Measuring Exploration Success: An alternate to the discovery-cost-per-ounce method of quantifying exploration effectiveness

Deborah Lord[1], Mike Etheridge[2], Marcus Willson[3], Greg Hall[4], Phillip Uttley[5]

1 SRK Consulting Australasia PO Box 943, West Perth, WA 6872 AUSTRALIA dlord@srk.com.au

2 SRK Consulting Australasia PO Box 422, Milsons Point, Sydney NSW 2061 AUSTRALIA.

3 Placer (Granny Smith) Pty Limited PO Box 33, Laverton, WA 6440 AUSTRALIA

4 Placer Dome Asia Pacific PO Box 764, Cloverdale, WA 6985 AUSTRALIA

5 SRK Consulting Australasia PO Box 250, Deakin West, ACT 2600 AUSTRALIA

Abstract

SRK Consulting is researching and developing a range of methods for **assessing and managing exploration risk, progress and value.** As part of the research, a collaborative project was undertaken with Placer Granny Smith (the operating company of the Granny Smith Joint Venture owned by Placer Dome Asia Pacific 60% and Delta Gold 40%) and Placer Dome Asia Pacific, to review and quantify exploration success in a mature program that has delivered several mines. In particular, an objective was to develop a measurement technique that is more commercially robust and informative than the traditional 'cost per resource ounce discovered' method.

The project reviewed gold exploration over the past 13 years in the Laverton District of Western Australia (Figure 1). Placer Granny Smith has spent AUD$52 million (around US$30 million at recent exchange rates) defining 12 deposits with combined resources of more than 10 million ounces (310 tonnes) of gold. Exploration centered on the Archean Granny Smith Gold Deposit, and was primarily targeted at outlining additional resources to feed through the Granny Smith Mill. At an overall cost per resource ounce of less than US$3, this has clearly been a successful program. However, our analysis demonstrates that this figure fails to provide a complete value picture, and that the program could have delivered even greater value to the participating companies.

While the quantitative results of the review are specific to the Laverton District, the methodology can be applied to near-mine, advanced and grassroots exploration programs for any deposit style in any geological environment. Key outcomes of the review are as follows:

- Measuring exploration success in terms of the NPV of the deposit outlined produces a markedly different and arguably more commercially realistic outcome to measuring it in relation to the average cost of resources defined.

- Early recognition and prompt drill testing of key targets is critical in optimizing opportunities and realizing exploration value. Indeed, the principal destroyer of value in exploration is spending too much time and money prior to drill testing the best targets in any area.

- Continual and robust ranking of exploration targets should be undertaken. Exploration should aim to rapidly identify and systematically test the best exploration targets, rather than systematically exploring the project areas.

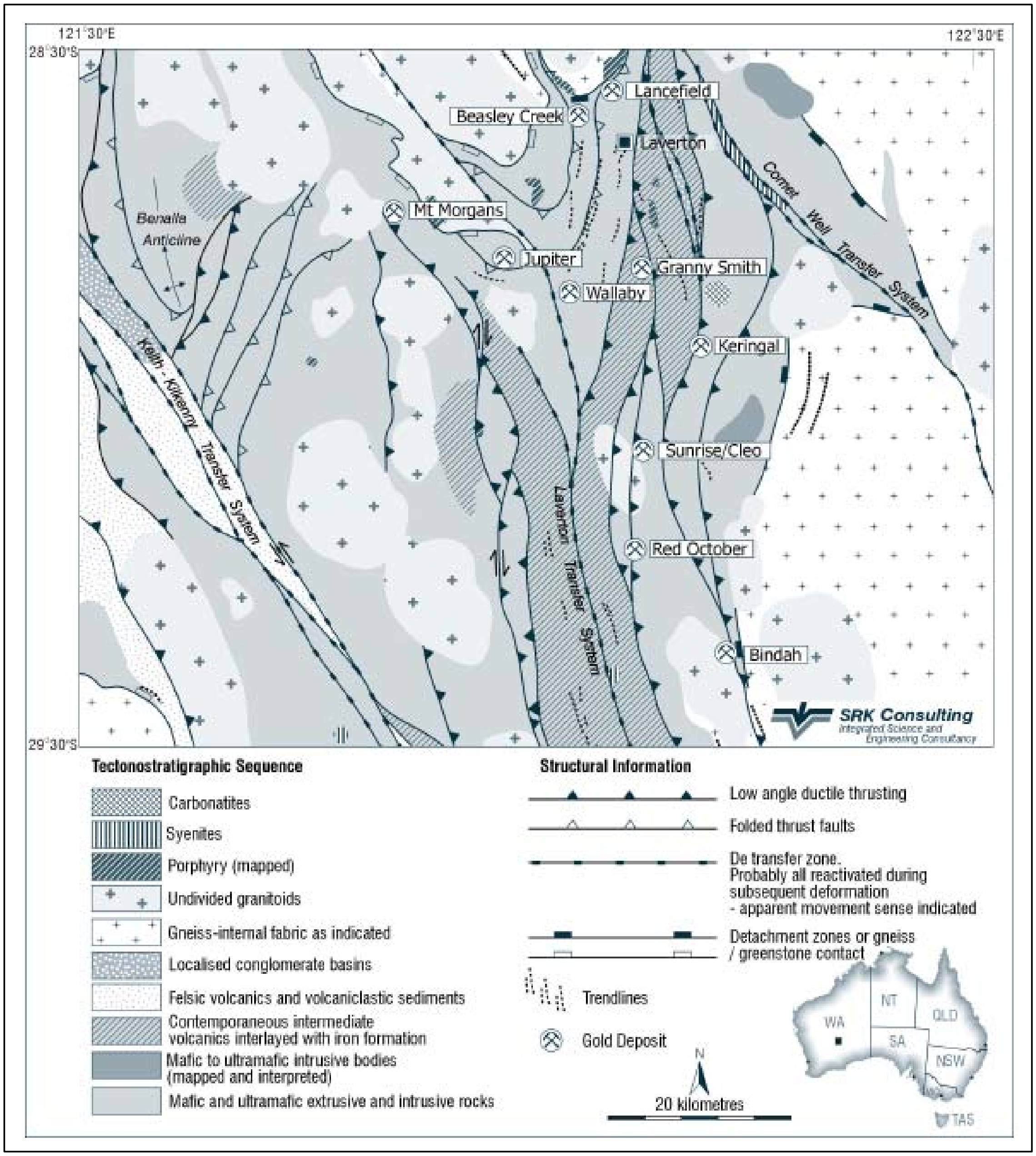

Figure 1. Regional geology of the Laverton District of Western Australia showing principal gold deposits, owned by various companies. Solid geological interpretation is modified from SRK Consulting multi-client product (1999).

Especially in the current climate of a depressed resources sector, the exploration industry needs to compete aggressively for the investor's dollar. The industry needs more robust and quantitative methodologies for measuring exploration effectiveness, and for informing management, investors and shareholders of exploration risk, reward, value and progress to discovery. SRK's probabilistic methods provide such a framework.

Introduction to the methodology

A method to measure exploration risk, progress and value

Mineral exploration is essentially an economic activity (Etheridge and Henley, 1997; Dummett, 2000; Singer and Kouda, 1999; Mackenzie, 1998), and as such it must deliver tangible value to its investors. However, because of the long lead times for discovery, it is difficult to measure that value and report on progress at the more conventional business reporting time scales. This difference in value generation and reporting time scales is one of the fundamental barriers to effective strategic planning, management and communication between the practitioners of exploration and their corporate managers and investors.

SRK Consulting has been developing a range of probabilistic risk assessment and management tools for mineral exploration, and these methods are being extended to the measurement and communication of exploration progress and value in language that is much more commercial than technical. The underlying methodology is very similar to that which is commonplace in the petroleum exploration industry and a number of other high-risk business endeavors.

The particular objectives of the study described here and undertaken with Placer Granny Smith were as follows:

1. To use the extensive records of exploration programs, methods, models and expenditure in the Placer Granny Smith files to build a comprehensive case study of the relations between exploration risk, progress, decision points and value creation over a large, long term and successful program.

2. To compare the more and less successful projects within the overall exploration program, particularly to identify where alternative decision strategies and risk management practices may have influenced the value delivered to the stakeholders.

3. To analyze the relationships between expenditure, resource ounces discovered and real commercial value delivered by the different projects and the program overall.

Estimating value at any stage of exploration

One aspect of our risk assessment methodology **involves relating the probability of exploration success to the value of the target sought** to estimate the technical value of an exploration project at any stage in its progress. The measure most commonly used to provide the target value is the Net Present Value (NPV) of the threshold resource that has to be delivered for a particular deposit style, region, etc. If exploration fails to deliver a deposit exceeding the company's threshold NPV, then shareholder value will be destroyed and the business of exploration becomes uneconomic.

There are many factors that contribute to the economic feasibility of a mine (e.g. metal prices, mining costs, methods, metallurgical factors, permitting issues, proximity to existing infrastructure or mill, etc.). These are all embedded into the target NPV. Linking NPV's with typical deposit sizes in terms of tonnes, grade and mining costs these represent is useful for the explorationist. This will differ considerably depending upon the deposit style being sought and the exploration environment (near mine versus grass-roots programs). However, in an attempt to relate profitability to exploration effectiveness, the SRK preferred method **links the deposit target value to exploration very simply**, based on examination of the following criteria:

- **Exploration stage** or position of the Prospect on the pathway to discovery and possible exploitation.
- **Probability of Success** or the likelihood that the Prospect will advance to the next stage of exploration (P_s).
- **Cost** of advancing the prospect to the next exploration stage (C).
- **Target Value,** being the company's corporate target range or threshold NPV's (TV).

In our approach, the **Expected Value** of an exploration prospect (at any particular exploration stage) is defined as the probability of the exploration project advancing to the next exploration stage times the Target Value, less the cost of advancing to the next stage. This is shown in the following formula (e.g. Mackenzie, 1998):

$$\mathbf{EV = P_s . TV - C}$$

(Where EV = Expected Value; TV = Target Value; P_s = Probability of advancing exploration project; and C = Cost of advancing exploration project)

This simple formula generates an **Expected Value** for each prospect at each of the main exploration stages, or decision points, by working back from the company's target value.

Definition of exploration stages

The principal exploration stages are shown in Table 1.

Measuring exploration value for early stage exploration prospects

By incorporating the target value rather than the resource ounces, and knowing average exploration costs to advance exploration it is possible to estimate an Expected Value at each exploration stage. The difficulty then becomes estimating the probability of success or likelihood that a prospect will advance to the next exploration stage.

The probability of success for very early phase exploration prospects is based on the elements of the geological mineralization model present at the individual prospect area. SRK uses a simple approach **firmly based on the geological process model, its critical success factors and the application of Bayesian probabilistic analysis.** This method requires:

- Building the underlying geological process model.
- Identifying the critical success factors, and
- Assigning probabilities to each factor.

Stage A. Ground Acquisition (Project Generation)	Goals: ♦ *To build an expert team for the belt/region* ♦ *To have knowledge, knowledge management and data / information availability for the belt* ♦ *To select and acquire ground in well endowed belts, considering availability, political/environmental risks*
Probabilities/risks associated with progressing from Stage A to Stage B, i.e. $P_{(A-B)}$ *Probability that the process of Ground Acquisition (A) will result in the acquisition of high quality, well endowed and available ground that is worthy of further work*	
Stage B. Prospect Definition (Reconnaissance Exploration)	Goals: ♦ *To define drillable targets (often via geochemical, geophysical surveying)* ♦ *To build area knowledge, quality data management systems, suitable geological models* ♦ *To use efficient exploration methods, geologic skills of exploration team* ♦ *To define prospect risks and target ranking tools, exploration audit process* ♦ *To test presence of mineralizing system*
Probabilities/risks associated with progressing from Stage B to Stage C, i.e. $P_{(B-C)}$ *Probability that this process will define drillable targets (features that meet criteria of the geological model and knowledge of the area)*	
Stage C. Drill Testing (Systematic RC, DD)	Goals: ♦ *To test geological and mineralization models, interpreted from mapping and geochemical sampling* ♦ *To test geological information gathered during prospect definition* ♦ *To test presence of mineralizing system to the stage of indication of sufficient continuity and grade as to indicate potential for an economic resource.*
Probabilities/risks associated with progressing from Stage C to Stage D, i.e. $P_{(C-D)}$ *Probability that the drill testing phase will result in one or more "economic drill intersections" that would be further drill tested* *The decision to continue would be supported by other geological information that would give some initial confidence in the continuity of mineralization*	
Stage D. Resource Delineation	Goals: ♦ *To have confidence in size and grade potential, continuity of grade and geological setting* ♦ *To understand controls on grade distribution (low cost curve position)*
Probabilities/risks associated with progressing from Stage D to Stage E, i.e. $P_{(D-E)}$ *Probability that a "drill-out" will result in the definition of a preliminary resource that is sufficiently robust at present prices to warrant proceeding to feasibility*	
Stage E. Feasibility	Goals: ♦ *To determine metallurgy, metal prices, mineability, cost, prices, mineral balance sheet* ♦ *To result in decision to mine, asset with defined NPV*
Probabilities/risks associated with progressing from Stage E to target NPV *Probability that the feasibility study will deliver an ore reserve*	

Table 1. Definition of exploration stages.

The probability of the occurrence of a mineral deposit can be derived from the product of the relative probabilities of each of the critical success factors, assuming that probabilities of occurrence of each of the critical factors are independent:

$$\mathbf{P = P_1 \times P_2 \times P_3 \times P_4 ... P_n}$$

(Where P = probability of advancing exploration project and $P_{1\text{-}4..n}$ = probability of occurrence of each of the critical success factors of the geological process model).

Placer Granny Smith is currently evaluating this method to rank their early phase exploration prospects. Application of the Bayesian methodology to the project area is generically demonstrated below:

- **The geological process model for mineralization is established**. This involves identification of the critical processes without which a deposit would not have formed. In general terms the following apply; P_1 represents the probability of occurrence of a source of mineralizing fluid, P_2 relates to the presence of structure of right age to provide fluid conduit to the site of deposition. P_3 refers to the structural or physical components of the site of mineralization – structural trap site or area of dilation and finally, P_4 corresponds to the chemical processes that ensured efficient metal precipitation or deposition at the trap site.

- **For each of these features of the geological process model, a value between 1.0 and 0.0 is assigned**. A value of 1.0 indicates that the process component definitely operated at the required level, and 0.0 indicates that it definitely did not operate. A value of 0.5 is assigned where information about the factor is not known or data are not available. Therefore a relative probability > 0.5 indicates that there is a degree of evidence that the factor is present, whereas a relative probability < 0.5 indicates that there is a degree of evidence that the process component did not operate.

- **Each exploration project is carefully reviewed in relation to the geological process model for the target or region.** Relative probabilities are assigned to each factor for each project. For example for P_3 a favorable trap site might be that the prospect is located in an area with rock types of high rheology contrast (given say 0.7) or in an area where aeromagnetic interpretation indicates abundant thrust faulting (say 0.8). While an area of one monotonous rock sequence and no evidence of faulting is considered to be less favorable (say 0.3). Any feature allocated 0.5 (unknown) highlights the need for this information to be gathered at this prospect to advance exploration. **A worked example is shown in Table 2.**

- **These four factors are then multiplied together to form an overall probability, P_S,** that all of the essential components of the ore system are present in the target or region. This is assumed to be the same as the probability that there is mineralization at the target region, and therefore that the prospect could advance to the next stage of exploration.

Prospect Name	P1	P2	P3	P4	P_S - Product of Probabilities assigned
Prospect X	1.0	0.8	0.7	0.9	0.50
Prospect Y	0.5	0.8	0.9	0.9	0.32
Prospect Z	0.3	0.8	0.9	0.9	0.19

Table 2. Examples of prospect ranking using Bayesian methodology.

The benefits of the Bayesian probabilistic approach include:

- Semi quantitative, geologically based, simple to apply and mathematically sound.

- Consistent disciplined approach to evaluating targets within and between regions, and encourages detailed evaluation of each prospect.

- Facilitates communication of exploration risk with management and professional staff from other disciplines.

- Assesses exploration risk profile and cost in a consistent and quantitative method.

- Highlights where more information is required (e.g. when P = 0.5) and how the exploration programs may be designed accordingly.

Measuring exploration value for later stage exploration prospects

To estimate the probability of success or likelihood that an advanced stage exploration prospect will proceed to the next exploration stage requires estimation of regional or belt-wide probabilities for the style of target sought by the company. A range of probabilities can be estimated at each exploration stage based on the high knowledge and experience in each belt, e.g. number of prospects generated, the number that advanced to drilling and to resource definition and finally to feasibility studies. Accumulation of knowledge in the early exploration stages and strong focus in 'well-endowed' belts or in belts with a high level of geological knowledge is a major value-creating step in the exploration business.

Higher belt-wide probabilities can be achieved by the company being focussed in a 'well-endowed' belt and / or by building up high knowledge of the belt. Note that a high level knowledge of the belt could comprise either 'intellectual' knowledge about the geology of the belt or 'historic' knowledge based on previous productivity of the region. The former becomes critically important in the valuation of new 'grassroots' exploration plays where the mineralization potential has not been realized as the deposits have yet to be found. Even where historic production has not occurred, a belt could still be considered highly prospective and correspondingly highly-valued if there is high 'intellectual' knowledge of the belt and the company is exploring using a well constrained, explicit model for mineralization.

It is worth stressing that continued accumulation of increasingly detailed knowledge of a belt will not continue to increase the value of an exploration property. At some point the cost of data gathering will start to destroy the value of the project. It is recognized that **the crucial step** in adding value to an exploration property is obtaining an 'economic' drill intercept and drilling should proceed at a relatively early stage.

In general, projects with very high value (NPV) will be harder to find and therefore have lower probabilities of success (especially low if the company is exploring in a less endowed belt). The converse will apply when projects will have much lower target NPV's than the corporate targets, such as near-mine small resources sought for existing mills, etc, but much higher probabilities of success. In near mine environments, deposits with modest contained gold may have relatively large NPV's because of their low capital cost. These are of great value to existing mining operations.

One of the main aims of the Laverton District review is to study in detail a mature exploration belt in order to generate a robust set of probabilities and costs for later stage exploration properties. While the set of numbers generated will be most appropriate for the Laverton greenstone belt and the deposit model(s) being sought by Placer Granny Smith, these probabilities and costs will also be applicable in similar Archaean greenstone terranes. The method behind the evaluation is also relevant to a wide range of commodities and exploration environments.

Measuring Laverton Exploration Success

The data reviewed

Exploration in the Laverton District was prompted by the discovery of the Granny Smith Deposit in 1987 (Hall and Holyland, 1990). Initially, exploration was funded independently by Placer Dome Asia Pacific. In 1993, the Granny Smith Extended Joint Venture was established, with exploration funding contributed by the Placer Granny Smith partners – Placer Dome Asia Pacific 60% and Delta Gold 40%.

In the Laverton District, data from statutory government Annual Technical and Expenditure Reports were compiled for 21 exploration project areas between 1987 and 1999. Exploration was divided into the series of exploration stages (defined in Table 1) and the number of prospects generated was compared to the associated expenditure per exploration stage. This allowed individual prospects and budgets to be tracked through the exploration process.

During the 13-year period AUD$52 million was spent on exploration and 12 economic deposits were defined, with combined resources of more than 10 million ounces (310 tonnes) of gold. The actual Net Present Value and the profit returned from these resources is confidential, but relative values will clearly demonstrate that there is not always a relationship between the resource size and profitability.

The 21 exploration projects reviewed are listed below, in order of decreasing expenditure (Table 3). Projects were classified in terms of favorable geological domains and less favorable domains, based on confidential company criteria. Costs are in actual dollars, and were not inflated into current dollar values. Placer consider that exploration technology changes over time, and that their increase in exploration effectiveness over the period studied is likely to offset inflation. Furthermore drilling rates for example (which contribute a large proportion to the total exploration expenditure), are cheaper in 2000 current dollars than they were in 1988 in unescalated dollars for similar ground conditions. Simply escalating the exploration expenditure per year according to annual inflation was not considered to adequately account for these factors and so actual dollars were used for this analysis. Similarly the NPV values used were dollar values at decision to mine and do not take into account inflation, changes in the gold price, etc.

Exploration activity for each year was summarized for individual exploration projects including; lease numbers, how many exploration prospects were at each exploration stage (taking into account projects at the same stage that have been on-going over multiple years or reporting periods), plus associated exploration costs per exploration stage. Where reported costs were attributable to more than one exploration stage, these costs were apportioned to the relevant exploration stage accordingly (taking into account typical cost of meters drilled and samples collected). Note that, due to inconsistent recording of legal, lease rental and tenement acquisition and option payments, these were not included.

Project	Project Duration	Geological Domain	Total Expenditure (AUD$)
Project 1	6 years	Favorable Domain	$14.0 M
Project 2	13 years	Favorable Domain	$12.5 M
Project 3	7 years	Favorable Domain	$11.4 M
Project 4	9 years	Favorable Domain	$9.1 M
Project 5	7 years	Less Favorable Domain	$2.0 M
Project 6	3 years	Favorable Domain	$1.1 M
Project 7	7 years	Favorable Domain	$0.7 M
Project 8	6 years	Favorable Domain	$0.3 M
Project 9	4 years	Favorable Domain	$0.2 M
Project 10	2 years	Less Favorable Domain	$0.2 M
Project 11	4 years	Favorable Domain	$0.2 M
Project 12	2 years	Favorable Domain	$0.1 M
Project 13	2 years	Favorable Domain	$0.1 M
Project 14	1 year	Less Favorable Domain	$0.1 M
Project 15	2 years	Less Favorable Domain	$0.1 M
Project 16	2 years	Less Favorable Domain	$0.1 M
Project 17	3 years	Favorable Domain	$0.04M
Project 18	2 years	Favorable Domain	$0.04M
Project 19	1 year	Favorable Domain	$0.02M
Project 20	1 year	Less Favorable Domain	$0.02M
Project 21	1 year	Less Favorable Domain	$0.01M
Generative Exploration	13 years	Throughout the district	Additional $2.2M

Table 3. Summary of exploration projects reviewed at Laverton.

Laverton exploration probabilities of success and costs

Information was extracted on the number of prospects at each exploration stage versus associated exploration costs. For brevity, the 7 major projects are detailed and others summarized, as compiled in Table 4.

This table shows average exploration expenditures to advance exploration prospects through the five exploration stages based on Placer Granny Smith's 13 years exploration history in the Laverton District. It also provides a summary of the number of prospects that advanced from one stage to the next allowing an average probability of success to be calculated.

Project Name	Project Generation Stage (A)	Reconnaissance Stage (B)	Drill Testing Stage (C)	Resource Delineation Stage (D)	Feasibility Stage (E)	Total Project Exploration Expenditure
Project 1						
Number of Prospects	0	5	8	3	2	
Combined Cost	$0	$0.27M	$2.81M	$0.28M	$10.68M	$14.04M
Project 2						
Number of Prospects	5	18	7	6	5	
Combined Cost	$0.19M	$1.81M	$1.50M	$2.22M	$6.73M	$12.45M
Project 3						
Number of Prospects	3	18	1	1	1	
Combined Cost	$0.18M	$3.86M	$0.35M	$2.53M	$4.43M	$11.34M
Project 4						
Number of Prospects	2	26	5	3	2	
Combined Cost	$0.01M	$1.79M	$0.74M	$1.54M	$4.98M	$9.05M
Project 5						
Number of Prospects	7	30	1	0	0	
Combined Cost	$0.01M	$1.70M	$0.34M	$0	$0	$2.04M
Project 6						
Number of Prospects	0	2	3	1	1	
Combined Cost	$0	$0.25M	$0.26M	$0.16M	$0.46M	$1.13M
Project 7						
Number of Prospects	0	3	1	1	2	
Combined Cost	$0	$0.20M	$0.06M	$0.15M	$0.34M	$0.74M
Other Projects (combined)						
Number of Prospects	10	54	0	0	0	
Combined Cost	$0.08M	$1.49M	$0	$0	$0	$1.57M
Generative Exploration						
Number of Prospects	263	0	0	0	0	0
Combined Cost	$2.20M	$0	$0	$0	$0	$0
Total number of Prospects	290	156	26	15	13	
Total cost for all Prospects at each exploration stage	$2.7M	$11.4M	$6.0M	$6.9M	$27.6M	$52.4M

Table 4. Summary table of Laverton projects showing number of exploration prospects, cost of exploration (AUD$), and average cost per prospect for each of the exploration stages (AUD$).

Synthesizing the above data, a summary table (Table 5), was generated (note all are AUD$, and unadjusted to current dollars).

Exploration stage	Number of prospects	Expenditure (AUD$ 1987-99)	Ave. Cost / Prospect (AUD$)	Probability of advancing from previous stage
Generative	290	$2.7M	$10K	
Reconnaissance	156	$11.4M	$70K	0.54: 1 in 2
Systematic Drill Testing	26	$6.0M	$230K	0.17: 1 in 6
Resource Delineation	15	$6.9M	$460K	0.58: 1 in 2
Feasibility	13	$27.6M	$2.1M	0.87: 5 of 6
Mine	12			0.90: 9 of 10

Table 5. Synthesis of historical exploration activity by exploration stage.

Findings of the analysis for the Laverton District can be summarized as follows;

- The average probability for exploration projects advancing **from generative to reconnaissance exploration stage is 0.54** (or almost 1 in 2), with an associated average exploration expenditure of AUD$70 000. This reflects the maturity of exploration where many targets identified have now been tested.

- The probability that the project **proceeded to systematic drill testing stage is 0.17** (or 1 in 6), requiring on average AUD$230 000 of expenditure. These early stage probabilities are similar to the range SRK have identified in other project reviews.

- However, later stage exploration probabilities at Laverton are considered quite high. The probability of **transition to resource delineation stage is 0.58** (or 1 in 2 projects), and **subsequently 87% (or 5 out of 6) of these projects advanced to feasibility**. The success rate reflects the gold endowment of the district and the mature near-mine exploration environment.

- Average expenditure to advance through resource delineation stage is AUD$460 000 and through feasibility stage is AUD$2 100 000.

Resources defined and exploration effectiveness

A summary of resources defined, discovery cost per ounce and relative NPV values for individual exploration projects between 1987 and 1999 is shown in Table 6 and graphically in Figure 2.

Project	Total expenditure to 1999 (AUD$)	Resources defined or gold produced	Discovery cost per ounce per project (AUD$)	Relative NPV
Project 1	$14.0M	2.83 Moz (86t)	$4.9	Highest
Project 2	$12.5M	2.29 Moz (70t)	$5.5	Medium
Project 3	$11.4M	4.47 Moz (136t)	$2.6	Medium
Project 4	$9.1M	0.55 Moz (17t)	$16.5	Medium
Project 5	$2.0M	None	Not applicable	0
Project 6	$1.1M	0.05 Moz (1.5t)	$22.0	Lower
Project 7	$0.7M	0.05 Moz (1.6t)	$14.0	Lower

Table 6. Various measures of exploration success. Summary of exploration expenditure per project versus resources defined (either current resource / production / resource at decision to mine).

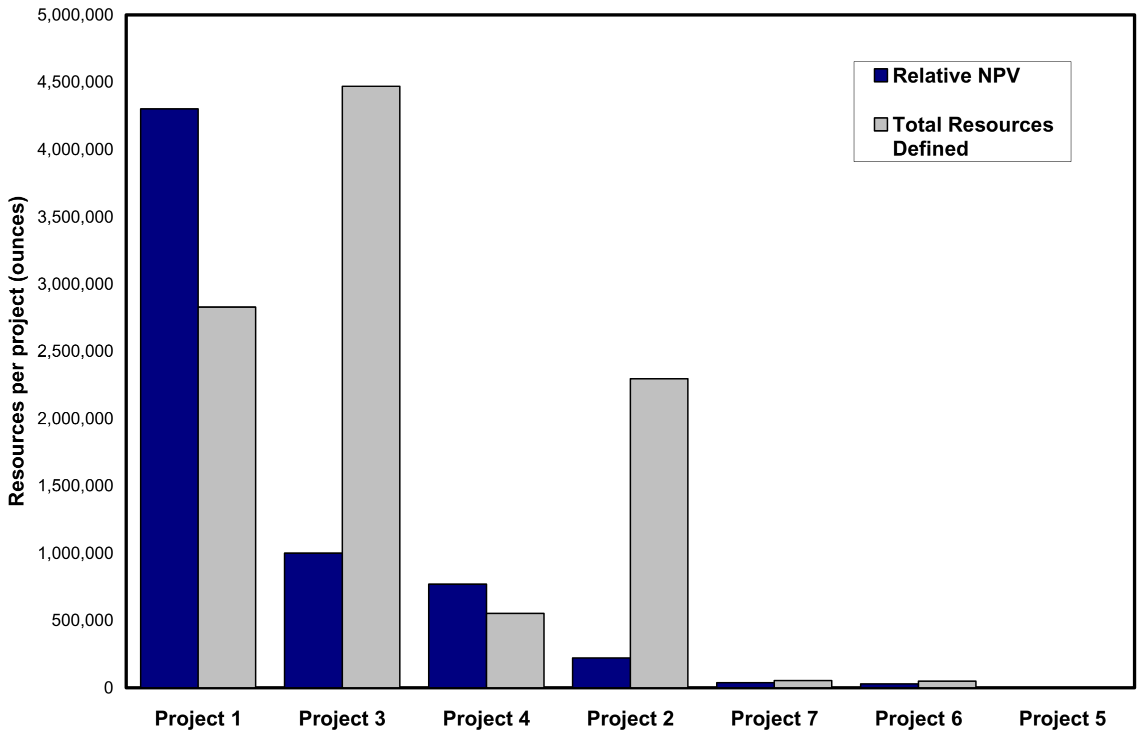

Figure 2. Graph of relative NPV (axis not labeled as data confidential) and resources defined per project at Laverton.

The first 4 projects have delivered the bulk of the resources defined by Placer Granny Smith and confirm a very successful exploration campaign and the gold endowment of this belt. The principal findings include;

- **Project 1 is the most successful project** in the Laverton District. It is the most economically attractive (in NPV terms), contains one of the largest resources and also has a low discovery cost per ounce. These combine to deliver excellent use of exploration expenditure.

Project 4 also has a relatively high NPV **despite containing only modest resources.** It has a quite high discovery cost per ounce (and required a proportionally higher drill budget) than the larger resources such as Projects 1 and 2.

- Projects 2 and 3 have **moderate relative NPV's**. However in terms of resources delivered and discovery cost per ounce, the more traditional measure of exploration success, they could be considered the best exploration successes.

- **It is important not to measure exploration success only by resource ounces defined.** The economics of larger resources versus smaller deposits (which have disproportional NPV's compared to sizes of resources defined) should be factored into where exploration dollars are spent.

- Obviously there will be more smaller resources than larger deposits. **Linking the resource and NPV of the exploration target to where exploration dollars are expended is critical to optimizing exploration value.**

Project 5 stands out as having high exploration expenditure with no resources defined. The location of Project 5 in the less geologically favorable geological domain raises the question as to why exploration continued. In this Project, the ratio of reconnaissance stage prospects to drill testing stage is 30 to 1 and is the highest for any Project. In this case reconnaissance stage exploration continued too long and project value was destroyed in the process.

A large part of the total exploration expenditure was spent on reconnaissance stage exploration (AUD$11M). This phase is a crucial value-adding phase of exploration. A review of **when** key exploration stages were reached for each exploration project highlights a couple of significant lost opportunities;

- Project 3 was acquired and the exploration target that yielded the resource was immediately recognized as the best exploration target. However that target was not effectively drilled for 5 years.

- Within Project 4 potentially significant mineralization was discovered in the mid-1990's, but substantial drilling of the prospect was not carried out until two years later.

Conclusions

A methodology is presented to measure exploration success and value which challenges the traditional discovery cost per ounce of gold. SRK's preferred methodology links profitability of the target deposit to the exploration prospect. Critical factors to estimate for individual prospects include:

- Project exploration stage (i.e. generative, reconnaissance, systematic drill testing, resource delineation, feasibility).
- The probability the prospect will advance to the next exploration stage.
- The associated cost of advancing the prospect.
- Target value, being the threshold or range of NPV's that provides a minimum return to the company, as based on geological parameters of target tonnages and grades.

An 'Expected Value' can then be determined using the simple formula (e.g. Mackenzie, 1998):

$$\mathbf{EV = P_s. TV - C}$$

(Where EV = Expected Value; TV = Target Value; P_s = Probability of advancing exploration project; and C = Cost of advancing exploration project).

A review of historic exploration was undertaken in the Laverton District, Western Australia to examine the probability of success and associated costs, to gain an understanding of typical exploration profiles over time. Placer Granny Smith's exploration expenditure amounted to around AUD$52 million over 13 years for 21 exploration projects. Data compilation of exploration activity and associated expenditure concentrated on defining key exploration stages and decision points. Six exploration projects contained a combined total of twelve gold resources.

Comparing the resources defined at each project to the actual NPV / Profit estimated at decision to mine demonstrates that some of the smaller resources have disproportionately high NPVs. There are obviously also more smaller-resources than larger deposits. It is clearly important not to measure exploration success only as discovery cost per ounce of resource defined. The relationship between resource size and characteristics like 'mineability', should be factored into where exploration dollars are spent, particularly in near-mine exploration environments.

It is also useful to examine exploration expenditure over time, in particular where exploration dollars were focussed. The time review of exploration yielded two obvious lost opportunities at Laverton, where exploration targets were recognized but not immediately followed up. These targets ultimately yielded significant resources, but the decline in the gold price in the interim, combined with decreased operating efficiency, resulted in a significant opportunity cost.

The prompt recognition and early drill testing of the best exploration targets is critical in optimizing and realizing value of exploration properties. The transitions from reconnaissance stage to drill testing stage, and through to resource delineation stage should be minimized. Exploration should aim to test **the best** exploration targets systematically, rather than 'blanket' exploration of project areas. **The geological ability within a company to put the first 'economic drill intersection' into its proper geological setting and recognize its true importance is a critical factor in exploration success.**

Constant appraisal of exploration targets is required. SRK's method of measuring exploration value can also be integrated into an effective prospect-ranking scheme. This ranking methodology will assist with recognition, documentation and direction of exploration funds to effectively test the best exploration targets.

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ACKNOWLEDGEMENTS

Placer (Granny Smith) Pty Limited, Placer Dome Asia Pacific and Delta Gold are kindly thanked for permission to publish this article. Tony Rudd of Placer Granny Smith assisted with compilation of historic exploration data. The methodology discussed in this paper is being developed by SRK Consulting and in addition to the SRK authors listed, Peter Williams and Stuart Munroe are acknowledged for their involvement.