CHAPTER ONE
INTRODUCTION

1.1 The Problem

Opal pricing, as currently performed, is a complicated procedure. Opals are a heterogenous commodity and, because no two are alike, judgements have to be made about the value of each gem individually. Valuers make these judgements on the basis of numerous characteristics inherent in most of the stones to some degree. However no one can say just how much value is contributed by any particular characteristic. All experts who have contributed to this research emphasize that they have gained their ability to price opals through many years of experience with the gem.

Problems occur when aggregating the values of inherent characteristics in a commodity to determine the value of that commodity, because of the varying proportions of those characteristics. This problem is compounded by two facts. One, the number of characteristics, some quantitative and others qualitative, contributing to the aggregate value may be too numerous to handle ordinarily when constructing an index of value. Two, the values of the inherent characteristics are seldom revealed directly, instead, only the aggregate value of the commodity is given. It is difficult to use the aggregate values for comparisons between similar commodities or for predicting the value of a similar commodity containing a different combination of known characteristics. Comparisons of this type are usually done over time, but may be done, at a single point in time, in cases where the aggregate values vary from item to item. The latter situation, where aggregate values may vary from item to item at a single point of time, occurs when information about the commodity is limited. If detailed information was available on all the characteristics present in a commodity, and on the relative weights of each of these characteristics, then it would be possible to derive the aggregate value. However, a small change in the weight of one of these characteristics would imply a new aggregate value. The problems of deriving a price index are compounded when there are qualitative characteristics which cannot be directly valued.

1.2 The Technique

This is a study of hedonic pricing applied to opals. The hedonic pricing technique uses the multiple regression approach to isolate the set of statistically significant characteristics from the large number of characteristics inherent in a commodity. The estimated coefficients or weights of these significant characteristics can then be used to predict or construct a consistent index of value. The method, which has been used extensively in the analysis of housing and automobile prices, has the facility of incorporating qualitative characteristics as discrete variables in the multiple regression analysis.

The hedonic technique has not previously been applied to gemstones. Opals, however, are ideally suited to study by this methodology. Precious opal is regarded as precious only in so far as it contains some proportion of specified characteristics. Each of numerous characteristics may contribute to an opal's value, and additionally, each opal will contain different proportions of these characteristics. The hedonic method can be used to construct price indexes based upon these inherent characteristics.

1.3 Importance of the Problem

Australia mines about ninety-five per cent of the world's production of opal. (The other five per cent comes from mines in Mexico, the United States, Honduras, Hungary, Ecuador and Brazil [van Brugge, 1980].) Although there is currently no commercial use for this stone, the five to ten per cent of opal which is brilliantly coloured is coveted by collectors and jewelers worldwide for its aesthetic value. Total national exports of all products in the 1983-84 year were valued at over 24 billion dollars (Australian Bureau of Statistics, 1983-84a). One tenth of one per cent of those exports, nearly 25 million dollars (24,968,000), were opals (Australian Bureau of Statistics 1983-84b). These statistics do not include gems bought in Australia by overseas visitors.

Despite the dominance of Australia in the world opal market, one of the two commonly accepted nomenclatures used to appraise opals was not created in this country.[1] The two nomenclatures (Appendix A), one the International Precious Opal Nomenclature (IPON) and the other by the Australian Gem Industry Association (AGIA), contain fourteen characteristics to be considered when evaluating an opal. Each of these fourteen characteristics is then further divided into subcategories. The complexity of the nomenclature using these categories and subcategories is undeniable. Opal evaluation presently requires a great deal of specialized knowledge (information) and years of experience. The specialized nature of the information required and the lack of an adequate information flow may have been one contributing factor to the present situation in which some facets of the market are concentrated in the hands of a few individuals.

A single consistent nomenclature with estimated relative weights for each characteristic, made widely available, would improve the information flow between people interested in opals. This would be of benefit to all those involved in the industry because of the improved market efficiency which would follow that change. Because people purchasing opals would then hae greater faith in their purchase price, an increase in the demand for the gem could be expected. As Australia is the world's greatest producer of precious opal, this result could only be beneficial to the nation's economy.

The objectives of this study are:

1) to identify which of the different characteristics which are given in the IPON and AGIA nomenclatures are important,
2) to estimate the implicit contribution of each significant characteristic to the value of an opal by developing a model from which aggregate prices of individual stones can be predicted, and
3) to test the consistency of opal valuations, as currently performed, by groups of opal wholesalers, opal retailers and non-experts.

1.4 Design of the Study

The objectives of this study require a body of data on prices and characteristics of opals as well as a method for testing experts' and non-experts' abilities to evaluate the gem. The data required to fulfill objectives one and two was obtained by creating a combined certificate of appraisal. This certificate was developed utilizing characteristics from both the IPON and the AGIA nomenclatures. A specimen copy of this combined certificate is shown in Appendix B. Each combined certificate assesses the qualities of characteristics and proportions of a different stone. The wholesale value of each gem so assessed is given

[1] The International Precious Opal Nomenclature was developed in Stockholm, Sweden, in 1980, by a committee presided over by Henno J. Narris.

on the certificate as of the end of February 1985. The accuracy of the data is limited by the fact that each stone has been assessed by only one merchant. However, the sample of combined certificates of appraisal were completed separately by ten different merchants. Data for the third aim of the study was collected by asking eight merchants, some of whom also filled out combined certificates of appraisal, to estimate the value of a "master-set" of twelve opals.[2] These same twelve opals were then taken to non-experts to be ranked by preference and value.

Hedonic regressions were run using the data from the combined certificates of appraisal. These regressions isolated the significant characteristics from among the numerous inherent traits used in appraising opals. These significant characteristics were then built into a pricing model which was tested on a small sample of stones. The data from experts and non-experts was tested for internal structure and for any correlations between the two groups. Tests were also preformed to measure the correlation between non-experts' preference rankings and their value orderings.

1.5 Outline of Chapters

The second chapter is a summary of conditions in the opal market today. The chapter includes a review of literature relevant to the market for opals and the pricing of precious stones. The third chapter is a review of analytical techniques and the literature relevant to the econometric method being used. The fourth chapter outlines the survey design explaining the data collection process and the limitations of the data set. The fifth chapter reports on the results of estimated regressions. The sixth and final chapter gives a summary of the research and reports on the implications of the study.

[2] These stones (photographs in Appendix C) were provided for this purpose by Tom van Brugge of Opalsearch Pty.Ltd and Gregory Sherman of Sherman Opals. Six of these stones were included in the larger sample of gems appraised using the combined certificate of appraisal.

CHAPTER TWO
THE OPAL MARKET

2.1 Introduction

Preliminary investigations into the opal market were undertaken, by the author,in the latter half of 1984. The chapter which follows is based largely upon that earlier work. Apart from a review of available literature on opals, the previous study included interviews with a number of people from every stage in the market. Unless otherwise indicated, the statistics contained in this chapter come from that (unpublished) study.

2.2 Review of Literature

A review of available literature on the opal market revealed that very little work has been done on this industry. Watkins (1984) studied the economic prospects of opal mining in the Lightning Ridge area. Other works on opals which are available are primarily geological texts describing the geomorphology of opals. Those less technical are, generally, gem hunters guides to mining for fun and profit. A few articles have appeared in financial journals, notably *Rydge's* and the *Australian Stock Exchange Journal.*[1] Two people have become associated, in the minds of opal merchants, with research and writing on opals. These are Barrie O'Leary, author of *A Field Guide to Australian Opals* (1977), and Archie Kalokerinos, *Australian Precious Opal* (1971) and *In Search of Opal* (1967). Although these books are predominantly guides to mining opal, they do present information useful to an understanding of the economics of the opal market. Some people involved in the production and distribution of opals are also trying to increase public awareness of the gem. Tom van Brugge of van Brugge Holdings Pty.Ltd. (owners of the mining company Opalsearch Pty.Ltd. and the retail outlet, in Sydney, called Opal Spectrum Pty.Ltd.) has published several articles on opals. Two other merchants, Peter Sherman of Sherman Opals and Dag Johnson of Opex Opal Inc. lecture on opals whenever the opportunity presents itself.

The state government departments of mining and energy in Queensland, New South Wales and South Australia all undertake some research in the area in an attempt to assess the value of opal production in their respective states. The quality of the state records has improved over the last decade but is still incomplete. The poor quality and inconsistencies in state records are, largely, a result of the conditions of mining and the temperament of the miners from whom this data must be gathered. These individuals are highly independent, generally asocial men working alone or, at times, in pairs. The work environment is hot, dry and largely undesirable. Few people stay on the fields long and those who do are unlikely to report their total production figures to any "meddling" officials. (Miners tend toward reclusive behavior and traditionally oppose authority.) The published statistics are created from a composite of data, that is, that gathered directly at the mines, that derived by formulas based on figures from buyers on the fields and extrapolation from official guesstimates based on equipment in use or other visible factors (see, for example,

[1] The articles in *Rydge's*, May 1979, Jan. 1981 (O'Leary), and June 1981, as well as the *Australian Stock Exchange Journal* article by van Brugge, January 1980, all dealt with the concept of investing in gemstones. The *Rydge's* article of September 1969 described the flotation of Opalton Pty.Ltd., an opal mining company in Queensland.

the *South Australian Department of Mines and Energy report BK.NO.79/111*,[Crettenden 1980,27]). The opal industry, as stated earlier, has seldom been researched. Very little information about it is publicly available.

2.3 The Market

The lack of real information about the opal market contributes to its inefficiency and fragmentation. Price inefficiencies are highlighted by the fact that high quality opals may be sold for two to three times their Australian value when an international boundary is crossed. This indicates a poor flow of information about the gem. Such price differentials, in the perfect market situation, should lead to stones being exported in bulk, creating domestic scarcity and thus bidding up domestic prices. Eventually there would tend to be an equalization of domestic and foreign prices.

The marketing of opals can be observed in three, possibly four, stages; that is, from the miner to the wholesaler, from the wholesaler to the retailer, and from the retailer to the end buyer (consumer). The fourth stage is that occupied by the opal cutter who enters either late in the mining stage or early in the wholesaling one. Each of the three major stages or submarkets are briefly described below.

2.3.1 Submarket 1: Miners

Opal is extracted from the ground, most often by hand pick although some miners with claims where the opal is in shallow beds will rent a bulldozer to tear the opal from the ground. Once extracted, the opal is lifted to the surface using a variety of methods which range from the simple, hand operated winch to blowers (which operate like vacuum cleaners). The average capital investment per mine has been calculated by P.P. Crettenden *et al.* (1980,27) at between twenty-three and twenty-four thousand dollars. Mining operations are limited in size due to the irregularity of fine quality opal deposits and to government regulations which restrict operations to fifty square metres per active miner with, at maximum, four miners amalgamated.[2] These size limitations prevent miners from making use of the economies generally associated with a larger scale of operations. It also limits the size of research and development in the opal industry by confining operations to small scale entrepreneurs who do not have the finances for relevant improvements. The government restrictions on mining maintain the status quo in the industry.

2.3.2 Submarket 2: Wholesalers

No size restrictions are placed on the wholesalers. Nevertheless they too operate on a small scale. Most wholesale companies are wholly owned and operated by members of the families which founded them. Because opals are difficult to differentiate as a product, it is hard for a new firm to break into the market by offering a new or revised version of the gem.[3] (Pseudo-differentiation may occur by emphasizing particular characteristics of some opals over others.) The wholesale firms contacted for the preliminary study were all established more than a quarter century ago. Their expertise in evaluating opal has been

[2] These regulations have been adopted separately by each state and apply to all fields.

[3] A new opal product was offered by the first Mr. Marks of Percy Marks, Sydney, when he developed the opal doublet.

established through experience. The knowledge they utilize in making judgements about the quality of opals is difficult to transfer and acts as a barrier to entry for new enterprises.

2.3.3 Submarket 3: Retailers

Opal retailers and wholesalers are distinguished, one from another, more by the quality of opal sold than by any other feature. There are a large number of retailers even if one counts only those who specialize in the gem. Because there are so many, and because they buy from the few wholesalers existent, the retailers are price takers. Despite this the retail markup is considerable (being at times, well over 300%) and is sustained largely by the end buyer's (consumer's) lack of information about opals.

2.4 Efficiency

Economists define an efficient market as:
"a market consisting of a sufficiently large number of buyers and sellers, no one of which buys or sells more than a small fraction of the total, where the commodity being traded is regarded as homogenous, where the only criterion for the transaction is that no better bargain is available elsewhere, and where all traders are aware of all offers available" (Lancaster 1974,50). There are five attributes of efficiency included in the quotation above.

1) A large number of buyers and sellers
2) each buying/selling a fraction of the total commodity being traded.
3) That the commodity is regarded as an homogenous good,
4) that no better bargain exists,
5) and all traders are aware of or have information about all offers.

Attributes 4 and 5, above, are interlinked and arise out of the free flow of information assumption underlying efficient markets. The opal market cannot, using this definition, be considered efficient. The first attribute of an efficient market occurs, for opals, at only one stage, that is, between retailer and end buyer. There is at this level, however, no real information flow or "awareness" on the part of consumers, as required by attribute 5 of an efficient market. The usual consumer of precious opal makes his/her choice of a gem on the basis of aesthetic preference with little awareness of the inherent characteristics considered by the merchant when pricing the stone. (This, however, will be tested further in Chapter Five.) The only stage at which the information flow about opals is adequate (not perfect) is the first, between miners and wholesalers.

2.5 Price Elasticity

The wholesale opal market, because it is concentrated in the hands of less than ten dominant merchants, could be considered an oligopoly. Reekie (1979) has stated that when firms are limited in number and can forsee the impact of their decisions upon their rivals, price leadership will arise. Caves (1977,48) states additionally, that under these conditions, "price adjustments...seem to aim at protecting maximum joint profits for the industry". While these statements may be true and while the wholesale opal market does appear oligopolistic, influences external to it restrict the extent to which these powers can be exercised. Primarily, opals are an inessential good. Because they are a luxury, consumers can quite easily do without the stone. Additionally, there is a high elasticity of substitution between opals and other coloured gemstones. The price elasticity of demand, which measures the responsiveness of quantity demanded to changes in price, is, for these reasons, quite high.

The demand for opals, and hence too the price, is responsive to the changing economic climate. The depression, for example, saw wholesale opal production figures in New South Wales fall from nearly $27,000 in 1927 to $2,000 in 1932 (MacNevin 1980,10). The demand for opals did not really return until the 1950's when opal once again brought the late 1920's price of $20 per carat. Thereafter price climbed fairly steadily until the oil embargo of May 1973 when prices dropped by 40 to 50 per cent (Peter Sherman, personal correspondence 1984). When large bankruptcies occurred in the gemstone industry in Japan (a major consumer of Australian opal) prices fell again, this time by about a third.

Because of the variability of prices and the substitutability of other gemstones, it is necessary to recognize that since the model to be developed in Chapter Five is based upon data collected at a specific time the model will not be valid for all time. Despite this, the relative value of inherent characteristics will not be likely to be altered by varying market conditions over the short run and the model should, therefore, be useful in the short to medium term.

2.6 Summary

The (limited) literature available on the topic of opals deals almost exclusively with mining. Reading it, however, and conversing with those within the industry, highlights the informational inefficiencies in the market as a whole. The market is not efficient in the economists sense of that word. The market is fragmented into three (or four) stages, consisting of miners, retailers, and wholesalers (and cutters). The wholesalers dominate the market and probably set prices in an oligopolistic way, but are subject to some control by conditions outside the industry. The pricing model developed in this dissertation is unlikely to remain valid after major shifts in these conditions yet should be useful in the short run.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This chapter presents a review of major studies that have used the hedonic technique. It also presents the rationale behind the use of this method. When measurements of a number of characteristics possessed by similar goods are regressed against the prices for those goods a value can be estimated for each specific characteristic. The statistically significant characteristics can then be used to compute a price index for the good in question. The technique of analyzing commodities through multiple regression analysis of the inherent characteristics, (as previously outlined in Chapter One), to determine the value of their separate characteristics, is called 'hedonic pricing'.

3.2 The Hedonic Method

The hedonic method, as stated in Chapter One, section 2, uses multiple regression analysis to isolate the set of statistically significant characteristics from the large number of characteristics inherent in a commodity. An estimated coefficient is then associated with each characteristic. This coefficient is accurate within a specified range or confidence interval which can be determined. The variables, with their respective coefficients, are then incorporated into an equation which can be used to predict an estimated value for the commodity.

The use of the hedonic method is not new. Zvi Griliches (1971, 55-87) provided a strong theoretical justification for its use in developing price indexes for automobiles. The ideas were not original even then, having been developed earlier by Court (1939), with extensions presented by Stone (1956).

The Griliches (1971) study investigated the relationship between automobile prices (multiple brands and models) and the characteristics or specifications of each. That is, the horse-power, the weight, length, type of steering, type of brakes, type of transmissions etcetera. All of these traits were possessed by the vehicles in a number of mixes. Multicollinearity between some of the variables led to "some instability in the estimated implicit prices" (Griliches 1971,56) of the variables but the problems were overcome by using dummy variables and/or selecting the best single variable from among the collinear ones. An equation was developed:

$$\ell n P_{it} = A_0 + A_1 X_{1it} + A_2 X_{2it} + A_n X_{nit} + U_{it}$$

where P is the price, the X's are the inherent characteristics, and U is a random disturbance term. This equation "can be used to estimate change in price to changes in the subset of quantifiable qualities" (Griliches 1971,59). Because the dependent variable is the log of price, the coefficients of variables which are included in logarithmic form which result from the regressions can be interpreted as price elasticities. That is, they "can be interpreted as the estimated change in price due to a unit change in a particular 'quality' holding other qualities constant" (Griliches 1971,67).

The results of the study were tested on the used car market. While no perfect correlation was expected due to the fact that new and used cars are no longer identical commodities, it was determined that the estimated implicit prices were "well within the range of their respective standard errors" (Griliches 1971,77).

3.3 Housing and Other Hedonic Studies

The hedonic technique has been used on tractors (Fettig 1963) air quality (Brookshire, *et al.* 1982, Witte, *et al.* 1979, and Harrison and Rubinfeld 1978), electrical goods (Dean and DePodwin 1961, Gavett 1967), computers (Chow 1967), and housing (Correll, *et al.* 1978, McLeod 1983, Li and Brown 1980 and Abelson 1979). Most of these studies have not greatly expanded the theoretical base developed by Griliches. The hedonic price functions were initially interpreted as reflecting only the marginal production costs of the characteristics (McLeod 1983, 391). A typical example is the study by Abelson (1979) which estimated hedonic prices on attributes of housing for two suburbs in Sydney. This study was based on four standard regression models;

1) an ordinary linear regression,
2) a semi logarithmic regression (with a linear dependent variable),
3) a logarithmic dependent variable and linear independent variables and
4) the double log or logarithmic dependent and independent variables.

It went on to demonstrate that hedonic prices "provide a basis from which the values of amenities to be used in cost benefit studies can be estimated".

The study by Correll *et al.* (1978), used hedonic techniques to determine the benefits to be derived from "greenbelts" in neighborhoods. The Harrison and Rubinfeld (1978) study of the demand for clean air followed these same hedonic techniques. It went further than previous studies however, by using the "marginal valuations of characteristics implied by the estimated hedonic price function to develop estimates of inverse demand curves for individual characteristics" (McLeod 1983,389). The Li and Brown (1980) study included 781 sales of houses in fifteen suburbs of Boston. Characteristics were entered in the regressions in both linear and nonlinear forms. Rankings made by individuals were used to quantify qualitative attributes such as scenic views. The results showed the necessity for very careful structuring of the model and for recognizing the implications of linear assumptions when using hedonic techniques.

The most recent article reviewed, (McLeod 1983), which summarizes the work of Freeman (1974) and Rosen (1974) shows, as Harrison and Rubinfeld (1978) did, that inverse demand curves can be estimated from the information derived from multiple regression techniques.

3.4 Multicollinearity in Hedonic Regressions

Multicollinearity in the explanatory variables is a common problem for studies using the hedonic technique. An article by Phoebus Dhrymes, "On the Measurement of Price and Quality Changes in Some Consumer Capital Goods" (1967), reviewed work which had been done on automobiles and on refrigerators. The samples used are unimportant, the selection of the semilog form for the regression models was made simply "for convenience" (Dhrymes 1967,504). Dhrymes's contribution is his theoretical justification for the use of the principal components method when multicollinearity threatens the stability of an hedonic model. Problems with collinearity had, in the past, been dealt with in a somewhat unsatisfactory way by omitting variables or using dummy variables in order to identify at least some coefficients of the collinear variables. "Principal components regression is a method of inspecting the sample data or design matrix for directions of variability and using this information to reduce the dimensionality of the estimation problem. The reduction in dimensionality is achieved by imposing exact linear constraints that are sample specific but have certain minimum variance properties that make their use attractive" (Judge *et al.* 1980). The sum of the variances of the principal components is equal to the sum of the variances of the original, collinear, variables yet the problems of multicollinearity are circumvented. Fewer variables may be employed in the regressions depending upon the contribution of the derived principal components to the variation of the larger number of collinear variables in question.

3.5 Hedonic Pricing in Market Equilibrium

The Rosen (1974) study, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition", has implications for this work. His research extends the theory of the hedonic price function, through a series of derivations, in order to determine "the relative marginal contribution of a characteristic to the market price" (McLeod 1983, 389). Rosen (1974) demonstrates that the marginal price for various attributes will not be linear unless arbitrage is possible with regards to individual characteristics. He proves, in the article, that when a bundle of attributes cannot be untied and re-presented in another package a logarithmic function is a necessity. (This is important for the eventual choice of the functional form in Chapter Five.)

3.6 Summary

The theory behind the use of the hedonic method of regression analysis is not new. It was first developed over forty-five years ago by Court (1939) and used again by Stone (1956). Its application to price indexes was first suggested by Zvi Griliches (1971), whose theoretical justification for its use has been central to the further refinement of the technique. The technique has previously been applied to a broad array of manufactured goods. Its application to heterogenous goods is well demonstrated in the housing studies of Correll, *et al.* (1978), McLeod (1983), Li and Brown (1980) and Abelson (1979). Abelson (1979) compared linear, log-linear, and log-log models. Li and Brown (1980) used rankings for qualitative attributes, and McLeod and others have derived demand curves. Dhrymes (1967) used principal component analysis to solve the problem of multicollinearity and Rosen (1974) showed that log models are preferred over linear or log-linear models when arbitrage is not possible.

CHAPTER FOUR
DATA COLLECTION

4.1 Introduction

This chapter presents a description and basic analysis of the data used in this study. The data on the characteristics which may contribute to the value of specific gems could have been gathered in a number of ways. Because the previous study by the author (Cornelius 1984) indicated that most merchants already possessed a number of certificates of authentication which appraised gems by characteristics, it was decided that an attempt would be made to obtain copies of these. A preliminary inquiry with a respected AGIA merchant indicated no problem with this plan and even resulted in an invitation to the annual AGIA meeting. At this meeting the research was to be described and the assistance needed from merchants explained. Before leaving for Sydney and the meeting of the Association, letters were sent to wholesale merchants who had assisted with the previous study. The time of the meeting was reconfirmed upon arrival. Earlier contacts were then followed up. These contacts were, generally, disappointing. Most merchants preferred to wait for the Association's response to the study.

The AGIA, because of an adverse previous experience with studies undertaken by an academic, chose not to assist with the data collection for this research. However, individual merchants were willing to assist in ways other than the provision of actual certificates of authentication. To overcome the lack of official certificates a combined certificate of appraisal was created based upon characteristics contained in both the AGIA and IPON opal certificates. The AGIA and IPON nomenclatures are shown in Appendix A, the combined certificate is shown in Appendix B. The combined certificate of appraisal requested data on the characteristics and the wholesale price of each gem as of February 1985.

Two merchants volunteered to lend several opals of varying qualities to the researcher in order to collect data for the third part of the study. That part was aimed at testing the consistency of opal valuations done by experts and by non-experts. These opals are referred to later as the "master-set". The use of non-experts allowed for the assessment of correlations between estimated wholesale values, as given by the experts, and consumer preference.

Requests for assistance with the new, combined certificates of appraisal and with the valuations of the "master-set" were sent to Sydney. The responses were limited but seven definite appointments were obtained. The second trip to Sydney resulted in fifty-eight completed combined certificates of appraisal, photographs of the twelve stones in the "master-set", eight expert valuations of each gem in the "master-set" and thirteen non-expert assessments of the twelve gemstones. Of the fifty-eight combined certificates of appraisal, thirty-one were filled out by retailers and twenty-seven by wholesalers. Two retailers gave their data in retail prices, the others all agreed to list wholesale information. One of the two retailers stated his mark-up and that information was used in transforming retail prices to the wholesale figures.

Finally, four additional combined certificates of appraisal were filled out by a local, Armidale, merchant in order to provide data for testing the model. The merchant, a retailer, estimated the wholesale value on four of the five gems appraised.

4.2 Terms Utilized on the Combined Certificate of Appraisal

The characteristics included on the combined certificate of appraisal are defined in detail below:

DESCRIPTION: A category defining the opal as a solid or a created or treated stone. Among the created stones are doublets and triplets as well as synthetic opals. The doublets and triplets include some actual natural opal. The synthetics are laboratory products but are not "fake" stones. The components of a synthetic are the same as for a natural stone. Treated stones are those which have undergone procedures to enhance the colour of the gem. The combined certificate of appraisal sought information on solid, natural opals only.

VARIETY: This refers to the basic type of opal. That is, a black or dark stone, a boulder, white or crystal. Each of these types can be seen in the photographs in Appendix C. A black opal is not necessarily black. The term refers to any opal with a dark body colour or matrix. The brilliant colours which come through this surface may actually dominate the stone but their hues will change as the stone is turned. It is the base or matrix colour which helps to determine the variety. White opals are any stone with a white to milky matrix. Crystal opals and the subgroup jelly opals have a relatively clear or translucent matrix. The white and crystal opals are often combined as a single grouping (see the IPON certificate, Appendix A) and will be so combined for this study. Boulder opals are a naturally formed doublet having coloured opal on the surface and an ironstone base.

ORIGIN: This category is ignored in the IPON certificate but included by the AGIA in their certificates of appraisal. The category may be important in that some areas are said to produce more stable stones (less subject to crazing) than are other areas. Origin, in large part, correlates with type or variety. For example, white opals usually come from South Australia, largely from a field called Coober Pedy. They were once found at another South Australian field, Andamooka, but this has been mined out. Most black opals come from a New South Wales field, Lightning Ridge. Although a relatively new South Australian field, Mintabe, produces a "black" opal, its matrix is dark grey. All boulder opals come from Queensland, the best known field being Quilpie although many stones in this sample are from Pincella.

WEIGHT and DIMENSIONS: The opal weight is defined in terms of a carat which is equivalent to 205/1000 of a gram. Dimensions are given in millimetres, for example 18 x 12.8 x 5.1, with the first number referring to the length of the stone, followed by width then depth. The depth is not given for triplets or doublets.

COLOUR: This refers to the hues of the spectrum visible in the opal and not part of the matrix. The IPON classification system uses the term fire instead of colour. In that system when the stone has more than three colours it is termed semi-multifire, when it has all colours of the spectrum it is termed multifire. The AGIA specification is less clearly defined and presented numerous problems to the merchants assessing it. Some included only the most dominant colour(s), others every colour present from any angle. Some preferred to list the colours present in order of rarity while others listed them in order of quantity. I have tried to divide this information into two categories. The first indicates the dominant shade, ie. hot colours (red, orange, yellow) or cool colours (green, blue, violet). When both predominate at different times depending upon the angle from which the stone is viewed, that is assessed as a third category. A fourth possibility is also recognized. Some opals have numerous sparks of colour from a predominantly milky or grey matrix. Others (usually boulder opals) have a strong mix of potch or ironstone and colour. Those stones where the matrix or potch is predominant are classified as "matrix". All four possibilities are analyzed under the term "shade". The number of colours present are then determined and listed under "colours" as one, two, three, and four or more.

COLOUR PROPORTION and BACKING: This category refers to the per cent of colour throughout the gem. This varied from five to one hundred per cent. Boulder opals, for example, will never be one hundred per cent colour because they are, in part, defined by the ironstone backing on which the sheet of colour is overlaid. Black opal is often backed by a dark potch, although the percentage of potch varies. White opal, too, may have a potch backing. The amount of potch makes no difference to the classification of the gem by description or variety. The IPON category of "Backing:% Potch" refers to this same item. It was retained in the combined certificate only to affirm the information given under the colour proportion classification. "Backing:% Potch" is not used in the analysis section.

SHAPE: The shape category as given on the AGIA certificate includes only three shapes: oval, round, and freeshape. The IPON certificate includes eleven additional categories. Among those not included by the AGIA but seen during research were the marquis, teardrop, rectangle and square. Teardrop was added to the combined certificate, and was applied to both the true teardrop shape and to the very similar shape known as "pear". The marquis is very much like an oval and was included under that category while the rectangular or square gems were included with the freeshapes.

CABOCHON: This term refers to the curvature of the gem above the setting line (see drawing). Gems are cut so that there is a slight ridge for the claws of the setting to hold each stone. It usually requires a magnifying lens to see the setting line.

PATTERN: Pattern, as defined by the AGIA (fine, medium, broad), was easier to utilize than that of the IPON, which calls for specific named patterns and does not include all those patterns which are named in the industry. The terms fine, medium and broad are generalizations made about the size of the splashes of colour in the gem. Fine refers to those in which pin pricks of colour speckle the opal. A medium pattern means that the flashes of colour are greater than in the fine specification but not so broad as to cover large portions of the stone at once. A broad pattern occurs when a large patch of the gem is covered by the same colour at any given time.

FINISH: Some merchants took this to refer solely to the polish of the gem. Discussions resulted in understanding 'finish' to be a reference to the overall aesthetic of a gem; its polish, the appropriateness of the cut, the balance of its dimensions, etc. With this definition there was some fear of a high correlation between finish and other characteristics. That possibility will be assessed later.

QUALITY: The final AGIA characteristic, quality, is divided into nine parts in the combined certificate. These divisions have been reduced to three for the analysis. Finest

Gem A and B are in one grouping, Gem A, B and C are put together as the second group and all commercial grades A, B, C, and D comprise the third. This characteristic cannot be assessed without long term experience in the industry. It seems to depend upon all the previous characteristics plus the subjective judgement of the merchant. The correlation, if any, between quality and the other characteristics will be assessed at a later stage.

Three characteristics not contained in the AGIA certificate but drawn from the IPON certificate are luminance, clarity and rarity.

LUMINANCE: This is the brilliance of the fire or colours in the gem. AGIA merchants will state the luminance of the gem when they state its colour. It is clearer, however, to use a separate category when assessing the characteristics which may contribute to value.

CLARITY: Clarity refers to the existence of potch or inclusions visible from the face of the gem. The IPON defines the categories as:

very good = no visible inclusions
good = minor visible inclusions
medium = visible small inclusions
poor = obvious inclusions

RARITY: The IPON category of rarity does not include a range for the more common, commercial opals. The addition of "not rare" leaves rarity divided into six parts. Combining these for analysis we have the exceptional and very very rare, the very rare and rare and the medium rare and not rare. This results in three divisions somewhat comparable to those used for quality.

4.3 Characteristics of the Sample Gems

The information contained in the fifty-eight combined certificates of appraisal is presented in Tables 4.1 and 4.2. Table 4.1 shows the mean wholesale price, percentage of colour, dimensions and weight of the sampled gems. These characteristics are assessed using continuous variables. The table also gives the standard deviation and indicates the minimum and maximum figures for each variable. The standard deviation of the wholesale prices in the sample is \$799 per carat. This represents a range from \$4000 per carat for a fine black opal, to \$3 per carat for a poor quality white stone. The highest price given, \$4000 a carat for a black opal, is an extreme outlier; especially on a wholesale basis. The merchant who displayed this gem did not have it for sale. It was taken from his private collection. The wholesale figure of \$4000 was given because he had once been offered that amount and turned it down. He remains unwilling, today, to sell the gem even at twice that rate. His attitude toward this particular gem makes the quoted wholesale value questionable. The gem is, for this reason, later dropped from the analysis. This leaves another black opal, at \$2289 per carat, as the highest priced gem in the sample. Dropping the \$4000 per carat stone from the sample reduces the effective sample size to fifty-seven. The least expensive stone, a small (1.6 carat) white opal, is a typical example of the commercially available, mass produced (mass cut) stones used in costume jewelery. Created gems such as triplets and doublets are not included in the sample of gems appraised for this study. It should be noted, however, that many created gems are far more valuable than the natural stones with poor characteristics. If the commercial stone used in the doublet or triplet was of as poor a quality it would not be worth the labour involved in creating it.

TABLE 4.1: Sample Data from the Combined Certificates of Appraisal

ALL OPALS: (58 stones in the sample)

	Price per/ct	Colour	Length	Width	Depth	Weight
	$	%	mm	mm	mm	cts
Mean:	534.0	65	18.00	12.80	5.10	12.00
S.D.:	799.0	34	9.66	6.00	2.20	24.00
min:	3.0	5	4.25	4.00	1.00	0.30
max:	4000.0	100	58.00	32.00	14.00	167.50

BLACK OPALS: (23 stones in the sample)

	Price per/ct	Colour	Length	Width	Depth	Weight
	$	%	mm	mm	mm	cts
mean:	1107.0	52	16.57	12.22	5.00	10.42
S.D.:	1019.4	31	8.13	6.18	2.26	17.02
min:	5.0	5	6.00	4.00	1.00	0.30
max:	4000.0	100	45.00	31.00	9.80	83.17

BOULDER OPALS: (15 stones in the sample)

	Price per/ct	Colour	Length	Width	Depth	Weight
	$	%	mm	mm	mm	cts
mean:	219.0	50	19.35	10.81	4.25	6.96
S.D.:	226.0	31	9.66	4.78	1.18	6.74
min:	5.0	10	4.25	4.25	2.50	0.37
max:	800.0	95	41.00	21.50	6.00	27.83

LIGHT OPALS: (20 stones in the sample)

	Price per/ct	Colour	Length	Width	Depth	Weight
	$	%	mm	mm	mm	cts
mean:	111.0	93	18.65	14.84	5.79	17.66
S.D.:	91.0	19	11.41	6.48	2.55	36.32
min:	3.0	20	6.00	8.50	2.50	0.70
max:	300.0	100	58.00	32.00	14.00	167.50

Colour proportion on the gems in the sample ranges from a low of five per cent to a high of one hundred per cent. The crystal opals, being transparent, have the highest proportion of colour throughout the stone. If there were potch backing the gem, the stone would no longer be a crystal, for the backing would colour the matrix, making it a white or black opal. Boulder opals, in contrast, cannot be one hundred per cent colour for boulder opals are natural doublets.

The lengths of the sampled stones vary from 4.25mm to 58mm. The weights vary from .3 of a carat to 167.5 carats. The mean size of the sampled opals was 18mm x 12.8mm x 5.1mm, with a mean weight of 12 carats. No stone in the sample had dimensions which were disproportionate, that is, the length was aesthetically balanced against the width and depth. Weight will, of course, be dependent upon the size of the opal.[1]

Table 4.2 contains data on discontinuous characteristics. The traits covered are shape, shade of colour, cabochon, pattern, finish, quality, luminance, clarity, and rarity. The majority of black opals were oval cut with predominantly cool, (green, blue, violet) colours. The boulder opals were largely freeshape and, again, the predominant colouring was cool. The majority of light opals were, as the black stones, oval cut. Their predominant shade was matrix, that is the colour flashed from a white or milky background. Of the three types, the light opals had the largest percentage of stones with a high to very high cabochon. Boulder opals had a fairly even distribution of patterns, very similar to those of light opals. Both types had more gems with a fine pattern than with either a medium or broad one. Black opals, by contrast, had a high percentage of gems with a broad pattern. The finish on the light opals was better, generally, than that on the black or boulder stones, however, the black gems had no stones with fair or poor finishes while the boulder and light opals did. The highest percentage of commercial stones in the sample were from the boulders and, at the opposite extreme, the highest percentage of 'finest gems' were black opals. The luminance of the colour in the sample stones was well distributed with only twelve per cent labelled 'poor'. Overall, the clarity of the gems was very good. Understandably, the boulder opals had the largest percentage of stones with inclusions. The rarest gems in the sample were the black opals although the majority of these were not rare. No boulder opals were considered very rare but one light gem was. The greatest number of stones in the "not rare" category were light opals. Altogether nine per cent of the gems were very rare, twenty-two per cent rare and sixty-nine per cent not rare.

4.4 The Master Set: Evaluations

The dozen opals, lent by merchants, were used as a "master-set" for the purpose of evaluations. They varied in variety and quality. The stones can be seen in the photographs in Appendix C. There were two black opals; stones number 1 and 11. Number 1 was of good quality being in the middle or "Gem" rank. Number 11, a black jelly opal, was not nearly as fine a stone for it had only a slight violet fire to it. The two boulder opals, numbers 7 and 12, were of equally different qualities, number 7 being the best of the two. Two white opals were also included, these being quite large stones: number 3 was 25mm x 19.2mm x 5.2mm, number 4 was even larger, 33.9mm x 25.3mm x 7.6mm. These two white opals appeared to be of about equal quality. The only crystal in the master set, stone number 2, was of Gem B quality. It suffered, as far as the valuers were concerned,

[1] Slight variations in the density of an opal occur due to the effects of the environment during formation.

TABLE 4.2: Sample Data on the Discontinuous Characteristics from the Combined Certificate of Appraisal

Sample Gem's Characteristics by Type

SHAPE

	BLACK	BOULDER	LIGHT	TOTAL %
FREE	13.0	53.0	5	21.0
OVAL	78.0	20.0	70	60.0
ROUND	9.0	7.0	5	7.0
TEAR	0.0	20.0	20	12.0
%	100	100	100	100
GEMS	23	15	20	58

SHADE

	BLACK	BOULDER	LIGHT	TOTAL %
HOT	17.5	0.0	10	10.0
BOTH	26.0	20.0	10	19.0
MATRIX	17.5	27.0	55	33.0
COOL	39.0	53.0	25	38.0
%	100	100	100	100
GEMS	23	15	20	58

CABOCHON (DOME)

	BLACK	BOULDER	LIGHT	TOTAL %
V.HIGH	4.5	0.0	5	3.5
HIGH	4.5	0.0	30	12.0
MED.	39.0	33.0	35	36.0
LOW	52.0	53.0	30	45.0
N/A	0.0	14.0	0	3.5
%	100	100	100	100
GEMS	23	15	20	58

PATTERN

	BLACK	BOULDER	LIGHT	TOTAL %
FINE	9.0	40.0	35	26.0
MED.	35.0	33.0	30	33.0
BROAD	56.0	27.0	35	41.0
%	100	100	100	100
GEMS	23	15	20	58

FINISH

	BLACK	BOULDER	LIGHT	TOTAL %
V.GOOD	43.5	13.3	65	43.0
GOOD	56.5	40.0	15	40.0
FAIR	0.0	33.4	20	14.0
POOR	0.0	13.3	0	3.0
%	100	100	100	100
GEMS	23	15	20	58

Table 4.2:continued

FINISH	BLACK	BOULDER	LIGHT	TOTAL %
V.GOOD	43.5	13.3	65	43.0
GOOD	56.5	40.0	15	40.0
FAIR	0.0	33.4	20	14.0
POOR	0.0	13.3	0	3.0
%	100	100	100	100
GEMS	23	15	20	58

QUALITY	BLACK	BOULDER	LIGHT	TOTAL %
FINEST GEM	26	0	0	12
GEM	44	40	50	45
COMMER-CIAL	30	60	45	43
%	100	100	100	100
GEMS	23	15	20	58

LUMINANCE	BLACK	BOULDER	LIGHT	TOTAL %
V.HIGH	35	40	20	31
GOOD	13	33	45	29
MED.	43	20	15	28
POOR	9	7	20	12
%	100	100	100	100
GEMS	23	15	20	58

CLARITY	BLACK	BOULDER	LIGHT	TOTAL %
V.GOOD	74	27	70	60
GOOD	22	33	25	26
MED/POOR	4	40	5	14
%	100	100	100	100
GEMS	23	15	20	58

RARITY	BLACK	BOULDER	LIGHT	TOTAL %
V.RARE	18	0	5	9
RARE	30	27	10	22
NOT RARE	52	73	85	69
%	100	100	100	100
GEMS	23	15	20	58

only because it did not contain colours from the full spectrum. Two stones included in the "master-set" were treated matrices, both from the Andamooka opal fields in South Australia. One was extremely dull and dark, the other quite bright with numerous specks of fire. These were, respectively, stones 6 and 8. Three triplets were included, numbers 5,9, and 10. One of the three, by far the most brilliant,(number 9), was a Gilson synthetic.[2]

The eight opal merchants who estimated values for the gems in the "master-set" consisted of four retailers and four wholesalers. They valued the triplets and boulder opals on a total price basis, the other stones were priced per carat weight. All values presented in Table 4.3

TABLE 4.3: Estimates of Wholesale Value

#	Type	Weight	WHOLESALERS				RETAILERS			
			A	B	C	D	A	B	C	D
1	black	2.15	2795	1720	2580	2580	1800	2150	5375	269
2	crystal	6.14	982	860	1105	1075	614	737	749	614
3	white	16.01	720	1201	961	2001	1761	1921	961	1921
4	white	34.46	1206	1723	1206	2585	2757	4308	1723	6031
5	triplet	n/a	100	150	80	75	200	32	50	100
6	treated	3.25	10	10	10	16	10	60	33	33
7	boulder	17.34	700	350	800	250	800	340	300	867
8	treated	6.27	–	94	125	–	188	150	94	–
9	triplet	n/a	–	50	20	–	60	36	10	15
10	triplet	n/a	70	60	85	–	180	28	25	15
11	black	2.31	80	95	60	–	130	100	23	58
12	boulder	1.78	–	53	62	–	250	71	6	62

are given on the basis of the total wholesale value for the stone in dollars. The first column gives the stone number, the second, its type, the third its carat weight. Thereafter each column represents a different valuer. Reading across the rows gives all the prices quoted by all valuers for any given stone. The mean value estimate and standard deviation for each stone is given in Table 4.4.

The stone with the highest mean estimated value is number 4, a large white opal. This does not, it should be remembered, indicate that the stone has the highest value per carat. The small black opal with the second highest total estimated value (stone number 1) is the most valuable stone per carat. The least valuable opals in the sample are numbers 6 and 9. The first, number 6, is a treated stone, the second, number 9, is the Gilson synthetic triplet. The standard deviations of the estimated value on the opals in the sample tends to be greater the higher the total estimated value. This should be expected however, and does not by itself reveal any major problems in the valuers estimations. The mean value ordering by experts can be determined from Table 4.4. The value ranking, in decending order by total value, is as follows: 4, 1, 3, 2, 7, 8, 5, 12, 11, 10, 9, and 6. This ranking is of

[2] A Gilson synthetic is a high quality laboratory produced stone developed in the Gilson laboratories in Switzerland. A wide variety of synthetic opals have been manufactured but the Gilson remains among the best.

Table 4.4: Mean and Standard Deviations of Expert Assigned Values for the "Master-Set"

stone number	mean value $	SD $
1	2409	1439
2	842	195
3	1431	523
4	2692	1693
5	98	54
6	23	18
7	551	263
8	130	40
9	32	20
10	66	57
11	78	35
12	84	85

interest when compared to the two assessments made by non-experts utilizing these same stones. Their rankings are presented in Table 4.5.

Two sets of non-experts were asked to rank the opals in the "master-set" by value and then by their personal aesthetic preference. One set of non-experts were females between twenty-five and fifty. The other set were investment (banking) specialists in the same age group. Neither set of respondents claimed any knowledge of opals either individually or as a group. Each non-expert ranked the opals while isolated from the remainder of their group. As stated, the non-experts' preference rankings and value orderings are presented in Table 4.5. Chapter Five continues the analysis of this data.

4.5 Summary

A combined certificate of appraisal was created utilizing traits given by both the IPON certificate and the Australian Gem Industry certificate. Fifty-eight of these certificates were collected during personal interviews. Twenty-seven of them were filled out by wholesalers and thirty-one by retailers. There were twenty-three black opals, fifteen boulder and eighteen light opals in the sample. Of these the light opals had the highest total distribution of colour and the black opals had the highest mean value. Four additional combined certificates of appraisal were collected later for testing the pricing model.

The information gathered in combined certificates of appraisal was supplemented by the use of a "master-set" of twelve opals, lent for the purpose of evaluating expert and non-expert assessments of the gemstones. The opals in the "master-set" were of a broad variety including black, boulder, and light (crystal and white) opals as well as created or treated stones. The "master-set" was ranked by non-experts in order of estimated value and by preference. The same stones were given an estimated wholesale value by the experts.

TABLE 4.5: Assessments of the "Master-Set" by Non-Experts

pr=preference ranking/vo=value ordering

Set One: females age 25-50

2	10	5	8	1	4	3	7	9	6	11	12	pr
2	8	3	1	10	4	9	5	6	11	7	12	vo
10	7	1	5	9	4	3	12	2	11	8	6	pr
8	3	4	6	11	2	1	7	12	5	10	9	vo
9	5	3	8	10	2	4	1	11	7	12	6	pr
9	3	5	4	10	8	2	11	1	7	6	12	vo
2	12	1	11	10	9	8	5	3	7	4	6	pr
10	9	5	4	7	3	8	2	1	6	11	12	vo
11	7	1	2	10	3	9	4	5	12	6	8	pr
2	9	11	3	4	1	7	10	5	12	6	8	vo
5	2	8	9	3	4	11	10	6	7	12	1	pr
5	2	9	8	11	6	10	3	12	4	7	1	vo

Set Two: investment (banking) specialists

3	2	4	11	8	9	10	1	12	7	5	6	pr
12	1	11	3	7	9	4	5	6	2	8	10	vo
7	4	3	5	2	10	1	8	12	6	11	9	pr
4	3	7	2	5	10	8	1	12	6	9	11	vo
11	1	6	2	9	5	3	4	7	10	12	8	pr
2	11	1	3	4	6	12	7	10	5	8	9	vo
11	9	3	2	10	1	7	8	6	12	4	5	pr
11	1	3	7	6	4	10	9	5	2	12	8	vo
9	1	5	10	8	12	6	11	7	4	3	2	pr
9	11	1	5	10	12	7	8	6	2	3	4	vo
9	2	1	11	12	3	6	8	7	10	4	5	pr
1	9	2	8	5	3	11	10	7	12	6	4	vo
1	12	10	11	5	6	7	9	2	8	3	4	pr
4	3	10	7	2	1	12	9	8	11	5	6	vo

CHAPTER FIVE
EMPIRICAL RESULTS

5.1 Introduction

This chapter presents the results of using the hedonic technique to study the price structure of three major types of opals. It is based upon the data described in Chapter Four, and addresses the first two objectives given in Chapter One. These were: to identify which of the different characteristics given in the standard nomenclatures are important, and to estimate the implicit contribution of each to the value of an opal. The third objective, to test the consistency of opal valuations by groups of opal experts and non-experts, is addressed in the final section of this chapter.

This first section presents the results of the multiple regression analysis of different characteristics on the price of opals. The independent variables have been selected from the nomenclatures developed by both the AGIA and by the IPON Committee. All characteristics included on the AGIA certificate were originally included as independent variables in the regressions. Those few characteristics not contained in the AGIA certificates but included on the IPON certificate were added to the list of independent variables (see Appendix A). The remaining characteristics on the IPON certificate overlapped with those on the AGIA certificate and were, therefore, not explicitly included. The hedonic technique, as described in Chapter Three, is used to derive implicit prices for the various characteristics of the opals.

Most variables used in the regressions are either discrete but ordered, or continuous. The discrete variables are cabochon, pattern, finish, quality, fire, clarity, and rarity. These have each been measured on ordinal scales, eg. good, medium, poor or fine, medium, broad. The continuous variables are weight, length, width, depth, and per cent colour. The variables for type, shade and shape were problematic. The classifications are:

TYPE	SHADE	SHAPE
light	matrix	round
boulder	cool	free
black	hot	teardrop
	both	oval

Selecting a specific order for these variables would have implied some assumptions about the variations between the categories or the value ordering of the categories. These characteristics were, therefore, entered into the regressions using dummy variables as follows:

D1=1 for black =0 for others	D1*=1 for hot =0 for others	D1**=1 for round =0 for others
D2=1 for boulder =0 for others	D2*=1 for both =0 for others	D2**=1 for free =0 for others
	D3*=1 for matrix =0 for others	D3**=1 for teardrop =0 for others

This means that the intercept takes into account values for the light opals, cool colours, and oval shapes. Regressions were run using Type, Shade, and Shape.[1] These regressions explained less of the variations in price than do those regressions using dummies for the specified variables and were, therefore, not reported here.

5.2 Regression Models

A number of regression models were tried using both the linear and logarithmic functional forms. Some variables were, at one point, entered in quadratic form but, because the estimated coefficients were insignificant and did not add greatly to the explanatory power of the models, the linear form was preferred.

Length, width, depth and weight are highly correlated. The correlation coefficients of the four variables are presented in Table 5.1.

TABLE 5.1: Correlation Matrix of Dimension Variables

	Weight	Length	Width	Depth
Weight	1.00			
Length	0.8049	1.00		
Width	0.7427	0.7341	1.00	
Depth	0.7530	0.6764	0.7851	1.00

The problem created by this correlation was initially resolved by using length as a proxy for these characteristics on the grounds that length dictated the other variables. A long, thin stone is not as aesthetically pleasing in jewelery as is a well balanced gem. The width and depth of the stone generally must be in proportion to the length. Additionally, weight is a product of these other variables so it too could be presumed to be reflected by the single variable, length. Multicollinearity was later approached using principal component analysis (see section 5.3).

The results of the first set of regressions are set out in Table 5.2 for the models using all the AGIA and IPON characteristics.[2] The table shows the results of regressions using both the linear and logarithmic models. The linear model takes the form:

$$\hat{P}_i = a_0 + b_1 X_{1i} + b_2 X_{2i} + \ldots + b_n X_{ni}$$

where $\hat{P}_i$ is the estimated Price of the ith stone per carat and X's are characteristics of the ith stone, b_i is the estimated coefficient of the ith characteristic, a_0 is the intercept, i=1,2,...,57. The logarithmic model is similar in form:

$$\ell n\hat{P}_i = a_0 + b_1 \ell n X_{1i} + b_2 \ell n X_{2i} + b_n \ell n X_{ni}$$

[1] Shade was specified as both hot and cool colours (4), hot colours (3), cool colours (2), or matrix (1). Type was specified as black (4), boulder (3), white (2) or crystal (1); and shape was specified as oval (4), round (3), teardrop (2), and freeshape (1).

[2] Characteristics considered collinear with others on the certificates have been excluded. For example, the variable 'origin' has been dropped from all regressions because it was perfectly correlated with the variable for type in this sample. That is, all the boulder opals were from QLD, all the black opals were from Lightning Ridge or Mintabe (three stones), and all the white opals from Coober Pedy in South Australia.

TABLE 5.2: REGRESSIONS USING ALL VARIABLES

VARIABLE	LINEAR MODEL EST. COEFFICIENT (ST.ERROR)	LOGARITHMIC MODEL EST. COEFFICIENT (ST.ERROR)
INTERCEPT	-484.40	4.30**
	(432.80)	(1.75)
BLACK (OPAL)	362.70**	0.90**
	(147.40)	(0.37)
BOULDER (OPAL)	-92.60	-0.29
	(180.20)	(0.48)
LENGTH	-15.10*	-0.34
	(7.45)	(0.39)
COLOURS (NO.OF)	-4.44	0.42
	(73.67)	(0.44)
PER CENT (OF COLOUR)	-7.62**	-0.43*
	(2.14)	(0.25)
ROUND (SHAPE)	128.60	0.05
	(238.1)	(0.68)
FREE (SHAPE)	87.90	0.40
	(159.10)	(0.42)
TEARDROP (SHAPE)	206.10	0.54
	(186.70)	(0.48)
CABACHONE	108.71	0.27
	(70.94)	(0.51)
PATTERN	-19.72	-0.17
	(73.41)	(0.35)
FINISH	-20.60	-0.07
	(106.80)	(0.74)
QUALITY	437.20**	1.67*
	(173.30)	(0.75)
LUMINANCE	15.72	1.60**
	(68.91)	(0.43)
CLARITY	101.00	0.15
	(125.60)	(0.62)
RARITY	224.10	0.58
	(173.70)	(0.69)
HOT (SHADE)	-59.60	-0.28
	(179.10)	(0.47)
BOTH (HOT AND COOL SHADES)	85.90	-0.21
	(151.20)	(0.39)
MATRIX (WITH SHADES)	65.60	-0.51
	(143.00)	(0.39)
R-SQUARED	.810	.844
$\bar{R}$-SQUARED	.719	.771
RESIDUAL SUM OF SQUARES	4599333	32.0629

* denotes significance at the five per cent level.
** denotes significance at the one per cent level.

Where $\ell n \hat{P}_i$ is the log of the estimated price of the ith stone per carat and $(\ell n)X$'s are logs of the characteristics of the ith stone, b_i is the estimated coefficient of the characteristic, a_0 is the intercept, i=1,2,...,57. The dummy variables were not entered in logarithmic form.

The R-squared statistic (coefficient of determination) shows how much of the variation in the dependent (price) variable is explained by the independent variables in the regression. The regressions using all non-collinear characteristics from the AGIA and IPON certificates, reported in Table 5.2, have R-square and $\overline{R}$-square values of 0.81,0.72 and 0.84,0.77 respectively for the linear and logarithmic models. This means that the independent variables in these models explain eighty-one and eighty-four per cent of sample variation in the respective dependent variables (price and log of price), and at least seventy-two per cent and seventy-seven per cent of the variation respectively when the coefficient of determination is adjusted for degrees of freedom. The explanatory power of the regressions using all available variables is slightly better than that using those on the AGIA certificate of authentication alone. This is due to the larger number of explanatory variables in the combined model. In the linear model (Table 5.2), only four variables are significant at the five per cent level of significance. Only five are significant at the five per cent level in the logarithmic model. Those significant at the five per cent level for the linear model are: type (black), length, per cent of colour, and quality. length is also significant at the one per cent level. For the logarithmic model the significant variables at the five per cent level of significance are the intercept, type (black), per cent of colour, quality and luminance. The intercept, type (black) and luminance are also significant at the one per cent level. The logarithmic model is similar to the linear one in that many of the same variables show degrees of significance. The per cent of colour distribution throughout the gem and the quality classification is significant at the five per cent level in this regression. The intercept and luminance are significant at a one per cent level.

Note that the per cent of colour has a negative coefficient indicating that the more colour throughout the stone the less value can be attributed to it. The expected result would have been the opposite of this, however this conclusion can be explained with reference to the gems in the sample. The fact that an opal is black contributes greatly to the value of the gem. To obtain this colouration most black opals are backed by black or very dark potch. Potch, by definition, contains no luminance or colour flashes. Boulder opals also, by definition, cannot be one hundred per cent colour. Only light opals have colour distributed throughout the gem. This sample of fifty-eight gems included twenty light stones. While some of these light stones were of gem quality, the mean per carat value was only \$111, whereas that for boulder opals was \$219 and for black opals was \$1107. The black and boulder opals, therefore, dominated the model forcing the estimated coefficient for the per cent colour to be negative. Had the sample included only light opals this coefficient would, in all likelihood, have been positive. (This explanation for the unexpected result has been confirmed by Gregory Sherman of Sherman Opals, Sydney.)

Regressions using only variables from the AGIA certificate are presented in Table 5.3. The table shows the somewhat lower explanatory power of the respective models. The $\overline{R}$-squared values are 0.70 and 0.68 as compared to 0.72 and 0.77 in the models using a combination of all non-collinear characteristics from the AGIA and IPON lists. The higher (adjusted) coefficient of determination in the regressions using all non-collinear variables is due to the larger number of explanatory variables (see Doran and Guise [1984, 107]). This time 'fire' or luminance, a significant variable in the first set of regressions but not contained in the AGIA classification, was not included. Still, five variables were significant in the linear model and six in the logarithmic. The significant variables for the linear model are type (black), length, per cent of colour, cabochon and quality. For the logarithmic model they are the intercept, type (black), number of colours, shape (teardrop), quality and shade (matrix). Variables significant at the one per cent level are per cent of colour (in the linear model) and quality (in the logarithmic model). The rest are significant at the five per cent level of significance. As in the regressions with all non-collinear variables, the coefficient for length, a proxy for all dimensional variables, is negative. This result suggests that although the total price is greater for a larger than for a smaller stone with identical qualities, the value per carat decreases. The number of significant variables from the AGIA regressions is greater than in the regressions with all variables included, but they explain less of the variation in the price.

Regressions were run using the significant variables from the logarithmic model in Table 5.3. The estimated regression equation is:

$$\ell n\hat{P} = 3.886 + 1.062X_1 + 0.068X_2$$

$$1.126\ell nX_3 - 0.213X_4 + 0.437X_5 + 0.921X_6$$

$$+ 2.853\ell nX_7 - 0.277X_8 - 0.119X_9 - 0.892X_{10}$$

$$- 0.408\ell nX_{11}$$

where X_1 and X_2 are dummy variables for black and boulder opals respectively, X_3 is the log of the number of colours inthe gem, X_4, X_5, and X_6 are dummy variables for the shape of the stone, X_7 is the log of quality, X_8, X_9 and X_{10} are dummy variables for the dominant colour and X_{11} is the log of the length of the opal. The $\bar{R}$-squared in the logarithmic model increased by 1.8 per cent using only significant variables from the original model.

The same changes were made in the regressions from Table 5.2 (using the significant variables from the all variable original. The estimated regression equation in this case is:

$$\ell n\hat{P} = 4.37 + 0.859X_1 - 0.095X_2$$

$$= 0.459\ell nX_3 - 2.28\ell nX_4 + 1.997\ell nX_5$$

$$- 0.337\ell nX_6$$

where X_1 and X_2 are again dummy variables for black and boulder opals respectively and X_3, X_4,X_5, and X_6 are logs of the per cent of colour, quality, luminance and length respectively. In this case the $\bar{R}$-squared of the logarithmic model increased by 3.9 per cent!

To determine whether the linear or logarithmic model is to be preferred an L-test was performed following Doran and Guise (1984,139).

The results of this test show statistically that the logarithmic model is to be preferred. The calculated L value is 56.18 which is significant at the one per cent level, therefore the hypothesis that the log model is significant is accepted.

Note that for linear models the predicted value is not always positive. It may be possible to overcome misunderstandings about the value in these cases, by looking at the confidence intervals for an explanation of the variation possible. When the model is

TABLE 5.3: REGRESSIONS USING AGIA VARIABLES

VARIABLE	LINEAR MODEL EST. COEFFICIENT (ST.ERROR)	LOGARITHMIC MODEL EST. COEFFICIENT (ST.ERROR)
INTERCEPT	-205.10	4.48*
	(418.80)	(1.89)
BLACK (OPAL)	347.20*	0.89*
	(150.50)	(0.44)
BOULDER (OPAL)	145.40	-0.02
	(175.40)	(0.52)
LENGTH	-17.12*	-0.44
	(7.38)	(0.45)
COLOURS (NO.OF)	5.95	1.03*
	(73.11)	(0.49)
PERCENT (OF COLOUR)	-8.03**	-0.31
	(1.96)	(0.25)
ROUND (SHAPE)	-68.30	-0.16
	(211.50)	(0.67)
FREE (SHAPE)	99.20	0.40
	(150.20)	(0.46)
TEARDROP (SHAPE)	260.90	1.06*
	(183.30)	(0.55)
CABACHONE	126.60*	0.11
	(70.83)	(0.57)
PATTERN	-35.25	-0.01
	(72.19)	(0.40)
FINISH	-14.10	0.26
	(79.96)	(0.63)
QUALITY	662.60*	2.79**
	(135.50)	(0.65)
HOT (SHADE)	-129.70	-0.32
	(181.30)	(0.54)
BOTH (HOT AND COOL SHADES)	122.10	-0.16
	(150.70)	(0.45)
MATRIX (WITH SHADES)	41.30	-0.88*
	(144.50)	(0.44)
R-SQUARED	.783	.767
$\bar{R}$-SQUARED	.703	.682
RESIDUAL SUM OF SQUARES	5244289	48.043

* denotes significance at the five per cent level.

** denotes significance at the one per cent level.

$$L = \frac{N}{2}\left|\ell n\left[\frac{RSS_1/c^2}{RSS_2}\right]\right| \sim \chi^2(1) \text{ reject } H_0 \text{ if } L > 3.84$$

$$L = \frac{N}{2}\left|\ell n\left[\frac{4688607/c^2}{33.5697}\right]\right| \text{where } c = \exp\left[\frac{\sum \ell n Y_i}{n}\right]$$

$$\text{Now } \exp\left[\frac{\sum n\ Y_i}{n}\right] = \text{average at log price values}$$

$$= 4.9365$$

$$\therefore c = \exp(4.9365)$$

$$= 139.2819$$

$$\therefore c^2 = 19399.45$$

$$\text{Then } L = \frac{N}{2}\left|\ell n\left[\frac{241.6876}{33.6597}\right]\right|$$

$$= \frac{N}{2}|\ell n 7.1803|$$

$$= \frac{N}{2}(1.9713)$$

$$= 56.183$$

$\therefore$ calculated $L > 3.84$(very significant)

$\therefore$ reject H_0

limited by a necessarily non-negative dependent variable (price in this case), the regression analysis could be performed using more powerful econometric techniques. However, since the selected estimated model is in logarithmic form this problem does not arise. The decision to use the logarithmic model is also supported by Rosen (1974,37) who has shown theoretically that when a bundle of characteristics can not be untied, that is when arbitrage can not be practised in relation to the individual attributes of the good, a logarithmic model is preferred.

To test the significance of the variables which are not highlighted in these first regressions, they were dropped entirely and an F-test performed on the residual sums of squares, for two sets of regression runs, both with and without dummy variables.[3] The data and F-tests are shown below:

It was concluded that the excluded variables are not significant in either case. As can be seen, the same variables are significant as were significant in the original logarithmic regression. The $\overline{R}$-squared reveals an improvement in the explanatory power of the

[3] Shade alone was used as the independent variable for that characteristic instead of using dummy variables for each possible dominant colour scheme. Type was used instead of specifying black or not black etc. and shape was used instead of the dummies for each specific shape. (See footnote 1, this chapter.)

AGIA variables, using dummies

$$\text{Restricted Model } R^2 = .76 \qquad \bar{R}^2 = .70 \qquad RSS = 50.246$$

$$\text{Unrestricted Model } R^2 = .76 \qquad \bar{R}^2 = .68 \qquad RSS = 48.043$$

$$F = \frac{(50.246 - 48.043)/4}{(48.043/57) - 15} = \frac{.55015}{1.1438809} = .4815$$

IPON and AGIA variables, using dummies

$$\text{Restricted Model } R^2 = .81 \qquad \bar{R}^2 = .79 \qquad RSS = 38.965$$

$$\text{Unrestricted Model } R^2 = .844 \qquad \bar{R}^2 = .77 \qquad RSS = 32.0629$$

$$F = \frac{(38.965 - 32.0629)/12}{(32.0629/57) - 18} = \frac{.575175}{.8221256} = .6995$$

independent variables.

5.3 Principal Components

The use of a single proxy variable for a set of collinear ones, is generally to be avoided. Dhrymes (1967), in the article reviewed in Chapter Three, suggested the use of principal components formed from the collinear variables in order to avoid problems of multicollinearity and to retain all the information in the regression. Principal components were derived for length, width, weight and depth as well as for all the variables dealing with colour that is, shade, per cent of colour, pattern, clarity and number of colours. The latter, that is variables dealing with colour, had been insignificant in the first regressions. It was thought, however, that there could be information contained in these variables that would be significant when combined. The principal components were obtained using SHAZAM, an econometric computer program developed by White (1978). The analysis of the colour variables resulted in no significant restructuring of the components and was, therefore, dropped. However, the new arrangement of the information created when a principal components analysis was run on the dimensional characteristics was very useful. The first component contained eighty-three per cent of the variation from the four variables. The second component contained only ten per cent more of the variation. Because the regression run with the first principal component did not result in increased significance for the dimensional elements it did not appear necessary to include the next principal component in any regressions. The regressions using the first (dimensional) principal component instead of length, and the other significant variables from the original logarithmic models, are shown in Tables 5.4 and 5.5 (second columns). The use of the first principal component as a proxy for all dimensional variables has not significantly altered the results and is not used in the final model, where length is selected as a proxy for the dimensional variables.

It can be stated, on the basis of these regressions and the tests performed upon them, that the type of stone and the luminance of the colour displayed are the most significant contributors to the value per carat of an opal. The other, major, factor that needs to be considered is the quality classification assigned to the gem by specialists.

TABLE 5.4: REGRESSIONS USING SIGNIFICANT VARIABLES FROM THE ALL VARIABLE LOGARITHMIC MODEL

VARIABLE	USING LENGTH AS A PROXY FOR ALL DIMENSIONAL VARIABLES EST. COEFFICIENT (ST.ERROR)	USING THE FIRST PRINCIPAL COMPONENT AS A PROXY FOR ALL DIMENSIONAL VARIABLES EST. COEFFICIENT (ST.ERROR)
INTERCEPT	4.370**	3.416**
	4 (1.135)	(0.806)
BLACK	0.859**	0.860**
	(0.318)	(0.330)
BOULDER	0.095	0.032
	(0.342)	(0.348)
PERCENT	-0.459**	-0.452**
	(0.168)	(0.169)
QUALITY	2.280**	2.214**
	(0.429)	(0.440)
LUMINANCE	1.997**	2.035**
	(0.330)	(0.331)
DIMENSION	-0.337	0.478
	(0.273)	(0.586)
R-SQUARED	.83	.81
$\bar{R}$-SQUARED	.81	.78
RESIDUAL SUM OF SQUARES	35.92	39.63

** denotes significance at the ten per cent level.

TABLE 5.5: REGRESSIONS USING SIGNIFICANT VARIABLES FROM THE AGIA VARIABLE LOGARITHMIC MODEL

VARIABLE	USING LENGTH AS A PROXY FOR ALL DIMENSIONAL VARIABLES EST. COEFFICIENT (ST.ERROR)	USING THE FIRST PRINCIPAL COMPONENT AS A PROXY FOR ALL DIMENSIONAL VARIABLES EST. COEFFICIENT (ST.ERROR)
INTERCEPT	3.386**	2.439**
	(1.005)	(0.551)
BLACK	1.062**	1.008**
	(0.387)	(0.395)
BOULDER	0.068	-0.029
	(0.453)	(0.462)
COLOURS	1.126**	1.062*
	(0.463)	(0.459)
ROUND	-0.213	-0.099
	(0.607)	(0.594)
FREE	0.437	0.453
	(0.433)	(0.442)
TEARDROP	0.921*	0.912
	(0.516)	(0.520)
QUALITY	2.853**	2.754**
	(0.522)	(0.524)
HOT	-0.277	-0.294
	(0.525)	(0.528)
BOTH	-0.119	-0.122**
	(0.433)	(0.443)
MATRIX	-0.892*	-1.027
	(0.426)	(0.394)
DIMENSION	-0.408	0.468
	(0.414)	(0.806)
R-SQUARED	.76	.75
$\bar{R}$-SQUARED	.70	.69
RESIDUAL SUM OF SQUARES	50.246	50.952

* denotes significance at the five per cent level.
** denotes significance at the one per cent level

5.4 Results

The selected estimated hedonic model for opal prices is set out below. It should be noted that the model is logarithmic.

$$\hat{P} = \underset{(1.135)}{4.370} + \underset{(0.318)}{0.859}X_1 + \underset{(0.342}{0.095}X_2 - \underset{(0.168)}{0.459}X_3$$

$$+\underset{(0.429)}{2.280}X_4 + \underset{(0.330)}{1.997}X_5 - \underset{(0.273)}{0.337}X_6$$

Where

1. $\hat{P}$=estimated log of Price (in dollars per carat)
2. X_1=Type (1 if black, 0 otherwise)
3. X_2=Type (1 if boulder, 0 otherwise)
4. X_3=log of Per Cent of Colour (expressed as a percentage)
5. X_4=log of Quality (where quality = 3 for finest gem A/B, 2 for gem A/B/C and 1 for commercial stones A/B/C/D)
6. X_5=log of Luminance (where luminance =
   4 for very high
   3 for good
   2 for medium
   1 for poor)
7. X_6=log of Length (measured in mm.)

Suppose that for a given hypothetical stone the following characteristics are inherent. The type is boulder (X_1 = 0, and X_2 = 1), it has 60(X_3 = 4.094), is of Gem quality (X_4 = 0.693), the fire (luminance) is medium (X_5 = 0.693) and the stone is 4mm long (X_6 = 1.386). The predicted price of the gem, based upon the model, is \$ 161.10 per carat.

The model was illustrated with a small sample of four light opals. The significant characteristics, the given wholesale value and the estimated value determined by the logarithmic model are given in Table 5.6. The

TABLE 5.6: AN ILLUSTRATION of the MODEL

	Stone#1	Stone#2	Stone#3	Stone#4
Type	light	light	light	light
% Colour	80	100	90	100
Quality	commercial	commercial	commercial	commercial
Luminance	good	medium	medium	medium
Length	10.34mm	12mm	10.34mm	15mm
Wholesale Value	\$ 75	\$ 80	\$ 90	\$ 75
Estimated Value	\$ 69	\$ 69	\$ 96	\$ 61

predicted wholesale value for each stone, based upon the model, is within \$ 14 of the given value. Only four stones were used, there was no variation in type or quality and little variation in the per cent of colour, luminance or length. The wholesale values are much the same or, in two instances, identical. Since the predicted values represent point estimates it is generally desirable to compute confidence intervals that represent interval estimates. These confidence intervals can be computed using the standard errors of the estimated coefficients and the estimated covariances. This, in turn, is available as a standard output from most regression packages.

5.5 Consistency in Valuations

This section assesses the responses reported in Chapter Four, Tables 4.3 to 4.5, which provide information from which the consistency of valuations performed by both experts and non-experts may be judged. The eight "experts" in the opal industry were made up of four retail and four wholesale gem merchants specializing in opals. The same gems were also presented to two sets of non-experts, as described in Chapter Four, section 4.

The value estimates made by wholesalers, retailers and both groups combined are presented in Table 5.7. Total values were used instead of per carat values for several reasons. One, comparisons to be drawn between expert and non-expert rankings would be clearer if both value estimates were in the same terms. Two, triplets are never valued by per carat weight and, therefore, would have had to be ignored. Three, because the coefficients of variation between the total value estimates and the per carat value estimates were nearly identical, the use of total value estimates has made no difference to the reporting of expert assessments. Four, it was thought to be easier for the non-expert to rank stones by total value rather than by per carat value. Five, it enables comparisons to be made between preferences and value estimates.

The fourth stone in the "master-set", a large white opal, had the greatest mean value (\$2692) and the greatest standard deviation (\$1693) in the value estimates. These figures can be attributed to the high mean value (\$3705) given it by the retail opal merchants in the study. The lowest mean value given to any of the stones was \$23 for a treated (boiled in sugar and sulphuric acid) matrix. The mean value given to this stone by the wholesalers was only \$12, but again the mean valuation over both groups was raised by the retailers' mean of \$39. It is interesting to note that the standard deviation of value estimates on this stone by the wholesalers is only \$3, whereas for the retailers it is \$23.

The experts' judgements across stones can be compared on the basis of the coefficients of variation (CV) of their valuations. These are constructed by dividing the standard deviation by the mean values. A CV of over 0.5 has been interpreted as indicating a large (or excessive) variation in the valuations. This is obviously an unsatisfactory result if one is expecting accurate or true estimates of value from the experts. Looking at the coefficients of variation for both wholesalers and retailers together the variations in value given are seen to be overly large. Seven of the gems have a CV above 0.5, and five are under 0.5. The wholesalers valuations have smaller CV's than the retailers. Only one gem, white opal number 3, has a higher wholesaler CV than the CV obtained using retailer valuations, 0.455 compared to 0.280.

These results suggest that the wholesalers will evaluate solid, natural, black or light gems relatively equally. Created gems, whether treated, triplet or synthetic, will be valued less consistently. The wholesalers' familiarity with the boulder opal does not seem to be

TABLE 5.7: FIGURES BASED UPON EXPERT VALUATIONS

WHOLESALERS

STONE NO.	MEAN VALUE	STANDARD DEVIATION	COEFFICIENT of VARIATION
# 1	2419	477	0.197
# 2	1006	110	0.110
# 3	1221	556	0.455
# 4	1680	651	0.387
# 5	101	34	0.339
# 6	12	3	0.250
# 7	525	266	0.507
# 8	110	22	0.199
# 9	35	21	0.606
# 10	72	13	0.175
# 11	78	18	0.225
# 12	58	6	0.110

RETAILERS

STONE NO.	MEAN VALUE	STANDARD DEVIATION	COEFFICIENT of VARIATION
# 1	2399	2146	0.894
# 2	679	75	0.110
# 3	1641	460	0.280
# 4	3705	1880	0.507
# 5	96	75	0.785
# 6	39	23	0.576
# 7	577	298	0.517
# 8	144	47	0.328
# 9	30	23	0.760
# 10	62	79	1.272
# 11	78	47	0.602
# 12	97	106	1.090

WHOLESALERS AND RETAILERS TOGETHER

STONE NO.	MEAN VALUE	STANDARD DEVIATION	COEFFICIENT of VARIATION
# 1	2409	1439	0.597
# 2	842	195	0.232
# 3	1431	523	0.365
# 4	2692	1693	0.629
# 5	98	54	0.554
# 6	23	18	0.787
# 7	551	263	0.478
# 8	130	40	0.307
# 9	32	20	0.631
# 10	66	57	0.856
# 11	78	35	0.445
# 12	84	85	1.006

as great as with the other natural opals and it may be for this reason that it is subject to less accurate evaluation.[4] Of the gems in the "master-set", the experts expressed the most difficulty with one of the boulder opals, number 7, and with the synthetic stone, number 9. By turning back to the total value estimates given for the boulder we can see that the large coefficient of variation given by both groups is due to four merchants pricing the gem around $250 and the other four around $700. The Gilson triplet was usually recognized as "odd" or "unusual" but was not always recognized as a synthetic.

The valuations given by the retailers highlight the inefficient distribution of information in the industry. That is, although the same gem is being assessed by retailers and wholesalers there is an inconsistency in the valuations between the groups and even within groups. The discrepancy seems to occur because different merchants ascribe different values to the characteristics they perceive. Coefficients of variation over 1.0 (triplet number 10 at 1.27 and boulder number 12 at 1.09) should never occur in an efficient market. Only three stones had retailers' CV's less than 0.5. (Crystal number 2 , white number 3 and treated number 8.) All three of these stones were of a high quality for their type, but other high quality stones were not assessed as accurately by the group as a whole. Retailer valuations seem to be highly variable. More information about the values of inherent characteristics in the opal must be made available if market efficiency is to be improved at all.

Comparisons between the experts' value orderings and between expert and non-expert value orderings were made as a further test of the market's informational efficiency. It is also of interest to compare the non-experts value orderings with their preference rankings. Friedman's analysis of variance test[5] was used to confirm the hypothesis of a definite structure among the value orderings given by experts. The null hypothesis in this case, was that there would be no structure in the experts' rankings. The calculated $\chi^2 = 37.86$ which was significant at the one per cent level. The null hypothesis was, therefore, rejected. The fact that the experts can and do recognize the relative value of opals yet do not ascribe the same value to the gems is a symptom of an inefficient information flow in the market.

There was no apparent difference between the two groups of non-experts in their ability to accurately evaluate opals. Some non-experts had a slight advantage over others in that they understood that triplets are created gems and could separate them from the other stones, however this advantage is not reflected in their final value ordering.

Non-experts cannot be expected to have as strong a value ordering as the experts but it was hoped that they would be able to rank the gems fairly accurately by relative value. The null hypothesis was, again, that no structure exists in the value ordering. As a result of the Friedman's two-way analysis of variance test the χ^2 was calculated to be 19.3787 and the null-hypothesis is rejected, but only at the ten per cent level of significance.[6] By contrast with their value orderings, the non-experts exhibit no structure in their preference rankings. The calculated χ^2 on tests of non-expert preference rankings is 13.5325.

The two-way analysis of variance test assumes equal variance between items in the

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[4] The lack of familiarity with the boulder opal is probably due to the relatively recent release of these stones into the New South Wales market.

[5] see Daniel and Terrell (1979) *Business Statistics* pp410:440

[6] The hypothesis cannot be rejected at the 5% level of significance but considering the group being analyzed, ie. non-experts, the implied structure at the 10% level of significance is great enough to justify rejecting the null hypothesis.

data set. This assumption does not hold when comparing expert's and non-expert's value ordering or when comparing the non-expert's value orderings and preference rankings. A non-parametric test was selected to perform these analyses. Spearmans rank correlation,

$$r_s = \frac{1 - 6d_i}{n^2 - 1}$$

where d_i = the difference in ranks, and n = the number of observations, was used to compute test statistics for the correlation between the preference ranking and the value ranking assigned by non-experts (see Table 5.8). Only one individual, from the second group of non-experts, displayed any significant correlation between preference ranking and value ranking and this was a negative correlation. Another individual had a significant positive correlation between value rankings and the value rankings of the wholesalers. No other correlations were significant between preferences and value or between non-expert and expert value rankings.

The existence of a structured ordering in the values assigned by the experts, coupled with the fact that their estimated values for each opal vary considerably, implies that the information between experts about the relative value of gemstones is adequate but this information either does not reach the consumer or else other market inadequacies create the conditions which allow the observed price variation. Consumer ignorance is attested by the lack of correlation between expert and non-expert value orderings. The implications of this for the marketing of opals are disscussed in Chapter Six, section four.

5.6 Summary

A number of linear and logarithmic models were tried, using characteristics from the combined certificates of appraisal to explain the variations in price that are due to variations in inherent characteristics. A logarithmic regression model using dummy variables for shade, shape, and type was selected from these. The statistically significant characteristics, according to the model, are type, per cent of colour, quality, luminance and length. An F-test on the logarithmic model containing all characteristics confirms that the excluded variables are not significant. Those variables which are significant contributors to value were combined to create the selected estimated logarithmic model for opal prices, ie.:

$$\begin{aligned}\hat{P} = \underset{(1.135)}{4.370} + \underset{(0.318)}{0.859X_1} + \underset{(0.342)}{0.095X_2} - \underset{(0.168)}{0.459X_3} \\ + \underset{(0.429)}{2.280X_4} + \underset{(0.330)}{1.997X_5} - \underset{(0.273)}{0.337X_6}\end{aligned}$$

where the variables are defined in section 5.4.

This chapter, additionally, reports on the results of analysis of variance tests by which expert and non-expert value orderings were shown to be structured. Using Spearman's rank correlation tests it was found that no correlation existed between non-expert value orderings and preferences, nor between expert and non-expert value orderings. Although experts are aware of the relative value of different types of opals there is significant variation in the actual valuations of individual stones. Non-expert valuations, while internally structured, bear no correlation to those of the experts.

TABLE 5.8: SPEARMAN CORRELATION COEFFICIENTS

	P	E1	E2		P	E1	E2
V1	.0839	.4476	.3833	V2	.0210	.4406	-.2167
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.398	SIG.072	SIG.154		SIG.474	SIG.076	SIG.288
V3	-.2867	.1189	.3333	V4	-.1329	0.0	.1000
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.183	SIG.356	SIG.190		SIG.500	SIG.399	
V5	.1259	.2587	.6667	V6	.2448	-.4406	-.2500
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.348	SIG.208	SIG.025		SIG.222	SIG.076	SIG.258
V7	-.0350	.2238	.3667	V8	.8476	.7343	.3500
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.457	SIG.242	SIG.166		SIG.000	SIG.003	SIG.178
V9	.0210	.4476	.6833	V10	.1331	.1538	.2500
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.474	SIG.072	SIG.021		SIG.340	SIG.317	SIG.258
V11	.1399	-.4895	-.1000	V12	-.0210	.1259	.5167
	N(12)	N(12)	N(9)		N(12)	N(12)	N(9)
	SIG.340	SIG.053	SIG.399		SIG.424	SIG.348	SIG.077
V13	-.5315	.6364	.5667				
	N(12)	N(12)	N(9)				
	SIG.038	SIG.O13	SIG.056				

- V1 to V13 are non-expert value orderings
- P represents non-expert preference rankings
- E1 represents wholesale expert rankings
- E2 represents retail expert rankings

CHAPTER SIX
CONCLUSION

6.1 Introduction

This dissertation has been directed toward developing a simplified pricing model for opals so that the information needed to properly assess the gem can be more widely disseminated. The limited information available to those interested in the opal industry and the fragmented nature of the market have done little to promote its efficiency. Opal export contributes significatly to the nation's economy, making up 0.1% of all Australian exports, at a total value of $24,968,000 p.a. yet there has never been a consistent opal nomenclature developed to provide an accurate means of judging the value of individual gems. Because the development of a pricing formula based on a consistent nomenclature will provide a means for improving the efficiency of the opal industry, this study is justified.

6.2 Summary of the Chapters

A review of literature on the opal industry, elaborated in Chapter Two, indicated that very little analytical work has been undertaken on opal pricing or on the industry in general. This lack of information extends not only to the general public, but throughout the various levels of the industry. The opal market is, therefore, inefficient and fragmented. The wholesalers, because they possess information, dominate the industry. Chapter Three offers a review of the literature on the hedonic technique demonstrating its applicability to the problem of pricing a single commodity made up of multiple inherent parts or characteristics. Hedonic regressions are not new having been applied by Griliches (1971) and Dhrymes (1967) among others. The method has been used to analyze a broad range of heterogenous goods from automobiles to housing and air quality. Although the technique has never been previously applied to opals, the unique combination of qualitative and quantitative characteristics inherent in each stone make this method an appropriate choice for developing an opal pricing model. The selection of logarithmic over linear or log-linear models was analyzed by Abelson (1979) and by Rosen (1974). Rosen proved that when arbitrage could not be performed in regards to individual characteristics, the logarithmic model is to be preferred over any other.

The data sets, described in Chapter Four, consist of fifty-eight combined certificates of appraisal which depict the qualities of fourteen characteristics for each of fifty-eight stones appraised. The certificates were filled out by retailers and wholesalers with both groups providing the wholesale, per carat value of each gem. Additionally a "master-set" of twelve opals were evaluated by both experts and non-experts so that data existed on their respective value orderings as well as on a set of non-expert preference rankings.

Chapter Five developed a pricing model for opals. The logarithmic model was selected after a number of trials for it provided a better explanation of the variation in prices than did the other models. This selection was justified by an L-test which confirmed the advantage of the logarithmic model. The logarithmic model;

$$\ell\mathrm{n}\hat{P} = 4.370 + 0.859X_1 + 0.095X_2 - 0.459\ell\mathrm{n}X_3$$

$$+2.280\ell\mathrm{n}X_4 + 1.997\ell\mathrm{n}X_5 - 0.337\ell\mathrm{n}X_6$$

is based upon five significant characteristics, type(X_1, X_2), per cent of colour (X_3), quality (X_4), luminance (X_5) and length (X_6). It includes a negative estimated coefficient for per cent of colour and length. The negative estimated coefficient for per cent of colour is probably a sample specific result. Had there been enough gems to test each variety of opal separately this coefficient would be expected to be positive for light stones. The negative coefficient for the length of the opal was to be expected, for, as the size increases the price per carat declines.

The model was illustrated using four light opals provided by a local retailer. The retailer gave the wholesale cost of each gem before taxes and, in each case, the predicted value was within fourteen dollars of the given value. The model needs to be tested using a greater variety of gems with a broader range of characteristics.

The results of the non-parametric tests reported in this chapter are discussed in the next two sections.

6.3 Implications for Pricing

Relative value orderings among experts showed a definite structure. This indicates an awareness on their part of the relative value of individual gems. The variance in actual estimated values is, however, great. The retailers, especially, seem not to have ready access to pricing information. The value ordering by non-experts, although internally structured, had no correlation with that of the experts. This lack of consumer knowledge seems to give the retailer *carte blanche* to set prices arbitrarily. This is reflected in the very broad range of markups used by retailers. These markups are from twenty-five to three hundered per cent or more (Cornelius 1984).

Consistency in valuations could be promoted by the application of a simple estimated pricing index, as in the model above. This should result in smaller variations between prices for specific types of stones. Knowledge distributed more evenly throughout the industry would decrease the possibility of achieving abnormal profits, but this should be offset by an increased throughput due to increased consumer demand. More reliable opal pricing and some stability in the prices over time should also, given the assumption of economic rationality, give rise to a significant correlation between preference and value as ascribed by the general public; a correlation that does not currently exist.

6.4 Implications for Marketing

The non-parametric tests were used not only to test the correlations between valuations performed by the two groups of experts but between experts and non-experts. Additionally tests were run to find any correlations between non-expert preferences and value rankings. The results of these tests, if noted in the industry, should lead to an altered approach to marketing the opal. These results indicated an ignorance, on the part of consumers (non-experts) to the value structure as it was given by the experts. There was no correlation between the non-expert and expert value orderings nor between the non-expert preference ranking and the expert value ordering.

As with any other commodity the consumer must be educated about the opal. Diamonds are an excellent example of the role consumer education can play in influencing the market. Through advertising most laymen are aware of the "four C's" of diamond valuation, colour, clarity, cut, and carat weight. Ask the average non-expert about opals, however, and the responses are varied and ill-informed. In fact, many consumers are not even aware that the opal is a precious stone and are amazed to learn how valuable some of the gems may be. The first, necessary step, indicated by this research, is a campaign aimed at educating the consumer to the significant characteristics which contribute to an opals value.

6.5 Limitations of the Study

There were an insufficient number of gems in the sample to perform the tests by type and, therefore, certain assumptions have had to be made in regard to some of the significant results. For example, the negative coefficient associated with per cent of colour has been explained by a reference to opal type and, while the explanation is confirmed by an experienced and respected wholesaler, it has not been tested.

The limited sample size also made it necessary to exclude some characteristics which may have contributed to value. Extremely rare patterns such as the harlequin, could and probably do contribute to value. The rarity of these has prevented this characteristic from being included in the sampled gems and has, therefore, been left untested.

Another characteristic, the origin of the gem, was also dropped in this study because the types of the sample stones were perfectly correlated with origin. A larger sample with gems of the same variety but mined from many separate fields would have allowed this characteristic, too, to be tested. A study of one type of opal using gems from many different fields or even countries of origin may discover that this factor contributes to the inherent value of the gem, as some experts believe. With the data available herein "type" could be replaced with "origin" and have equally consistent results.

Finally, no time series data were available, a fact which restricts any effective forecasting from this model. Despite this the relative value of the characteristics should remain stable and the model valid at least in the short run. However, no proof of the model's stability over time exists.

6.6 Implications for Future Research

The opal industry, despite its contribution to the Australian economy, has seldom been studied. This is due, in large part, to the lack of data available to researchers. Greater access to data would allow the estimated pricing model given in this study to be refined. Access to data would create the possibility of time series analysis and allow the forecasting of prices. Additionally, the use of time series data would enable investors to compare opals with other investment options in collectibles such as coins or stamps. If ways could be found to circumvent the data collection difficulties then stability tests of static models and/or a time series appraisal could build better pricing models.

The elasticity of substitution between opals and other coloured gemstones is high. It would be interesting to examine the information available to consumers about sapphires, emeralds, or rubies compared to that available on opals. Relationships between the opal market and other gem markets could also be studied. This research has touched, in a limited fashion, an area in which a great number of questions are yet to be answered.

APPENDIX A

Specimen Opal Certificates
AGIA and IPON

the australian gem industry association ltd

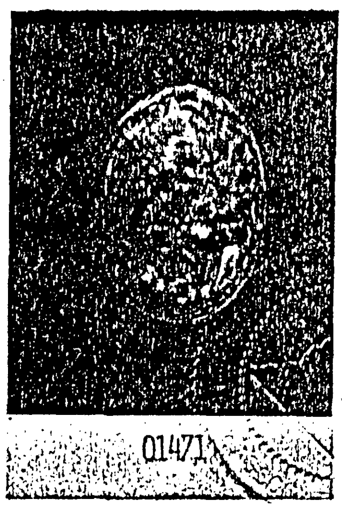
opal certificate

01471

laboratory report

Sydney, February 21, 1985

DESCRIPTION	:	SOLID OPAL
VARIETY	:	CRYSTAL
ORIGIN	:	LIGHTNING RIDGE (NEW SOUTH WALES)
WEIGHT	:	6.14 cts.
DIMENSIONS	:	15.00 x 11.00 x 5.50 mm
COLOUR	:	BRILLIANT/GREEN BLUE UNDERTONE
COLOUR PROPORTION	:	100%
SHAPE	:	OVAL
CABOCHON	:	HIGH
PATTERN	:	BROAD
FINISH	:	VERY GOOD
QUALITY	:	GEM B



this certificate is issued & authorised by the A.G.I.A.

[redacted]

g.p.o. box 1067 sydney n.s.w. australia 2001
g.p.o. box 164 unley south australia 5061

Certificate of the Australian Gem Industry Association Limited

The Australian Gem Industry Association Limited ("AGIA") has been asked to appraise the gem.

This certificate is submitted by AGIA and accepted by AGIA's client ("the client") upon and subject to the following terms and conditions:

1. AGIA has examined the gem carefully with specialised instruments and has prepared this certificate on the gem to the best of its knowledge and professional standards.
2. AGIA's opinion as to the finish grade of the gem is based on its degree of excellence of colour, polish, symmetry, proportion and finish.
3. The client recognises and accepts that as opinions on the characteristics of gems may vary neither AGIA nor any member of AGIA's committee or staff shall at any time be held liable for any different appraisal made of the gem as a result of other opinions, or other grading methods being applied, or otherwise.
4. The client recognises and accepts that this certificate is not a valuation of the gem but is only AGIA's appraisal of the gem in respect of matters noted in this certificate and does not constitute any guarantee or warranty as to the value of the gem.
5. AGIA expressly disclaims any liability to the client and to any other party in respect of the opinions expressed in this certificate.

Vocabulary

Description	:	Solid	Doublet Laminate	Triplet Laminate	
Variety	:	Natural Matrix White (Light) Crystal	Treated Matrix Dark Boulder	Black (Dark) Light Boulder	
Origin	:	Lightning Ridge Queensland Andamooka Coober Pedy Mintabie Other	New South Wales South Australia South Australia South Australia		
Weights	:	Carats			
Dimensions	:	mm x mm x mm			
Colour	:	Brilliant	Strong	Medium	Weak
Colour Proportion	:	%			
Shape	:	Oval	Round	Freeshape	
Cabochon	:	Very High	High	Medium	Low	N/Applicable
Pattern	:	Fine	Medium	Broad	
Finish	:	Very Good	Good	Fair	Poor
Quality	:	Finest Gem A/B	Gem A/B/C	Commercial A/B/C/D	
Remarks	:				

OPAL CERTIFICATE
OF AUTHENTICATION

issued by

TWD Gemmological Laboratories Sydney Australia

Established to meet 100% International Gemmological Standards*

Laboratory Certificate No. SPECIMEN

This examination has been scientifically carried out by a Gemmologist/I.P.O.N. licensed Opal Grader.

Classification: ONE NATURAL SOLID BLACK PRECIOUS OPAL

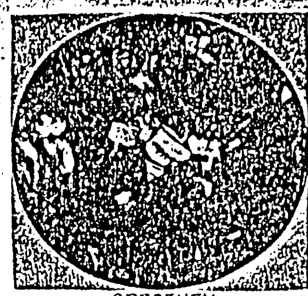
Weight (CT): 11.29 CARAT

Measurements: 21.93mm X 20.90mm X 6.50mm

GRADE		POINTS
A Type and Backing	BV	-0%
B1 Fire and Fire Range	RM	1000
B2 Luminance and Clarity	VG	6400
B3 Pattern and Distribution	HFG	3200
B4 Cut and Proportion	RV	1000
POINTS TOTAL:		11600

C RARITY GRADE VVR 3

COMMENTS:



Date:

SPECIMEN
Gemmologist

*Fully accredited laboratories to authenticate and certify Opals in accordance with I.P.O.N. (International Precious Opal Nomenclature) accepted world wide.

ORIGINAL TWD Gemmological Laboratories Sydney Australia

International Precious Opal Nomenclature Certificate
(I.P.O.N.)

A-1 Type

Black	Semi Black	Boulder	Black Crystal	White Crystal	White
X					

A-2 Backing

Very Good	Good	Medium	Poor
X			

Percentage Variation %

B-1 (I) Fire

Red	Orange	Yellow	Green	Blue	Violet
X					

(II) Fire Range

M = Multifire X
S = Semi Multifire

Maximum Points 1000

B-2 (I) Luminance

Very High	Good	Medium	Poor
X			

Maximum Points 8000

(II) Clarity

Very Good	Good	Medium	Poor
	X		

B-3 (I) Pattern

Harlequin	Rolling Flash	Flash	Pinfire
X		X	

Maximum Points 4000

(II) Distribution

Very Good	Good	Medium	Poor
	X		

B-4 (I) Cut
(II) Proportion

Very Good	Good	Medium	Poor
O			

Maximum Points 1000

C RARITY GRADE

Exc	V. Very Rare			Very Rare			Rare			Medium Rare		
	1	2	3	1	2	3	1	2	3	1	2	3
				X								

Maximum Points 14000

SPECIMEN
Gemmologist

TWD Gemmological Laboratories Sydney Australia

APPENDIX B

The Combined Certificate
of Appraisal

CHARACTERISTICS TO BE WEIGHTED: FROM AGIA SPECIFICATIONS

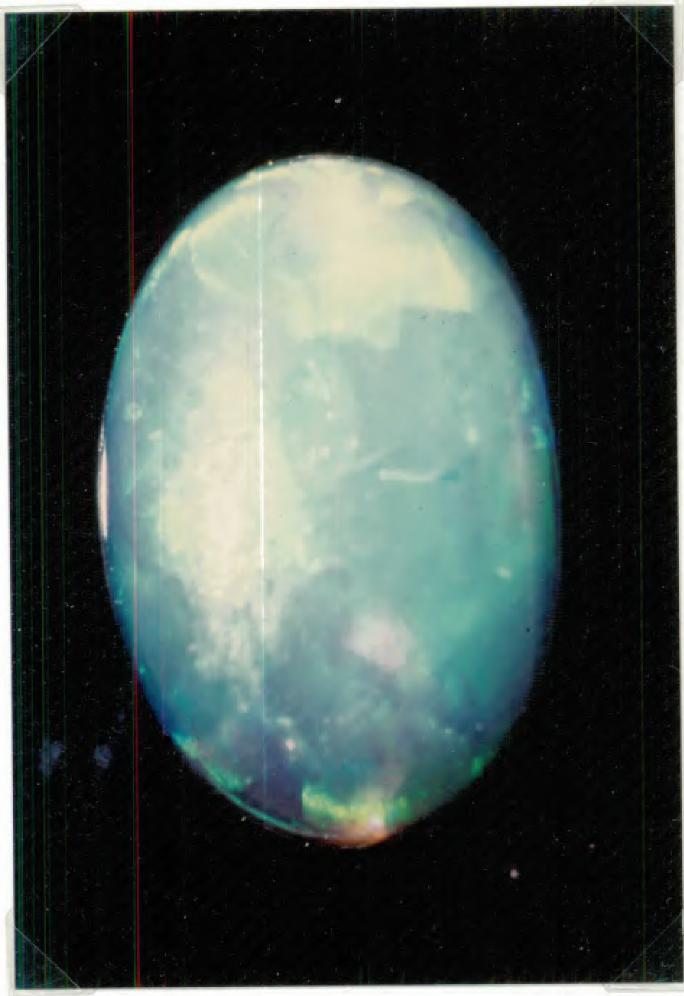
1. DESCRIPTION:all solids
2. VARIETY:
3. ORIGIN:
4. WEIGHT:
5. DIMENSIONS:
6. COLOUR:
7. COLOUR PROPORTION:%
8. SHAPE:oval, round, teardrop, freeshape
9. CABOCHON:very high,high,medium,low,n/applicable
10. PATTERN:fine, medium, or broad
11. FINISH:very good, good, fair, poor
12. QUALITY:finest gemA/B,gemA/B/C,commercial A/B/C/D

ADDITIONAL CHARACTERISTICS: FROM IPON SPECIFICATIONS

1. BACKING:%potch
2. LUMINANCE:very high,good, medium, poor
3. CLARITY:(inclusions)very good,good,medium,poor
4. RARITY:exceptional,very very rare,very rare,rare,not rare

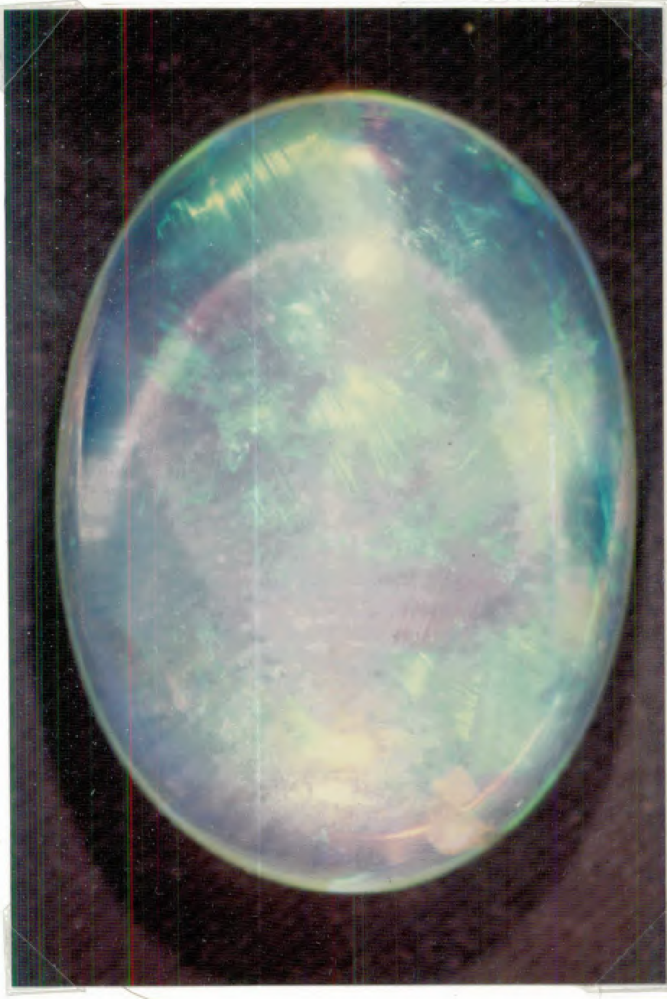
APPENDIX C

Photographs

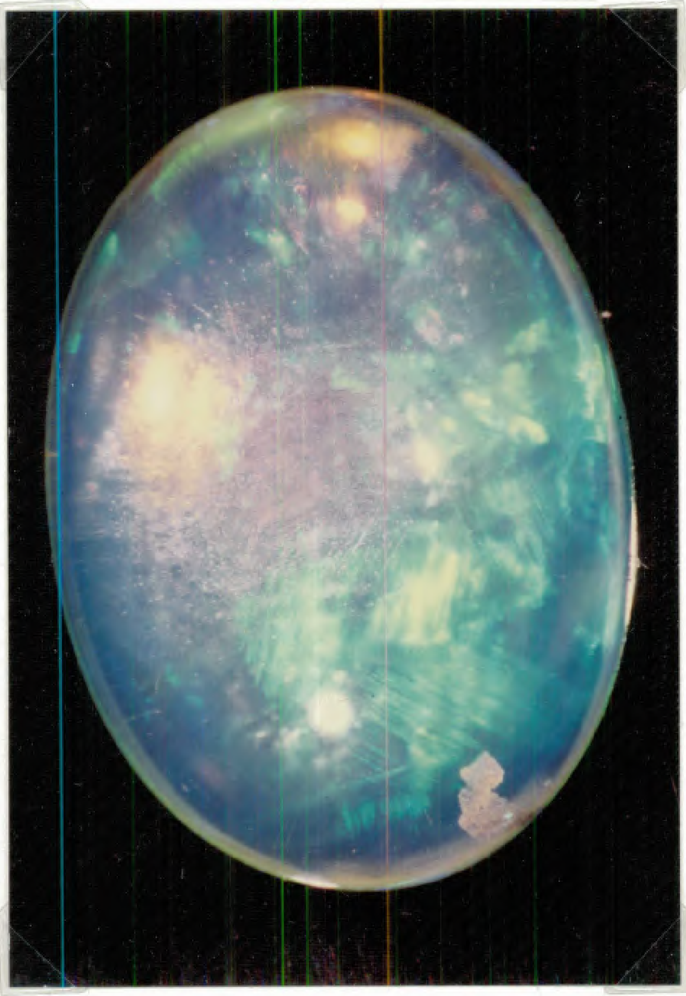


#1 BLACK OPAL 2.15 carats 11.2x7.7x4.2

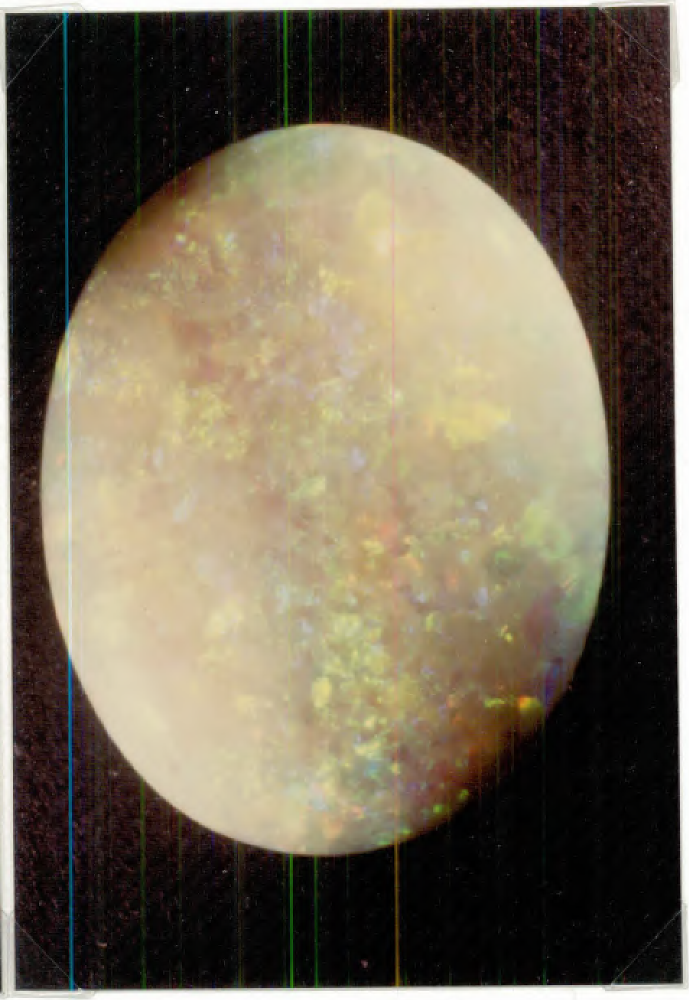
#1 BLACK OPAL 2.15 carats 11.2x7.7x4.2



#2 CRYSTAL OPAL 6.14 carats 15x11x5.5

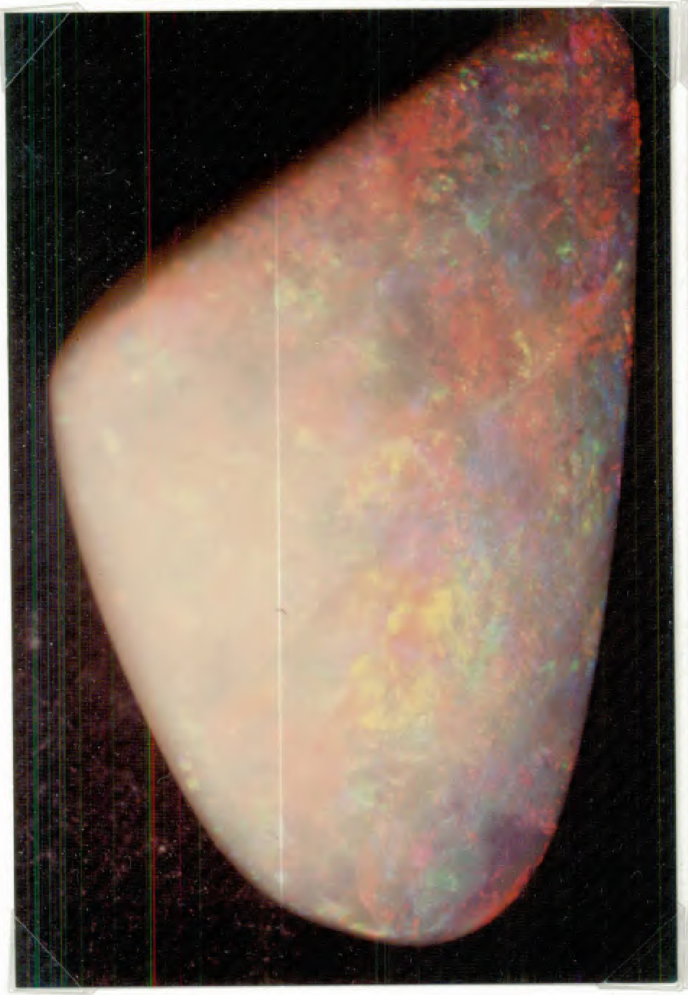


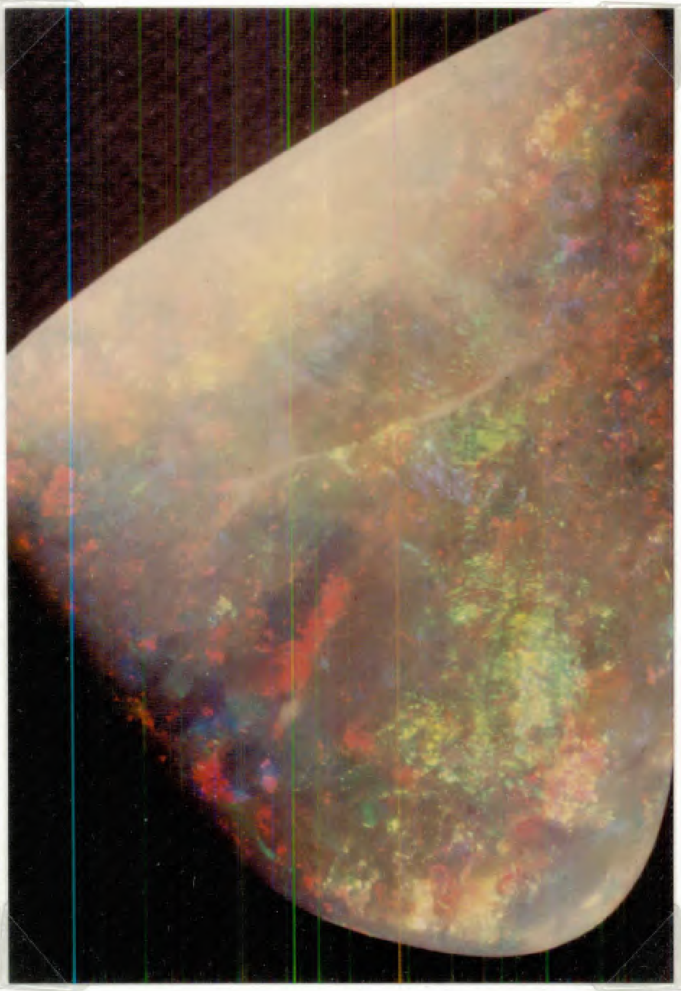
#2 CRYSTAL OPAL 6.14 carats 15x11x5.5



#3 WHITE OPAL 16.10 carats 25x19.2x5.2

#3 WHITE OPAL 16.10 carats 25x19.2x5.2

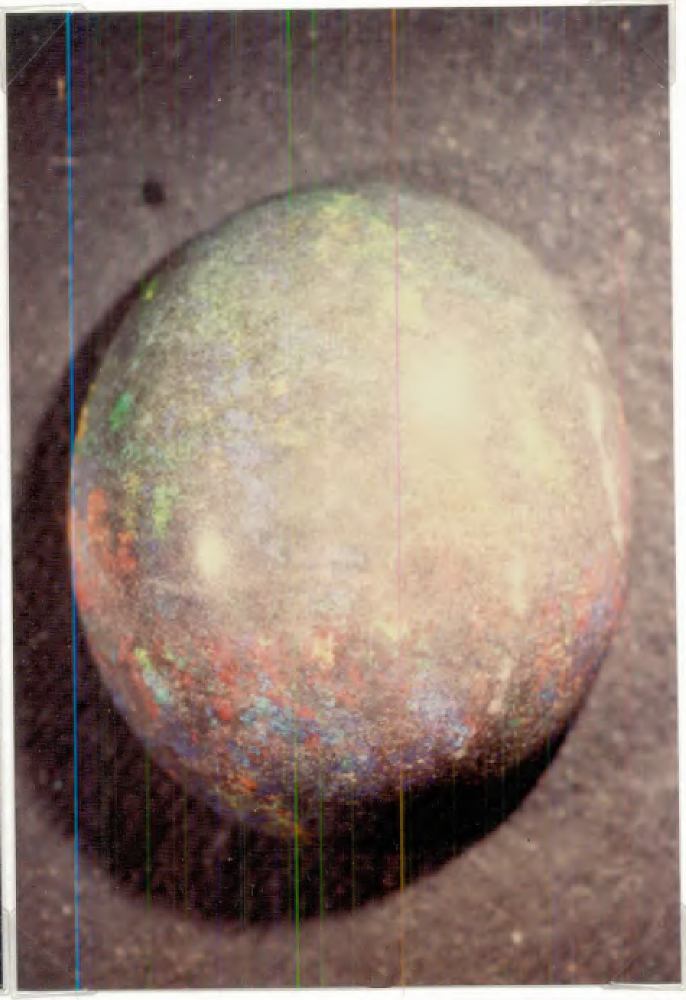




#4 WHITE OPAL 34.46 carats 33.9x25.3x7.6

#4 WHITE OPAL 34.46 carats 33.9x25.3x7.6

#5 TRIPLET-21.9x11.8x4.8



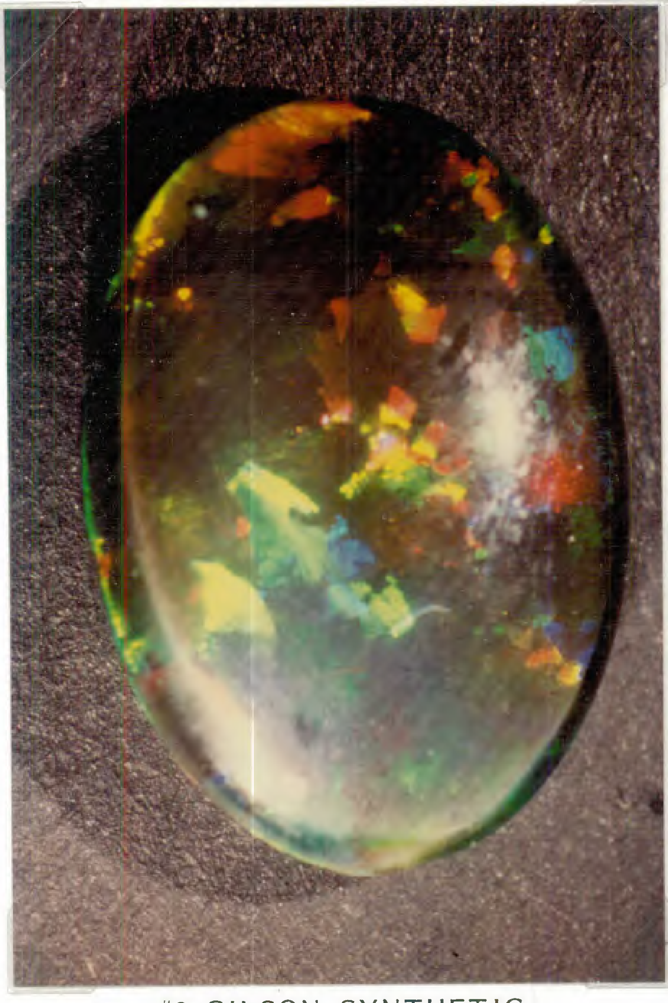
#6 TREATED MATRIX 3.25 carats 12.2x10.2x4.7

#7 BOULDER OPAL 17.34 carats 24.8x10.9x6.5

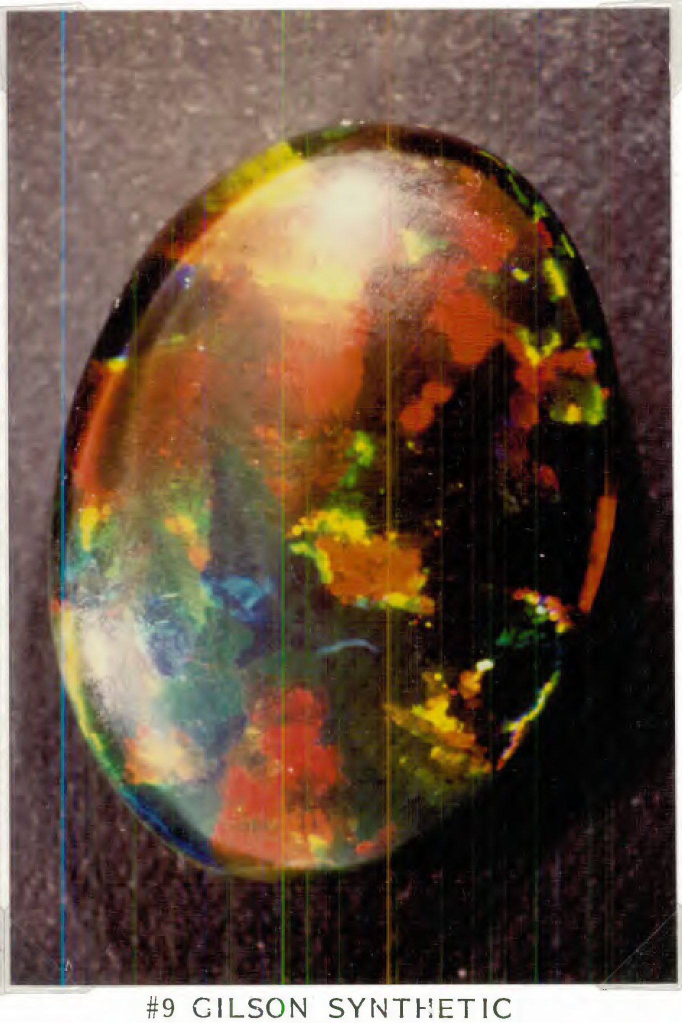
#7 BOULDER OPAL 17.34 carats 24.8x10.9x6.5

#8 TREATED MATRIX 6.27 carats 18x13x4.5

#8 TREATED MATRIX 6.27 carats 18x13x4.5

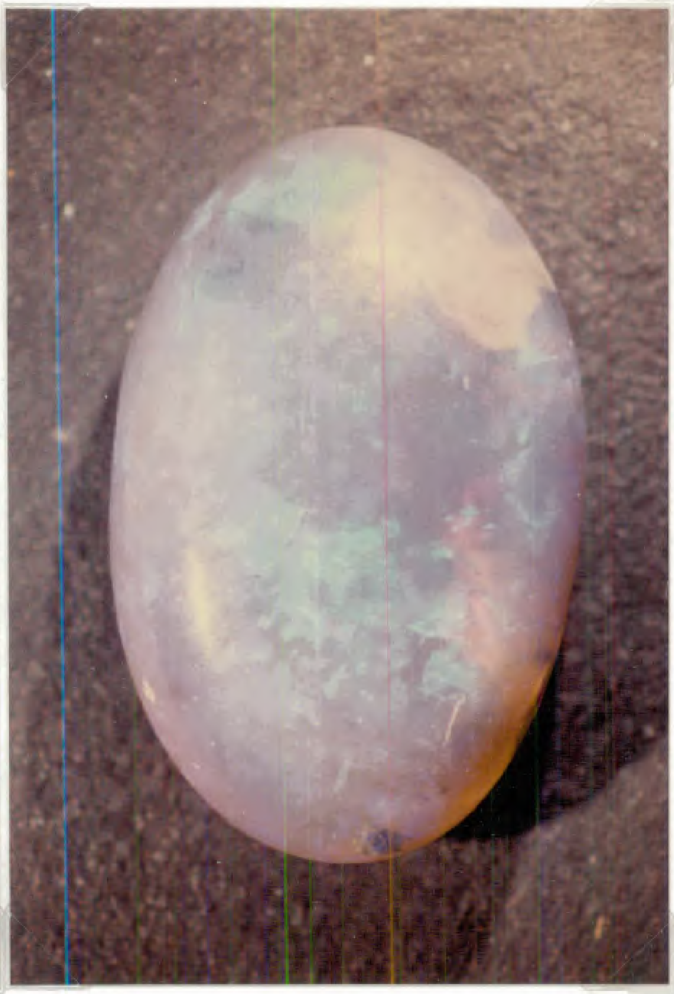


#9 GILSON SYNTHETIC TRIPLET-14x10x4

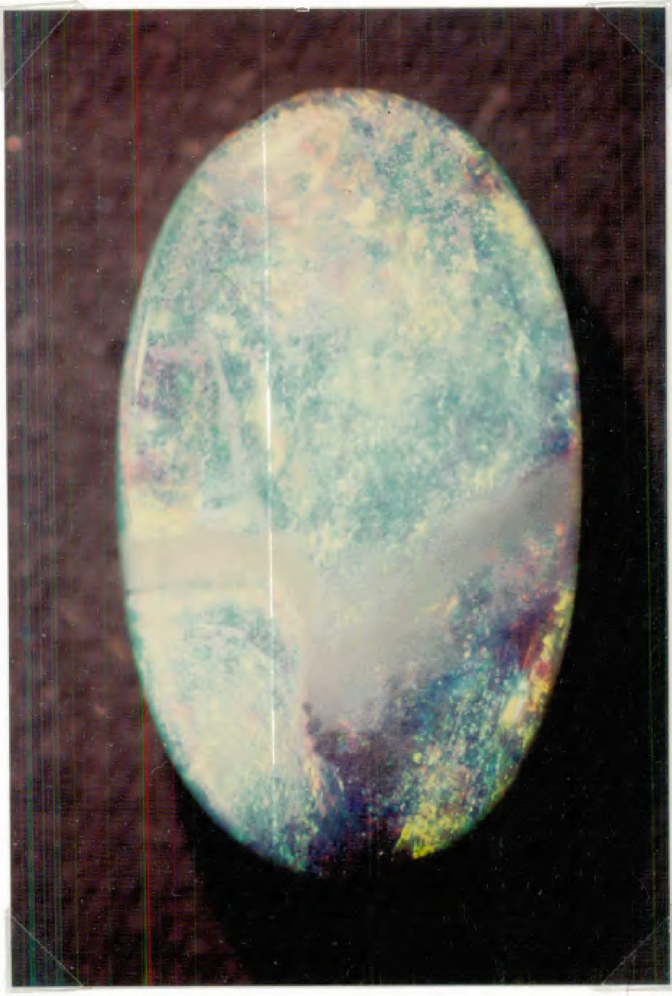


#9 GILSON SYNTHETIC TRIPLET-14x10x4

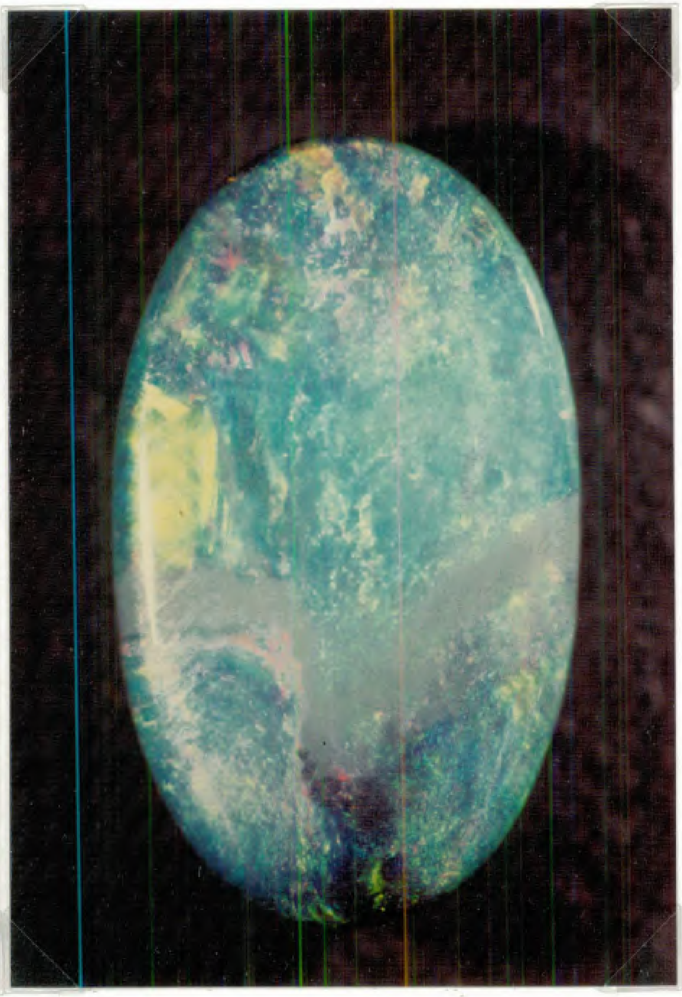
#10 TRIPLET-20x15x4



#11 BLACK JELLY OPAL 2.31 carats 12x7.7x4.5



#12 BOULDER OPAL 1.78 carats 10.3x6x3



#12 BOULDER OPAL 1.78 carats 10.3x6x3

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