THE IMPACT OF INTERNAL WHITISH AND REFLECTIVE GRAINING ON THE CLARITY GRADING OF D-TO-Z COLOR DIAMONDS AT THE GIA LABORATORY

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Unlike many other characteristics that affect the clarity grade of a diamond, determination of the impact of "whitish" graining and "reflective" graining requires analysis that goes beyond visibility at 10× magnification. The importance of this determination is further underscored by the fact that such graining often is the only characteristic present in large, high-clarity, high-color diamonds. This article reviews the history of reporting on such graining by the GIA Laboratory, considers the causes of the different types of graining most commonly encountered, and examines the methodology and critical assessment GIA graders use to determine the impact of such graining on the clarity grade of a diamond.

One of the most misunderstood features in diamond clarity grading is the impact of graining, especially internal "whitish" or "reflective" graining (see, e.g., figure 1). R. E. Kane's 1980 *Gems & Gemology* article, "The Elusive Nature of Graining in Gem Quality Diamonds," gave the reader an overview of the causes of graining, illustrated the range of appearances associated with it, and generally outlined its relationship to clarity grading at the GIA Laboratory (see also Kane, 1982). The present article looks at this subject 25 years—and literally millions of diamonds—later.

For the purposes of diamond grading, *graining* refers to optical discontinuities that are observable with a 10× loupe or a standard gemological microscope. The overall transparency of a diamond can be affected by these discontinuities to varying extent. While fractures and cleavages are also discontinuities, an important difference is that with graining no open space (i.e., air/diamond interface) is present. Whitish graining can be classified into banded, tatami, and overall haziness, whereas reflective graining typically consists of internal reflective planes.

Many of the forms graining takes (e.g., surface lines or colored bands) are readily observed, and their relationship to clarity can be understood with standard diamond grading conditions and criteria (i.e., ease of visibility at 10× magnification and location). But whitish graining and reflective graining are often more difficult to distinguish and relate to clarity, since their visibility is influenced more by optical factors such as the type of lighting and the angles of observation in relation to the lighting.

Note: The photomicrographs provided in this article represent a static view of a graining feature, and are often taken from a viewing angle in which the feature is most obvious. It is important to remember that one factor in determining graining's impact on a clarity grade is the effect of subtle movement of the diamond during observation. While the feature illustrated in the image may appear obvious, the determination mentioned in the caption reflects Laboratory awareness of all the factors that influence the clarity grade.

See end of article for About the Authors and Acknowledgments.

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Figure 1. The 30+ ct pear shape and 18 ct oval shown here are representative of the large colorless to near-colorless diamonds in which whitish graining may affect the clarity. This effect is often misunderstood due to the elusive nature of such graining. The photomicrograph illustrates a classic example of the cottony banding encountered in whitish graining that will have an impact on the clarity grade. Photo © Harold & Erica Van Pelt; photomicrograph by Vincent Cracco, magnified 21×.

Also, because such graining is a natural part of the diamond structure, many trade members do not believe it should be a clarity characteristic. However, undeniably there are varying degrees of visibility associated with whitish and reflective graining, which has resulted in considerable debate over the impact it should have on the clarity grade (Nir Livnat, pers. comm., 2006).

Other challenges to understanding the impact of such graining on the clarity grade relate in part to the fact that a more complex decision-making process is required to assess whitish or reflective graining than is usually required with most other internal features. This process must take into account the ability not only to discern the feature at 10× magnification, but also to determine its form (i.e., lines, planes, broad areas), texture (i.e., cottony, sheen-like, hazy), and the angle(s) at which it is visible.

In the early years of diamond grading at GIA, the complexity of assessing whitish graining was complicated by the fact that this characteristic was encountered only infrequently at the laboratory. In recent years it has been further complicated (and its importance enhanced) by other factors. For one, in our experience whitish graining is most commonly encountered in large (e.g., over 4 ct) diamonds. Most of these large diamonds are type II (a diamond type that is relatively free of nitrogen) and often absent of solid inclusions (see, e.g., Moses and Wang, 2006). Another factor is that the complex interaction of light with a diamond's cut when viewed in the face-up position may restrict the observation of this often subtle, visually elusive feature to the pavilion, where such graining can impact the most critical clarity determination of Flawless/Internally Flawless (FL/IF) versus VVS_1 (figure 2). This reinforces the importance of consistent interpretation of this feature, given the potential impact on the value of the diamond.

While reflective graining (figure 3) is observed more often in smaller, type I diamonds and frequently in association with other inclusions, its assessment requires many of the considerations—and complex decision making—described above for whitish graining. Therefore, this article will focus on assessing the appearances and grading of whitish graining in particular, with specific reference to reflective graining where appropriate.

Following an overview of GIA's history of reporting on graining (particularly whitish), we will

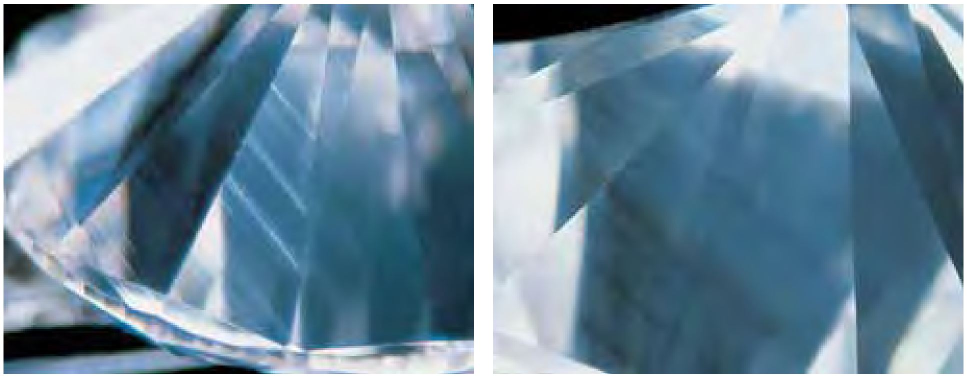


Figure 2. Illustrated here are two appearances associated with whitish graining that affects the clarity grade. These diamonds had no other internal features visible at 10× and the graining was only seen through the pavilion, which resulted in a clarity grade of VVS$_1$. Photomicrographs by Vincent Cracco; magnified 21× (left) and 15× (right).

summarize the causes of whitish and reflective graining and then describe the system GIA uses to determine the effect of such graining on a diamond's clarity grade.

HISTORY OF REPORTING AND CLARITY GRADING WHITISH GRAINING AT GIA

The evolution of grading whitish graining is an interesting case study of how diamond grading has developed since its early days. As with many areas of study, in diamond grading the collection of data over time allows the observers to make refinements and clarify the methods used to make assessments. This section presents an overview of the developing awareness of this feature and changes in reporting through the years.

While GIA has issued diamond grading reports since the mid-1950s, it was only in the late 1960s and the 1970s that requests for its grading services began to grow. With the investment craze of the late 1970s—when purchases of goods such as diamonds, silver, and gold were promoted as a hedge against inflation—demand for "certificate" goods rose dramatically. This resulted in huge increases in report production and staffing at GIA. Even though the boom had become a bust by the end of 1980, the trade was now using grading reports routinely in diamond transactions. In fact, laboratory records show that GIA graded more diamonds in the decade of the 1980s than in the previous 25 years of diamond grading combined.

Consequently, early reporting on diamonds with whitish graining was generalized, with broad categories for the appearances and descriptions used. Several years elapsed before senior graders had examined enough diamonds with graining to enable them to review and refine the grading criteria related to this feature. A review of reports and personal notes written by celebrated gemologist G. Robert Crowningshield during the late 1960s and early 1970s indicates that it was not until this period that diamonds with low diaphaneity were seen in the laboratory. The Spring 1970 issue of *Gems & Gemology* (p. 157) provides insight into the developing awareness of this distinctive appearance when Crowningshield reported the following on examining a "milky" diamond:

> We were reminded of certain important diamonds we have graded recently that were just slightly misty but in which no zones nor parallel bands could be seen and no particles whatever, even under highest magnification. Two such stones were top color and free of any imperfections otherwise. It was acknowledged that the slightly lower transparency did affect the value, but we have been at a loss how to arrive at a meaningful grade. It is possible that these stones represent a new source of gem diamonds. If so, we must arrive at an acceptable grade for them so as to be fair to the diamonds and to potential customers.

The following year, Crowningshield (1971a) speculated that these "grained stones" might be from Russia. However, diamantaire Louis Glick (pers. comm., 2006) recently confirmed that he and others had purchased and manufactured similar diamonds in the late 1960s and early 1970s that originated from Sierra Leone. As more of these diamonds were submitted to the laboratory, it became clear that this feature often occurred in larger diamonds high on the D-to-Z color grading scale. It also became apparent that this "misty" appearance was being seen in diamonds from many sources. Recognizing that the loss of transparency affected value, as mentioned above, the laboratory began to systematically report on readily observed graining during the early 1970s. The earliest reporting took the form of a comment. For example, in June 1970 an important 13+ ct, D-color diamond with sufficient graining to impact its transparency was graded

Figure 3. Reflective graining is seen here as: left, an obvious reflective plane; right, linear "fingers" extending along a plane that is more transparent than the "fingers." With no other inclusions noted, both diamonds would receive a clarity grade of VVS$_1$, since the graining was only visible through the pavilion. Photomicrographs by Mitchell Moore and Vincent Cracco.

IF with an asterisk following the clarity grade. The corresponding comment stated: "Near transparent due to unusual internal texture."

This approach continued throughout much of the early 1970s: Diamonds that exhibited graining but had no other inclusions received clarity grades of FL or IF together with a comment regarding their reduced transparency. Changes in the wording of the comment indicated the continued evolution in thinking as more diamonds with graining were seen. For example, comments from the early 1970s often described the appearance without noting an impact on clarity grade. The comment noted above for the 13+ ct diamond from 1970 is one such example, and a 1973 comment for a 5+ ct pear-shaped diamond stated: "Nothing generally regarded as a flaw or imperfection observed, however whitish internal graining is present." Less-descriptive comments were seen later in 1973, such as the simple "Graining is present" noted on the report for a 2 ct marquise brilliant graded IF.

Although early in the 1970s Crowningshield (1971b) described an example where he felt the graining affected the clarity grade, it took much of the decade for the laboratory staff to reach a level of certainty as to when the appearance of whitish graining could diminish clarity as much as fractures or solid inclusions. A 1977 report on a 4+ ct marquise brilliant noted a clarity grade of VVS$_1$ and included a comment stating: "Based on extensive whitish graining." A 6+ ct pear shape was also graded VVS$_1$ with a comment noting: "Based on parallel whitish graining not shown [on the report diagram]." By the late 1970s, not only was the degree of other internal graining that did not affect the clarity grade (referred to as transparent graining) noted on the report (see below), but clarity grades lower than VVS$_1$ were also assigned for whitish graining when the effect was severe.

During the 1980s, whitish graining was routinely treated like other clarity characteristics and graded on its visibility at 10× magnification with the microscope and loupe. On occasion, the grading decision was based on visibility with the unaided eye. At that time, the methodology used to assess graining (i.e., angle at which the stone was observed, distance and angle of the feature in relation to the light source, and degree of visibility) was still broadly defined in the grading process. The use of such broadly applied methods resulted in a greater range of interpretation of this feature and, therefore, finer and more limited areas of graining that could potentially affect the clarity grade. Such assessments were quite different from those made in the first half of the previous decade, when large areas of graining did not affect the clarity grade *per se*.

This evolution in the assessment of graining resulted in perceived inconsistencies in reporting when diamonds of similar appearance, graded at different times over a period of many months or years, were seen together. While the laboratory instituted a number of policies internally to ensure more consistent performance, the lack of external communication on the subject left the trade in doubt about the grading policy. In looking back over 50 years of reporting and grading graining at the GIA Laboratory, we can summarize the related policies as follows, in chronological order:

- 1950s through the late 1960s—Whitish graining was not considered a clarity characteristic and was not noted on the report. With no other inclusions present, a diamond would be graded FL/IF. Observed graining was sometimes noted for "in-house" identification.

- Early 1970s—Whitish graining was usually not considered a clarity characteristic, but the reduced diaphaneity was acknowledged through a report comment. A diamond could receive a grade of FL/IF and yet have one of a number of different report comments noting the presence of graining.

- Mid-1970s to about 1980—Whitish graining was routinely considered a clarity characteristic. If it was easily seen at 10× magnification, with no other internal features visible, the appropriate clarity grade was assigned with a comment noting that it was based on whitish graining. If transparent graining was present, the diamond was assigned a FL or IF clarity grade, with an additional report comment noting the degree of graining (i.e., *significant*, *moderate*, or *slight*). Other types of graining (e.g., reflective or colored bands) were plotted on the report diagram and noted in the key to symbols.

- About 1980 to the mid-1980s—Whitish graining was considered a clarity characteristic and noted in a report comment when it affected the clarity grade. During this period, *all* diamonds were given an assessment for transparent graining (*significant*, *moderate*, *slight*, or *nil*), and the degree of observed graining that did not affect clarity was given its *own entry line* on all reports. We continued to plot other types of graining that affected the clarity grade on report diagrams.

- Late 1980s to the early 1990s—Whitish graining was considered a clarity characteristic and noted in a report comment when it affected the clarity grade. However, graining that was not severe (i.e., that did not impact the clarity grade) was again indicated on in-house records only (for identification)—unless it was significant, in which case it was still reported in a comment. Other types of graining that affected clarity were plotted on the report diagram.

- Mid-1990s to the present—Whitish graining continues to be considered a clarity characteristic and, when severe enough to affect the clarity grade, is noted in a report comment ("The clarity grade is based on internal graining that is not shown [on the report diagram]"). Any other type of graining that affects the clarity grade is no longer plotted on the report diagram but appears as a report comment, with the same wording as for whitish graining. Significant transparent, colorless graining (that does not affect the clarity grade) continues to be recorded in a report comment, with the current terminology being "Transparent internal graining is present." For all graining observed, whether or not it affects the clarity grade, the precise type and its degree are noted internally for identification purposes.

OVERVIEW OF THE CAUSES OF WHITISH AND REFLECTIVE GRAINING

An "ideal" or "perfect" diamond is composed solely of carbon, and all the carbon atoms are packed in a cubic structure that is repeated continuously throughout the crystal. Physical properties, including optical characteristics, are uniformly distributed in such a diamond. However, virtually all diamond crystals contain discontinuities in this regular pattern of carbon atoms. For example, plastic deformation is a common feature in natural diamonds. When stress is applied to a diamond above a certain temperature, the crystal lattice is distorted along specific planes. This causes a disruption in the regularity of the crystal lattice that is known as a dislocation, and these dislocations remain after the stress is released (Wilks and Wilks, 1991). The presence of impurities (i.e., other elements, such as nitrogen or boron) will also disturb the packing of carbon atoms in the diamond lattice. In addition, some carbon atoms may not be positioned correctly within the lattice structure.

The dislocation of carbon atoms is the predominant cause of graining features in diamond; such dislocations can be introduced either during or after the diamond has formed (Wilks and Wilks, 1991). When these lattice defects or dislocations occur with sufficient density to change the stone's refractive index or other physical properties, they may create optical disturbances strong enough to be observed with 10× magnification that may have a negative impact on the overall transparency of a faceted diamond. This section focuses on the causes of whitish and reflective graining. For a brief overview of the causes of some other types of graining that are commonly encountered during diamond grading at the Laboratory, see box A.

Banded or Tatami Whitish Graining. Some whitish graining appears as straight or wave-like lines or bands in an otherwise "clean" diamond (figure 4, left). Sometimes a group of nearly parallel lines or bands may occur together. These lines are more visible when the stone is examined in a specific orientation, and will disappear when the stone is rotated.

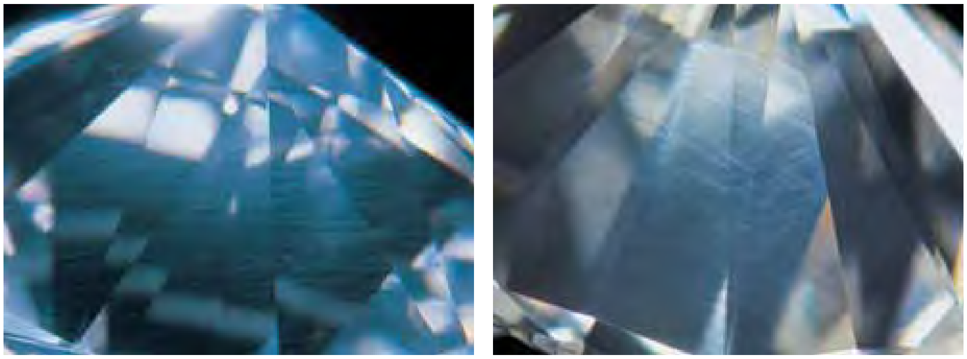


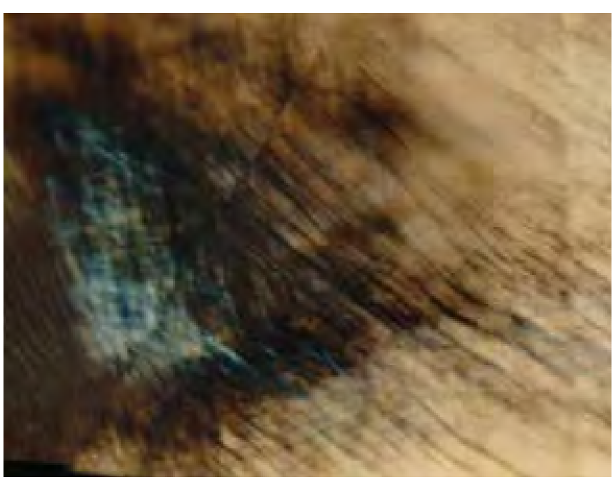
Figure 4. One form of whitish graining appears as wave-like linear bands observed over a wide area of the diamond (left). Whitish "tatami" graining is seen when bands develop in two directions (right). Photomicrographs by Vincent Cracco; magnified 12× (left) and 15× (right).

One notable feature of these lines is their whitish or silky appearance when examined with a microscope and darkfield illumination; another is their dominant development in one direction.

When these whitish lines or bands are well developed in two major directions, a cross-hatched or "tatami" pattern is produced (figure 4, right; Lang, 1967; Moses et al., 1999). In extreme cases, the graining is so intense and widespread that the observer has the sensation of looking through a screen (i.e., the "crisp" appearance is diminished; see, e.g., Moses and Wang, 2006).

Dislocations in the diamond lattice are the main cause of banded or tatami graining. Lattice distortion affects many physical properties, such as refractive index. Instead of light following its typical path through the diamond, in the distorted region it is refracted or diffused due to the difference in R. I. between that region and the surrounding lattice (Fontanella et al., 1977; Balzaretti and da Jornada, 1996). As a result, when examined with crossed polarizers, high-order interference colors may be observed along the graining planes (figure 5).

Figure 5. When examined with crossed polarizers, the graining planes in figure 4 (right) are delineated by the high-order interference colors associated with dislocations in the diamond lattice. Photomicrograph by W. Wang; magnified 27×.



Hazy Whitish Graining. Cloud-like inclusions in diamond typically are composed of numerous tiny microscopic crystals and occur in the cubic growth sector (Shah and Lang, 1963; Fritsch and Scarratt, 1993). When these inclusions are too small to be recognized as individual pinpoint-like crystals with standard microscopic examination, they collectively appear as an overall haziness (figure 6) due to the scattering of light. Such haziness may occur in a very small region, but it typically is seen throughout most of the stone; on rare occasions, it may occur as bands (see Jang-Green, 2006). Because this overall haziness appears to be related to the growth structure (and the individual pinpoints cannot be resolved at the 10× magnification used for clarity grading), in gemology it is usually considered a form of whitish graining.

Reflective Graining. Plastic deformation often generates a number of closely spaced parallel planes in some types of diamonds (usually type IaA with high concentrations of nitrogen). It is widely believed that the areas on both sides of the plane slid slightly relative to one another, creating the so-called slip bands (Wilks and Wilks, 1991; Fritsch et al., 2006). Occasionally, the damage to the diamond lattice along slip planes is intense within a very narrow region. When these slip bands are viewed with reflected light in a specific orientation, they may appear as reflective graining (again, see figure 3). As noted above, there are fundamental differences between reflective graining and a fracture or cleavage, since the former involves no air/diamond interface and typically will be observed only in a specific orientation.

Although understanding the cause and resultant

BOX A: OTHER TYPES OF GRAINING SEEN IN D-TO-Z DIAMONDS

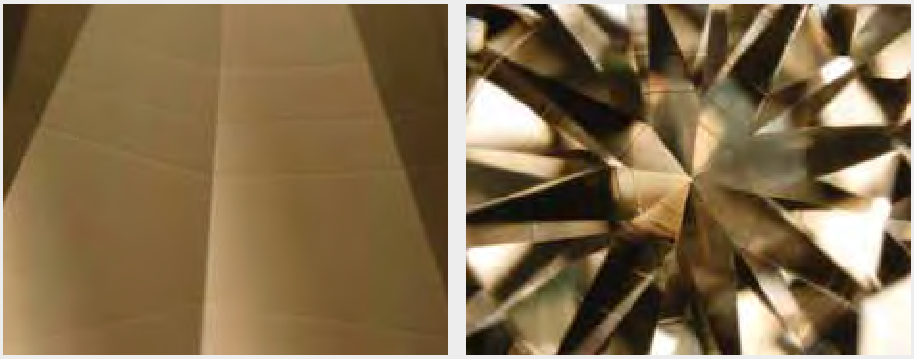


Figure A-1. Occasionally surface grain lines (left) "ring" the diamond and, when the same stone is viewed table up, create a "spider-like" web appearance due to reflections (right). If they are extensive and obvious in the face-up position, these surface grain lines can affect clarity (here, VVS$_1$). Photomicrographs by W. Wang; magnified 60× (left) and 30× (right).

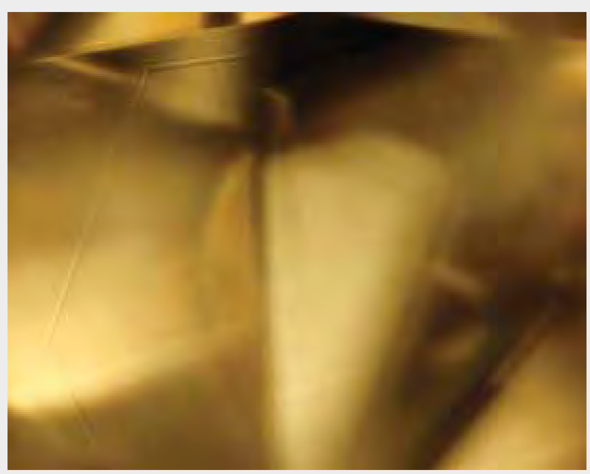
In addition to whitish and reflective graining, two other types of graining are commonly encountered in D-to-Z diamonds during the grading process: surface graining and colorless transparent internal graining. These either relate to, or may be confused with, internal reflective graining. The following provides a brief description of their typical appearances and causes, as well as a summary of how each may affect the clarity grade.

Surface Graining. As mentioned in the main text, plastic deformation is the likely cause of reflective graining. The parallel planar features (slip bands) generated in this process may appear to be completely internal or to originate from the surface of the diamond where discernable lines are seen (i.e., surface grain lines; see figure A-1). In some cases, these slip bands are only visible on the surface, where they are most easily seen with reflected light. They may not be evident internally if the optical disturbance was quite limited and not severe enough to appear as reflective planes. Nevertheless, if extensive, they may affect the clarity grade.

Another common cause of surface graining is a change in crystallographic orientation (i.e., twinning). For example, a macle is a twinned diamond crystal with a flattened morphology caused by a 180° rotation in the crystal orientation. Since diamond hardness is dependent on crystallographic orientation (e.g., the {111} direction is much harder than the {110} direction), the plane of the twinned crystal may be visible on the surface as a grain line after faceting. This line is brought out during the polishing process, when a shallow step is created at the twin boundary due to the differences in hardness across the twin plane.

Surface graining can also relate to growth sectors that formed differentially during the crystallization of the diamond. Different growth sectors in a single-crystal diamond may have significant differences in impurity concentration (e.g., nitrogen), resulting in observable optical discontinuities at the growth sector boundaries due to slight differences in R.I. The planes may (see below) or may not be visible internally, depending on the degree of associated optical disturbance. Variations in impurity concentrations between various growth sectors will also affect their hardness. Diamond with a high concentration of nitrogen (up to several hundred parts per million) is distinctly softer than pure diamond (Field, 1979; Yan et al., 2004). Surface graining formed in this way follows diamond

Figure A-2. Surface grain lines may be caused by variations in impurity concentrations (and thus hardness) among different growth sectors. Photomicrograph by W. Wang; magnified 70×.



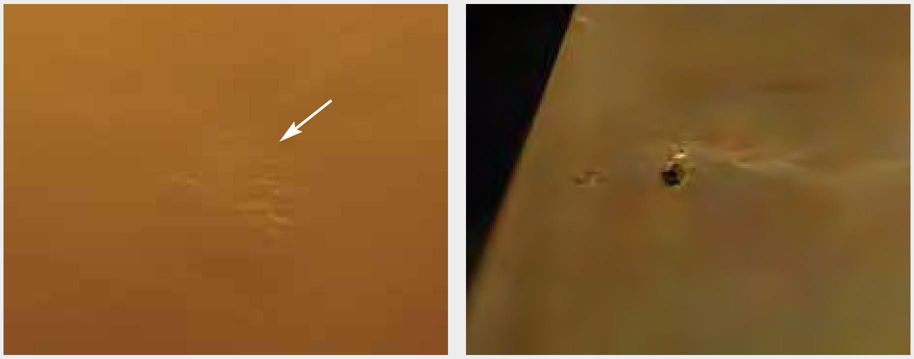


Figure A-3. Grain lines may be caused by the expansion of inclusions during transport of the diamond to the earth's surface. The extent of grain lines is typically proportional to the size of the inclusion (minute on the left as denoted by the arrow, and larger on the right). Photomicrographs by W. Wang; magnified 100× (left) and 70× (right).

growth zones, usually as straight and distinct lines. For example, the fine graining in figure A-2 exhibited a nearly hexagonal outline on the table facet.

Graining formed due to twinning or variations in growth sectors is normally not extensive and often appears subtle. In clarity grading, a diamond with no other clarity characteristics except surface graining cannot receive a grade of Flawless, but a grade of Internally Flawless is possible. Extensive, numerous surface grain lines can affect the clarity grade of an otherwise Internally Flawless diamond, and may result in grades of VVS or lower depending on the visibility of the graining when the diamond is examined face up.

Colorless Transparent Internal Graining. As mentioned in the main text (see "Nature"), graining that appears as bright lines (showing no internal plane) that fade with slight movement of the diamond is often confused with reflective graining. These areas of graining are usually transparent and rarely affect clarity. Two mechanisms are commonly associated with transparent graining.

One cause is the expansion of inclusions. During transport to the earth's surface, differential expansion occurs between a solid inclusion and the host diamond in response to decreasing pressure and temperature. The volume of the diamond (and thus the space the inclusion occupies) changes very little, but some mineral inclusions will expand significantly (Schrauder and Navon, 1993; Sobolev et al., 2000). This expansion exerts stress and may create a local lattice distortion in the surrounding diamond. Occasionally, graining with a wave-like appearance may be seen surrounding a small mineral inclusion. These lines are usually developed in a specific orientation, starting at the inclusion. Transparent grain lines formed in this way are relatively short and proportional to the size of the inclusions (figure A-3). Microscopic observation with crossed polarizers typically shows very high-order interference colors due to the internal strain surrounding such inclusions (see, e.g., Lu et al., 2001).

A second cause of colorless, transparent internal graining is octahedral growth zoning, which is typically referred to in a diamond as "cubic graining" due to its square or rectangular outline corresponding to an octahedral growth sector (figure A-4; see Wilks and Wilks, 1991; Sunagawa, 2006). This type of graining is caused by variations in impurity concentrations in different growth sectors, as described above. The graining is created by optical differences at the boundaries of these growth zones. Like graining caused by the expansion of inclusions, this type of graining is occasionally confused with reflective graining since it will appear bright in some positions.

Figure A-4. Transparent internal graining that follows a diamond's octahedral growth sector typically has a square or rectangular outline. This type of graining typically fades in and out of view as the diamond is moved; it is not common for such graining to impact the clarity grade. Photomicrograph by W. Wang; magnified 40×.

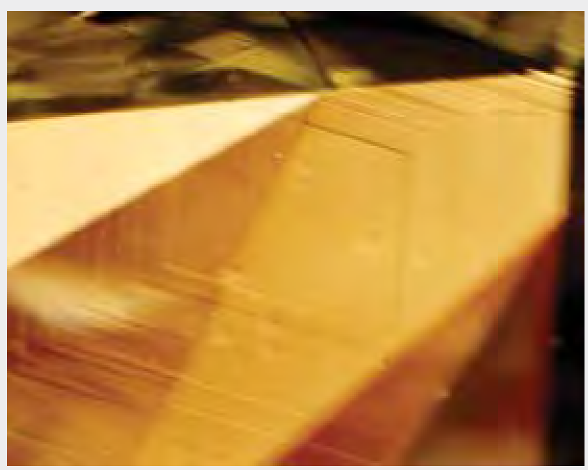


Figure 6. A whitish overall haziness believed to be the result of submicroscopic inclusions is also referred to as whitish graining in gemology. It appears to be related to the growth structure of the diamond. The transparency of this 5.68 ct diamond was noticeably affected when viewed face-up, which would result in a grade in the SI range even if no other inclusions were present. Photo by Vincent Cracco.

appearance of whitish and reflective graining in a diamond helps the grader identify its presence, the greater challenge is assessing the degree to which such graining affects the clarity grade. Following is the protocol used in the GIA Laboratory to observe graining and determine whether it influences the clarity grade—and, if so, to what degree.

THE GIA SYSTEM FOR GRADING WHITISH AND REFLECTIVE GRAINING

The most important aspect of grading whitish and reflective graining is the initial determination as to whether the graining has any impact on the clarity of the diamond. Again, it is important to remember that visibility at 10× magnification is not the only determining factor, as illustrated by many of the examples provided below. Once it has been established that a graining feature has an impact, the other criteria for determining a diamond's clarity grade also come into play (i.e., visibility from the crown or pavilion, and ease of visibility—subtle, noticeable, or obvious with the loupe, or readily seen with the unaided eye).

As with other aspects of grading, a controlled observation environment and assessment methodology are critical for consistent results. In fact, any determination requiring visual observation also requires strict control of the lighting, viewing environment, and spatial relationship of the observer to the object.

Light Source and Viewing Environment. The ability to observe graining is strongly impacted by optical effects. Therefore, the control of lighting for both the surrounding environment and that used for examination of the diamond is critical. In the GIA Laboratory, observations are made in a room with subdued fluorescent ceiling lights that limit surface reflection and optimize the natural light/dark contrasts observed in the diamond. Windows are shaded to control external lighting. Initially, features are located and identified with a GIA Instruments microscope. The microscope's well light source (used to create the darkfield illumination seen through the microscope oculars) consists of one 25 watt halogen bulb. Halogen bulbs have output in the long-wave ultraviolet region of the spectrum which, on rare occasions, could cause confusion between haziness caused by graining and the "oily" disruption in transparency that can be observed in very strongly fluorescent diamonds. In the instances where graining is questioned in very strongly fluorescent diamonds, a UV filter is placed over the microscope well. The filter prevents the light source's UV component from exciting fluorescence in the diamond, so any noticeable haziness observed in the microscope is considered the effect of graining. Once features are located and identified at 10× magnification in the microscope, the final grade is determined using a fully corrected 10× loupe and the microscope's overhead light source: two 4-watt, 6-inch-long (15 cm) fluorescent bulbs with a color temperature of approximately 6500 K (the cover for the overhead light source also filters UV). Fluorescent lights are readily available worldwide and are a diamond industry standard. It has long been the position of the GIA Laboratory that in serving the interests of the industry we must use practical equipment that can be duplicated by the trade. For this reason, we make our final clarity grade determination using fluorescent lights.

Viewing Geometry. Both whitish graining and reflective graining are often elusive, and subtle changes in the viewing angle between the observer and the diamond can result in these features fading in and out of visibility. For initial assessments in the microscope, we have noted that different graders may reach different conclusions when near a clarity-grade boundary depending on the relationship of the stone holder and angle of the diamond to the observer (i.e., whether they place the holder on the right or left side of the microscope, as is usually determined by whether they are right- or left-handed) or when the distance from the diamond to the light source in the microscope well differs. These potential conflicts are minimized through the use of the loupe and overhead light in the final determination. The diamond is held in a stone holder or tweezers approximately 2–3 inches (5–8 cm) below the microscope's fluorescent overhead light source and from equal to the front edge of the light to 2 inches (5 cm) in front of it (figure 7). This position creates a dark field for determining the contrast between areas of graining and the rest of the diamond. In our experience, it is helpful to have a black background behind the light and the stone whenever a diamond is being examined with a loupe. This practice, which creates a consistent background and uncluttered visual field behind the diamond, is useful for evaluating graining as well.

Because the observation of whitish or reflective graining may be fleeting, the diamond must be examined through a range of motion. If the characteristic fades from view with little movement, it is not likely to affect the clarity grade. The images in figure 8 illustrate the way an internal grain line can be obscure and then appear obvious and then obscure again through a subtle range of motion. In this instance, the graining feature faded from view with very slight movement, so it did not affect the clarity grade. Also important is the angle at which the graining is seen relative to a facet. Graining observed at an extreme angle to a facet (figure 9) is less likely to impact clarity than one seen perpendicular to the facet.

Figure 7. A consistent observation methodology is critical to assess the effect of graining on clarity. The final determination is made with a loupe as the diamond is held under the microscope's overhead light source—approximately 2–3 inches (5–8 cm) below the light source and in an area between the front edge of the lamp casing to approximately 2 inches beyond that edge. A black background is placed behind the light and the stone to keep the visual field clear and create a dark field for viewing. Photo by Valerie Power.

Clarity Factors. As the student of diamond grading knows, determination of a clarity grade requires consideration of five factors: size, nature, number, relief, and location. All of these factors also enter into the process of assigning a clarity grade with respect to graining. While they are discussed separately here, they are weighed together for the final determination. As mentioned previously, for whitish and reflective graining, the critical first decision in this process is whether or not the observed graining is a clarity characteristic. Once that has been established, the same standard guidelines used for other internal features are applied to establish the clarity grade. Our experience has been, with whitish graining in particular, that the distinction between FL/IF and VVS is the most common and certainly the most important clarity determination. It is much more unusual to encounter diamonds with extensive whitish graining that would result in their being graded below VVS_2. In the following discussion, the grades indicated assume that there are no additional internal features that would affect the clarity of the diamond.

Figure 8. These three photos illustrate the way some graining fades in and out of view when the diamond is moved through a range of motion. The photo on the left shows, through the pavilion, a very subtle area of graining that, when moved slightly (center) becomes quite obvious. Yet, with little continued movement (right) it disappears. In instances such as this, the graining would not affect the clarity grade. Photomicrographs by Vincent Cracco; magnified 21×.

Size. Whitish or reflective graining is less likely to have an effect on the clarity grade if it is observed in only a small area within a single facet (figure 10), especially if it is seen only through a pavilion facet. With such limited whitish or reflective graining, a diamond may still be graded FL/IF. Conversely, when whitish or reflective graining is observed readily through the pavilion, a VVS_1 grade will result (with even lower grades issued for such graining visible through the crown or table, as discussed under "Location" below).

Figure 9. Some graining is visible only at extreme angles to the facet through which it is viewed, such as that seen on the far right in this 10+ ct pear-shaped diamond. In instances such as this where the graining is in a limited area and only observed at an extreme angle, it does not impact the clarity grade. Photomicrograph by Vincent Cracco; magnified 10×.

Nature. Whitish graining that forms in distinct cottony or sheen-like bands will affect clarity when it is readily visible with the loupe through a subtle range of motion. When whitish graining is not well defined (figure 11) and does not noticeably diminish transparency, it is still possible that the stone will receive a grade of FL/IF. With regard to reflective graining, distinct internal reflective planes will affect the clarity grade (figure 12, left). However, isolated bright lines—with no internal planes visible—will not readily affect clarity, and the diamond could receive a FL/IF grade (figure 12, right, and box A).

A noticeable overall haziness (again, see figure 6) will also impact the stone's transparency and thus its clarity grade. If such graining is visible only through the pavilion or is subtle face-up, typically a VVS grade will apply (figure 13, left). Noticeable haziness observed through the crown of the diamond will likely result in a clarity grade of VS (figure 13, center). Obvious and eye-visible haziness in grades in the SI range (figure 13, right). At the laboratory, reference diamonds exhibiting a gradation of haziness are used to help determine the boundary at which clarity is affected.

Number. As is the case with pinpoint inclusions, a diamond may have numerous whitish bands or

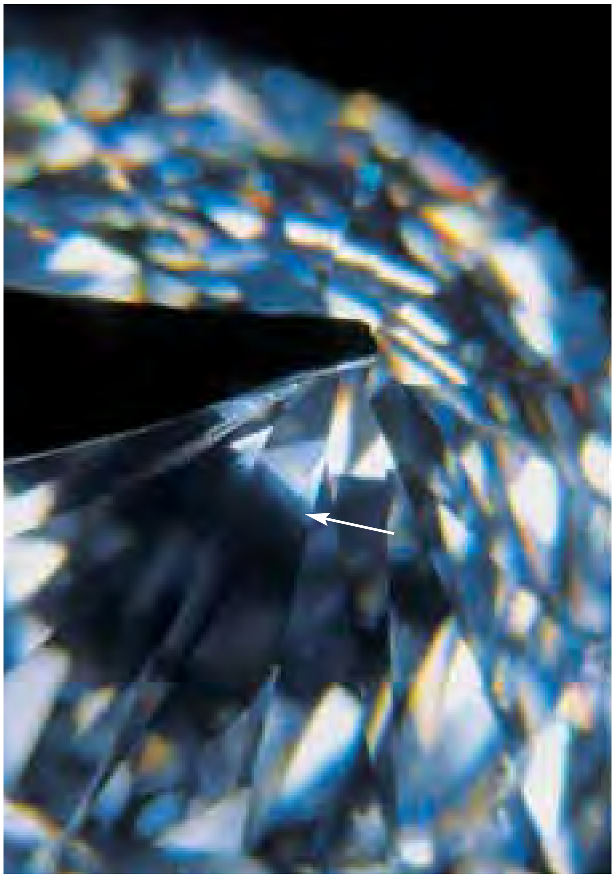


Figure 10. When graining is seen in limited areas, such as that evident near the culet in this diamond, it is not likely to affect the clarity grade. Photomicrograph by Vincent Cracco; magnified 10×.

Figure 11. One type of whitish graining that usually affects the clarity grade is banding (i.e., alternating cottony or sheen-like lines or bands with dark areas between, as in figures 1 and 2). Whitish graining that has a more amorphous appearance, as illustrated here, and does not diminish transparency when observed through a range of motion, would not affect the clarity grade. Photomicrograph by Vincent Cracco; magnified 12×.

reflective grain lines and still receive a clarity grade as high as VVS_1 if the bands or lines are only observed through the pavilion. However, the higher the quantity of grain lines observed through the crown, the more likely it is that the clarity grade will decrease accordingly. Often, the extent of the area over which bands or lines occur (i.e., "size" versus "number") is more relevant than the quantity of lines.

Relief. In the clarity grading of solid inclusions, *relief* refers to how readily a feature stands out from the surrounding diamond. For graining, relief is complex because, as mentioned above, it is not only a matter of visibility at 10× magnification, but it is also a question of the form and texture it takes. Because of this, the contrast exhibited by the graining is very important. Similar to the examples given in "Nature" above, a sheen-like area of graining that does not appear to band (figure 14, left) or affect transparency face-up may not affect the clarity grade, whereas the same characteristic seen with alternating dark bands would likely lower the grade (figure 14, right), because the contrast of grain lines with dark bands results in the greater visibility of the feature. If this feature is visible with the loupe through the pavilion only, the highest grade possible would

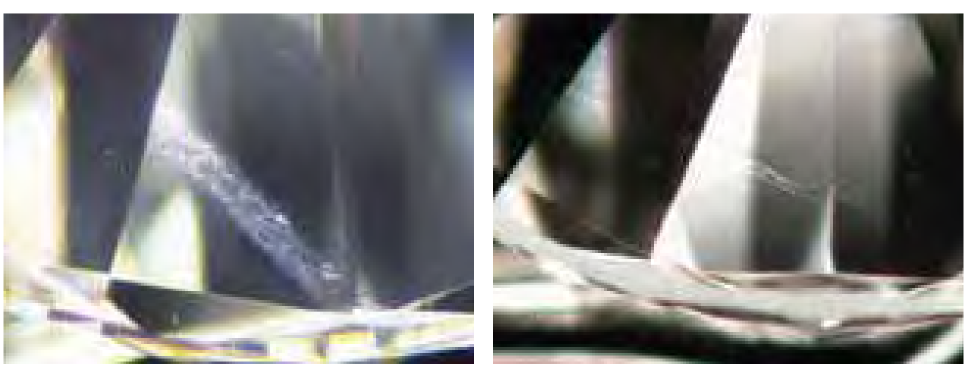


Figure 12. An obvious reflective internal plane (left) reduces the clarity grade of an otherwise clean diamond to VVS_1 if only seen through the pavilion. Bright lines with no internal planar depth (right) typically would not affect the clarity grade, as they usually fade with subtle movement. Photomicrographs by Vincent Cracco (left, 25×) and Mitchell Moore (right, 20×).

Figure 13. As overall haziness becomes more noticeable in the face-up position, the clarity grade is lowered accordingly. The 3+ ct round brilliant-cut diamond on the left has subtle haziness, which is responsible for the VVS clarity grade. More noticeable is the haziness in the 3+ ct cushion cut in the center, which resulted in a VS clarity grade. The haziness in the half-carat round brilliant on the right was so pronounced that it was graded in the SI range. Photos by Yuan Chan.

likely be VVS_1. When visible through the crown of the diamond, location and size will result in a grade of VVS_2 or lower.

As noted above and illustrated in figure 8, range of motion is important in assessing relief as well. A readily observed grain line that fades out with very subtle movement is less likely to impact clarity than one that remains visible when moved through a greater range.

With regard to relief, it is important to mention one other type of graining that is noted on laboratory reports. Transparent, colorless graining that has an overall rain-like or silvery appearance (figure 15) when the diamond is viewed face-up (without diminishing transparency or forming bands) usually does not affect clarity but, as mentioned earlier, is reported in the comments section as "Transparent internal graining is present."

Location. Location is very important in determining the impact of whitish or reflective graining on the clarity grade of the diamond. Again as noted above, when such graining is observed through the crown, it will likely have a greater impact (i.e., resulting in a lower grade) than graining observed through the pavilion only, and an even lower grade will be given if the graining is seen in the table area. Location will take precedence over size (extent) as well. For example, long lines or bands covering large areas of numerous facets will likely be graded VVS_1 if they are only visible from the pavilion. As part of "location," the angle of observation is considered as well. Consequently, a very limited area of graining observed at an extreme angle through the crown or pavilion may not impact the clarity grade (again, see figure 9).

SUMMARY

The GIA Laboratory strives to report consistently on all aspects of diamond grading. This article outlines the history and development of reporting on a feature that may significantly impact the clarity grade of some of the largest, highest-quality dia-

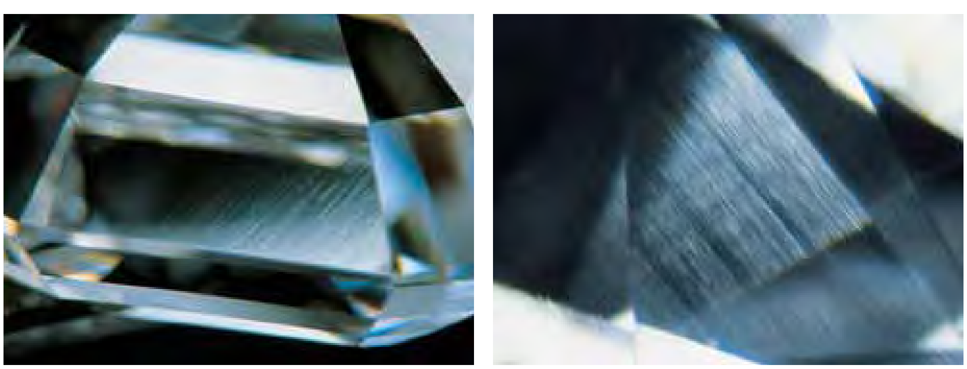


Figure 14. Overall uninterrupted sheen-like graining (left) that does not affect overall transparency when observed through a range of motion may not impact the clarity grade. The contrast seen within bands of graining (right) is more likely to affect the grade given. Photomicrographs by Vincent Cracco; magnified 15× (left) and 47× (right).

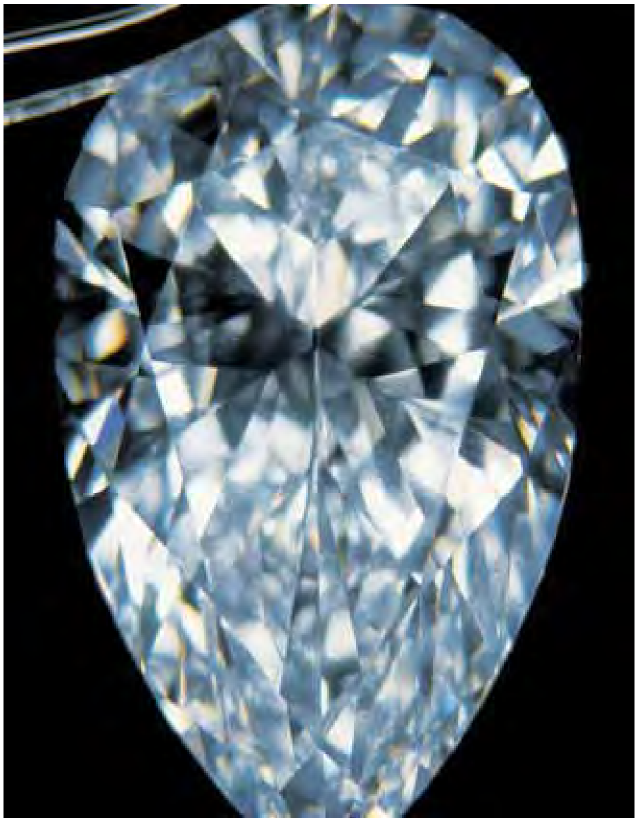


Figure 15. Occasionally graining is observed that exhibits an overall rain-like appearance and is noticeable face up through a range of motion. While such graining does not diminish transparency, as seen in this 10+ ct diamond (left), its obvious visual disruption to the appearance of the diamond (above) results in a report comment noting "Transparent internal graining is present." Photos by Vincent Cracco; photomicrograph magnified 30×.

monds encountered. The process of assessing the effect of graining on a clarity grade involves all the classic factors of size, nature, number, relief, and location. However, it also requires consideration of important additional factors, including an understanding of the elusive nature of graining, its visibility under standard grading procedures, its form and texture, and the angle at which it is observed.

In the early years of diamond grading at GIA, staff members saw relatively few diamonds with whitish graining in particular. As a result, such diamonds were categorized broadly, typically with a note describing the presence of certain appearance factors indicative of such graining. As more diamonds with graining were seen, the need grew for refined criteria. Currently, diamonds that show whitish or reflective graining as bands, lines, or planes in extended areas through a range of motion could receive a clarity grade lower than FL/IF regardless of the absence of fractures or solid inclusions. Consistent with all other aspects of assigning a clarity grade, such a characteristic visible only through the pavilion will typically result in a VVS grade. If it is visible through the crown or table, correspondingly lower grades are assigned based on greater quantity and visibility.

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