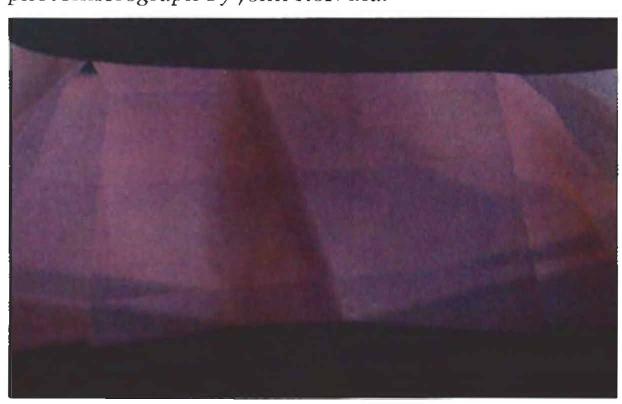


Figure 12. Color zoning coincides with the flame-like or irregular-shaped twinned area in some synthetic amethysts of Japanese manufacture, as this photo of the stone in figure 11, taken without the polarizers, indicates. Magnified 6×; photomicrograph by John Koivula.



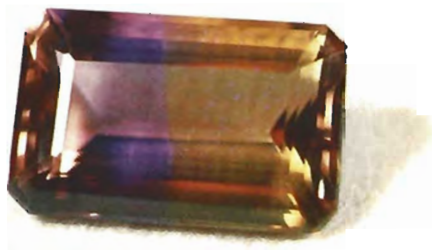


Figure 13. This bi-colored quartz is also known as "ametrine" or amethyst/citrine. Photo by David Hargett.

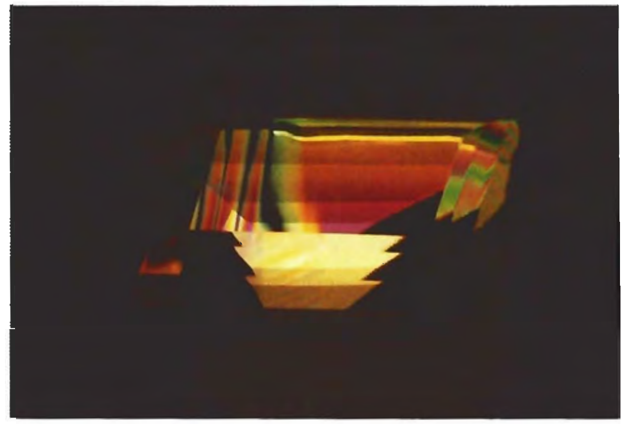
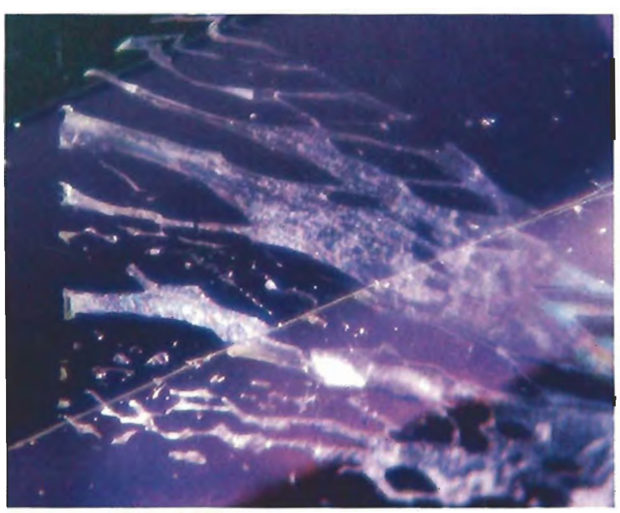


Figure 14. When amethyst/citrine quartz is viewed with a polariscope, the presence of twinning in the amethyst section indicates that the stone is natural. Photo by Shane McClure.

"nailhead," inclusions (observed very rarely) proves hydrothermal synthetic origin. Occasionally, portions of the seed crystal will occur in a synthetic stone and they are highly diagnostic. They usually appear as a slightly cloudy white or yellowish plane often peppered with high-relief "breadcrumbs" (figure 16). Although "breadcrumbs" may (very rarely) be found in natural amethyst, a gemologist seeing them in an otherwise flawless, untwinned stone would be well advised *not* to call it natural!

In the course of this study, 105 natural amethysts were examined with regard to color zoning.

Figure 15. Liquid-filled fingerprint inclusions are now sometimes seen in synthetic amethyst, as shown here, as well as in natural stones. Magnified 20×; photomicrograph by David Hargett.



The pigmenting of amethyst is associated with Brazil twinning, and thus characteristically the deepest color lies under the major rhombohedron, whereas the sections under the minor rhombo-

Figure 16. "Breadcrumb" inclusions, although seen (very rarely) in natural amethyst, usually provide a good clue that the host stone is synthetic, as shown here in a synthetic amethyst of Japanese manufacture. Magnified 45×; photomicrograph by David Hargett.

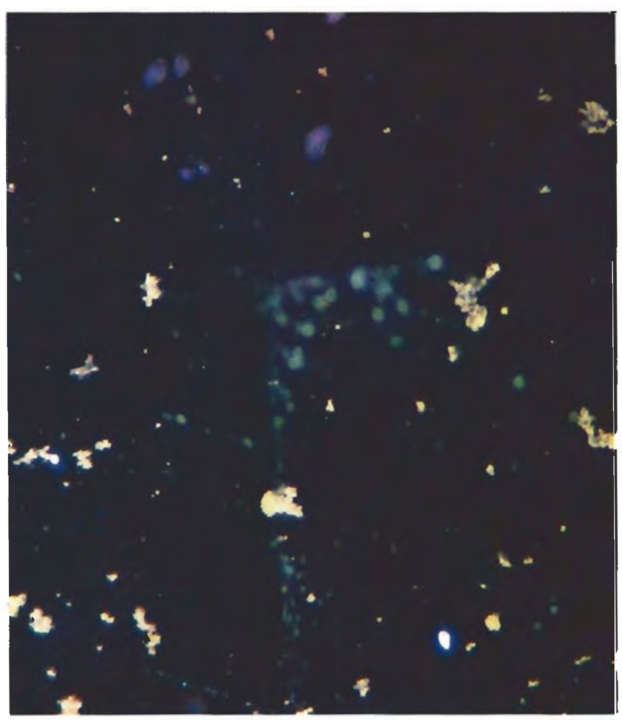


Figure 17. This basal section of amethyst clearly illustrates the deeply pigmented sectors under the major rhombohedron and the nearly colorless sectors under the minor rhombohedron that are characteristic of color zoning in natural amethyst. Photo by Cornelius Hurlbut.

hedron may be colorless or nearly so (figure 17). Even under the major rhombohedron the color may not be uniform. According to Frondel (1962), "The amethyst color may be equally developed in successive twin lamallae, but more often alternate lamellae, either right or left, are selectively pigmented."

Color zoning was present in all 105 natural amethysts examined. In a few, zoning was in one direction only, that is, parallel to but one rhombohedron face. In most, color zoning was parallel to two or three of the rhombohedron faces from which the stones were cut. Brazil twinning was present in all but two of the stones. One of these showed color banding parallel to two rhombohedron faces; the other had color banding parallel to three.

In the limited number (6) of faceted synthetic amethysts examined for color zoning, all were untwinned. Five were of uniform color throughout, which is rarely if ever seen in natural amethyst (again, see figure 17). One showed imperfect color zoning parallel to a rhombohedron face that was interpreted as being parallel to the seed from which the crystal was grown. In addition to the cut stones, there was available a piece of synthetic rough which included the colorless seed plate cut parallel to a rhombohedron face. This was flawless, untwinned material with a faint color zoning parallel to the seed. The observations indicate an uncertain identity of an untwinned stone with one

Figure 18. When color zoning is seen in a synthetic amethyst (here, 10.86 ct), it is limited to darker and lighter shades of purple. Photo by Shane McClure.

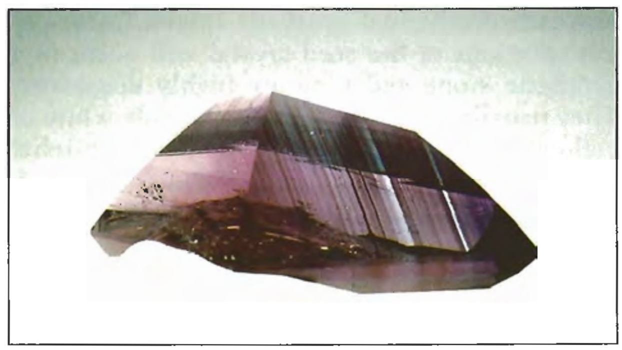


Figure 19. The color zoning in natural amethyst (here, 7.04 ct) is typically straight or angular in two or three directions, and consists of zones of purple and violetish blue or colorless material. Photo by Shane McClure.

direction of color zoning. But if the zoning is in two or three directions, a natural origin is indicated. It should be noted that the zoning observed in most synthetic stones is limited to darker and lighter shades of purple (figure 18); parallel zones of purple and violetish blue or colorless material and angular zoning indicate natural amethyst (see figure 19). Other gemologists (e.g., Sondra Francis, pers. comm., who has studied this phenomenon in depth) report that many synthetic amethysts are indeed zoned but confirm the zoning differences noted above between natural and synthetic stones.

In recent years, gemological and mineralogical investigators have noted in print the rippled fracture surface of natural amethyst and even outlined a procedure for frosting the surface of an unknown amethyst (by slight regrinding with fine grit on a soft wheel at low speed) so that it is possible to see with the unaided eye the twin lamellae of the natural stone (Schneider and Dröschel, 1983). Of course, the stone must then be repolished.

Considerable attention has also been paid in Europe to attempts to distinguish amethysts by infrared spectrometry (Katz, 1962; Chakraborty and Lehmann, 1978; Zecchini, 1976; and Lind and Schmetzer, 1983). Problems with specimen orientation, as well as the practical difficulties encountered in transmitting spectral signals through faceted gemstones, have thus far thwarted attempts to provide a routine method of identification through infrared spectra. However, new infrared instrumentation is now available, and results to date are promising for this approach to the separation of natural and synthetic amethyst.

CONCLUSION

While some "experienced" amethyst dealers have reported no difficulty in separating synthetic amethysts from natural stones merely by looking, others who have mastered the "Schmetzer" test have reported that their stock is badly mixed. One dealer stated that even parcels from his own cutting shops abroad have had as much as 25% synthetic amethyst mixed with the natural. It is the authors' hope that this article will serve to reassure the ethical trade that this no longer need be the case, that the practice of salting synthetics into parcels of natural stones can be effectively deterred.

Although the reader is reminded that the use of twinning cannot be 100% effective, in preparing for this article the authors tested more than 1300 amethysts of known origin (over 1100 natural and 200 synthetic). By noting inclusions, color zoning, and twinning, all the stones could be satisfactorily identified.

On the basis of information currently available, we conclude that the presence of Brazil law twinning in an otherwise flawless amethyst proves natural origin. However, twinning in the form of an acutely angled, flame-like pattern positively identifies synthetic origin. With practice, there should be no confusion between these twinning patterns.

In the absence of twinning, synthetic origin is probable, but further evidence is required to make a positive identification. Angular or straight zoning with colorless or violetish blue zones next to purple areas characterizes natural amethyst. The presence of zones of only light and dark purple or the complete absence of zoning indicates synthetic origin, but does not provide conclusive proof of origin. Characteristic inclusions can also provide proof of origin.

If no other conclusive evidence of origin is available, infrared spectrometry appears to contain such proof, once the practical aspects of routine application have been resolved. Ongoing research in this area promises to solve the few remaining difficulties in identifying natural and synthetic amethyst. However, this study indicates that the overwhelming majority of stones on the market today can be distinguished by the methods already available.

REFERENCES

Balakirev V.G., Tsinober L.I., Tsyganov E.M. (1975) Electron microscope study of Brazil twins in synthetic amethysts. *Soviet Physical Crystallography*, Vol. 19, pp. 517–520.

Balitsky V.S. (1980) Synthetic amethyst: Its history, methods of growing, morphology, and peculiar features. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 29, pp. 5–16.

Chakraborty P., Lehmann G. (1978) Distribution of OH in synthetic and natural quartz crystals. *Journal of Solid State Chemistry*, Vol. 17, pp. 305–311.

Frondel C. (1962) *Dana's System of Mineralogy*, 7th ed., Vol. III: *Silica Minerals*. John Wiley & Sons, New York.

Gübelin E. J., Koivula J. I. (1986) *Photoatlas of Inclusions in Gemstones*. ABC Edition, Zurich.

Katz A. (1962) Hydrogen in quartz. *Phillips Research Reports*, Vol. 17, pp. 133–135 and 201–279.

Koivula J.I. (1980) Citrine-amethyst quartz—a gemologically new material. *Gems & Gemology*, Vol. 16, No. 9, pp. 290–293.

Lind Th., Schmetzer K. (1983) A method for measuring the infrared spectra of faceted gems such as natural and synthetic amethysts. *Journal of Gemmology*, Vol. 18, No. 5, pp. 411–420.

Lind Th., Schmetzer K., Bank H. (1983) Untersuchungsmethoden zur Unterscheidung von natürlichen und synthetischen Amethysten. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 32, No. 2/3, pp. 126–137.

Schlössin H.H., Lang A.R. (1965) A study of repeated twinning, lattice imperfections and impurity distribution in amethyst. *Philosophical Magazine*, Vol. 12, pp. 283–296.

Schmetzer K. (1985) Ein verbesserter Probenhalter und seine Anwendung auf Probleme der Unterscheidung natüralicher und synthetischer Rubine sowie natürlicher und synthetischer Amethyste. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, pp. 30–47.

Schmetzer K. (1986) An improved sample holder and its use in the distinction of natural and synthetic ruby as well as natural and synthetic amethyst. *Journal of Gemmology*, Vol. 20, No. 1, pp. 20–33.

Schneider W.L., Dröschel R. (1983) Beobachtungen an polysynthetisch verzwillingten Quarzen-ein Beitrag zur Unterscheidung natürlicher und synthetischer Amethyste. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 32, pp. 28–38.

Zecchini P. (1976) Étude de l'absorption infrarouge de quartz d'origine naturelle ou de synthese. *Revue de Gemmologie Association Française de Gemmologie*, No. 60, pp. 14–17.