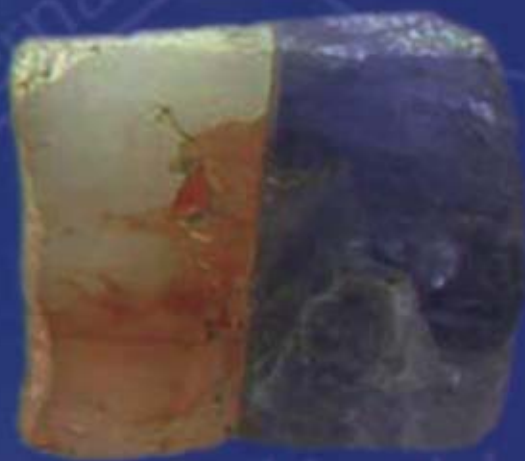


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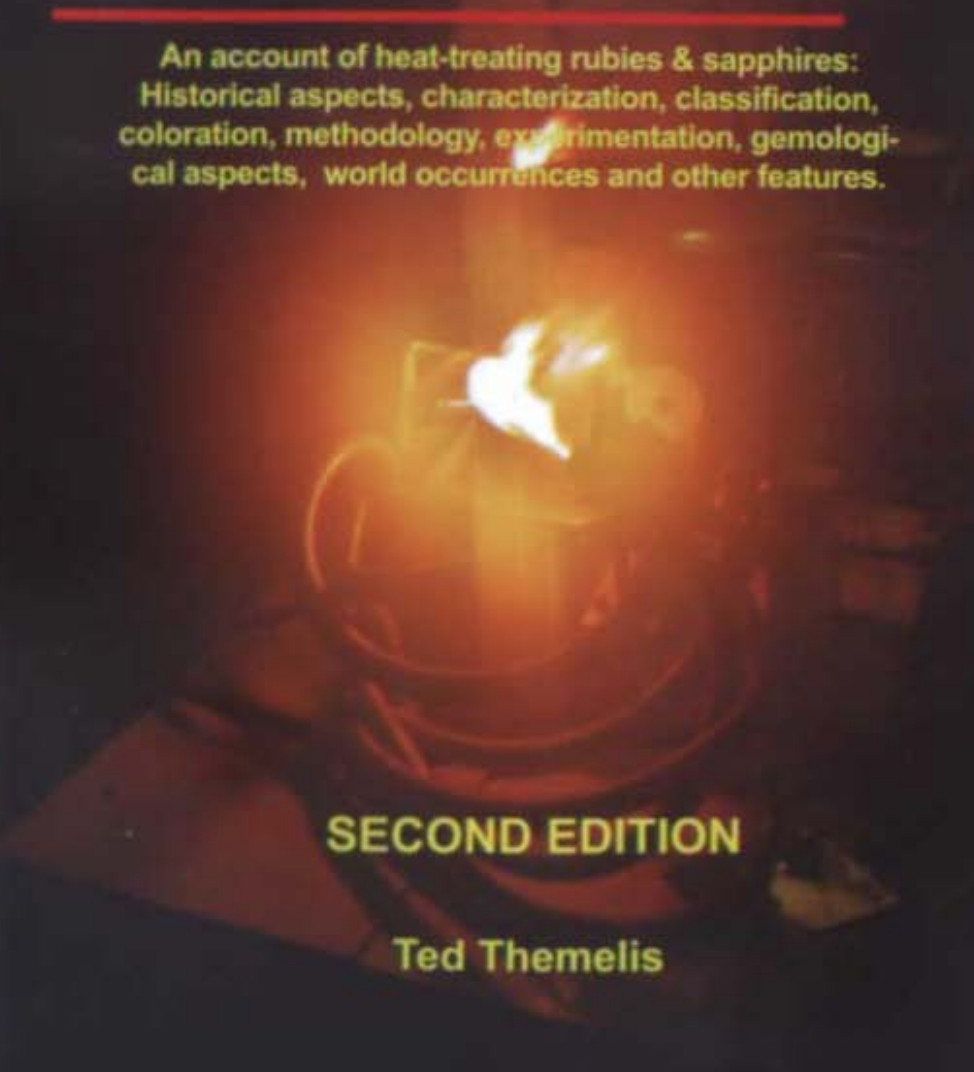


TED THEMELIS

# The Heat Treatment of Ruby & Sapphire

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An account of heat-treating rubies & sapphires:  
Historical aspects, characterization, classification,  
coloration, methodology, experimentation, gemologi-  
cal aspects, world occurrences and other features.



**SECOND EDITION**

**Ted Themelis**

...dedicated to  
my son Angelo

## The Heat Treatment of Ruby & Sapphire SECOND EDITION

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Concept, layout, design & production: Ted Themelis



Angelo Themelis heat treating geuda using the Sri Lankan Lakmini gas combustion furnace.

### Acknowledgements

I would like to thank my Thai colleagues who wish to remain anonymous who provided help, support and fruitful discussions in the last 25 years of treating gems. Dhamikka Fernando, Alan Hodgkinson, Gary Bowersox, Bruce Davidson, Dr. John Saul, Christopher Smith, Andreas Lambrakis, Dr. J. L. Emmett, Dr. F. Pezzotta and others who provided helpful comments and edited portions of this book. Many thanks to my son Angelo for his illustrations, graphics, computer skills and ideas. Also, to Saringan Teerakanont for taking many photos which appear in this book and to Pompat Teerakanont. Finally, I would like to express my appreciation and gratitude to Peter Grumitt who edit this book.

I would also like to thank those who have responded to my work with negative and even inappropriate comments. It helped me to identify the vicious nature of these multifaced individuals, who tried to bury my work on gem treatments for their own egos and benefits.

Bangkok, April 2010

Ted Themelis

Acknowledgements



### CAUTION

This book is a private publication and it is sold without warranty of any kind with respect to the use of information from this work. Nothing contained in this book shall be construed to constitute permission or act as a recommendation to practice any of the heat treatment methods described herein. The mixture of fluxes, gases and other chemical additives used in the described heating processes may be poisonous and/or highly explosive. The author discourages the use of these chemical additives, unless the treating processes follow proper procedures performed by qualified technicians under laboratory conditions.

Although every precaution has been taken in preparing this book, neither the author, nor the publisher, assumes any responsibility for errors or omissions; nor is any liability assumed for damages/claims resulting from the use of any information, apparatus, methods, procedures, or processes described in this book.



Warning Notice

## Preface

Since the publication of the first book *The Heat Treatment of Ruby & Sapphire* by Ted Themelis in 1992, there have been many updates in the gem heating technology, as well as in the furnace technology for treating rubies-sapphires. This second edition of the book provides the best information on the subject suitable for gemologists, jewelers, gem dealers, gem treaters and anyone who has keen interest in the heat treatment of ruby-sapphire.

This volume is written based on the author's individual efforts reflecting his work and experience in heat-treating rubies-sapphires since the early-1980's; hence, no reference is given to the literature (with few exceptions and where deemed necessary). Most of the rubies-sapphires used in the author's experiments discussed in this book have derived from confirmed localities and they are now part of the author's extensive collection of untreated/treated rubies-sapphires. These specimens were purchased by the author from bona fide sources, other stones were collected

*The first edition of "The Heat Treatment of Ruby and Sapphire" published in 1992.*



during his numerous and repeated visits to the gem mines around the world.

Every conceivable effort is made to use suitable specimens for the treatment experiments discussed in this book. Many of these specimens were carefully prepared and cut in two halves: one half serving as control sample; the other half treated according to predetermined parameters. This is the best way to compare the resulting features, side-by-side, before-after the heating. Nearly all experiments discussed in this book were performed at the author's gem treatment facility in Clearwater FL., Torrance CA., Houston TX. (USA) and in Bangkok (Thailand). Additional experiments were performed in various gem treatment facilities in Sri Lanka, S.Korea, India and elsewhere and reported herein.

This book focuses on the practical applications in heat-treating rubies-sapphires, avoiding lengthy and detailed scientific explanations which are often conflicting as referenced from different sources. However, the few scientific issues discussed in this book are presented in a rough, non-scientific format as external descriptions only. No attempt is made to provide a complete scientific explanation or theorize the issues. This book is not a scientific publication and it is written at the 6<sup>th</sup> to 7<sup>th</sup> grade level, suitable for almost everyone. However, it is expected that the reader should have basic knowledge of science to follow this book comfortably. Some issues and various numeric values reported in this book may not agree with published works from other authors and/or from information appearing in the Internet.

The terms and values of the expressions: oxidizing/reducing atmosphere, diffusion time, temperature, heating/cooling rates, etc. discussed in this book are given as external description only.

All photos were taken by the author for the purpose to emphasize a point or a technical detail, except where otherwise noted and proper credit is given to the source. All sketches were also prepared by the author and edited by his son Angelo. Some photos appear dull and left purposely unedited. Few photographs were taken under

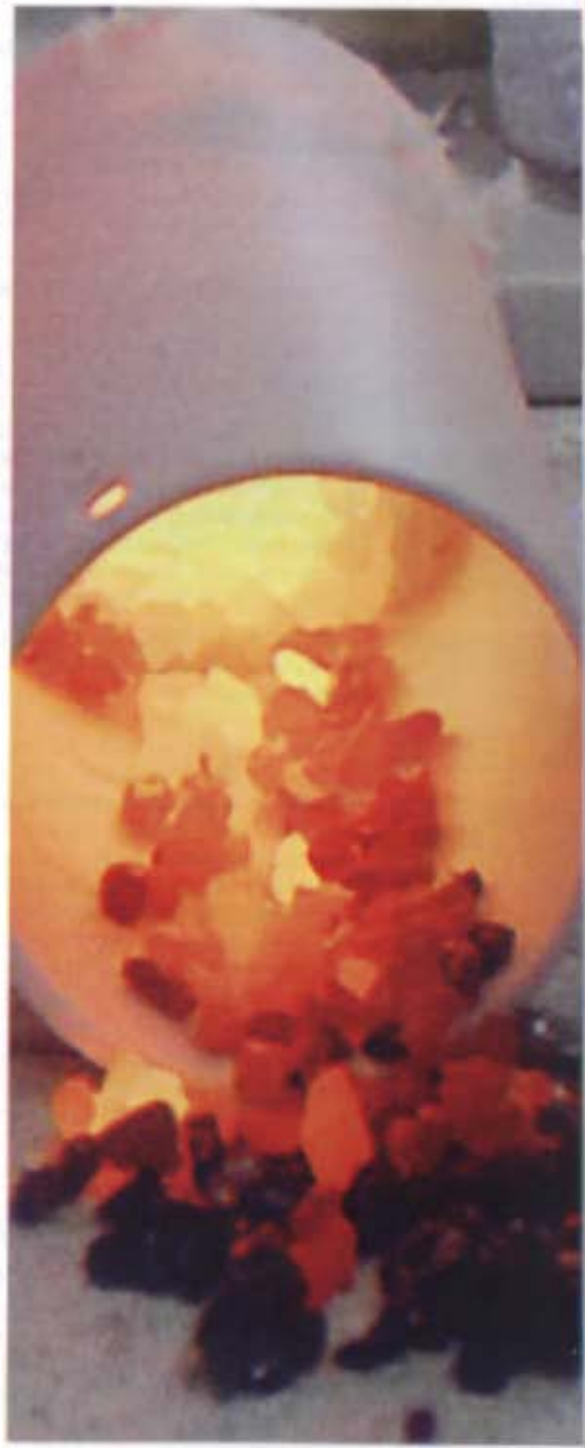
unsuitable conditions, but their importance supersedes their poor quality. Nearly all images appear for the first time in the literature.

Heat-treating ruby-sapphire, like all other gem treatments, is based on observations combined with theory, alchemy, experimentation, experience and luck. There are two schools of thought: the gem treaters (producers) and everybody else (users). The producers supply the industry with treated gems with or without limited disclosure, keeping the constantly changing treatment processes secret, while the users are constantly investigating and speculating on the nature of the treated gems, often arriving at erroneous, conflicting and confusing conclusions. Thus, some gemological knowledge taught by various institutions in reference to gem treatments is theoretical intending to shape obedient gemologists to support the establishment. Since most of the gems in the market are treated, the establishment has formulated interpretations of the product to facilitate easy sales without liability.








In the course of writing this book many references from the gemological references and elsewhere were reviewed (see extensive bibliography). It was found that these references though may be technically correct, do not communicate with the average layman reader, often leading the erroneous conclusions. However, only selected original references are cited.

Some producers, including the author, have developed independent, liberal thinking with complete ideological freedom and often provocative explanations; they may be viewed as radicals of the industry.




In this book the author offers his own explanations on the various assignments in heat-treating ruby-sapphire. It is hoped that the readers will learn not only the technical aspects in heat-treating ruby-sapphire, but more importantly to be inspired and develop their own visions and guiding ideas in their professional careers without the political influence of the gem-jewelry industry.



## TABLE OF

	<b>Chapter 1. Introduction</b> • Definitions-Clarifications • Types of Treatments of Ruby-Sapphire • From the Gems Mines to the End User • History of the Heat Treatment of Ruby-Sapphire • Market Share - Production Grades of Ruby-Sapphire • Cost Effectiveness Index • Failed Heat Treatment Facilities • Heat Treatment Facilities • Twenty-Four Questions & Answers in Heat-treating Ruby-Sapphire	<b>1-27</b>
	<b>Chapter 2. Attributes and the Effect of Heat in Ruby-Sapphire</b> • Color in Ruby-Sapphire • Color Irregularities • Clarity • Diaphaneity • Porosity • Minerals Mixed with Ruby-Sapphire • Other Features in Ruby-Sapphire	<b>28-41</b>
	<b>Chapter 3. Classification of the Heat Treatment Processes</b> • Classification of the Most Important Heat Treatment Processes of Ruby-Sapphire • Models and Description of Selected Heat Treatment Processes of Ruby-Sapphire • Most important Heat Treatment Processes of Ruby-Sapphire	<b>42-49</b>
	<b>Chapter 4. Additives in Heat-Treating Ruby-Sapphire</b> • Type of Additives • Flux • What is glass? • Description of Chemical Additives	<b>50-57</b>
	<b>Chapter 5. Methodology in Heat-Treating Ruby-Sapphire</b> • Heat-Treating Technology • Furnace Technology • Methods and Procedures (Step-1. Gem Identification, Step-2. Chemical Cleaning, Step-3. Shaping, Step-4. Pre-burning, Step-5. Assessment, Visual Observations, Step-6. Application of Chemical Additives, Crucibles, Sealing the Crucible, Step-7. Select Atmospheric Conditions, Step-8. Heat Treatment Profile, Step-9. Retrieving the Stones, Cooling-down) • Flowchart of the Heat Treatment Process	<b>58-79</b>
	<b>Chapter 6. Coloration and Heat Treatment Processes</b> • Heat-Treating Ruby-Pink Sapphire • Heat-Treating Orange, Orange-Brown Sapphire • Heat-Treating Yellow Sapphire • Heat-Treating Blue Sapphire • Heat-Treating Geuda • Heat-Treating Green, Blue/Green, Green-Yellow Sapphire • Heat-Treating Violet, Purple, Color-Change Sapphire • Heat-Treating Silky and Asteriated Ruby-Sapphire • Other Heat Treatment Processes	<b>80-113</b>
	<b>Chapter 7. Surface &amp; Subsurface Diffusion Processes of Ruby-Sapphire</b> • Background • Color Diffusion • Classification • Color Diffusion Mechanism • Surface Color Diffusion Processes • Surface Star Diffusion Processes • Detection and Identification • Stability • Comments	<b>114-127</b>

## CONTENTS

<b>Chapter 8. Fracture Filling Processes of Ruby-Sapphire</b> • Introduction • Classification • Chemical Additives • Types of Fracture-Filling Processes • Borax-based Filling Processes • Desolvation Process • Lead-based Filling Processes • Lead-Filled Blue Sapphire Process • Lead-filled Star Ruby Process • Detection and Identification • Lead Filler Removal • Stability • Comparison • Comments	<b>128-145</b>	
<b>Chapter 9. Beryllium Process of Ruby-Sapphire</b> • Background • About beryllium • Purpose of the Beryllium Treatment • Heating Parameters • The Beryllium Process • Practical Applications • Detection of Beryllium • LIBS Method	<b>146-179</b>	
<b>Chapter 10. Heat Treating Furnaces &amp; Apparatuses</b> • Furnace Apparatuses (Type of Heating Methods, Comparison Features, Furnace Modules) • Combustion Methods and Equipment (Power Control Module, Heating Chamber Module) • Blow-pipe Method • Bellows-pulling Method • Charcoal Kiln • Thai Diesel Furnace • Gas Combustion Furnaces (Air/Gas Furnaces, Oxygen/LPG Furnaces, Oxygen/Gas/Air Furnaces, Oxygen/Acetylene Furnace) • Electric Resistance Furnaces • Graphite Furnace • Specialty Furnaces	<b>180-211</b>	
<b>Chapter 11. World occurrences, Description and Heat Treatment of Ruby-Sapphire</b> • Preamble • Afghanistan • Australia • Bolivia • Botswana • Brazil • Burma (Myanmar) • Cambodia • Cameroon • Canada • Chile • China • Colombia • Congo Democratic Rep. • Cote d' Ivoire • Czech Rep. • Ethiopia • Finland • France • Germany • Greece • Greenland • Guinea • India • Indonesia • Italy • Japan • Kenya • Laos • Macedonia • Madagascar • Malawi • Malaysia • Mexico • Mongolia • Mozambique • Namibia • Nepal • New Zealand • Nigeria • Norway • Pakistan • Poland • Russia • Rwanda & Burundi • Sierra Leone • Somalia • South Africa • Sri Lanka • Swaziland • Sweden • Switzerland • Tajikistan • Tanzania • Thailand • United Kingdom • USA • Vietnam • Zimbabwe	<b>212-351</b>	
<b>Chapter 12. The Heat Treatment of Synthetic Ruby-Sapphire</b> • Heat-Treating Flux-Grown Ruby-Sapphire • Heat Treating Flame-fusion Ruby-Sapphire • Quench-Cracked Process • Combination Processes	<b>352-360</b>	
<b>Chapter 13. Problems in Heat-Treating Ruby-Sapphire</b> • Mechanical Failure • Atmosphere Conditions • Over-temperature • Chemical Contamination	<b>361-367</b>	
Author's biography, Other books by T.Themelis .....	<b>368</b>	
Further Reading .....	<b>369-380</b>	
Index .....	<b>381-384</b>	

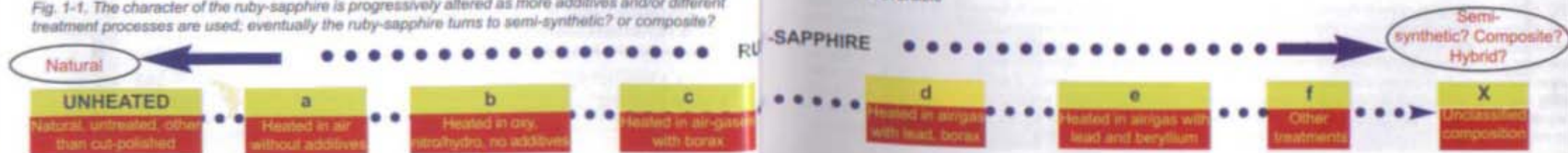
During the past several decades, a heat-treated ruby-sapphire was the exception rather than the rule. Nowadays it is the opposite, where the gem-jewelry industry as well the consumer market has embraced the heat-treated rubies-sapphires as viable products to satisfy increased demand. At the same time, old concepts on gems were slowly revised, new definitions were introduced altering the true character of the gems and affected everyone involved, from the gem dealers to jewelers, before reaching the ultimate consumer. This created misunderstanding and confusion leading to mistrust of the product and for valuable gems, trustworthy gemological laboratory reports were demanded before concluding a gemstone sale.

It is of paramount importance to understand the various types of heating process of ruby-sapphire that seriously alter the value and the character of the stone. Fig. 1-1 demonstrates the effect of the various heating process in ruby-sapphire. Starting from the simplest process (a), the value and the character of the stone is progressively reduced according to the type of heating processes (b to f), before they turn "semi-synthetic", "composite", or hybrid?".

### Definitions & Clarifications

• **What is a gem?** Webster's *Unabridged Dictionary* defines "gem" as "a certain mineral or rock or organic substance cut and polished used for ornament." The ornament is thought to be beautiful, rare, portable and valuable, but all these attributes are highly subjective. In the market, treated cut and polished minerals or rocks or organic substances are also considered as "gems," including rubies-sapphires, all implying "gem-quality" status. At the author's opinion, an inorganic or organic gem material should not be treated in any way, other than cutting, polishing and cleaning to be called a "gem".

Fig. 1-1. The character of the ruby-sapphire is progressively altered as more additives and/or different treatment processes are used; eventually the ruby-sapphire turns to semi-synthetic? or composite?



• **Definition of Corundum.** In this book the term corundum refers to all types of ruby-sapphire. Red corundum is referred to as ruby. [Note: In the olden days, pink sapphire was referred to as "pink ruby."] All other corundum is referred to as sapphire with the appropriate color prefix, i.e. pink sapphire, orange sapphire, blue sapphire, yellow sapphire, purple sapphire, etc. Truly colorless corundum (leucosapphire) exists in nature, but is extremely rare. There is no international agreement on the terms, definitions, attributes, and practices applied to gems.

• **Definition of a treated gemstone.** A treated gemstone is an inorganic or organic gem material that has been subjected to one or more treating processes (heating, bleaching, coating, etc.) aiming to alter its appearance, physical and/or chemical properties.

• **Treatment vs. Enhancement.** The word "enhanced" means "to make greater, better." The word "treat" means "to subject to some process (thermal, chemical, etc.) or combination of processes". Generally, the word "treatment" has a negative connotation, so the word "enhanced" is adopted by the industry to facilitate easier sales. When treating ruby-sapphire, color/clarity may be a) enhanced (improvement), b) remain the same (no improvement) or c) become worse. Thus, heated ruby-sapphire should not be assumed to be "enhanced", unless the enhancement is proven by comparing the stone before and after the treatment. In many cases only the treader knows if the gem was in fact "enhanced".

• **Classification of gemstones.** Generally, the author classifies the gemstones as follows:  
 Type-I: Untreated  
 Type-II: Treated  
 Type-III: Untreated or treated synthetic gems, doublet gems, composite gems, etc.

• **Naming heat-treated gemstones.** Often, dealers call the treated stones "natural", referring the fact that the substance is natural. But when the stone is heated at high temperature, the nature of the substance changes (altered cracks, melting guest crystals, exploding liquid inclusions, etc.), while the color is also altered one way or another. In the author's opinion, a heat-treated stone is a treated stone.

• **Qualifications.** To maintain the "corundum" status the treated rubies-sapphires (Type II) must meet the following criteria:

- Maintain nearly the same physical and chemical properties
  - Maintain same or improved stability-durability
  - Clarity alteration is according to common treatment practices and is highly subjective
- If above conditions are not met, the corundum may be re-classified. Example: Ruby heat-treated with significant amounts of lead may be considered "glass-ruby composite" (Type III).

• **Quality.** The quality of the treated gemstones is proportional to their quality prior to treatment. Low-quality rough stones will produce low-quality heat-treated stones. Low-quality rubies-sapphires cannot turn to high quality after the treatment.

• **Stability-durability scale.** This refers to the degree of stability and durability of the treated stones under normal wear, lighting and other considerations. Suggested scale:

- Stable
- Conditionally stable
- Unstable

• **Special care.** Depending the type of treatment, treated rubies-sapphires may require special care. Example: Lead-treated rubies and surface color-diffusion-treated sapphires (few rubies) require special precautions to preserve their stability and durability.

• **Reversibility of treatment.** The type of treatment process may be classified as follows:

- Reversible
- Conditionally reversible
- Irreversible

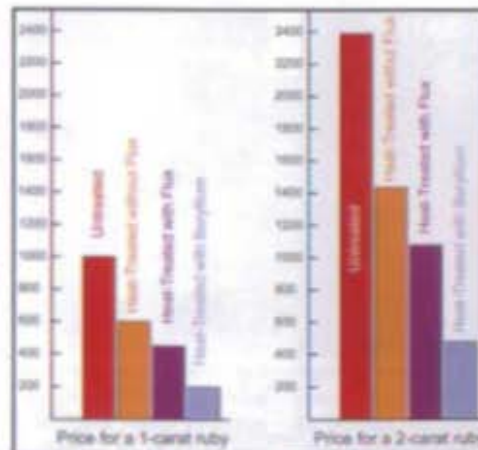


Fig. 1-2. Market value of 1 and 3 ct ruby heat-treated under different methods.

• **Frequency scale.** Designates the frequency of the treated stones encountered in the open market. Suggested scale:

- Always (heat-treated)
- Usually (heat-treated)
- Occasionally (heat-treated)
- Rarely (heat-treated)

• **Repeatability of treatment.** The same type or different type of treatment process(es) or methodology may be applied to suitable rubies-sapphires.

• **Acceptability in the market.** Treated rubies-sapphires are generally accepted in the market provided that the treatment is properly disclosed.

• **Detection of treatment.** Detection of treatments is almost always possible by a qualified gemological laboratory.

• **Disclosure of gem treatments.** Ethical trading of the treated gems demands full disclosure of the treatment(s) at all levels of gem merchandising, though not always possible or internationally agreed.

## Chapter 6.

# Coloration and Heat Treatment Processes

Fig. 6-1. Heat-treated rubies-pink sapphires of different qualities and mode of occurrences.



Mogok 3.07 ct



Thai 6.01 ct



Madagascar 2.43 ct



Tanzania 2.11 ct

### HEAT-TREATING RUBY-PINK SAPPHIRE

#### Color description

For centuries people described the color of the ruby-pink sapphires in various ways, sometimes quite dramatically.

- In Burma (Myanmar) the red color of the preferred ruby is called *pigeon blood red* (*koth-way*, in Burmese) and it is described as resembling the color of the first few droplets of a freshly killed pigeon. Similar descriptions such as *rabbit-blood red* (*yeong-twe*), *chicken-blood red*, etc., are of lower preference.
- Thais describe rubies having red hue with slight purplish or brownish tinge as *red stone* (*ploy-daeng*, in Thai); slightly yellowish red coloration characterized by numerous fingerprint liquid inclusions is referred to as *design* (*lai-thai*, in Thai).

The color of the ruby may be described on the basis of its overall appearance when observed in the face-up position. Ruby is never pure red in color. In layman's terms, ruby ranges in hue from crimson red, reddish/orange red to red/violet; the saturation ranges from dull to vivid; the tone, a critical attribute, varies from very light to very dark. A bright, red color in ruby indicates a negligible amount of iron. This phenomenon causes some rubies, noted from Mogok to show intense fluorescence in the visible light, thus intensifying their already vibrant red coloration.

#### Causes of color

The coloration of the ruby is due to chromium ( $\text{Cr}^{3+}$ ) present in corundum as  $\text{Cr}_2\text{O}_3$  impurities replacing some  $\text{Al}^{3+}$  atoms. About 0.1 wt.% of  $\text{Cr}^{3+}$  in corundum can produce red color. As the concentration of the  $\text{Cr}^{3+}$  is reduced, the red hue is proportionally reduced; thus, about 0.04% of  $\text{Cr}^{3+}$  will produce intense pink, whereas about 0.03% of  $\text{Cr}^{3+}$  will produce light pink.

Various impurities in a ruby-pink sapphire in solution may alter its overall appearance. When titanium and iron are present in ruby under certain conditions, violet/blue, or purplish/blue tinge is produced. Iron as an impurity in solution in corundum produces little or no color unless the concentration is well above 0.1 wt.% Fe. As the concentrations of these color-bearing impurities in ruby-pink sapphire increases, the tinged coloration is proportionally intensified.

#### Localities

Ruby-pink sapphire is mined in Burma (Mogok and Mong-Hsu), Sri Lanka (mostly pink sapphires), Thailand, Tanzania, Kenya, Madag-

agascar, Mozambique, etc.; inconsistent ruby-pink sapphire mining is taking place in Vietnam, Cambodia, India, Afghanistan, Pakistan, Malawi, Colombia, Tajikistan, and elsewhere.

#### Heat-Treatment

Most of the rubies-pink sapphires in the market are heat-treated for the following reasons:

- Reduce bluish/purplish tinge
- Reduce blue/purple patches, streaks
- Reduce/remove rutile silk

Pink sapphires may turn orange or pad-like

sapphires by creating trapped hole color centers if heat-treated in an oxidizing atmosphere.

Lightening the dark red color in ruby by reducing its chromium concentration, when heating in air without the use of chemical additives is very difficult, due to the following reasons:

- The  $\text{Cr}_2\text{O}_3$  is always in solution.
- The melting point of  $\text{Cr}_2\text{O}_3$  is  $\sim 2330^\circ\text{C}$  which exceeds the melting point of  $\text{Al}_2\text{O}_3$  ( $\sim 2025^\circ\text{C}$ ).
- Very low value of the diffusion coefficient

### Distinction between Red Corundum (Ruby) and Pink Sapphire



Fig. 6-2. An untreated Burmese ruby of 0.47 ct (left) and an untreated 1.42 ct Tanzanian pink sapphire (right), both with silk distracting their aesthetic appearance.

In the early days of gemology, some traders described the color of rubies according to their "strength." In 1909, Julius Wodiska described ruby in his book *Precious Stones*:

*"The colour-tone of the ruby varies greatly and the presence of deep, intense tones of red causes the term 'masculine' to be applied to a gem while the paler tints suggest the term 'feminine.' Rubies range from a delicate pink tint through pale rose to reddish white, pure red, carmine red, or blood red. A tinge of blue or violet is frequently discernable in these shades."*

Although the term "pink sapphire" is not mentioned in Wodiska's book there is an indirect attempt to separate the masculine red corundum from the feminine lighter red corundum. Some speculation implies that masculine ruby represents Burmese or Thai material, while the term feminine ruby represents Sri Lankan raspberry "light-colored red" rubies with high luster. Reference to pink sapphire in the gemological literature is given by G.F. Herbert in the sixth edition of his book *Gemstones* (1930):

*"The tint of the red stones varies considerably in depth; jewelers term them, when pale, pink sapphires, but of course, no sharp distinction can be drawn between them and rubies."*

Nowadays, the appropriate color designation of pink sapphire and ruby is still debated in the gemological community and in the gem trading centers. Some gemologists and gem traders call ruby any corundum having at least 50% overall red coloration; if the red color is less than 50%, they call it pink sapphire. Tone is very critical; thus, corundum with red hue, vivid saturation and light tone could be called pink sapphire. Corundum with red hue, vivid saturation, and medium tone, would be called rubies. Others simply call ruby any corundum with red/pink hue, disregarding all other color attributes. Determination of ruby should not be based only on the apparent color, but also in the chemistry where  $\text{Cr}_2\text{O}_3$  must be greater than  $\text{Fe}_2\text{O}_3$ , as well as in the absorption spectra signatures.



Fig. 10-60. Bottom-loaded electric resistance 1700°C box furnace by Linberg Co. Houston, TX., 1996.

Life expectancy of the  $\text{MoSi}_2$  heating elements in a continuously operated furnace (which is the most advantageous operating condition) may be up to 3000 hours; this depends mainly on the maximum operating temperature and atmospheric conditions. For example, Kanthal-Super 1900- grade elements may last up to ~2,800 to 3,000 hours when operated at 1800°C in air. If the operating temperature is increased to 1825°C, the life expectancy drops dramatically to 300-400 hours or less and only few hours (if any) when heated at 1850°C. Most treaters in Chanthaburi use low-cost Chinese-made heating elements that last ~40-50 hours, sufficient for a couple of heating processes.

Fig. 10-61. Gemlab model 181-3A vertical muffle top loaded 1800°C furnace equipped with atmosphere control for  $\text{CO}/\text{CO}_2$ ,  $\text{H}_2/\text{N}_2$  and special apparatus for producing  $\text{H}_2\text{H}_2\text{O}/\text{N}_2$ . Clearwater, FL. 1993

Fig. 10-62. Angelo, author's son, assembling a Gemlab furnace. Houston, TX., 1996



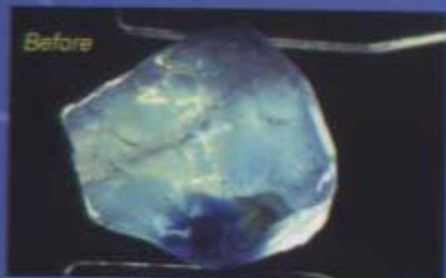
Fig. 10-63. Gemlab model 181 1800°C vertical muffle, bottom loading electric resistance furnace fabricated by the author and available commercially. The furnace system consists of a) the furnace module, b) power module, and c) atmosphere control module. The furnace operates from any 208/240 Vac @ 50 Hz, 15 Amp single-phase electric outlet Capacity 3000 ct of ruby-sapphire per load. Los Angeles, CA. 2003.



Fig. 10-64. Bottom-loaded electric resistance 1750°C furnace. Bangkok, 2003.

Fig. 10-65. A high temperature special box furnace Model HT 1800-Plus, made by Linn Company (Germany). The furnace is equipped with gas and/or vacuum tight chamber using Kanthal-Super 1900 heating elements. (Courtesy Linn GmbH)





Sapphire before (top) and after (bottom) heated at 1650°C in air without chemical additives.

**Text & photographs:** Ted Themelis  
**Graphics:** Angelo Themelis  
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 Over 1100 color photos, diagrams  
**Design & production:** Ted Themelis

Other books by the same author:

- Beryllium-Treated Rubies & Sapphires* (2003)
- Flux-Enhanced Rubies & Sapphires* (2004)
- Mogok-Valley of Rubies & Sapphires* (2000)
- Gems & Mines of Mogok* (2001)
- The Heat Treatment of Ruby & Sapphire* (1992)



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MADE IN THAILAND

**ABOVE:**  
 Ruby traders,  
 Sri Lanka, 1980s

**FRONT COVER:**  
 A Sri Lankan peach  
 sapphire before (left  
 part) and after  
 heating (right part)

## The Heat Treatment of Ruby & Sapphire

SECOND EDITION  
 by TED THEMELIS

An account of heat-treating rubies & sapphires: Historical aspects, characterization, classification, coloration, methodology, heat-treatment experimentation, gemological aspects, world occurrences and other features.



The last decade has shown a rapid increase in our knowledge of the gem treatment techniques and applications. Whatever happened in the last few years due the discovery of the beryllium process, it didn't happen in the last thirty years since the discovery of the geuda treatment process. This work is based on the first edition of the highly acclaimed book of Ted Themelis' *The Heat Treatment of Ruby & Sapphire* published in 1992. This new edition is fully illustrated and updated providing the newest information on the heat treatment of ruby-sapphire.

Nearly all heat treatment experiments described in this book were performed at the author's gem treatment laboratory in Bangkok (Thailand). Other experiments were performed by various gem treaters from around the world, carefully recorded and presented herein for the layman.

This book is a private, non-scientific publication providing the gemologist, jeweler, and gem connoisseur, student of gemology and gem enthusiast the latest and most authoritative information in the subject available anywhere at any cost.

<http://www.themelis.com>