References

Editor's Note: In order to encourage free debate, we have invited a number of individuals closely involved with this subject to comment on the above article. They were provided with pre-publication copies of the article, and their comments are reproduced below. To be fair to these writers, the editor has resisted his urge to comment on their comments (and this was not easy, let me tell you). However, we are most interested in what our readers might have to say on the issue, and hope to publish readers' responses in future issues. And one more thing. We tried to get comments from all of those actively involved in issuing origin reports. Unfortunately, despite repeated attempts, we were not able to pry comments out of Charles Carmona of Guild Laboratories or Cap Beesley of American Gemological Laboratories. Readers will have to use their own minds to figure out what might mean.

Inclusions As Criteria In Gemstone Origin Reports
By
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Richard W. Hughes has asked for my comments on the question of the use of gemstone “origin reports” and in particular on his paper on that subject in this same issue. As a mineralogist-geochemist who has only seen the fringes of the field of gemology over the years, it is not appropriate for me to discuss the uses being made of “origin reports” in the gem trade. I can only say that Mr. Hughes’ paper seems to present a very coherent, well-documented and cogent review of the subject. Although I have read many scientific papers dealing with the inclu-

sions in gems and the possibility of their use in determining origin, I have never seen an actual “origin report,” and hence my only comments deal with the validity of the inclusion criteria that might be used in issuing any such report. These comments are quite apart from the difficulties mentioned by Mr. Hughes of obtaining material of verifiable origin on which to establish such criteria.

I will discuss two aspects: first, the effects of the inherent variation in the inclusion population in samples from a given locality, and second, the general similarity of the inclusion populations in samples from many different localities.

Variation of the Inclusion Parameters Within Samples From a Given Locality

Many different kinds of inclusions, both fluid and solid, can be trapped in a given mineral from a given locality. The reasons for this wide range lie in the basic nature of the origin of inclusions. *Primary* inclusions,
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Inclusions As Criteria In Gemstone Origin Reports

By Edwin Boeder
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Richard W. Hughes has asked for my comments on the question of the use of gemstone “origin reports” and in particular on his paper on that subject in this same issue. As a mineralogist-geochemist who has only seen the fringes of the field of gemology over the years, it is not appropriate for me to discuss the uses being made of “origin reports” in the gem trade. I can only say that Mr. Hughes’ paper seems to present a very coherent, well-documented and cogent review of the subject. Although I have read many scientific papers dealing with the inclusions in gems and the possibility of their use in determining origin, I have never seen an actual “origin report,” and hence my only comments deal with the validity of the inclusion criteria that might be used in issuing any such report. These comments are quite apart from the difficulties mentioned by Mr. Hughes of obtaining material of suitable origin. I will try to keep my comments within the scope of this particular criteria.

I will discuss two aspects: first, the effects of the inherent variation in the inclusion population in samples from a given locality, and second, the general similarity of the inclusion populations in samples from many different localities.

Variation of the Inclusion Parameters Within Samples From a Given Locality

Many different kinds of inclusions, both fluid and solid, can be trapped in a given mineral from a given locality. The reasons for this wide range lie in the basic nature of the origin of the inclusions. **Primary inclusions**, formed during the growth of the host crystal, can trap any solid, liquid, or vapor phases that happen to be present at the time of growth. The much more common **secondary inclusions** result from a result of fractures of the host crystal that form at some later time; this “later” time may be immediately after completion of the growth of the host crystal, or as much as billions of years later.

The latter are a much richer gem minerals, the bulk of my inclusion work has been on non-gem materials, but I am certain that the principles involved in the two groups of materials are identical; the only real difference is in the rarity of gem minerals, and in the necessarily low abundance of inclusions in high quality stones. When I study the inclusions in many samples of a given mineral from a given locality (personally collected so there is no ambiguity as to sample origin), I usually find a large range in inclusion types, habits, and compositions in the different samples. The primary solid inclusions represent the trapping of those other solid phases that just happened to be present at the time of growth and which were enclosed rather than pushed aside by the growing crystal. If different solid phases were present in different parts of the deposit, the solid inclusions that are trapped will differ similarly. Even the fluid that is trapped in primary inclusions can show gross differences in composition between the core and rim of a single host crystal, if the conditions have changed during that growth. Since some of the larger crystals in metasomatic rocks have recently been shown to have grown at rates in the range of only a meter per a million years, it would not be surprising to find that the composition of the fluids bathing the crystal had changed during its growth.

Sections of the inclusions (especially those in the majority of the inclusions making up the “feathers,” etc., in gems), represent one or more periods of fracturing and rehealing of the host crystal. It is very common to find that such fracturing has occurred at different times in the same crystal, and one and other times perhaps millions of years apart, and in the presence of very different fluids. So two different “feathers” in a single crystal may contain very different fluids.

Since such wide variations in the inclusions in different crystals or parts of a crystal from a single locality are so common, it may be difficult or even impossible to set up (on the basis of included “inclusions”) a permissive “origin report” to be written for a single sample of the host mineral from that locality. Various specific inclusion parameters seen in the single sample may match features seen in other samples from the same locality, but the wide range of possible parameter values, and the all-too-common “atypical” inclusions diminish the degree of confidence in any assignment of the sample to that locality. Without knowing about the inclusions in samples from known localities, I would find it exceedingly difficult to have to work in reverse, as the gemologist must do, and identify the locality of origin by the study of the inclusions in a given sample. Presented with a single sample from one of the many localities I have studied, I might be able to venture an “educated guess” as to the locality of origin, but the chance of being wrong, and in most cases I could say with some confidence that certain other localities were impossible, but I could not go beyond that. Perhaps in the future, when more inclusion parameters can be determined with increased precision, this basic uncertainty may be reduced. Thus, non-destructive chemical (and isotopic) analyses of the minor and trace elements in the fluids of inclusions might provide “fingerprints” that will greatly reduce the ambiguity in the assignment of origin, but will never eliminate it.

Similarity of Inclusion Populations in Samples From Different Localities

Gemstones, just as other natural crystals, have crystallized in a variety of geological environments, but even so, there is a relatively limited range for any given gem. Thus most gem quartzes have formed in only a very few limited types of environment, with a certain variety of crystallographic and morphological as a result of specific domain features. Rocks and minerals that are similar to each other but are not necessarily interrelated, such as quartz crystals, are considered to be genetically similar to each other, but are not necessarily interrelated, such as quartz crystals, are considered to be genetically similar to each other, but not related. The similarity of inclusions in samples from different localities is thus a result of the similarity of the environments in which they were formed. In other words, the inclusions are a reflection of the geological environment. This similarity of inclusions can effectively exclude specific geologic environments. Thus fine fibrous amphibole inclusions are not expected in stones from a mafic rock, or rough geology.

Similarly, liquid inclusions in most minerals nearly contain water + NaCl, as major components. The amount of the latter varies widely. For many years it was generally accepted that emeralds containing highly saline inclusions (i.e., a saturated water solution plus a daughter crystal of NaCl) came from Colombia, and these are indeed characteristic of inclusions in Colombian emeralds, but since then similar inclusions have been described in emeralds from other localities. CO2 is a major component in the fluid inclusions in most rock types that can effectively sequester NaCl and hence is not definitive of any specific locality.

If all the above caveats seem unduly pessimistic as to the significance of “origin reports,” I must note that I have discussed only one of the many parameters that may be involved in judging the origin of a stone; I am not qualified to discuss color and its distribution and possible modification, fluorescence, other chemical or microchemical indexes, etc. In closing, let me add one additional caveat. "Origin reports" must distinguish between synthetic and natural stones, as this is of far greater importance in commerce than the difference between different localities, large as these are. In the past, the inclusions in gems have provided reliable criteria for differentiating. Synthetic stones have generally been characterized by mass, size, variability of the crystals, their location in the stone, and the internal characteristics of those from nature, and also not contain those that were characteristic of the natural stones. These differences are caused by the use of entirely different growth processes and conditions, and not just those that were characteristic of the natural stones. Thus the manufacture of large
corundum crystals in various colors by flame fusion provides high quality material for pennies per carat.

But it should be noted that the huge difference in value compared with natural stones provides a great incentive to eliminate these recognizable differences in the final product. Once careful study shows the nature of the inclusions present in (and believed to be characteristic of) the natural stones, it is highly likely that attempts will be made to grow synthetic stones by processes such that the inclusions will also appear natural. Present laboratory equipment can duplicate the pressure, temperature, and chemical environment under which any gem has formed in nature. This has been done with emeralds, which have been grown synthetically with strongly saline inclusions, and I have no reason to doubt that other natural-appearing gems will be similarly produced and sold, if they have not been already.

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Dear Richard:

With regard to your article, "A Question of Origin," I agree with your basic premise that where determining country of origin in a gem is concerned, there is some truth in the saying "ignorance is bliss." The more knowledge one gains on this subject, the more complex the problem of geographical origin becomes. While an experienced, knowledgeable inclusion expert can identify country of origin for some stones, in most cases it is impossible to determine the precise country of origin. The inclusion identification work that is done by a few colleagues and myself at GIA is done as a scientific endeavor to expand our knowledge of gems—not to prepare country of origin reports.

Your statement that "the consumer could then be told honestly that these [origin reports] are intended for collectors and researchers" is in part incorrect, because most researchers have no need for origin reports of the type produced by the various geological laboratories that issue them. Most inclusion researchers study the stones themselves and draw information from the various professional geological and other earth science publications. In the 25 years that I have done research in this field, I have never found a need for an origin report.

With regard to your comments on there being more than one sapphire mining area in the state of Montana, please be assured that when Dr. Gubelin and I discuss inclusions in sapphires from Yogo Gulch in the Photocalas, we are most definitely referring to stones from that specific locality. Also, in your discussion of Kashmir sapphires you state: "Since the mine is (and has been for many years) off-limits to foreigners, the question arises as to where gemologists got the study samples." You fail to mention or reference, however, a relatively recent major article on the Kashmir deposit in which the authors obtained their information and samples first-hand at the.

mining area (D. Atkinson and R. Kothavala, "Kashmir Sapphire," Gems & Gemology, Vol. 19, No. 2, 1983, pp. 64-76). For someone interested in scientific research on Kashmir sapphires, a 1983 article would seem to be at least as valuable as one published in 1890—especially considering the technological advances that have occurred in the interim. I am sure the gemological community is also looking forward to the results of your research on the 1 kg (5000 ct) of known Kashmir sapphire rough you had the good fortune to obtain.

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Dear Richard,

Thank you for the pre-publication copy of your paper 'A Question of Origin'. Your well-documented arguments against using origin reports to support price premiums for selected colored stones, should stimulate gemologists to think this very real problem through, rather than dismissing your arguments as being commercially unrealistic, or worse still, acquiescing to the rather dubiously-based status quo.

Personally, I fully support the general thrust of your arguments, and wish to raise several additional points for consideration.

1. Researchers, species collectors and investors excepted, why do human beings purchase colored stones? Surely the major factor influencing the desirability and subsequent purchase of a colored stone must be those visual characteristics contributing to the particular gem's beauty and rarity. It is a fact that geography has little proven influence over the appearance of a colored stone.

2. Why should the presence of any visually detectable inclusion(s) in a colored stone not logically degrade, rather than sometimes upgrade, the value of the stone? Clarity should be a significant determinant of value; the country of origin of the gemstone's inclusion should not practically influence its global value.

3. If origin reports are of such significance to the value of colored stones, why are these not routinely prepared for all colored stones?

4. If the gemologist wishes, or is forced by perceived necessity, to issue an origin report for a particular colored stone, then what data does he or she have to support their assignment of origin to that colored stone? The factual answer to this question is ... precious little. Certainly, several most useful photocalas of gemstone inclusions have been published, but none of these present an exhaustive review of characteristic inclusions found in colored stones from all past or present mines. This comparative information is essential if the origin of a colored stone is to be determined with any degree of accuracy. Yes, sys-