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Best Practice in Small-scale Gemstone Mining

DFID Knowledge and Research Project

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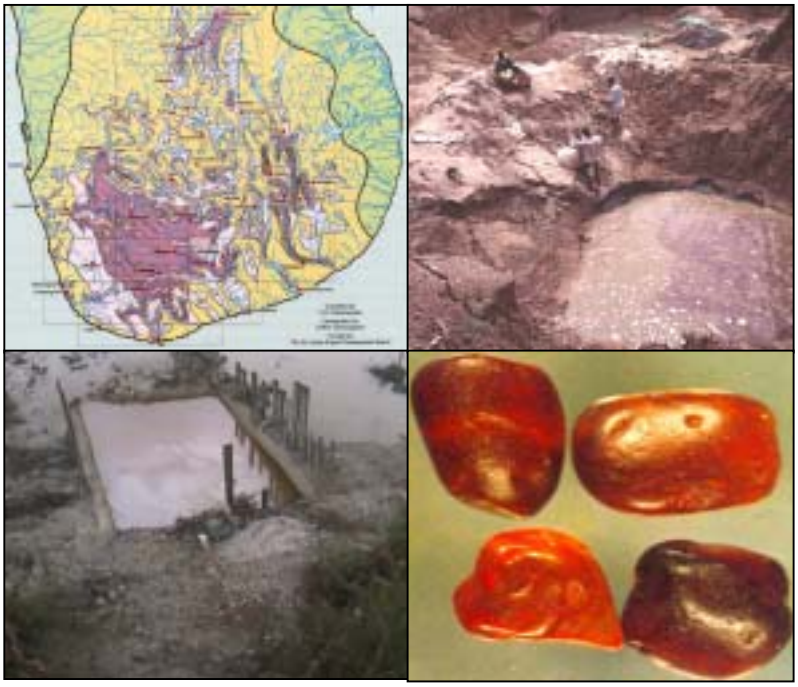
SRI LANKA NATIONAL FACTSHEET



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Disclaimer

This project is an output from a project (R7115) funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID.

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List of Abbreviations

GSBM	Geological Survey and Bureau of Mines
HSWC	Highland South Western Complex
IFS	Institute of Fundamental Studies, Kandy
KC	Kadugannawa Complex
NGJA	National Gem and Jewellery Authority
SGJE	State Gem and Jewellery Exchange

SRI LANKA NATIONAL FACTSHEET

EXECUTIVE SUMMARY

This factsheet documents the general operational procedures followed by small-scale miners, which often skips conventional exploration and development stages. This is triggered by the economic needs of small-scale miners to produce as much as possible immediately. The factsheet then goes onto make recommendations, based on findings from the field, on elements of best practice related to the prospecting, production, safety and environmental aspects of Sri Lankan small-scale gem and semi-precious stone mining. The project also conducted a needs assessment of small-scale miners and mine owners which found their main shared concern for further information was on gemstone identification and valuation (refer to project report by Amarasinghe, 1999; available at www.itcltd.com/final_reports.htm). The project intends to follow up this information demand by designing and tailoring a training workshop for gemstone miners responding to this need.

This information contained within this factsheet will be useful for project managers and extension workers in international and government agencies, NGOs, miners' associations, miners themselves and those requiring detailed information on the gemstone mining context in Sri Lanka. This material will be of relevance to those who working to support mining communities by providing knowledge and information on the technical and socio-economic context of small-scale gemstone mining.

Elements of Best Practice

The following recommendations for better practice within Sri Lanka also provide elements of best practice for gem mining that could be applicable also to other gem-mining countries (albeit with some qualifications in accordance with their own specific context):

Gemstone Prospecting and Mining

To maximise the benefit realised from gem resources in as sustainable and environmentally benign manner as possible, and to the benefit of the small-scale

miner the following practices on gem prospection and exploration should become more widespread:

- Assessment and monitoring of previous and current mining sites to compile a record of already mined sites.
- Gem miners should be made increasingly aware of some of the rarer, more valuable gemstones which potentially have a value greater than other more common gemstones but currently go unrecognised by small scale miners and are often simply discarded.
- A national survey to gain a realistic concept of the size, extent and location of gem reserves in Sri Lanka should be undertaken in order to make holistic and constructive plans for the industry. Such a survey could serve to identify "virgin" territory for potential future development and would enable the government to estimate the likely revenue potential and lifetime of the gem mining industry.

Operational Practices

Small-scale mining operational practices can be improved by better provision and sharing of information, and with simple methodological changes that may ensure that pits are not reworked and effort is not wasted:

- More effective dissemination of existing exploration and mining information from the NGJA, in local languages. This is too often locked away in official publications and inaccessible to the majority of gem miners.
- Introduction of appropriate, affordable and sustainable technical equipment and techniques.
- Store records within an accessible institution or location of what has been mined and where in order to avoid reworking old mines at much expense to finance, health and safety, and the environment.
- Agree a fair and open procedure to handle accidental gem discoveries, and the roles and responsibilities of the private and the public sector in such circumstances to minimise the environmental and socio-economic disruption that can be caused by gem rushes when discoveries are made.
- Awareness-raising of the impacts of river dredging.
- Clear and effective enforcement of regulations when it comes to river dredging.
- Reduce the need and the incentive to conduct illegal mining by simplifying and speeding up the licensing procedure; in conjunction with more regular follow-up by authorities to check mines are fulfilling their environmental obligations.

- Awareness raising of need for back-filling of gem pits once mining is complete.
- Awareness raising and training on capturing and storing the fine material that is washed out when searching for gems so that the material does not collect and block local waterways and is not lost for back-filling purposes.
- Need for training and/or new techniques to support the pit walls in deeper gem pits to prevent them collapsing.
- Transparency and cross-checking of gem processing, sorting and selection to maximise returns and minimise foul play.
- Government policies could encourage technical innovation and good practices in terms of working conditions, health and safety and environmental impact.
- Officially sanction and promote good practice in prospection, exploration and exploitation techniques.

Regulatory Practices

In order to simplify regulatory practices the following actions could be undertaken (some challenges for the Government and/or Gem Authority for which there are not available answers from this research, are also noted):

- The legislative and licensing system requires updating and consistent, reliable and honest enforcement to be effective. The introduction of a simpler flat fee system may be more widely accepted.
- Prevent exploitation of workers by awareness raising of the regulatory environment, and supporting better communication and information provision by the State Gem Authority. Challenge: Who is responsible for ensuring this and how is it monitored?
- Enforcing the practice of written contracts and ensuring that miners know their rights. Challenge: How could this be effectively enforced?
- Discourage illegal mining this aspect of the mining industry by making it less in the miners' interests to mine illegally ie. simple and more effective procedure to mine officially, and greater value gained.
- Resolution of conflict over land use requires considerable communication and the possibility of compromise on both sides before such conflicts can be resolved.
- Formally recognise mining co-operatives as professional working groups and allow them greater opportunity to take responsibility for their activities.

Health, Safety and Environment

In an attempt to reduce the health and safety risks and the environmental damage caused by mining the following actions could be implemented:

- The development and introduction of low cost, technically appropriate mining practices to reduce health and safety risks.
- The provision of appropriate technical advice for limiting environmental impact of gem mining.
- Effective enforcement of environmental regulations through a combination of approaches from the production of best practice guidelines, to training in techniques to minimise environmental impact, to regular monitoring.
- Provision of incentives by government for miners to participate in the schemes suggested above.
- Facilitate a situation whereby a portion of land could be bought from the State by a mining group for a fairly long period of time before it returns to State ownership.
- Survey and monitor the number and cause of injuries and deaths in the industry per year and take effective action based on those findings.
- Appropriate and realistic compensation schemes for injury or death ought to be considered.

Finance and Marketing

The following recommendations may help to secure finance for small-scale mining:

- A state sponsored start-up investment scheme would allow greater participation in the industry to those unable to secure funding from elsewhere.
- Eliminate or restrict the operation of pricing cartels operated by dealers.
- Encourage miners to organise their own auctions of their best gems to sell against sealed bids that they can either accept or decline.
- Easing of restrictions on foreign investment and foreign dealers buying directly from source rather than strictly through the State authority.

Institutions

Institutions play a key role in the shape and personality of any industry:

- The State should stimulate local value-adding industries to encourage the transition from a raw material producing industry to one exporting value-added materials and increase the skills base of the economy.

- Promote greater co-ordination between the various stakeholders to agree a coherent strategy for small-scale gem mining.
- Designate one body all stakeholders recognise as responsible for the well being and development of miners.
- Academic institutions should conduct research into the gem resources and the socio-economic context of small-scale mining.

Training Needs

The following are important points to consider when thinking about the development of small-scale miners:

- Conduct a local needs assessment then tailor a training course(s) to respond to those needs.
- Ensure appropriate training for small-scale gem miners is provided.

This report and further project information is available on ITC's website at **www.itcltd.com/final_reports.htm** under 'Best Practice in Small-scale Gemstone Mining'.

SRI LANKA NATIONAL FACTSHEET

1. PURPOSE OF THE RESEARCH AND FACTSHEET

Due to job losses in other economics sectors, and natural disasters such as drought, a growing number of people in developing countries are taking up small-scale gemstone mining. Many have little or no experience in gemstone prospecting and production, making their activities inefficient and hazardous. Some Governments are now taking steps to regularise their small-scale mining sectors. A World Bank convened meeting (May 1995) identified ineffective exploitation of mineral resources and environmental degradation as major problems in small-scale gemstone mining, and concluded that education and communication of information are vital to improve production, environmental protection and safety conditions.

The DFID gemstone project aims to promote socially and environmentally sensitive development of mineral resources. The project has contributed to the understanding of the socio-economic and technological conditions of small-scale gemstone mining, with a particular focus on Sri Lanka. This factsheet documents the general operational procedures followed by small-scale miners, which often skips conventional exploration and development stages. This is triggered by the economic needs of small-scale miners to produce as much as possible immediately. The factsheet then goes onto make recommendations, based on findings from the field, on elements of best practice related to the prospecting, production, safety and environmental aspects of Sri Lankan small-scale gem and semi-precious stone mining. The project also conducted a needs assessment of small-scale miners and mine owners which found their main shared concern for further information was on gemstone identification and valuation (refer to project report by Amarasinghe, 1999; available at www.itcltd.com/final_reports.htm). The project intends to follow up this information demand by designing and tailoring a training workshop for gemstone miners responding to this need.

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mining communities by providing knowledge and information on the technical and socio-economic context of small-scale gemstone mining.

2. BACKGROUND

2.1 The Small Scale Mining Industry

The majority of gem mining in Sri Lanka is carried out within communities by the local population. It is pre-dominantly a low-technology labour intensive industry carried out as part of the communities' normal cycle of activities, usually when the agricultural workload is at a minimum and when the paddy fields are not producing crops. In Sri Lanka gem mining is solely a male occupation. Further information on the socio-economic context of small-scale gemstone miners and mine owners in Sri Lanka can be found in Amarasinghe (1999) available at www.itcltd.com/final_reports.htm under Best Practices in small-scale gemstone mining. This study was carried out in three divisional secretariat areas namely Kuruwita, Opanayake and Pelmadulla.

2.2 Mine Owners

The mine owner, being the head of a mine, is responsible for various legal activities and requirements. The organisation and operation of a mine requires particular skills and some considerable experience of the industry. Mine owners tend to have been involved in gem mining for a significant period of time and the majority of them were middle aged. About half the owners interviewed by Amarasinghe were educated up to G.C.S.E "O" level and the majority had less than 4 members in their family, generally with only 2 dependent children (Amarasinghe, 1999). Mine owners generally have an interest in several businesses apart from gem mining including tea and rubber plantations and other commercial activities. The income from gem mining is often used to start or expand businesses that will have a more stable and regular income. The mine owners also tend to purchase more expensive houses and have a wealthier lifestyle that illustrates their social status. This helps in attracting gem sellers and other investors for further commercial activities.

Mine owners generally operate more than one mine up to a workable limit of 3 to 4. Only a small minority of owners have more than 6 mines. The majority of owners in

the sample work deep (shaft) mines, with a significant proportion working shallow mines. Deep mines in Sri Lanka were more common due to the lack of exploitable reserves recoverable by shallow pitting. Similarly river workings were the least common due in part to the lack of gem material available since most of the river deposits have already been worked over several times in the past. Interestingly, although the majority of mines are worked legally some owners also worked illegal mines and all the river workings were unlicensed because the National Gem and Jewellery Association had not held a land auction to license such workings for several years.

The numbers of staff employed by owners varied depending on the type of operation carried out with 5-6 people employed in shallow mines, 8-12 in deep mines and around 7 in river dredging. Total numbers employed tended to average between 11-16 depending on the number of mines owned. The length of time of involvement in the industry also varied but the majority of owners had worked in the industry for at least 6 years with some having worked up to 30 years in the business. Most of them took up mining as it was shown to be profitable and several had progressed to become mine owners after working as gem miners themselves, using what they had earned to invest in their own mines. Labourers are paid a weekly allowance of Rs. 60-100 (Us $1-2) as well as receiving a small percentage of the profit, along with their food and beverages. Owners are also required to make provision for compensation for injuries and accidents. Problems that have been causing mine owners particular difficulties in recent years include (Amarasinghe, 1999):

- a decline in the number of workable deposits
- a decline in demand for gems, particularly from the Far East
- recent policies for higher license fees and labour insurance fees charged by the NGJA
- The need for a license to mine agricultural land from a separate organisation, the Department of Agrarian Service (DAS).

These problems have combined to reduce the incentive for investment in gem mining and therefore the returns from the industry.

2.3 Mine Workers

Gem mining is a physically demanding and labour intensive occupation and which is restricted to the male population in Sri Lanka. Mine workers cover a wide range of ages from 18-50 with a relatively even distribution throughout this range. No children below the age of 18 are allowed to work in gem mining. Compared with mine owners, the majority of mineworkers tend to have a relatively low educational level, up to year 8 with only 23% having a higher educational standard. The need to start earning by working as a gem miner had usually curtailed their schooling.

Incomes amongst the mineworkers were found to be low and 80% of the workers surveyed by Amarasinghe (1999) were receiving Samurdhi poverty alleviation benefits from the government. This situation is exacerbated by the comparatively large size of mine workers families, the majority of which consist of 6 or more members, with more than 4 dependants being common.

Land ownership is also very low and is likely to have been a major stimulus for moving into gem mining to make a living. The main alternative employment of most mine workers is in agriculture (47%) with 16% having no alternative occupation. Despite this 80% of mine workers are entirely dependent on mining for their income and 90% of workers had monthly incomes of less than Rs. 3000 (US $55)[1].

Mine workers enter into a verbal agreement with a mine owner who is generally someone well known to the owner and local to the area. 70% of miners work in the industry because there is either no alternative employment or because they have specialist skills in the industry. Only a small proportion (20%) got involved with mining in anticipation of making high profits. Mineworkers tend to stay in the industry for several years with the greatest majority having worked in mining for 11-20 years. During any one year 80% of workers are employed for 7-10 months in mining, particularly in the more complex and labour intensive deep mines.

Every mine has two leading mine workers nominated as foremen. They are generally experienced workers who possess a wide knowledge. It is their duty to allocate duties to the workers and advise them. Mine workers are paid a weekly allowance for their labour. In the Kuruwita and Opanayake areas that Amarasinghe studied this payment was Rs. 100 (US $1.8) per worker and Rs. 125 (US $2) per head worker. However, in Pelmadulla it is Rs. 60 (US $1) per worker and Rs. 75 (US $1.4) per

[1] Exchange rate of Rs.55 to US $1

head worker. Along with the weekly allowance miners are supported with meals at mines. No other form of payment is made because miners are entitled to a share of the profits from the mine. However, every mineworker expressed the view that the living allowance that they receive was not at all sufficient to cover their needs. Apart from the weekly allowance, a mineworker is entitled to about 3 % of the gem income from a mine (Amarasinghe, 1999). Accordingly, if a gemstone worth Rs.100,000 (US $1,818) is found, he will receive a sum of Rs.3000 (US $54). Since a mineworker is considered as a shareholder he is not supposed to work a specific number of hours as a waged earner. They tend to work at a stretch from morning till evening and at times they have to work late hours in order to complete certain work. They also tend not to have holiday allowances (Amarasinghe, 1999) because once a mine is opened the work has to be continued non-stop. If a miner requires a period of absence due to illness or for any other reason he has to send another person to work on his behalf. That person will be employed on daily paid basis (Amarasinghe, 1999).

The main difficulties and concerns of mine workers include (Amarasinghe, 1999):

- low incomes
- lack of adequate health and safety provision
- poor working conditions
- Their inability to check or influence the amount money being paid to the mine owners for the gems by gem dealers and hence being paid to them as a share of the profits from the mine.

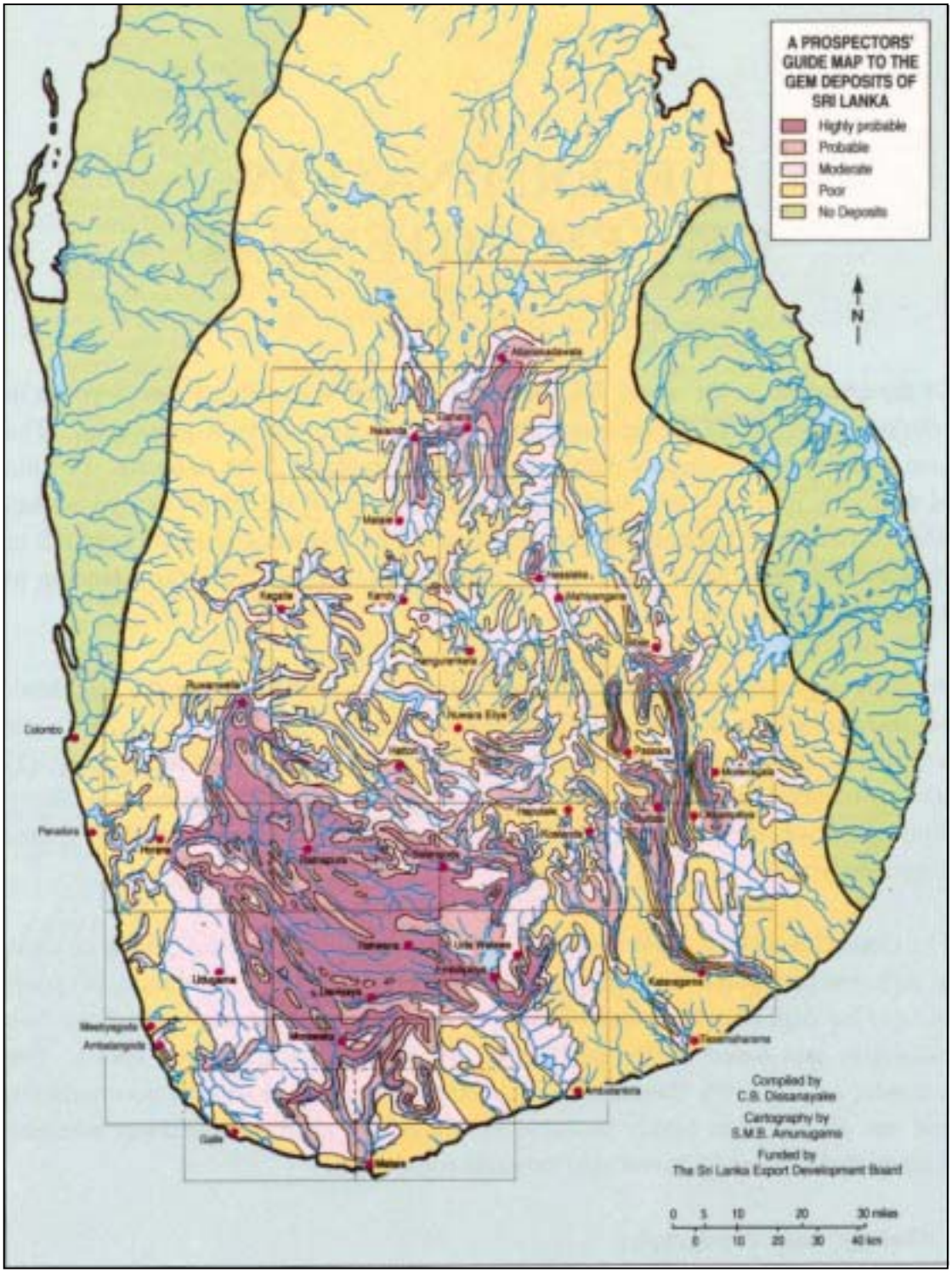
3. GEOLOGY

Sri Lanka has a unique combination of geology, topography and climate, which has resulted in the formation of a valuable non-renewable natural resource in the form of gem and semi-precious stones. The gem deposits of Sri Lanka contain a wide range of gem and semi-precious minerals some varieties of which are unique to the island and some that are particularly rare. It is probable that many of the rarer, more valuable gem minerals are not recognised by the gem miners and are overlooked during sorting.

The dominant gem mineral is corundum, in particularly the great variety of sapphires, rubies and geuda. The majority of gem deposits are secondary alluvial gravels and contain a range of gem minerals with local and regional variations in relative abundance.

Only one major study has been carried out to assess the extent of gem resources in Sri Lanka and this only addressed the probability of finding gem deposits. Supporting studies have been limited in scope and the results have not been widely applied. No accurate reserve calculation has been made of the gem resources in Sri Lanka however Figure 1 shows the geographic areas most likely to contain gem reserves. Annex 1 provides more detailed information on the geology of Sri Lanka and the chemistry of gemstones.

Figure 1: Gem Deposit Prospectivity Map for Sri Lanka



Source: Dissanayake and Rupasinghe; Gems and Gemology, 1993

4. OPERATIONAL PRACTICES

4.1 Prospecting and Exploration

There is no formalised exploration strategy for gemstone deposits within the illam despite recent research into geochemical methodologies carried out by the IFS and the University of Sabaragamuwa. There is no record of any systematic effort by the Sri Lankan government to try and estimate and categorise the nature, extent or worth of the gem-bearing resources of Sri Lanka other than through research grants to various university and research workers. In the field the main exploration guide for gemstones is the presence of the illam itself. Areas that may contain a suitable target illam are selected largely on prior experience, folklore and tradition. As there has been gem mining in Sri Lanka for at least 2000 years there is a large repository of local information and tradition available to local miners. The fact that most miners work and live locally and combine gem recovery with other occupations has implications for gemstone exploration and technology.

4.1.1 Exploration for Gem-bearing Illam

The most direct method of locating the illam is to investigate the active fluvial systems (rivers & streams) and identify any gem bearing horizons. It is then possible to extrapolate over the river valley the likely location of the illam under the topsoil.

In localities not exposed by river and stream systems but where the illam is suspected the main exploration tool is a sharpened steel pole about two metres in length. This is driven down through the soil. When the pole intersects the illam gravels the hard quartz gravel scratches the metal of the pole which can be seen when the pole is extracted but also felt through the pole as it is being inserted. This technique requires some skill in judging where the pole should be placed and also in recognising the “signature” of the different types of illam and other barren gravels on the pole as it is being used. The use of the pole is very effective where the illam lies at relatively shallow depth (approximately 2m and above). However in areas where the illam lies at depths greater than 2m then the only sure exploration method is to excavate trial pits and shafts. Plate 1 shows illam extracted from such a pit. In these instances, where exploration involves considerable manual labour, then full use is made of local information (previous pitting, gem sales from the area, local history) to

maximise the chances of success. The pole is often used from the bottom of the pit to check on how much extra digging is required.

Plate 1: Gem bearing illam gravel

Source: From a deep gem pit near Ratnapura, Sri Lanka.

Some exploration is purely accidental with illam and gems being exposed in the numerous irrigation ditches and banks constructed in paddy fields, wells, road cuttings and other construction work. These “accidental” discoveries often have serious environmental implications if they lead to a gem ‘rush’ (see Plate 2).

The scale of exploration is largely controlled by the nature of the gem miners. Casual, local exploration for and mining of shallow illam deposits is almost routine by most of the rural population and carried out during periods when the paddy is not being used for growing crops. However exploration and exploitation of deeper illam resources is not normally carried out on a casual basis since it requires a greater degree of technical knowledge, better funding and a dedicated work force.

Plate 2: A main road undermined by illegal gem extraction

The result of uncontrolled exploration and development.

4.2 Mining Methods – Extraction

The mining methods used in Sri Lanka are specifically developed and suited to the terrain. Compared to other gem producing countries some of the techniques are both simple and apparently obsolete. However, these methods are effective, adequately efficient and generally safe. Moreover the initial capital cost of mining operations is generally very low which permits greater involvement by relatively poor rural inhabitants.

The Sri Lankan government has in fact banned the use of heavy, mechanised mining methods in gem mining. This not only prevents rapid, destructive depletion of an irreplaceable resource but also maintains an alternative source of revenue for much of the rural population who otherwise would be dependent almost entirely on agriculture.

4.2.1 River Dredging

Perhaps the simplest type of mine workings are the river dredgings which are developed around the exploitation of present day stream gravels and illam exposed during down cutting and erosion by the river or stream. In their simplest form the dredging operation involves raking up a the river gravel or illam into a shallow pile using a long handled iron rake-like tool known locally as a ‘mammoty’, and letting the river wash away the fines (see Plate 3). The resulting coarse fraction is then picked over by workers to extract the gem minerals. Often riffles, small dams and other barriers are built up on the riverbed to control the current and direct it into riverbanks

or accumulations of gravel to assist in winnowing out the fine sediment and washing the gravels (see Plate 4).

Plate 3: Illegal dredging of riverbed gravels for gems

The gravel bar is an artificial construction and such features significantly modify the flow of the river resulting in damage to riverbanks and seriously affecting water supply.

In some instances, particularly where the river is too deep to permit traditional dredging methods bottom sediment is dredged into weighted baskets pulled across the riverbed on ropes. The resulting basket of sediment is then processed on the riverbank. River dredging is carried out both legally and illegally and if not closely controlled has significant negative environmental impact as well as health and safety implications for the workforce.

Plate 4: River gravels are dug out using a hoe and washed in-situ

Unwanted material is simply discarded with fine-grained mud and silts held in suspension in the water.

4.2.2 Gem Pits

At their least sophisticated gem pits are simply shallow (less than 2m deep) holes dug down until the illam is reached. The illam is then extracted and washed before being handed to an experienced sorter who picks out the gem minerals. All the labouring is carried out by hand, using hand tools and woven baskets, and the illam is washed, as it is extracted. Washing is usually carried out using water extracted from the pit or, more rarely, from nearby streams and rivers. When it is a legal, licensed operation then the pit is usually backfilled once mining has finished, particularly when pitting is taking place on agricultural land. This rarely happens if the mining is unlicensed and illegal.

The walls of these pits are generally unsupported and de-watering is usually carried out by manual methods (e.g. bailing, etc). However once the pit has gone beyond head height, the walls are generally supported by wooded planks and beams with the soil of the wall coated and supported with leaves, usually ferns, which also slow down water infiltration into the pit. Down to about 3 metres these pits are also generally pumped by hand and the illam washed, sorted and picked as it is extracted. The pits are also usually back-filled, not least to allow recovery of some of the wooded support material once mining has ceased. In some areas, where there is a

thick residual soil or overburden or where the ground is relatively dry and well-drained larger open pits called "pattah" may be dug (see Plate 5).

Plate 5: Construction of a small shallow 'pattah' gem pit

The pit is dug by hand and the walls are unsupported. The gem-bearing illam is washed in a nearby river.

These pattahs are often several tens of meters wide and often up to 4 meters deep with steps cut in the walls for access down to the gem gravel. The walls of these pits are totally unsupported and hence are prone to collapse in adverse conditions. Plate 6 shows an abandoned pattah about 30 metres in width and up to 5 metres deep.

Plate 6: A large abandoned pattah pit which has become flooded

Plate 7, below, shows pattah gem pits near Butalla in Sri Lanka.

Plate 7: Pattah pits in Butalla

Since many of the pattah pits are dug in relatively fine grained soils and silts the extraction of the gems from the matrix involves considerable washing and in one instance a sluice box was used for this purpose (refer to Plate 8; Henney, 1998). However once the gems are washed out of the soil, not only is a lot of fine grained material washed into rivers and streams but much of the material which should be used for back filling the pit is lost. As a result many of the pattah pits are left unfilled, partially collapsed and/or flooded. These become a health and safety hazard and a breeding ground for insects such as mosquitoes.

Plate 8: Sluice box used for processing clay rich sediments

Source: Large pattah pits near Pelmadulla, Sri Lanka.

4.2.3 Deep Gem Shafts and Tunnels

Once the illam is found at a depth greater than about 3 metres then the use of open pits is impractical and shafts are constructed. These shafts lead to drift levels which work along the illam layer as far as is possible before the pit and level becomes unsupportable. As with the deeper pits, wood, bamboo and leaves support the walls and numerous cross beams are placed to brace the wall supports and to provide access for the miners (see Plate 9).

Plate 9: Initial headworks of a new deep gem shaft near Ratnapura

Due to the greater depth manual extraction of water is not practical and usually an old diesel engine from a truck or bus is used to carry out pumping. In addition a ventilation pipe which doubles as a voice pipe is also used to ensure an adequate air flow to the miners underground. Lighting is provided by oil lamps, or more commonly wax candles although this does lead to additional ventilation problems. Usually manual winding gear or more rarely an electric winch is used to haul the gem bearing illam to the surface. Unlike other pit operations the illam is stored on the surface (see Plate 10) under supervision, then washed all at one time with all the workers and mine owners present to observe proceedings.

Plate 10: Makeshift temporary settlement and storage area for miners

Huts covering deep shaft gem workings, winding gear, miners' accommodation and the illam store near Ratnapura, Sri Lanka.

Some shafts extend 30-40 meters deep in areas where the illam is deeply buried but beyond this depth such shafts are not feasible due to the danger from collapse and sudden, breakthrough flooding. Usually, once the illam layer has been located, several shafts are sunk in succession to maximise recovery of the gems. As the shafts become exhausted they are usually allowed to flood to act as a sink and draw for water away from the neighbouring shafts and levels. Once the area has been exhausted then most shafts are backfilled but this is not always the case. Where illegal or poorly supervised mining has occurred unfilled shafts can present a serious hazard.

4.3 Mining Methods – Processing and Recovery

Almost all the processing of the illam (washing and cleaning), gem picking and sorting is carried out by hand. Large wicker baskets with a particular lipped design are used. A portion of the gem gravel is placed in the basket which is then dipped in and out of the water with a gentle swirling action which washes the fine clay, silt and sand away from the heavier gem minerals which tend to sink towards the base of the sediment. Eventually a skilled washer will reduce the initial illam down to a heavy mineral concentrate which should contain any gems that are present (see Plates 11-12).

Plate 11: Washing and sorting gem-bearing gravel near Ratnapura, Sri Lanka

Plate 12: Washed gem-bearing gravel ready for sorting near Ratnapura

A miner experienced in detecting the gem minerals then examines the basket. They pick out and sort any gems and hand them to another party for safekeeping. The gems are usually stored in a secure container until the end of the workday when they are examined by all the miners. Decisions are then made about what to sell and the likely price that the stones will fetch. Often, when the pit is being back-filled, the filling material will be washed and checked just to make sure that no gems have been

missed first time around. Where the illam is stored for later processing the exact methodology used is the same, except that several panners will work through the pile of illam at the same time with the rest of the miners looking on to ensure fair play. No mechanised equipment such as jigs or sieves are used to process the illam and no hydraulic hoses or pressure jets are used in Sri Lankan mining.

5. REGULATORY PRACTICES

5.1 Mineral Ownership and Licensing

Gem mining is carried out on both private and state land after obtaining permission from the owners and the state authorities. The sole licensing authority for gem mining in Sri Lanka is the National Gem and Jewellery Association (NGJA). For applications to mine on private land the NGJA will issue a license when certain conditions, mainly relating to payment of license fees, ensuring the health and safety of miners and the correct procedures to minimise environmental impacts, as laid out in the 1971 and 1992 Acts, are satisfied. Land belonging to the state, if it is suitable for gem mining, can be also obtained with the agreement of the NGJA, usually by lease. In most cases the NGJA will parcel up the prospects and invite bids at an auction for mining rights. Usually the lease is for one year in the first instance although longer leases can be obtained by negotiation. Similarly the NGJA will auction the mining rights for selected stretches of rivers and streams for an initial period of one year within which mining should be completed or the stake will be re-auctioned. No gem mining is allowed in State Parks and wildlife reserves however illegal mining often occurs.

Most mining is carried out by informal co-operatives of workers with a clear stratification of skills: labourers, experienced washers and sorters and usually at least one experienced gem picker. The ambitions of these co-operatives range from a village group shallow pitting their paddy fields between crops, to more seasoned miners who will tackle major mining operations to access the deep illam. In most cases, a landowner will reach an informal agreement with a co-operative to obtain a mining license to cover his ground then subcontract the actual gem mining to the co-operative in exchange for a share of the profits from the mining.

Other co-operatives effectively work as professional miners, particularly those working on less accessible illam deposits. They will obtain mining licences by themselves or in agreement with landowners. Similar groups are often employed by speculators who buy mining rights from the NGJA at auction then sub-contract to co-operatives to do the actual mining work. All this activity is carried out on an informal basis.

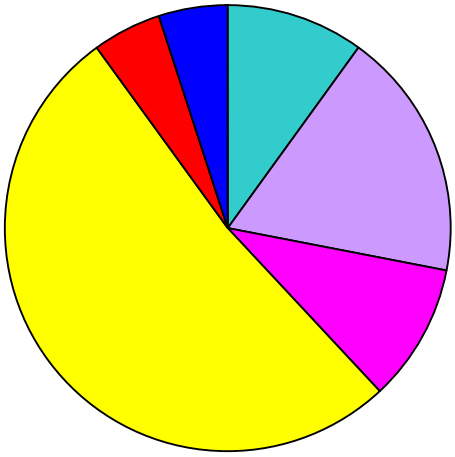
Mine owners are responsible for the selection of a plot of land for the proposed mine and for obtaining legal sanction. If the person concerned is the sole owner of the land they can apply for a license with land titles. On occasions where several people own the land a legal document with their consent to grant the land for mining should be produced.

The regional office of the National Gem and Jewellery Authority in Ratnapura issues permits for gem mines in Ratnapura district. A permit costs Rs.1000 (US $18)[2] and a refundable deposit of Rs.4000 (US $73) is also charged. Rs.1000 (US $18) is charged for each additional mine proposed on the particular parcel of land. When a mine is proposed on agricultural land it is necessary to get a permit from the Commissioner of the Agrarian Service Department to then send to the National Gem and Jewellery Authority. The permit costs Rs.350 (US $6) and a refundable deposit of Rs.1000 (US $18) is also charged.

As the activities of a mine are organised on a co-operative basis the payments for such investments are made from the gross outputs of a mine. Firstly, one tenth of the value of the income is paid towards the use of the water pump. Secondly, from the balance, another one fifth is paid for the share of the land. When there are several owners for a land the amount is divided according to the extent of share of each person. Thirdly, one tenth of the balance is paid for the owner or the holder of the license. From the balance all the expenditure hitherto invested for the mine such as expenditure for food for workers, fuel for the pump, logs and planks, and other equipment is deducted. Finally the balance amount is divided into two sections and one is divided equally among the mineworkers. The remaining is granted to the person who invested money for the weekly allowances for the workers (Amarasinghe, 1999), refer to Figure 2.

[2] 1999 Exchange rate Rs.55 = US $1

Figure 2: Example of the Division of Payments from a Co-operative Mine



5.2 Extent of Illegal Operations

Most illegal mining occurs on government land, often in rubber or tea plantations, and in active watercourses (rivers and streams). Illegal mining is the main source of environmental damage caused by gem mining in Sri Lanka. This is predominantly due to poor mining practice and the lack of remediative action once mining has ceased. This is because the miners have no vested interest in carrying out remedial work on what is generally not their property. Instead their efforts are directed towards exploiting new gem occurrences. There is some anecdotal evidence that the problem with illegal mining has increased during the period of the civil war in Sri Lanka, with displaced people from the north of the island moving into State land to extract gemstones – a ready source of income. Dissanayake & Rupasinghe (1995) estimate that there are at least as many illegal as legal mining operations in Sri Lanka with a figure of up to 15, 000 quoted. Gem mining is a means of obtaining ready cash for relatively little outlay if practised on land not already occupied by a local population.

6. HEALTH, SAFETY, ENVIRONMENT

6.1 Health and Safety Issues

There are a number of direct and indirect health and safety issues associated with gem mining. The most obvious risk is from injury or death during excavation and mining, particularly of the deeper shafts and adits used to exploit deeply buried illam. The construction of the shafts is rudimentary with extensive use of local timber, plant leaves and bamboo to support walls and roofs. There are no government-implemented regulations for such construction and no figures available for the number of deaths and serious injury resulting from accidents. Anecdotal evidence and interviews with miners suggest fatalities are rare but do occur, particularly during the monsoon season, when high rainfall can alter the engineering properties of the poorly consolidated soils and gravel into which the shafts are sunk. This is also a problem in some of the larger “pattah” style pits which have unsupported sides and are very prone to collapse during heavy rain. As well as collapse of workings there is also a prevalent risk from flooding, particularly in the deeper shafts, levels and adits. Although most have some kind of pumping system these can easily be overwhelmed by sudden influxes of water caused by encountering water bearing strata during mining and by inundation during the monsoon season. The high organic content of the gem bearing and surrounding sediments results in high concentrations of methane and hydrogen sulphide being present in the bottom of some deeper pits and this poses a possible health hazard where ventilation is inadequate.

A risk factor common to the majority of gem mining operations is the long-term immersion of feet, legs and hands in water during mining and particularly during the washing of the gravels. Several of the miner interviewed during fieldwork pointed to skin damage on hands and feet resulting from the effects of constant immersion. A risk factor not restricted to gem miners but possibly heightened due to the nature of the gem mining operation (digging and working in water filled pits) is that of snakebite and water-borne diseases. Sri Lanka has the highest incidence of death from snakebites per head of population in the world, mainly amongst the rural population, especially farmers although no detailed figures are available about the relative incidence between population groups.

A major health concern associated with old water-filled gem pits is malaria. These pits act as breeding grounds for the malarial mosquito, often in areas where malaria has been eradicated or has never previously been present. This has resulted in the reappearance of malaria in areas considered disease free and where the local population has little or no immunity to illness. This has a major impact on local health resources.

6.2 Environmental Impacts

6.2.1 Illegal Mining

Illegal mining is the major source of environmental damage associated with gem mining in Sri Lanka and has been formally recognised as an issue requiring some remedial action to prevent further long term damage (Dissanayake & Rupasinghe, 1995; Rupashinghe & Cooray, 1993; de Silva, 1987). These authors estimate that there are up to 15, 000 illegal gem-mining operations in Sri Lanka and identified six major impacts resulting from such gem mining:

i) Damage to natural vegetative cover, plantations and rice fields
ii) Degradation of the land and damage to stream and river banks
iii) Health hazards to miners
iv) Destruction of fauna
v) Sedimentation and water pollution

The following two sections describe in greater detail the environmental impacts associated with river dredging and gem pitting.

6.2.2 River Dredging

The dredging of river and stream beds for gems has several significant negative impacts on the environment (i to v listed above), the most immediate of which is the destruction of the natural watercourse by bank erosion and over deepening of the riverbed (often resulting in concomitant shallowing downstream). This has several knock on effects including enhancing the effects of flooding during the monsoon by breaking down the river bank and removing vegetation, in particular mature trees, which help reduce the extent of flooding and maintain the integrity of the river bank.

Such erosion of the riverbank also makes it hazardous for the local community to access what is in many instances the main supply of water for many domestic

activities. The constant agitation of the riverbed with the resulting release of fine-grained particulate material into the river can significantly reduce the quality and potability of the water several miles downstream from the mining site.

This contamination can also impact on the ecology of the flora and fauna of the river system by reducing the amount of light reaching the bed of the river and by obscuring and coating surfaces in the river system. This can affect fisheries by degrading the water and impacting on the invertebrate food supply for fish. This then has an obvious knock on effect on other fauna which use the river as a food supply.

6.2.3 Gem Pitting

The major problem with illegal gem pits is that they are totally unregulated. Not only do they ignore the government's legislation as promulgated by the National Gem and Jewellery Corporation but they also ignore the accepted norms and conventions of gem mining as recognised by the local community. In particular the failure to carry out even basic remediation work such as back-filling of pits or draining flooded workings is recognised as poor practice with significant negative environmental impacts. Impacts include sedimentation of clay and silt onto agricultural land and into watercourses from the spoil heaps associated with gem pits, and undermining and consequent subsidence of above agricultural or forestland (see Plate 13).

Plate 13: Example of environmental damage and a health and safety hazard

A mature tree undermined by gem extraction has toppled during a storm.

The raising of the beds of river channels by enhanced sedimentation reduces their capacity to carry floodwater. The resultant silting up of minor drainage and irrigation channels, thus reducing their effectiveness.

However some local communities carry out illegal mining on their own doorstep, usually when an accidental discovery of high value gems occurs. Examples of such illegal and often environmentally damaging activity include:

- the collapse of a metalled public road due to undermining by illegal gem pits
- the collapse of the walls of a rural hospital again undermined by illegal tunnelling in pursuit of gemstones
- the pollution and disruption of water supplies by flooding from unfilled or poorly maintained pits (see Plate 14).

Plate 14: An abandoned gem pit that has flooded

This presents a serious health risk as well as removing arable and forestland from useful cultivation.

Nevertheless legal and licensed gem pitting also shares many of the same problems, in particular failure to remove spoil heaps.

Although legislation to protect against environmental damage does exist in Sri Lanka destruction still occurs as legislation is rarely enforced.

6.3 Environmental Remediation

Legislation to minimise environmental damage caused by gem mining is included within the 1971 Act drawn up by the NGJA, reinforced by the Mines and Minerals Act of 1992 (Sections 61(1; 3)), and this is one of the functions of authority. In addition the Geological Survey and Mines Bureau has responsibility for monitoring and enforcing general mining legislation. However, as noted by Dissanayake & Rupasinghe (1995) enforcement of the regulations is difficult and largely ineffective. Within some communities, in particular those where gem mining is a supplement to agriculture, remediation of gem mining sites is carried out routinely. This is essential to restore the rice field to full productivity although this often requires the use of additional fertiliser as a result of the mixing of topsoil with infertile illam during back filling of old gem pits.

7. FINANCE AND MARKETING

7.1 Marketing Channels

All gem mining and trading in Sri Lanka falls under the auspices of the National Gem and Jewellery Corporation set up in 1971 and requires a license of one type or another. License fees start at 250Rs (US $4.50) for the license and 300Rs (US $5.5) per pit after the first two, which are free. Licenses are also required for selling and cutting gems with charges on a sliding scale depending on the volume of business carried out. There is a clear disincentive to transparency as regards these fees and many of the traders and cutters interviewed significantly understate the volume of trade carried out in order to save on paying license fees. This implies that:

1) the government is not obtaining the maximum amount of revenue it could
2) the official government statistics for the gem trade in Sri Lanka are a significant underestimate of the actual volume of trade.

7.2 Private Sector

The gem mining industry in Sri Lanka is essentially a private sector industry although the NGJA does provide a regulatory framework (licences, permits, land auctions, etc) and support for geuda heat treatment and processing facilities. However all other aspects of the industry are carried out with minimal state involvement.

7.3 Finance

Finance for gem mining is almost all derived from the local communities within which it takes place. Miners involved in all scales of gem mining indicated that commercial banks would not and do not invest or underwrite gem mining. The scale of finance involved ranges from several hundred rupees to pay some hired labourers and to pay for licenses through to several hundred thousand rupees to excavate and construct some of the 30-40m deep shafts. Much of this money has to be paid up front prior to the realisation of any funds from recovered gemstones. The increasing cost of raw materials has also been a problem encountered by small scale mine owners. For instance the cost of a truck load of logs (usually the rubber tree) which is used for framing the walls of a mine was Rs. 2500 (US $45) in 1990 and it has presently

increased up to Rs. 9500 (US $173). Accordingly the cost for logs and planks to be invested in a deep mine has been almost around Rs.70,000 (US $1,273). Furthermore, a large sum of money must be invested in water pumps, fuel and allowances for workers and for food. The increasing cost of investment and decline in production has resulted in difficult times for mine owners. This situation has greatly reduced their capability to fund re-investments in new mines. Mining is not an area that commercial banks will invest in and they are reluctant to grant loans for gem mining. Thus a shortage of capital to invest in the industry is also a problem faced by some mine owners.

8. INSTITUTIONS

8.1 The National Gem and Jewellery Authority

The State authority responsible for mining is now known as the National Gem and Jewellery Authority (NGJA). It was established in 1971 by Government Act no. 13 **to assist and improve the Sri Lankan gem industry and in particular to try and prevent the large scale smuggling of gems out of the country**. Its functions include the further development of the gem industry, to help improve skills and craftsmanship, to increase gem exports, to allocate state-owned land for gem mining and to regulate gem mining through the issuing of permits and licences.

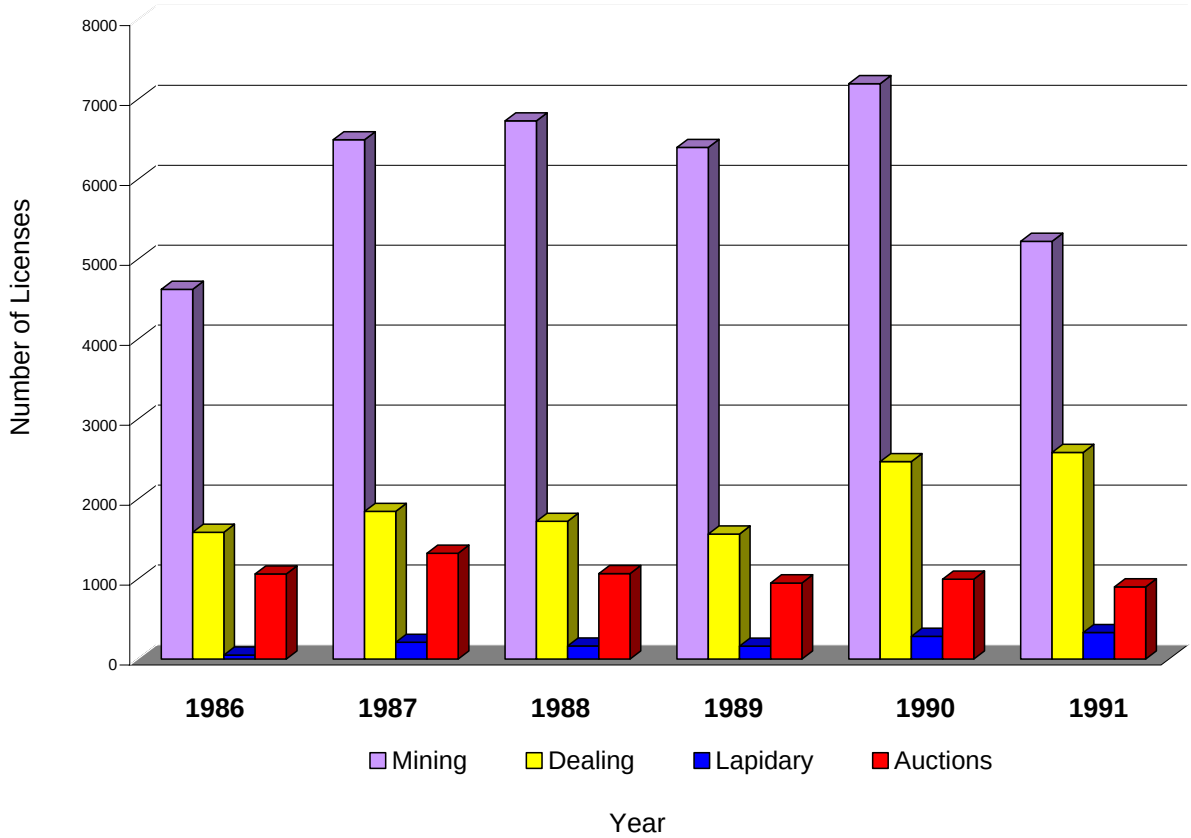
All the functions of the NGJA are run from its head office in Colombo and there are regional offices in Belideniya, Eheliyagoda, Matara, Monaragala, Morawaka, Naula and Ratnapura. Two sales centres aimed specifically at the tourist trade are located at the State Gem and Jewellery Exchange in Colombo and at Colombo International Airport. The NGJA is intended to assist the producer, purchaser and seller of gemstones and it has established a number of gem miners' co-ope (SGJE) rative societies in the Ratnapura district. In the lapidary (cutting and polishing) and jewellery sector the NGJA has set up training centres. Lapidaries are based in Colombo, Eheliyagoda, Naula and Ratnapura with jewellery centres in Colombo and Belideniya. New semi-automatic machinery has updated the lapidary industry and new technology has also been introduced by the NGJA to provide heat treatment facilities for the processing of geuda corundum with a centre established at Eheliyagoda.

Prior to the establishment of the NGJA government agents issued permits and licenses for gem mining but this was often a lengthy and time consuming business. The NGJA issues five categories of license:

1) Mining
2) Lapidary
3) Dealing
4) Gem auctions
5) Gem land auctions

The amount payable for the license depends upon the total value of the stones processed. Between 1986 and 1991 the number of licences issued in the different categories was as follows (see Figure 3):

Figure 3: Number of Licenses issued in the different categories



Source: after Airyaratna, 1993

The NGJA sells gem-mining land by public auction in Sri Lanka and this is a significant source of revenue for the government. Some of the more prospective blocks of land go for a considerable sum, for example in 1991 a 100m section of a river in Ratnapura (the Wey Ganga) was sold for Rs. 2 million (US $36.364). In 1978 the NGJA sold 600 blocks for Rs. 4.1 Million (US $74,545) and in 1979 sold 844 blocks for Rs. 844 Million (over US $15 million). Data for gem land auctions for the period 1986-1991 are given in Table 1.

Table 1: Data for gem land auctions for the period 1986-1991

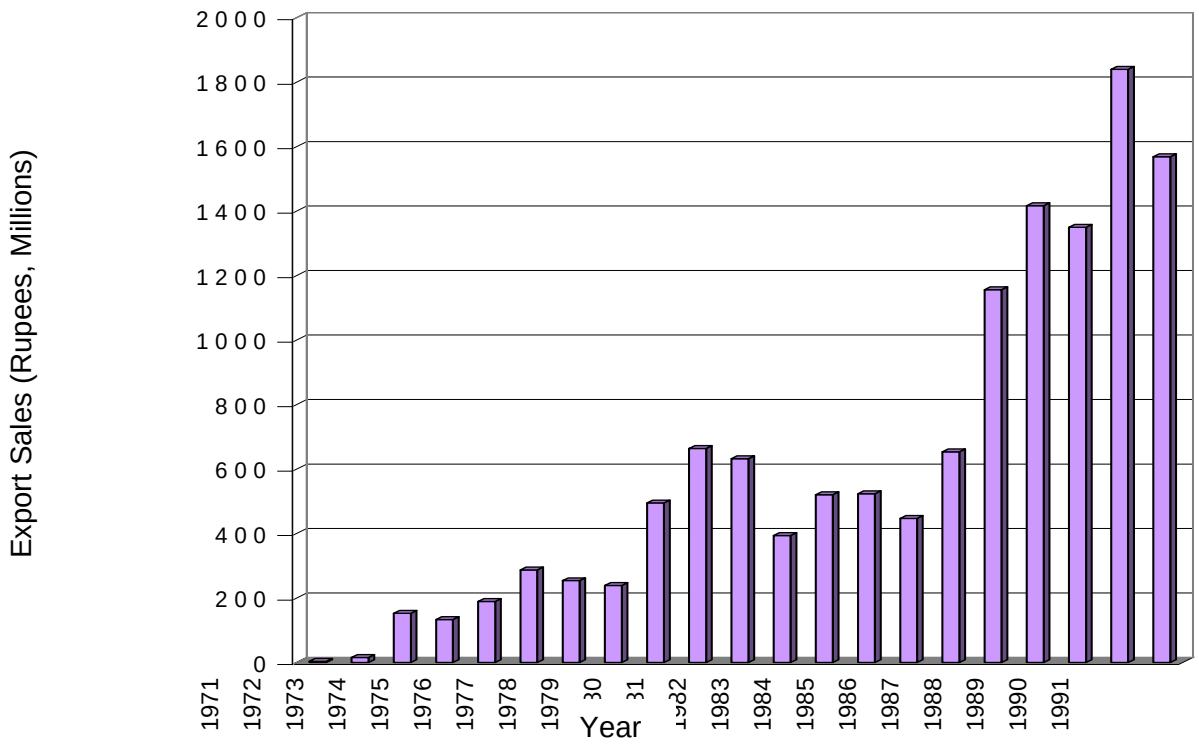
Year	Blocks Sold	Revenue (Rs. Mill)
1986	553	3.2
1987	1067	14.9
1988	1175	9.1
1989	1177	11.0
1990	1193	11.7
1991	1323	14.7

Source: Data taken from Airyaratna, 1993

The Sri Lanka Gem and Jewellery Exchange (SGJE) is a component part of the NGJA and operates in collaboration with the private sector. They provide a service for the gem and jewellery industry, the main function being to allow buyers and traders to meet gem dealers, make purchases and arrange export all under one roof. The SGJE has offices, which include its own Export Section, Assay Office and Gem Testing Unit which are used by both the industry and general public. In addition it has sub-offices of the Customs Service, Exchange Control, a specialised Post Office, a Freight Service, the State Insurance Corporation and a branch of the Bank of Ceylon. Traders and dealers can use a number of trading booths within the building to display their wares and conclude transactions, including foreign dealers.

Since the establishment of the NGJA reported gem sales have increased significantly as business has grown as the statistics in Figure 4 reveal.

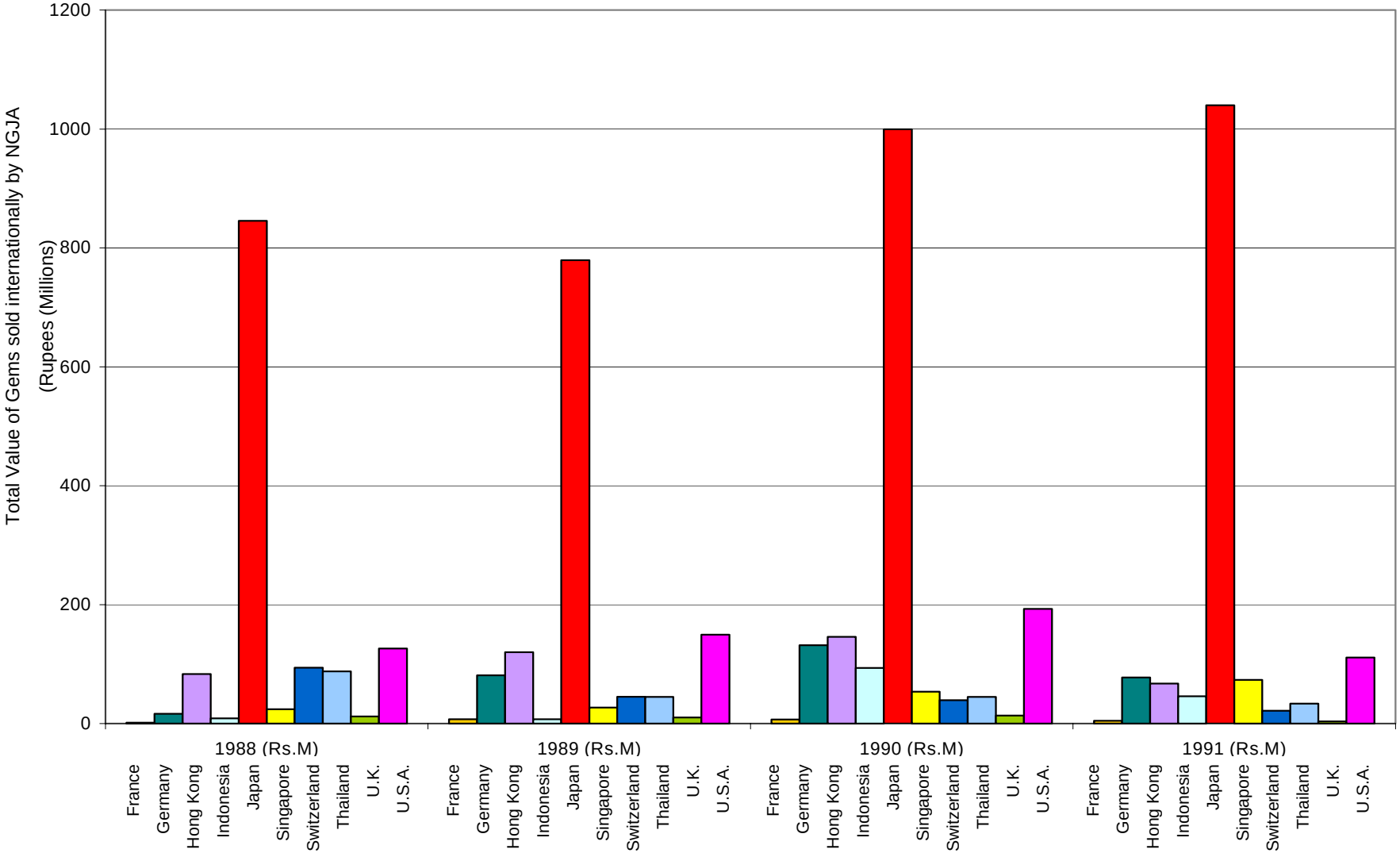
Figure 4: Export Sales through the NGJA valued in Rs. Million



Source: Airyaratna 1993

The overseas destinations of gems sold through the NGJA are shown in Figure 5.

Figure 5: Overseas destination of gems sold through the NGJA



Source: Data from Airyaratna, 1993

Clearly the majority of gemstones go to the Far East and the USA, with Germany and Switzerland being the main European consumers. No data is available for the Middle East although this has been cited by several dealers as a major export market in personal interviews (Henney, 1998).

8.2 The Geological Survey and Bureau of Mines

The Geological Survey and Bureau of Mines (GSBM) was established in 1992 to replace the existing Survey by the Mines and Minerals Act (No. 33). Its function is essentially to "regulate the exploration, mining, transportation, processing, trading or export of minerals" with the exception of hydrocarbons and gem minerals, specified in the 1971 Act establishing the NGJA. However some of its duties include supervision of general mining activities and these overlap with the NGJA's responsibilities in some areas, in particular environmental remediation and health and safety issues.

8.3 University and Academic Departments

Sri Lanka has several academic geological departments, part funded by the government as well as external national and international organisations. These include the Institute of Fundamental Studies in Kandy; the Department of Geology, at the University of Peridenyia, and the Department of Natural Resources at the University of Sabaragamuwa in Butalla. At the moment no major programme of research is being undertaken to investigate Sri Lanka's gem resources although some undergraduate and postgraduate projects are carried out in this area.

8.4 Commercial and Industrial Organisations

There are many small to medium scale gem dealers and traders in Sri Lanka but the industry is dominated by several large companies which can export in bulk, typified by the likes of ZAM Gems Ltd based in Kandy, which is one of the largest gem companies in Sri Lanka. ZAM, like many of the large companies, buy rough and cut gems from a succession of small and medium scale dealers, gem cutters and auction houses. They then process and market these products to customers, particularly those in the overseas export market. The role of personal contacts, reputations and ethnic networks within the industry is paramount. The larger companies play an

important role in placing subcontracts with local Sri Lankan gem cutters, often to cut and polish imported stones and Sri Lanka has a growing and important reputation as an emerging centre for diamond cutting. Other organisations involved in the gem industry include those representing professionals in the gem trade including:

- The Gemmologists Association of Sri Lanka which looks after the concerns of professional gemmologists who are required to assess the quality and verify the value of gemstone purchases and transactions;

- Sri Lankan Gem Traders Association which liases with the NGJA and other government bodies to promote the interest of the gem trade;

- The Geuda Heat Treaters Association of Sri Lanka which looks after and promotes the interest of the geuda industry.

9. EDUCATION, AWARENESS, INFORMATION

9.1 Training and Awareness Needs

In general in Sri Lanka there is a general recognition that in the gem industry the NGJA is the main point of contact and source of information regarding legislation and regulation as well as technical assistance for geuda treatment and processing. However, the results of a socio-economic survey (Amarasinghe, 1999) indicated some specific information and training needs identified by the mine owners and the miners themselves.

Mine owners were interested in specific technical assistance, in particular on the location of gem deposits (prospection and exploration) and the correct determination of the value of the gemstones.

Although gem mining in Sri Lanka is relatively un-mechanised there is some interest in training to maintain and repair water and ventilation pumping equipment, which, for many mine owners, represents a considerable capital investment. Some demand was also expressed for training in business management, given the increasingly unpredictable nature of the gem mining industry, although most mine owners actually

felt sufficiently well trained to manage their own accounts. The majority of mine owners also felt that they had sufficient information about mining legislation and labour regulations.

Mine workers emphasised the need for technical training in determining the correct value of gems and locating gem deposits. The valuation was of specific interest as there was concern that the buyers and mine owners are not always honest about the value of the gems found. The mineworkers also expressed a strong interest in obtaining training in first aid, due the high number of accidents, particularly those resulting from poor ventilation and collapse of workings. They were keen to learn about labour and mining regulations so that they were aware of their rights under the law.

9.2 Training and Awareness Opportunities

The results of the survey suggest that facilities for providing training in gem mining are poor. The NGJA does provide some information as regards licensing and legislation but this is mainly aimed at license holders who are most commonly the mine owners. Additionally the NGJA does support some technical training in geuda treatment and processing but these are again aimed more at upstream processing and marketing rather than the gem miners themselves. Some NGO's such as the Samurdhi Development societies and the Peoples Development Foundation do provide training in socio-economic topics but nothing specifically directed towards gem mining.

10. BEST PRACTICE IN SMALL-SCALE GEM MINING

10.1 Summary of Difficulties with Current Practice

The following sections synthesise the findings from the previous chapters on the small-scale gemstone-mining context in Sri Lanka and some of the problems found there. Section 10.2 then goes onto suggest some key elements of better practice in Sri Lanka, many of which will likely be applicable to other gem mining nations albeit with some qualifications.

10.1.1 Gemstone Prospecting and Mining

Many of the rarer, and therefore potentially more valuable gems, are not recognised by some of the less experienced miners and thus may be overlooked and discarded. This is due, in part, to the large variety of gem and semi-precious stones found in Sri Lanka, the widespread distribution but low abundance of rare gems, and the concomitant lack of knowledge and awareness of some of the miners.

There is little systematic prospection and exploration for gem resources and techniques used are rudimentary and site positioning ad hoc. There appears to be no single repository or record-collection of information on historic mining activities and therefore no knowledge (other than extremely local and short-term) of whether an area has been mined already. This is extremely wasteful and counter-productive.

There appears to be no up to date geological model for the size, extent and location of gem resources in Sri Lanka and no systematic assessment of resources or reserves seems to have been carried out by the government. This must limit the government's ability to make constructive plans for the industry.

10.1.2 Operational Practices

Some of the main points raised in Chapter 4 on operational practices in the small-scale gemstone-mining sector in Sri Lanka can be summarised as follows:

i) The exploration and development techniques in Sri Lanka are basic, labour intensive and essentially non-technical using local traditions and knowledge that have not changed significantly for generations.

ii) The policies of the Sri Lankan government have not encouraged technical innovation in gemstone exploration and mining.

iii) Large mechanised equipment (bulldozers, excavators etc) are not used for mining and are banned by the government.

iv) There are no formal or officially sanctioned exploration or mining practices. The pits are most often positioned and dug on the whim of the mine or landowner.

v) Gem sorting and selection is all carried out manually by one or two people with minimal cross-checking nor use of even simple corroborative tests.

vi) No recording of the nature and location of successful and unsuccessful pits is carried out or stored within any institution, often resulting in wasteful reworking of depleted or barren ground.

Finding good workable gem deposits is becoming increasingly difficult in Sri Lanka due to over working and due to the lack of proper exploration strategies at local, regional and national levels.

10.1.3 Regulatory Practices

Sri Lanka has established institutions and introduced legislation to cover gem mining. It has a recognised legislative framework and regulation system. However, in practice enforcement is piecemeal and ad hoc which leads to widespread disregard of parts of the legislation (refer to Chapter 5). The system therefore is somewhat ineffectual and is treated as a nuisance by the gem mining industry, which largely operates in the informal private sector. The procedure for applying for licenses is lengthy, expensive and slow, particularly when the agreement of the Agrarian Service is required.

Despite the introduction of a workers' registration and insurance scheme by the NGJA, working contracts and terms and conditions between mine owners and mine workers are agreed verbally and remain largely unwritten. Mine owners, whose priority is usually to keep their costs down and their returns high, tend to exploit the mineworkers.

Illegal mining is a serious and increasing problem and is almost on a scale as large as the legal mining sector. Those involved are mainly the rural poor and dispossessed refugees working gem deposits on State owned land to make a living, but also mine owners who hold legal title and licenses for a certain number of pits but then proceed to dig more than that number. The latter is particularly true for the deeper gem pits because these tend to require a greater capital investment. Illegal mining, if allowed to continue unchecked, will lead to degradation of the gem mineral resource base and the Sri Lankan natural environment.

10.1.4 Health, Safety and Environment

Health and safety issues rank amongst the greatest concerns of mine workers who fear injury, maiming and death. Despite legislation, it is the main area of dispute between workers and owners. The latter will dismiss workers who complain or are injured and there are no realistic compensation schemes (refer to Chapter 6).

The mining methods employed in small-scale gemstone mining are inherently hazardous but even the workers themselves do little to modify them to ensure minimal risk.

The environmental impact of gem mining is increasing as the industry expands, mainly due to the surge in illegal mining on government land and in state parks and wildlife reserves. This is due in part to changing aspirations. The general population is aware of the damage caused by gem mining but this does not deter or modify mining activities.

10.1.5 Finance and Marketing

Gem mining is essentially a co-operative activity with individuals pooling funds to invest in mining. There is no official support or assistance with mining investment. Private and personal investors dominate the arena. The lack of accessible start-up investment restricts development of the industry. Investment in mining is largely funded out of other economic activities (e.g. tea and rubber plantations, tourism) and the return is likewise fed back into investment in other businesses. Gem mining is an important economic stimulus in Sri Lanka but it is becoming an increasingly risky investment (refer to Chapter 7).

Marketing in Sri Lanka is traditionally very hierarchical and structured with gem miners selling their stones to local dealers who in turn trade material onto larger

regional dealers and companies who then sell to the major players in Kandy and Colombo. However more large companies are emerging which buy direct from local dealers or even from groups of miners. This maximises mark up and profit. Unfortunately small-scale miners rarely receive much benefit from this way of cutting out the middleman.

Dealers operate a price cartel when buying gems so miners are actually restricted in selling locally. There is little point in shopping around for a better offer.

Commercial banks will not support small-scale mining investment at a local level. Larger gem companies do use the commercial banking sector but not for investing in gem mines.

The discovery of geuda led to a significant expansion in gem mining and there is some evidence that the market is now saturated, acting as a disincentive to increasing investment.

10.1.6 Institutions

The State authority (NGJA) dominates the Sri Lankan gem mining industry. The Geological Survey and Bureau of Mines plays no significant role in the gem mining industry (refer to Chapter 8). This is perhaps one of the reasons that no serious assessment of gem resources has been carried out. However the NGJA has played a major role in developing the Sri Lankan geuda industry. This has been a major success in terms of generating revenue.

Academic institutions have played an important role in stimulating research into Sri Lanka's gem resources but lack the resources to undertake any significant research without external funding. There are few NGO's dedicated to gem mining but some do address socio-economic problems and issues that impact on gem mining, but no one body seems to address issues of a technical nature.

10.1.7 Training Needs

There is a clear need and demand for training expressed by both workers and mine owners (refer to Chapter 9). In particular there is a demand for technical training in finding gemstone deposits and in calculating the value of gemstones. Mineworkers also indicated a strong interest in first aid training, reflecting their fears over health and safety.

The current training provision in Sri Lanka is clearly not adequate and, apart from some specific technical assistance with Geuda processing, the NGJA makes no provision for training.

10.2 Recommendations for Elements of Best Practice

The following sections have been extrapolated from evidence in Sri Lanka of good and not-so-good practice and provide recommendations for better practice within Sri Lanka. These recommendations however also provide elements of best practice for gem mining that could, with benefit, be spread more widely in Sri Lanka and other countries (albeit with some qualifications in accordance with their own specific context).

10.2.1 Gemstone Prospecting and Mining

For the Sri Lankan government and people to maximise the benefit they realise from their gem resources in as sustainable and environmentally benign manner as possible, and to the benefit of the small-scale miner the following practices on gem prospection and exploration should become more widespread:

- Assessment and monitoring of previous and current mining sites to compile a record of already mined sites.

- Gem miners should be made increasingly aware of some of the rarer, more valuable gemstones which potentially have a value greater than other more common gemstones but currently go unrecognised by small scale miners and are often simply discarded.

- A national survey to gain a realistic concept of the size, extent and location of gem reserves in Sri Lanka should be undertaken in order to make holistic and constructive plans for the industry. Such a survey could serve to identify "virgin" territory for potential future development and would enable the government to estimate the likely revenue potential and lifetime of the gem mining industry.

10.2.2 Operational Practices

Small-scale mining operational practices can be improved by better provision and sharing of information, and with simple methodological changes that may ensure that pits are not reworked and effort is not wasted:

- More effective dissemination of existing exploration and mining information from the NGJA, in local languages. This is too often locked away in official publications and inaccessible to the majority of gem miners.

- Introduction of appropriate, affordable and sustainable technical equipment and techniques, for example:
  - labour-based techniques that provide employment for local populations;
  - government ban on the use of heavy mechanised equipment (to help minimise environmental impact; and to support labour-based techniques);
  - the use of portable sluice/riffle boxes for processing the illam;
  - the use of a settling pond to trap fines from water used in processing prior to its release into the watercourse;
  - the use of streak and hardness plates for mineral identification and simple hand lenses for judging clarity and flaws in gemstones;
  - the use of a simple soil auger, as opposed to a metal pole, would allow the retrieval of a sample of the illam for study prior to the pit being dug.

- Store records within an accessible institution or location of what has been mined and where in order to avoid reworking old mines at much expense to finance, health and safety, and the environment.

- A fair and open procedure to handle accidental gem discoveries, and the roles and responsibilities of the private and the public sector in such circumstances, debated and agreed clearly in order to minimise the environmental and socio-economic disruption that can be caused by gem rushes when discoveries are made.

- Awareness-raising of the impacts of river dredging which can cause considerable disruption to natural stream flows, movement of sedimentation and flooding patterns as well as affecting local wildlife.

- Clear and effective enforcement of regulations when it comes to river dredging to ensure health and safety of the miners and at risk populations (eg. from flooding) and to minimise any adverse negative impacts.

- Awareness raising of need for back-filling of gem pits once mining is complete to prevent them becoming a hazard, disrupting agriculture, and providing a breeding ground for mosquitoes and other insects which act as disease vectors.

- Backfilling of pits is usually undertaken where a pit is legal and the correct licensing procedure has been followed however where mining is illegal backfilling usually does not occur. This is likely due to the need for haste and due to the knowledge that there are no recorded details of ownership and responsibility and therefore little likelihood of follow-up by authorities. Implications for best practice could then be reducing the need and the incentive to conduct illegal mining by simplifying and speeding up the licensing procedure; in conjunction with more regular follow-up by authorities to check mines are fulfilling their environmental obligations.

- Awareness raising and training on capturing and storing the fine material that is washed out when searching for gems so that the material does not collect and block local waterways and is not lost for back-filling purposes.

- Need for training and/or new techniques to support the pit walls in deeper gem pits to prevent them collapsing.

- Transparency and cross-checking of gem processing, sorting and selection could help to maximise returns and minimise foul play, for example, several panners could sort through the illam at the same time with the rest of the team looking on. The use of basic equipment such as a hand lens, gem identification tables and some other simple tools could help corroborate identification and thus support an assessment of price.

- Government policies could encourage technical innovation and good practices in terms of working conditions, health and safety and environmental impact.

- There could be officially sanctioned and promoted good practice in prospection, exploration and exploitation techniques which would, over time, become normal procedure *if* they are not seen as too cumbersome or too costly.

10.2.3 Regulatory Practices

In order to simplify regulatory practices the following actions could be undertaken (some challenges for the Government and/or Gem Authority for which there are not available answers from this research, are also noted):

- The legislative and licensing system requires updating and consistent, reliable and honest enforcement to be effective. Given the widespread deception observed in license applications, particularly those involving a tiered fee system, a considerable sum of money is not being collected by the government. The introduction of a simpler flat fee system may be more widely accepted.

- Prevent exploitation of workers by awareness raising of the regulatory environment, and supporting better communication and information provision by the State Gem Authority. Challenge: Who is responsible for ensuring this and how is it monitored?

- Enforcing the practice of written contracts and terms and conditions rather than verbal agreements and ensuring that miners know their rights. Challenge: How could this be effectively enforced?

- Illegal mining depletes the gem reserve, contributes to environmental degradation, and results in a loss of revenue for the country – it is therefore not desirable. A methodology should be devised to discourage this aspect of the mining industry by making it less in the miners' interests to mine illegally ie. simple and more effective procedure to mine officially, and greater value gained. Challenge: This is most likely to be successful if there are incentives and benefits to miners to follow official channels but this raises some problems. How do you institutionalise and legislate such incentives? Is it a simple matter of awareness-raising (unlikely), or does it require some form of monetary incentive such as refunding a certain percentage of the licensing fee upon cessation and adequate back-filling of the mine?

- Where there is conflict over land use, such as in State parks and wildlife reserves illegal mining offer occurs, there needs to be both awareness raising of the miners' plight and awareness-raising among miners of the environmental value of such areas. Challenge: This requires considerable communication and the possibility of compromise on both sides before such conflicts can be resolved.

- Formally recognise mining co-operatives as professional working groups and allow them greater opportunity to take responsibility for their activities.

10.2.4 Health, Safety and Environment

In an attempt to reduce the health and safety risks and the environmental damage caused by mining the following actions could be implemented:

- The development and introduction of low cost, technically appropriate mining practices to reduce health and safety risks, for example:-
  - active pumping for ventilation in deeper pits
  - regulations and guidelines on the use of terraced face cutting techniques in pattah pits and shafts to prevent collapse and slumping

- The provision of appropriate technical advice for limiting environmental impact of gem mining, for example:-
  - the use of settling ponds to reduce contamination of the water supply
  - the correct stockpiling of excavated materials for latter backfilling of pits

- Effective enforcement of environmental regulations. Challenge: How could this best be done? Likely to be a combination of approaches from the production of best practice guidelines, to training in techniques to minimise environmental impact, to regular monitoring – but this all requires considerable resources.

- The provision of incentives by government for miners to participate in the schemes suggested above, for example the use of unemployed miners to drain and backfill old pits in exchange for enhanced benefit payments; or a reduction or refund of part of the license fee for correct remediation of gem workings.

- Miners would be more likely to have greater vested interest in conducting remedial work on land they own but they rarely own such land. A possible implication for best practice could be by facilitating a situation whereby a portion of land could be bought from the State by a mining group for a fairly long period of time before it returns to State ownership. Challenge: there are obviously other implications if such an approach and other demands on land use which would need to be considered.

- Survey and monitor the number and cause of injuries and deaths in the industry per year and take effective action based on those findings.

- Appropriate and realistic compensation schemes for injury or death ought to be considered. Challenge: would such a scheme be possible and desirable?

10.2.5 Finance and Marketing

The following few recommendations may help to secure finance for small-scale mining:

- A state sponsored start-up investment scheme would allow greater participation in the industry to those unable to secure funding from elsewhere.

- The elimination or restriction of pricing cartels operated by dealers, particularly at the local level may improve income levels directly, releasing more funds for future investment.

- This could be done by the miners themselves organising their own auctions of their best gems to sell against sealed bids that they can either accept or decline. Miners can discuss and agree appropriate pricing ranges beforehand, assuming they have that knowledge of desirable gem properties and current market information. This would require a degree of organisation and support amongst the miners themselves. Such activities would help cut out the middlemen and allow miners greater control over the marketing and sale of their products.

- Easing of restrictions on foreign investment and foreign dealers buying directly from source rather than strictly through the State authority.

10.2.6 Institutions

Institutions play a key role in the shape and personality of any industry:

- The State can play a valuable role in initially stimulating local value-adding industries such as the Geuda heat treatment in Sri Lanka, or local lapidary industries by incentives, tax relief, small-business grants, lease of equipment, or initial investment. The further development of local jewellery and craft industries, as has been done in Thailand, would encourage the transition from a raw material producing industry to one exporting added value materials and increase the skills base of the economy.

- Co-ordination between the various state authorities with overlapping responsibilities for the mining industry (for example, the sate gem marketing body, the national Chamber of Mines, the Geological Survey Department, the Environmental Department, Agrarian and/or Agricultural or Forestry Departments); and between those government stakeholders and the public research sector, and the private/co-operative mining sector to agree a coherent strategy for small-scale gem mining and define roles and responsibilities would have many advantages. To do this however would likely require considerable commitment, time and perseverance.

- There could be advantages in having one recognised body responsible for the well-being and development of miners.

- Academic institutions should have enough funding to support their crucial role in stimulating research into Sri Lanka's gem resources, and the socio-economic context of small-scale mining.

10.2.7 Training Needs

The following are important points to consider when thinking about the development of small-scale miners:

- Conduct a local needs assessment then tailor a training course(s) to respond to those needs. These are however likely to include a component on improving the finding of gemstones, awareness of how to calculate the value of gems, and a first aid component.

- NGO's involved in other socio-economic and aid programmes should be encouraged to provide training for small-scale gem miners, as should the State authority responsible for gem mining.

This report and further project information is available on ITC's website at **www.itcltd.com/final_reports.htm** under 'Best Practice in Small-scale Gemstone Mining'.

11. FURTHER INFORMATION

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ANNEX 1: GEOLOGY OF GEMSTONES

A1. GEOLOGY OF GEMSTONES

The bedrock geology of Sri Lanka is dominantly Proterozoic metasediments metamorphosed to granulite facies c. 600 Ma ago. There are three main subdivisions with the metamorphics intruded by several phases of granitic magmatism including pegmatites and a suspected carbonatite. Metamorphic lithologies include highly aluminous metasediments called Khondalites (type locality in India). The main gem bearing lithologies are found within the Highland Group that occupies the area of central-southern Sri Lanka with minor occurrences in the western most Vijayan Complex which underlies the eastern part of the island. The majority of the gem deposits are hosted within paleoplacers in alluvial gravels of Pleistocene to recent age and associated with river and stream systems in the central-southern area of the island. Some workers have correlated the major periods of gravel deposition with sea level changes and periods of peneplanation on. Some gems are recovered from active fluvial systems, either from recent gravels or from reworked paleoplacers. In some locations deep shafts sunk on the riverbank are working the same gem bearing gravels exposed in the bed of a nearby river. A few gem deposits are actually worked from very near to their bedrock source in the form of residual deposits left in karstic solution cavities within the weathered zone of calcareous metasediments (Dissanayake, 1995; Rupasinghe, 1995).

A1.1 Basement Geology of Sri Lanka

Geologically about 90% of the Sri Lankan basement is composed of highly metamorphosed Precambrian rocks. These rocks vary in composition and metamorphic grade. Pegmatites, mafic dykes are other magmatic rocks are also found in the Sri Lankan basement. The north-western area and a small area of the south-western coastline have Miocene limestone. Small isolated sedimentary sandstone formations belonging to the Jurassic period are found at Andigama and Tabbowa. Red earth, Ratnapura bed, coral reefs, beach sand, beach rocks and alluvium can be considered as Quaternary deposits belonging to Pleistocene and recent epochs. Recent studies have subdivided these rocks in Sri Lanka into three main lithotectonic units based on lithology and chronologic metamorphic history (Kroner et. al. 1991). They are as follows:

a) Highland South Western Complex
b) Wanni Complex
c) Vijayan Complex

A1.1.1 Highland South Western Complex (HSWC)

Former Highland series and south-western group (Cooray 1962; 1984) has been included together and named as Highland South-western Complex (HSWC). About 50% of the Precambrian basement of Sri Lanka belong to this unit. Deposition of supracrustal rocks took place at about 2000Ma years ago. The HSWC had undergone regional granulite grade metamorphism at 7500-9000°C temperatures and 8.5-7.5 K.bar pressures. This event took place at about 650-550 Ma years ago (Kroner et. al. 1991). The HSWC is composed of meta-sedimentary rocks such as quartzite, marbles, calc-silicates and garnet sillimanite-gneisses, meta-volcanic suits, mafic to granitic granitoid intrusives and mafic dykes.

A1.1.2 Vijayan Complex

The vijayan complex is exposed in eastern and southern Sri Lanka. The depositional age of supracrustal rocks of Vijayan complex is around 1100Ma. It has been subjected to amphibolite grade metamorphism around 456-591Ma. The vijayan basement is composed mainly of granitoid gneisses (Tonalite to Leucogranite) and migmatites. Metasedimentary rocks are found in minor amounts as xenoliths. In contrast to Wanni complex horndblend bearing calc-alkaline plutonic rocks are common in this unit (Kroner et. al. 1991).

A1.1.3 Wanni Complex

The former West Vijayan Complex (Cooray 1962; 1984) has been re named as the Wanni complex by Kroner et. al.. (1991). The wanni complex also has been subjected to the same Granulite grade metamorphism of HSWC. However its supracrustal rock deposition was simultaneous to the Vijayan complex (1100 Ma). Paleo-metamorphic pressures of the Vijayan complex are lower than that of HSWC. Granitoid gneisses (migmatitic to charnokitic gneisses) and minor metasediments are the main rock types in the area (Kroner et. al., 1991). Comparison of modal ages, and paleo-pressure data suggests that this unit is considered as a metamorphic separate complex.

The Kadugannawa Complex (KC) is situated within the HSWC, around Kandy and

Peradeniya. This complex has zircon dates (660Ma-550Ma) and Nd model ages (1100ma) comparable to the Wanni complex (Kroner et. al., 1991).

Parts of the Kadugannawa complex have experienced granulite grade metamorphism (Schenk et. al., 1991). Evidence for a retrogressive event has also been preserved at some locations. The KC is composed of hornblende - biotite and quartzo - feldspathic gneisses, minor amphibolites and anorthosite and supracrustal rocks. There is no evidence to show that the KC is a nappe structure of the Wanni complex. Therefore it is recognised as a differentiated suite of calc-alkaline intrusive rocks intruded into rocks of the HSWC around 890-1000Ma ago. Most gem-bearing areas of Sri Lanka are underlain by the granulite grade metamorphosed Highland Complex. Some gem occurrences, such as in the Okkampitiya gem fields, are found outside the Highland Complex. However it is thought that the gems originated in the Highland Complex and were later transported by rivers and deposited in this area.

A1.2 Geology of the Main Gem fields

The Ratnapura gem field, which is the largest and most famous, is situated in the Highland South-Western Complex of Sri Lanka (Kroner et. al. 1991). This area is mainly composed of meta-sedimentary rocks such as garnet sillimanite biotite gneiss, garnet quartzo-feldspathic gneiss, charnokitic gneiss, biotite hornblende gneiss and charnokites (Geological Survey & Mines Bureau, 1995). Metasediments such as marble and quartzite are found in few locations. All the lithological bands follow NW-SE trend. Structurally NW-SE trending synforms, antiforms and NNW-SSW trending shear zones are common structural features of the area. Metasediments such as garnet sillimanite gneiss, and marble, undifferentiated charnokitic gneiss and charnokite are the dominant rock types of Elahera gem fields (Geological Survey & Mines Bureau, 1995; Rupasinghe & Dissanayake, 1985). NS trending antiforms and NW-SE trending faults are common structural features in this area.

A1.3 Classification of Gem Deposits of Sri Lanka

Gem deposits of Sri Lanka can be basically classified as primary deposits and secondary deposits (Munasinghe & Dissanayake, 1981; Hearth, 1984). More than 90% of the gem mining of Sri Lanka is from secondary deposits (Dahanayake & Ranashinghe, 1981; Dahanayake, 1980). These secondary place deposits can be

further sub-divided as residual, eluvial and alluvial (Dahanayake et.al 1980; Refer to Figure 6). Primary deposits can be either igneous or metamorphosed. Pegmatites are the major type of magmatic gem deposit of Sri Lanka. Metamorphosed deposits can be further subdivided as skarn and meta-sedimentary deposits.

A1.3.1 Residual deposits

Residual deposits are characterised by layers of sediment containing gem phases mainly deposited in situ or very close (proximal) to nearby primary bedrock sources. Most of these deposits are associated with floodplains and stream channels. Alternating sand, clay and laterite layers with angular rock fragments are a common feature and are found at depths ranging from a few centimetres down to about 10 meters. This type of deposit is results from the in-situ weathering of local bedrock or perhaps an early alluvial source which leaves the resistant gem minerals together with poorly sorted, angular rock debris behind, sitting in a clay-sand matrix representing the weathered bedrock. Residual deposits are common in the Elahera gem field.

A1.3.2 Eluvial Deposits

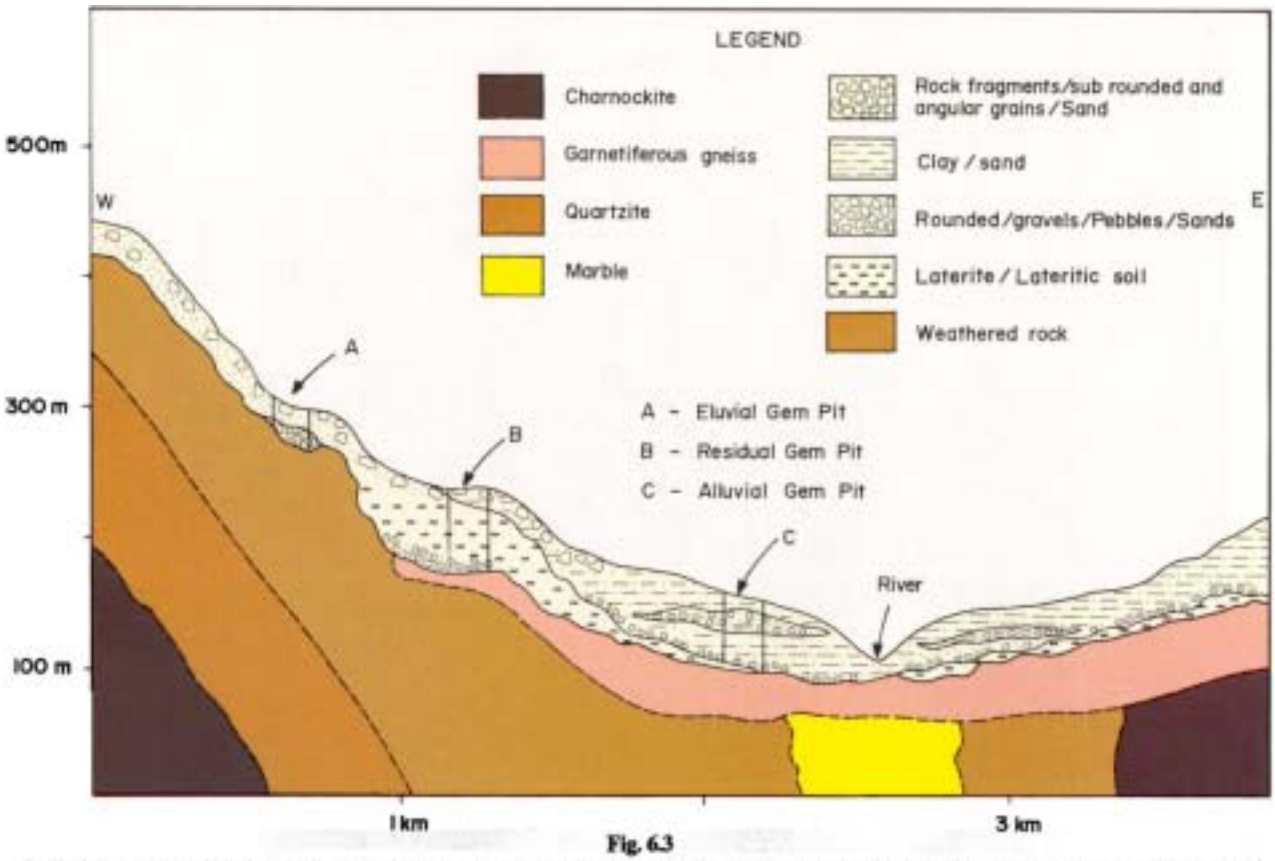
This type of deposit mainly results from gem-bearing material transported down slope by mass soil movements usually aided by water action. They are often found mantling hill slopes and on the sides of river and stream valleys where they often grade into true alluvial deposits. This type of deposit is characterised by rounded gem phases and rock fragments set in a clay/sand soil matrix. They are generally localised and impersistant in lateral extent.

A1.3.3 Alluvial Deposits

Gems transported by fluvial processes, especially by rivers, are deposited mainly within valleys and floodplains, forming alluvial deposits. These alluvial gem deposits are the most common deposit type in Sri Lanka (approximately 90% of deposits worked are alluvial) and are typified by the extensive deposits around and within the Ratnapura gem fields in south-central Sri Lanka. These deposits can reach to depths of 20-30m. The gem bearing gravel (illam) occurs as layers of different morphologies, thicknesses and extent within active and fossil fluvial systems. It is compositionally variable with sand, clay and pebble layers are found alternatively in these deposits. More than one gem bearing gravel layers belonging to different periods of deposition can be found at any one location. There is a broad correlation between the peneplanation surfaces observed in the topography of Sri Lanka and the location of

the major alluvial gem deposits suggesting a link between periods of increased fluvial activity in response to changes in sea level, possibly during the last glacial period (Gunaratne & Dissanayake, 1995). A distinctive feature of most alluvial gem deposits in Sri Lanka is the diversity of gem minerals found in deposits with most common phases being found in the majority of alluvial deposits together with local variations. A full description of the illam is given in Section A1.3.8.

Figure 6: Schematic Cross-section of Geology



Showing different modes of occurrence of gemstones in a region characterised by ridge and valley topography

A1.3.4 Metamorphic Gem Deposits: Skarn Deposit

The main primary source of gems in Sri Lanka is ultimately the metamorphic rocks that comprise 90% of the basement of the island. The intense tropical weathering is responsible for the decomposition of these metamorphic rocks and the release of the gem material into the surface sediments. However a number of small gem deposits are worked from the primary bedrock material of the HSWC representing a range of metamorphic environments and lithologies. Calcium bearing skarn and carbonate rocks are the major source of gems in Sri Lanka, particularly corundum (sapphire &

ruby) and spinel. Skarn deposits are formed particularly where intrusion of pegmatitic fluids which melts into the carbonate rocks has occurred (Dissanayake & Rupasinghe 1994). These gem phases are formed by reactions between the pegmatites and the calcareous rocks. In particular the following reactions occur place during the intrusion of the fluids:

- *Fluid + marble Scapolite + Corundum +* $MgCO_3$+CO_2
- $MgCO_3$ *+ Corundum + Spinel +* CO_2

Ferroaxinite and garnet are also commonly associated with calcium rich skarn deposits. Skarns containing corundum and spinel have been reported from the contact of intrusive granite and marble in Elahera gem fields and at Bakamuna, Kolonne and Ohiya (Cooray, 1984; Gunaratne & Dissanayake, 1995).

A1.3.5 Metamorphic Gem Deposits: Aluminious meta-sedimentary deposits

High-grade metamorphosed meta-sedimentary rocks of Highland complex are the major source gem minerals such as garnet, sillimanite and coderite. In particular many of the metamorphic rocks are enriched in alumina, with some highly aluminous compositions, called khondalites. These contain up to 30% Al_2O_3 and thus are very promising source materials for corundum and other aluminous gem phases. Examples of gem deposits reported or worked from such rocks include corundum recovered from a biotite-sillimanite gneiss at Polgahwela, geuda from khondolites near Haldummulla, corundum from Tannahena near Kandy and from Haputale. One particularly fine example of such a deposit containing fine, high quality deep blue-black sapphires from Aparekka near Matara has been described but it seems to have been worked out and its exact location is unclear (Wells, 1956; Gunaratne & Dissanayake, 1995).

A1.3.6 Magmatic deposits: Pegamatites

Pegmatites are coarse-grained, acid, granitic intrusions and several suites have been intruded into the metamorphic bedrock of Sri Lanka during several phases of activity throughout the geological evolution of the island. They have been reported as the source rock for gem deposits in several locations. Beryl and chrysoberyl containing pegmatites have been reported from Buttala area, some with exceptionally high quality blue-green aquamarines up to 800 carats in weight (Geological Survey Adm. Report 1968). Be-rich pegmatitic fluids are considered as the source of such gem bearing pegmatites (Rupasinghe et. al. 1984). Zircon bearing pegmatites have been

recorded from several locations and one such large deposit is found in Balangoda area (Cooray 1984). Topaz and tourmaline bearing pegmatites are found in the Nawalapitiya (Ranasinghe 1995) and Elahera areas as well as at Polwatte. One of the best-known pegmatite-hosted gem deposits is the moonstone occurrence at Meetiyagoda where a pegmatite intrudes the metamorphic basement and has been heavily weathered. Similar moonstone deposits have been reported from the areas around Balangoda and Kundasale and a new deposit of smoky moonstone was discovered at Imbulpe, east of Ratnapura (Harder, 1992). High quality corundum has been recovered from pegmatites in Moneragala and from the Okkampiitya region. Amethyst has been reported from Kekirawa along with citrine, including a yellow-purple bi-coloured variety called ametrine.

An unusual occurrence of geode-hosted corundum is found in pegmatites described by Kumaratilleke & Ranasinghe (1992) where well-formed yellow and blue sapphires are found in clay-filled hollows in weathered pegmatites. Such deposits have been reported from Badulla, Moneragala, Avissawella and at Getahetta.

A1.3.7 Structurally controlled gem deposits

Studies of remotely sensed data (aerial photos, satellite images) from gem-bearing terrain in several countries has shown that the locations of many deposits are controlled by structural (primary deposits) and morphotectonic (secondary deposits features). For example, zones of pegmatite dykes are controlled by major faults of other structural lineaments or faults and joints control river valleys and terraces. In Sri Lanka Gunaratne & Dissanayake (1995) describe a good example of such controls on gem deposits in the Bogawantalawa area. They also noted the complex effects of morphotectonic structures in either enhancing or degrading gem deposit formation in some situations.

A1.3.8 The gem bearing gravel: the Illam

The gem-bearing horizon within the residual/eluvial/alluvial deposit sediment is known as the illam. This is generally a 0.5-1.5m thick horizon of gem-bearing gravel capped above and below by blue-green coloured clay. However, both from reports and personal observation (Henney, 1998) there is considerable variation in the thickness, extent and composition of the illam, the later of which has appears to have some correlation with the gem content of the gravels. In some areas the illam is shallow (<3m below the surface), thin (ca. 10-20 cm), generally characterised by quartzose gravels and blue grey clay and is laterally impersistant, presumably

occupying depressions in the underlying bedrock surface. At other sites it is several tens of meters (20-30m) below the surface, 0.5-1.5 m thick and laterally extensive (several 100 m^2) and is occasionally repeated, with several illam horizons encountered as the shaft or pit is dug. This type of occurrence may represent a buried river valley or flood plain. Generally there is no way to predict multiple bands unless there has been earlier mining in the same area. Gem miners report however that there is no direct correlation between thickness of the illam and gem content and that the thinnest illam can yield significant gems whilst the thickest can be barren. In terms of bulk mineralogical composition of the illam there is a broad range from clay dominated to those containing fine-grained sand. The former are generally blue-green-grey in colour and have a high clay content whilst the sandier illams are dark greens, brown and black. Both are often associated with high contents of organic material which releases a pungent odour when the illam is excavated and in fact presents some difficulties when extracting the illam from deeper, poorly ventilated shafts and pits.

There is some evidence, mainly anecdotal, that the sandier illams are more often characterised by higher abundance of ”pashpurga” or yellow sapphire and are thus highly sought after and intensely worked when they are located. Illam is not always an alluvial facies and some occurrences are clearly elluvial and residual in origin. In particular the illam exploited for hessonite garnet near Buttala is in residual gravel within karstic solution hollows in weathered calcareous metasediments. This is a very local deposit and one instance the garnet is worked from the weathered bedrock itself. Mineralogically the illam is dominated by quartzose material with minor amounts of various resistate phase including opaques. The proportion of “gravel” to fines varies as does the grain size and degree of sorting and rounding within the gravel component.

A1.4 Gemstone Mineral Resources

Sri Lanka has long been well known for gems. Gem mining in Sri Lanka has a history of at least 2000 years and continues to the present day. The large number of gem varieties found in Sri Lanka that can be categorised as precious and semi-precious endow the island with a unique natural resource unmatched in its nature and diversity elsewhere in the world. Precious varieties such as sapphire, ruby, (corundum), crysoberyl and semi precious varieties such as topaz, beryl, spinel, zircon, garnet, tourmaline are found, mainly from the three major gem fields of Sri Lanka. Ekanite,

Sinhalite, Ceylonite, Taprobanite are some of the endemic gem varieties. The Ratnapura gem field situated in Central-SW Sri Lanka is the most famous and the Ratnapura, Kahawatta, Balangoda, Pelmadulla areas are the major gem mining areas of this central Sri Lankan gem field. Elahera and Okkampitiya are two other main gem fields situated the northern and NW slopes of the Central Highlands (Gunawardene & Rupasinghe, 1986). Many other smaller and scattered gem-bearing locations are found in the Central Highlands and in other southern parts of the country.

The gem fields of Sri Lanka are probably only rivalled by those of Brazil for the sheer range, quality and quantity of gem minerals found within them. The main gemstone varieties that are found in Sri Lanka are blue, yellow, white and gold sapphires including the unique "pashpurga" and "pathmarga" varieties, rubies, star rubies, star sapphires and geuda, all of which are members of the corundum group. Other common varieties include chyrsoberyl (including cats eye-cymophane), alexandrite, spinel, garnet, tourmaline, zircon, beryl, moonstone, topaz and quartz (e.g. citrine, amethyst). Much less abundant but highly valued due to their rarity are gems such as sinhalite, kornerupine, iolite, enstatite, epidote, axinite, andalusite, fibrolite, taaffeite and ekanite.

A1.4.1 Corundum

Members of the Corundum group are probably Sri Lanka's most famous and valuable gem resource, including as it does blue sapphire, ruby and the unique golden "pathmurga" sapphire. In Sri Lanka, corundum is widespread and is usually mined from secondary alluvial deposits although some "hard-rock" primary deposits are also known. The main primary source for this mineral group is thought to be the khondalite group of aluminous metamorphic rocks, which have garnet and corundum as essential constituents. Chemically all varieties of corundum are a simple oxide of aluminium (Al_20_3) and have similar physical, optical and chemical properties including a hardness (Mohs 9) second only to diamond (Mohs 10). Pure corundum is colourless but this absolute is rare in nature and most corundums are coloured by trace amounts of various metals including titanium, iron, chromium and manganese, which gives rise to the range of varieties of the mineral found in nature (sapphire, ruby etc.).

Sri Lankan corundum is typically characterised by minute inclusions of zircon that produces halos of micro cracks as well as fine, needle-like acicular inclusions of

rutile. These inclusions produce a series of unusual optical features, which are enhanced in some gem varieties. Corundum crystallises in the trigonal crystal system and can vary appreciably in form and habit. However most Sri Lankan corundum is found as hexagonal bi-pyramidal shapes, sometimes capped at one or both ends by a basal pinicoid. Corundum is also doubly refractive, with the refractive indices being 1.764 - 1.722 with the difference in refraction being a constant 0.008. Specific gravity is 3.99 and this, combined with its hardness explains its accumulation amongst the heavy resistate fraction within alluvial sediments.

The assessment of the quality of corundum and its gem potential depends upon a number of factors including its colour (intensity & distribution), transparency, lustre, texture, flaws, clarity and inclusions. In fact only 8-10 % of the corundum mined in Sri Lanka is of high gem quality not requiring any further heat treatment or processing to enhance colour.

The main variety of corundum mined in Sri Lanka is sapphire, in particular blue sapphire. The blue colour is derived from the presence of trace amounts of titanium and iron in the crystal structure. These are commonly regarded as the finest blue sapphires produced in the world. The paucity of stones from Kashmir and Cambodia now reaching the market show a wide range in blue coloration from light to dark but with exceptional clarity, transparency and size with many stones more than 10 carats in weight. The most favoured colour is an intense "cornflower" blue with a "velvety" lustre. There is some evidence that the colour of the sapphires varies from region to region in Sri Lanka, as has been observed elsewhere. In particular blue sapphires from Rambuka and Mattara have distinctive colorations unmatched elsewhere on the island. The colour and clarity of some sapphires can be enhanced by heat treatment and polishing.

Other notable varieties of sapphire from Sri Lanka are coloured yellow and orange, the former called "pusparga" and the latter "ratnapusparga". The colour in this case is controlled mainly by iron with minor chromium also present in the orange variety. Yellow sapphires are widespread but some of the best examples are have been recorded from the area around Aluthnuwara in the Balangoda area. Both varieties are highly sought, particularly if transparency and clarity are good. Another variety of yellow-orange sapphire that is especially prized and is unique to Sri Lanka is known as "pathmaraga". It shows a range of yellow-orange-pink-red colours, particularly as

flashes within the stone, depending on its orientation. Sapphires of other colours, most notably greens, browns and purples also occur but are not common.

Sri Lanka also produces some ruby although there is some controversy as to their true status as some authors argue that Sri Lankan rubies should really be classed as pink sapphires (Ariyaratna, 1993). The red coloration is produced by the presence of trace amounts of chromium in the mineral structure with greater amounts of chromium generally resulting in a deeper red colour. Sri Lankan rubies are generally much lighter red colour than the "classic" blood-red rubies of Burma and Thailand with the majority of gem quality stones being various shades of pink with a slight purple tinge. Although much less abundant than other corundums in Sri Lanka they are widespread being found in most major gem fields although the Uda-Walawe region produces some of the finest gem quality rubies.

A feature of some Sri Lankan corundum is the presence of microscope acicular mineral inclusions, usually rutile (TiO_2), orientated in a particular way relative to the c-axis of the corundum crystal structure. When these stones are cut and polished "en cabachon" style and illuminated from above, a six or occasionally 12-rayed star is observed on the surface of the crystal. The effect is best developed in dark coloured corundum where there is a large contrast between the colour of the crystal and the light coloured ray figure. These asterated sapphires and rubies, known as star sapphire and ruby are highly prized, particularly those with a solid, deep background colour and a sharply defined star figure.

A significant boost for the Sri Lankan gem industry was provided by the discovery of "geuda" corundum through the involvement of Thai gem dealers in the late 1970's. Geuda is a form of premature gem material. Its discovery has had a significant effect in enhancing the economic viability of many small gem-mining operations, which, until then, had been solely dependent upon gem quality coloured corundum to sustain them. In fact, prior to the recognition of its value as a commodity geuda had been discarded as worthless material during mining operations. An agreement was signed between the Sri Lankan government and Thailand in 1987 to legalise and regulate the geuda trade between the two countries. This has since lapsed but it did serve to stimulate the Sri Lankan geuda trade.

Geuda is a translucent to opaque variety of corundum with a milky, greasy or smoky appearance in reflected and transmitted light and some stones show a silky lustre. It

has little value of its own accord until it is heat treated during which the different varieties of geuda can take on a whole range of colours, depending upon trace constituents within them, and also undergo significant improvements in their clarity, transparency and lustre. In essence, worthless waste material can be converted into high value, gem-grade coloured sapphire by heating if it is suitable. The heating process, in its simplest form, dissolves the mineral micro-inclusions, usually rutile, back into the structure of the corundum.

There are many different types of geuda, all of which have different properties and responses to the treatment processes. The most effective treatments are obtained when selected types of geuda are heated together under tightly controlled conditions. Depending on its appearance and structure geuda that is suitable for heating is split into 5 main categories: silky, diesel, milky, dhum and ottu. Silky geuda, as its name suggest, has a silky sheen in reflected light produced by the mineral inclusions within it. Diesel geuda derives its name from the yellowish coloration of the material, which has been likened to the sheen of diesel fuel or grease. A key feature of this type of geuda is the good correlation between the depth of the yellow coloration and the intensity of the blue colour produced by the heating process. Milky geuda is a light blue -pale colour and is characterised by a milky translucence within crystals. Dhum geuda is colourless or light blue but shows a smoky brown colour when wet and illuminated by a bright light source. Ottu geuda generally show an irregular, patchy distribution of pale blue coloration.

Until the early 1980's the majority of geuda was purchased by Thai gem dealers who exported the material back to Thailand for heat treatment. However due to the reluctance of the Thai dealers to divulge their techniques, the Sri Lankan government, through the NGJA and the Institute of Fundamental Studies in Kandy, together with numerous other commercial and government organisations invested heavily in developing equipment and refining techniques for heat treating Sri Lankan geuda. Today Sri Lanka manufactures its own heat treatment furnaces that are comparable with those manufactured and used elsewhere and the country is largely self-sufficient in heat treatment technology.

The heat treatment process involves the prior selection of suitable geuda material which is free from flaws, cracks and defects which would otherwise cause the crystals to fracture or shatter during heating, possibly damaging the equipment as well as spoiling the sample load. The geuda can either be converted to a yellow or

blue colour by dissolving the rutile inclusions and altering the valence state of the colour controlling elements (Fe, Ti). In particular the yellow is controlled by the presence of Fe^{3+} and the blue by $(FeTi)^{6+}$. A temperature of 1600-1800°C for 2-6 hours, under an O_2 rich atmosphere, is required to achieve the colour change (Ariyaratna, 1993).

Such is the significance of the geuda trade to the Sri Lankan economy that the NGJA operates a special geuda trading organisation in Ratnapura where the purchase and export of geuda is arranged. The NGJA also supports the Geuda Heat Treaters Association, which assists the heat treatment industry with training, seminars and advice to geuda processors. These efforts have been largely successful in establishing the Sri Lanka geuda industry as is shown by sales and export statistics, which, despite widespread smuggling, show strong growth in this sector of the gem trade (refer to Table 2).

Table 2: Growth in the Gem Trade

Year	Weight (in carats)	Value (R.s million)
1987	-	188.6
1988	-	528.5
1989	-	554.3
1990	4 365042.66	597.1
1991	11 227879.72	634.1
1992(6 mths)	5 052343.17	268.6

Source: Data from Ariyaratna (1993)

A1.4.2 Chrysoberyl

There are 3 main varieties of chrysoberyl mined as gemstones in Sri Lanka namely chrysoberyl, alexandrite and cymophane. All are identical compositionally being aluminates of beryllium (Beryllium Aluminum Oxide: $BeAl_2O_4$) but have different appearances and gem properties. In its pure form chrysoberyl is colourless but it is often coloured by trace amounts of iron and chromium in its structure. Chrysoberyl crystallises in the orthorhomic system, generally occurring as interpenetrant complex twin crystals with single simple forms being rare. The mineral has a harness of Moh 8.5 and is doubly refractive (1.745-1.754) with a birfingence varing between 0.008 and 0.010. specific gravity is between 3.71 and 3.73, slightly less than corundum. In Sri Lanka, chrysoberyl is mainly found as water worn pebbles and fragments in alluvial deposits and has a wide distribution throughout the Sri Lankan gem fields.

One pegmatite hosted deposit at Pattara near to Morawaka yields good crystals of a transparent apple green colour, up to 8mm in size although the full extent and nature of the deposit is not known.

Simple chrysoberyl shows only a few colour variations, the most common being yellow-blue-green and varies from full transparency through to translucent and opaque varieties. The colour results from the presence of Fe3+ ions in the structure and fully transparent coloured types are the most favoured for gemstones.

A better known variety of chyrsoberyl is cymophane or Cats Eye. This variety has acicular mineral inclusions orientated at an angle to the vertical C- axis of the crystal which produces a chatoyancy effect best viewed when the crystal is cut and polished "en cabachon" and illuminated from directly overhead. The best effect is observed in cloudy or translucent stones. A 6-rayed star effect is also very occasionally observed in this mineral. Sri Lanka has the reputation of producing some of the world largest and best Cats Eye gemstones.

One of the most valued varieties of chyrosberyl is alexandrite which is characterised by a bluish-emerald green colour caused by the presence of trace amounts chromium in the structure. This mineral also has the unusual property of changing colour with a change between natural and artificial light, from green to a deep red colour, often with a hint of violet. Some Sri Lankan alexandrites also show chatoyancy but this is very rare. Alexandrite is not a common gemstone but is found in sediments in the Rakwana, Matugama, Pellawatte and Morawake regions. Sri Lanka does produce some large, clear stones that are highly valued.

A1.4.3 Spinel

This is one of the most common and widespread gems found in Sri Lanka and is closely associated with corundum due to their similar physical properties. Colours present include red, orange-red, blue, mauve and colourless. Colour is controlled by trace concentrations of certain metals with Cr producing reds, Fe and Co present in the blue stones and Mn in the purple. Stones > 10 carats are rare. Compositionally spinel is an magnesium aluminium oxide ($MgAl_2O_4$) but several other metals, including Fe, Zn, Mn, Co and Cr, can substitute into the structure replacing both Mg and Al, hence spinels show a range in optical and physical properties. Spinel crystallises in the cubic system, forming pointed octahedra, has a harness of Moh 8,

a specific gravity of 3.6-3.63 and a refractive index generally of 1.710 -1.717. Several main gem varieties are found in Sri Lanka.

Ceylonite is an iron bearing spinel ($MgFeAl_2O_4$) with a dark green-black coloration which takes a good polish in the less dark types. Black varieties are generally opaque. The presence of Fe in the structure increases the minerals RI (1.77-1.78 and SG (3.63-3.9). It is widespread in gem gravels in Sri Lanka.

Gahnite is a variety with Zn replacing the Mg and Fe ($ZnAl_2O_4$) and has an attractive green colour which produced an excellent gem in transparent stones. The presence of Zn gives gahsite a very high SG (4.0-4.62) and RI (1.805).

A1.4.4 Ghanospinel

This is a spinel with Zn and Mg in the structure and has a dark green-black colour and again SG (3.58-4.06) and RI (1.753) are high again due to the presence of Zn. One interesting but rare Sri Lankan subtype of ghanopsinel is actually a light blue colour but is very dense. Light blue Co bearing spinels are also found in gravels from Okkampitiya, Embilipitiya and Ratnapura. Spinels from the latter occurrence are also characterised by trace amounts of Ni, Fe, V and Ga.

Asterated and colour-change (violet-reddish violet spinels are also recorded from Sri Lanka, the former, as in corundum, originating from minute acicular rutile inclusions and the latter from trace contents of V and Cr in the mineral.

A1.4.5 Garnet

Garnet is a complex and compositionally diverse group of minerals showing extensive solid solution between members. In simplest terms two distinct subgroups or families have been identified, the Ca free group called the pyralspites (pyrope, almandine and spessartite) and the Ca bearing group called the ugrandites (uvarovite, grossular and andradite). Andradite and uvarovite have not been described as gem minerals from Sri Lanka. All garnets crystallise in the cubic system and have the general chemical composition $A_3B_2(SiO_4)_3$ with A = Mg or Fe^{2+} or Mn^{2+}; and B = Al or Fe^{3+} or Cr, Ti, Zr, V.

Garnet is abundant in all the Sri Lankan gem fields, as it is a very common constituent of the metamorphic basement rocks from which they are derived. Colours are variable, being a range of reds, purples, oranges and dark pinks, as is

transparency with the best gems being derived from being coloured transparent stones. The name rhodolite has been coined for purple red pyrope-almandine garnets of good clarity and transparency from the Elahera area. Hessonite (grossular) and spessarite are generally orange to orange-red in colour.

Pyrope ($Mg_3Al_2(SiO_4)_3$) is essentially an MgAl garnet but has varying amounts of Fe, Mn and Cr substituting into the structure. The latter elements give pyrope a deep, blood red colour. Hardness is Moh 7.25, specific gravity 3.7 to 3.8 and refractive index of 1.73-1.77. Pyrope is also notable for its relative lack of fractures and flaws. The deep red pyropes with a colour similar to Burmese rubies are highly valued and the gem fields around Embilipitya and Uda-Walawe are noted for their production of good pyropes.

Almandine ($Fe_3Al_2(SiO_4)_3$ is essentially and FeAl garnet with Fe^{2+} and Mn^{2+} in the structure as well. As a result it has a higher SG (3.9-4.3) and RI (1.77-.81) than prope and is also slightly harder (Moh 7.5). Its has a deep red-crimson colour, verging on brown and some stones are so dark that when cut and polished "en cabachon" they are actually hollowed out at the base to allow more light to pass into the crystal. They also suffer from a greater number of flaws, fractures and other imperfections than pyrope and are often only found as chips and fragments of larger crystals. Almandine is found in most Sri Lankan gem fields.

Spessartite (or Spessartine) ($Mn_3Al_2(SiO_4)_3$ is a manganoan garnet with minor amounts of Fe in the structure. It is generally of a red-brown colour but often with a hint of orange or yellow. SG (4.1-4.3) reflects the Mn content, as does the high RI (1.81). Hardness is Moh 7.25) and spessartite is generally free from flaws and imperfections. Colour is generally good although transparency is usually low but good gem spessartites are found in the majority of gem fields in Sri Lanka.

Grossular $Ca_3Al_2(SiO_4)_3$ is a Ca bearing garnet with minor Fe and Mn. One variety in particular, hessonite, is well known from Sri Lanka which produced some of the worlds finest examples. It has a distinctive orange-honey yellow colour which, in large stones, is highly prized. Unfortunately hessonite crystals suffer from many fractures and flaws and are only rarely found as large, complete stones. As a calcium garnet its SG (3.65) is noticeably lower than the Fe-Mn garnets as is RI (1.742-1.748). Hardness is Moh 7.25. The main source of hessonite is from residual/eluvial

deposits in the south of Sri Lanka around Kamburupitiya and Matara and less commonly alluvial deposits from the same area.

Some Sri Lankan garnets show colour change behaviour, with brown green colours in daylight changing to violet-raspberry red in artificial light. This is thought to be due to the presence of Cr, Ti and possibly V in the crystal structure. These garnets are very rare and hence much sought after.

A1.4.6 Tourmaline

The name tourmaline is derived from the Sinhalese term "thoramalli" reflecting the long history of gem tourmaline mining in Sri Lanka. Such is its ubiquity that other gems are often misidentified as tourmaline and mixed in with it during sales and auctions. Tourmaline is a complex borosilicate with the approximate general formula $XR_3Al_6B3Si_6O_{27}(OH)_4$ in which X= Na, Ca and R= can be a range of elements including Li, Mg, Fe, K, F and extra Al. The wide range in possible compositions gives rise to an equally wide range of physical and optical properties. Tourmaline crystallises in the trigonal system, often forming distinctive elongated striated prismatic crystals. Hardness varies between Moh 7 and 7.5, specific gravity between 3.0 and 3.2 with the refractive indices between 1.62 and 1.65. Colours are variable, reflecting the chemical composition, with blacks, browns and greens generally reflecting the presence of Fe and Mg in the structure. Often the crystals are colour zoned, either concentrically or along the length of the crystal, reflecting progressive changes in the composition of the crystals as they grew. Several distinctive varieties are recognised as gemstones in Sri Lanka, the most common being Uvaite and Dravite with Indicolite and Elbaite also present. Tourmalines are found in most of the main gem mining areas.

Elbaite is a Na, Li bearing tourmaline, which often shows light pink, red and blue colours. Specifically one variety, called indicolite, show a fine delicate blue colours, commonly a deep indigo which, if combined with good clarity and transparency is much sought after as a gemstone. Ligher blues are more common, often tinged with green and good quality indigo blue indicolite is rare in Sri Lanka but does occur.

Dravite is a Na, Mg bearing tourmaline characterised by dark brown to black colours and Uvaite is a brown-yellow tourmaline, named after Uva province in Sri Lanka where occurrences are particularly well developed. In both the coloration is controlled by Fe and occasionally Mn and Li.

Some tourmalines also show a chatoyant effects, a cats eye reflection, due to mineral inclusions, usually of epidote or a acicular tourmaline but no colour change tourmalines have yet been reported from Sri Lanka although they are found elsewhere.

A1.4.7 Zircon

Zircons are abundant in Sri Lanka and form the bulk of the exports of the less valuable gemstones from the country. Zircon has a simple composition, being essentially zirconium silicate ($ZrSiO_4$) but can accommodate significant amounts of other elements, in particular U and Th, into it structure. It crystallises in the tetragonal system with a specific gravity of 4.69, a hardness of Moh 7.5 and refractive indices of 1.928-1.945. This makes zircon a tough, dense mineral that survives well during weathering and through the alluvial transport cycle and thus a common component in alluvial gravels. Zircon is unusual in that it is found as two main structural types, "high" and "low" zircon, the "high" variety being the standard crystalline form described above. The "low" zircon is amorphous with the crystal structure having been destroyed by extensive radiation damage to the mineral by the radioactive emission from the incorporated U and Th as they decay. These "metamict" zircons are generally cloudy and have lower SG and RI values. The "low" zircon can often be converted back to the "high" state by heating at 1450 ^{o}C.

Zircon is found with a wide range of colours but blues, reddish browns, red, yellows and greens are the most common with colourless varieties less abundant although they have been obtained from gravels in the Matara district. Due to its high RI gem zircon show an intense fire when cut and polished. Heat treatment of zircons is common with reddish brown zircon transformed into lighter hued or even colourless stones. However this transformation is reversible by exposure to UV radiation, including that from sunlight, particularly for blue zircon. Heating can also produce chatoyancy in zircons and several magnificent cats eye zircons have been produced in this way.

A1.4.8 Beryl

Beryls are essentially Be Al silicates ($Be_3Al_2Si_6O_{18}$) containing trace amounts of various elements including Cs, Li, K, Na, Cr and Fe. Its has a SG of 2.70-2.82, a hardness of Moh 7.5 and RI of 1.58 to 1.585, these properties varying with changes in the composition of the mineral. Beryl crystallises in the hexagonal system and forms vertically striated prismatic crystals akin to those of tourmaline. Cs rich

varieties generally form more tabular crystals. Colours are variable but are dominated by shades of green and blue although some varieties are reddish-pink. The most famous variety of beryl is emerald but these have not been found in Sri Lanka. Morganite, a pale pink-red beryl and Heliodor, a golden yellow type, are also absent from Sri Lanka. However Sri Lanka does produce some high quality gem Aquamarines. As the name implies, these are a pale translucent green-blue variety of beryl with the colour derived from the presence of Fe^{3+} ions in the structure. It has an SG between 2.69-2.71 and RI between 1.570-1.575.

Aquamarine has been recovered gem gravel in a number of localities including Ratnapura, Rakwana, Galle, Matara and Tissamaharama. An in situ occurrence has been described from Lunugamvehera in SE Sri Lanka where fine blue coloured stones up to 800 carats in weight were found, However this site has been lost under a hydro-irrigation scheme. Aquamarine can be heat treated to improve its colour although this is not currently carried out in Sri Lanka, as the material is not suitable (Gunaratne & Dissanayake, 1995).

A1.4.9 Moonstone

Moonstone is one the gem variety of the K-feldspar, Orthoclase ($KalSi_3O_8$) and is the only gem feldspar reported from Sri Lanka that produces the worlds finest gem Moonstones. It is found as a greyish-white, occasionally yellowish minerals characterised by a shimmering iridescence that shows up well in polished specimens. It crystallises in the monoclinic system, has a hardness of Moh 6 and an SG of 2.56- 2.7 depending on its composition. They are generally translucent to opaque and show two good cleavages. The distinctive shimmering effects actually results from a very fine scale exsolved intermix of true orthoclase (specifically adularia) and albitic plagioclase called microperthite, the differing optical properties of the two phases producing the blue iridescence called adularescence. The best effects are observed in stones cut "en cabachon" style. Some moonstones also show chatoyancy and although this is not as well developed as in other mineral phases it is thought to be unique to Sri Lankan moonstones. In Sri Lanka the best moonstones are found in the in situ primary deposit at Meetiyagoda with lesser occurrences at Kundasale, Balangoda and at Imbulpe, east of Ratnapura. Moonstone is also commonly recovered from alluvial gravels in most of the main gem mining areas.

A1.4.10 Topaz

Topaz is an aluminium fluosilicate (Al_2SiO_4 (F, OH)$_2$ with trace amounts of Fe, Ca, Na and K. It crystallises in the orthorhombic system forming prismatic multifaceted crystals, often with one end terminated by a dipyramid 1st and 2nd order prism and a basal pinicoid with the other end terminated by a basal cleavage plane. Hardness is Moh 8, SG is 3.4-3.6, and increasing with increasing F content and RI is 1.61 to 1.64. Sri Lankan topaz is predominantly colourless although more rarely pale blue and blue green types also occur. The best topaz occurrences are Polwatte in the Matale-Rattota area, Balangoda and around Sigiriya. The real value of Sri Lankan topaz is in its excellent response to colour enhancement by irradiation which produces and intense light blue colour. The material from Sri Lanka is especially favoured as it takes on excellent colours and "cools" down quickly from the irradiation (either gamma, neutron or high energy electrons may be used as a source) process due to its low levels of impurities. No irradiation is carried out in Sri Lanka with the topaz being exported for processing.

A1.4.11 Quartz

Quartz has one of the simplest of mineral compositions as SiO_2 and is one of the most common and widespread mineral phases on Earth. It crystallises in the trigonal system and when best developed form pseudo hexagonal prisms often terminated by rhombohedrons giving the appearance of hexagonal dipyramids. It has a hardness of Moh 7, SG of 2.60-2.65 and RI of 1.544-1.553. Its pure form it is normally colourless or white, transparent to translucent but it is almost always contains trace impurities which affect the transparency and clarity as well as imparting a range of colours. Two major categories of quartz, distinguished on their structure are recognised, crystalline and crypotcrystalline, both of which contain varieties used as gems and semi-precious stones in Sri Lanka.

In the crystalline group rock crystal is the name given to high purity, clear, transparent quartz which is used as both a semi precious stone and in industrial processes.

Rainbow quartz is essentially a type of rock crystal within which minute cracks and films of air or fluid produce rainbow coloured interference patterns. Smoky quartz, as its name suggest is characterised by a dark brown to grey coloration in a translucent-transparent stone. The darkest varieties are almost black and are known as morion whilst the brown-grey varieties are known as Cairngorm. The origin of the smoky

colour is unclear, suggestion varies from radiation damage to organic inclusions, but it can be modified by heat treatment up to 200°C. Amethyst is violet-hued quartz with the colour derived from Mn bearing inclusions or possibly from the presence of potassium ferrocyanide or ferric thyocyanide. Sri Lanka produces some high quality amethyst from Kandy, Nuwara Eliya, Ratnapura and Avissawella., including an in situ occurrence of very high quality material from Kekirawa. Bi-coloured yellow and violet material is reported from the same vein and is known as ametrine. Citrine is a yellow quartz, the colour usually attributed to the presence of trace Fe, and Sri Lankan is much sought after on account of its fine colours but even this is generally heat treated to improve its quality. Rose quartz occurs in various shades of pink, Ti and Mn are the colouring agents, and generally forms large irregular masses rather than discrete crystals. Its is also usually semi transparent to opaque and is mainly carved and shaped as a semi precious stone. Good material is confined to the areas around Matale, Polonnaruwa, Sigiriya and Ratnapura. Asterated and chatoyancy (cats eye) quartz are found in Sri Lanka, the effects again resulting from various mineral inclusions, identified as sillimanite in the case of gems from Ratnapura. Colours are usually green, yellows and light browns with some greys as well.

In the cryptocrystalline form the quartz occurs as minute microscopic grains forming generally amorphous masses. Three main varieties are of interest in Sri Lanka:

- Chalcedony is a cryptocrystalline quartz characterised by a fibrous texture and forms amorphous boytroidial and mammilain masses, frequently banded and layered in terms of its colour, transparency and clarity.
- In detail agate is really a variety of chalcedony but is considered separately as it is distinguished by its concentrically arranged, variably - coloured bands which are often curved or wavy in shape. Agates are used for decorative purposes in low cost products and also are used in traditional Kandyan jewellery.
- Carnelian is a vivid red colour, stained by iron oxides, and is also used in bead making and traditional jewellery.

A1.4.12 Less common and unusual gemstones

Sinhalite is a borate of Mg, Fe and Al with the general composition (Mg(AlFe)BO_4. It crystallises in the orthorhombic system, has an SG of 3.48, RI of 1.765-1.712 and a hardness of Moh 7. It shows yellow-brown-green colours and was originally misidentified as a brown peridot when it was first discovered. It is almost exclusively

a Sri Lankan gem with good material being mined from alluvial deposits in the Elahera, Avissawella, Ratnapura and Uda-Walawe regions. The Elahera region in particular is known for its large yellow-brown stones.

Kornerupine is a Mg, Al borosilicate with the general composition $Mg_3Al_6(Si,Al,B)_5 O_{21}$ (OH). It crystallises in the orthorhombic system with an SG of 3.27 to 4.43, RI of 1.680 to 1.668 and a hardness of Moh 6.5. Sri Lankan gems from alluvial gravels are generally green-yellowish green-greenish brown and good stones are found in the southern part of the island, particularly at Avissawella, Ratnapura, Rakwana and Empilipitaya and also at Elahera. Some stones show a chatoyant effect, caused by rutile inclusions, which is best developed in the darker coloured stones.

Andalusite is aluminium silicate (Al_2SiO_5) and a common mineral in metamorphic rocks. It also crystallises in the orthorhombic system, has an SG of 3.15, RI of 1.634-1.648, is doubly refractive and has a hardness of Moh 7.5. Gem quality material is generally green-brown-yellow with rare red-brown and pinks and when cut into the usual tabular form, shows excellent internal flashes of red colour. The best Sri Lankan material comes from alluvial deposits at Hatton, Nawalapitiya and Avissawella. An unusual variety of anadalusite is Chiastolite which shows an distinctive cruciform feature formed by carbonaceous inclusions in crystals sliced horizontally but this is very rare in Sri Lanka.

Apatite is a Ca phosphate containing hydroxyl, chlorine and fluorine with the general formula $Ca_5(PO_4)_3(F, OH)$ and can also contain an appreciable amount of rare earth elements. It crystallises in the hexagonal system, SG is between 3.18 and 3.21, RI is 1.648-1.635 and a hardness of Moh 5. It is also doubly refractive. Most gem apatites from Sri Lanka are of blue, green and yellow coloration with excellent quality blue apatites being found in marbles in the region of Matale along with purple spinels. Similar occurrences are found at Hakgala near Nuwara Eliya. Some very rare examples of chatoyant apatites are found in Sri Lanka.

Scapolite is a member of the meionite-marialite solid solution series and is a Na, Ca, Al silicate with the general formula $(Na,Ca)_4Al_{3-6}Si_{6-9}O_{24}Cl, CO_3$. It crystallises in the tetragonal system, has an SG of 2.6 to 2.74, RI of 1.540 to 1.577 and a hardness of Moh 5 to 6. These properties vary with changes in composition with values generally increasing with higher Ca content. It occurs in a variety of colours including greens, yellows, violet and brown and some show chatoyancy when cut en "cabachon" due

to acicular micro inclusions. It also fluoresces under UV radiation. Gem scapolite is found in several places in Sri Lanka, including Ratnapura, Horana-Matugama, Embilipitaya- Uda-Walawe, Passara and Buttala.

Cordierite (Iolite) is a Mg, Al, Fe silicate of the general form $(Mg, Fe)_2Al_4Si_5O_{18}$ and crystallises in the orthorhombic system. It has an SG of 2.63 or higher, depending on Fe content, RI of 1.544 to 1.556 and a hardness of Moh 7.25. It shows a strong pleochroism, showing different colours when viewed in different directions to the crystal axes, and colours are generally yellow-light brown and purplish blue. In Sri Lanka, fine blue gem cordierites are found around Ratnapura, Embilipitaya and Matugama. Occasionally stones contain inclusions of heamatite which give rise to a red coloration within the gem, which are known as "blood shot" corderite.

Diopside is a Ca, Mg silicate with the general formula $CaMgSi_2O_6$ and is the Mg end member of a solid solution series with the Fe bearing Hedenbergite ($CaFeSi_2O_6$). It crystallises in the monoclinic system, has an SG of 3.29-3.32, RI of 1.670 -1.701 and is doubly refractive. Shades of dark green are the dominant colours and both asterism and chatoyancy do occur, mainly caused by inclusions of magnetite which result in the stone being magnetic, a useful diagnostic tool. It has a well-developed cleavage. The best diosides are found in the Avissawella, Haputale, Rakwana, Ratnapura, Morowaka and Kataragama gem fields.

Enstatite is another Mg silicate, but usually contains some Fe (giving bronzite and hypersthene), with the general formula (Mg, Fe) SiO_3. It crystallises in the orthorhombic system, has an SG of 3.2-3.5, RI is 1.718-1.723, values which vary with Fe content, and has a hardness of Moh 5.5. Colours are generally brown-greens and are occasionally asterated and show chatoyancy due to rutile inclusions. Good gem enstatites are found in Uda-Walawe, particularly around Chandrika Wewa, around Rakwana and Kartaragama.

Taaffeite is an exceptionally rare gem but very valuable because of this. The original cut crystal was thought to be a spinel but subsequent study showed that it was a totally new mineral, discovered in Sri Lanka. It is a Be, Mg, Al oxide ($BeMgAl_4O_8$) which crystallises in the hexagonal system, has an SG of 3.6, RI 1.718-1.723 and a hardness of Moh 8. Mauves, purples and lilacs are the most common colours with Fe^{3+} thought to be the colour causing agent along with trace amounts of Cr and V as well as Zn in some cases. Most of the world supply comes from Sri Lanka and the Uda-Walawe, Balangoda and Passara-Lunugala areas are best known sources.

Fibrolite (Sillimanite) is another form of Al_2SiO_5 but good gem material is rare due to the fibrous, acicular nature of most of the material. It crystallises in the orthorhombic system, has an SG of 3.23-3.27, RI of 1.663-1.684, is doubly refractive and has a hardness of Moh 7.5. colours are usually pale blues and green and the mineral is strongly pleochroic in 3 directions, showing different colours in different directions. Good gem material is found in the alluvial gravels of the Horona-Matugama, Morowaka and Ambalantota regions.

Epidote is a common mineral but rare as a gemstone although a related zoisite, Tanzanite, is a famous gem. It is a hydrated Ca, Al, Fe silicate with the general formula $Ca(Al, Fe)Al_2Si_3O_{12}(OH)$ and forms a solid solution series with clinozoisite. It crystallises in the monoclinic system, has an SG of 3.4, RI of 1.736-1.770 and a hardness of Moh6.5. Colours are generally yellow-greens and the mineral is strongly pleochroic. Good crystals are difficult to find as it has a strong cleavage and fragments easily. Good epidote has been found around Avissawella, Lunugala-Passara and the Rakwana-Bulutota region.

Idocrase is a Ca Al Mg silicate with the general formula $Ca_{10}\ Mg_2\ Al_4\ (SiO_4)_5\ (Si_2O_7)_2\ (OH)_4$ and also contains small amounts of Ti, F and B. The mineral crystallises in the tetragonal system, has an SG between 3.32 -3.47, RI between 1.700-1.721 and a hardness of Moh 6.5. In good material it forms prismatic tabular crystals with a dipyramid base and termination. Sri Lankan idocrase is generally yellow-green in colour with yellows dominant and is found in the Horton-Matugama-Pelawatte, Haputale and around Ambalantota. The massive, green variety, Californite, has not been reported from Sri Lanka.

Scheelite is more commonly an ore mineral for W but certain rare pale coloured varieties have been used as gemstones. It is a Ca W oxide ($CaWO_4$) and crystallises in the tetragonal system. Its has an SG of 5.9-6.1, RI of 1.918-1.934 and has a hardness of 4.5-5. It is not much favoured as a gem due to its relative softness but is concentrated in gravels due to its high density. Gem scheelite with pale yellow and orange colours has been found in gravels from Uda-Walawe and Ratnapura with a small in situ occurrence near Embilipitiya. A key distinguishing feature of scheelite is its bright fluorescence under UV light.

Danburite is a very rare gem and is a Ca borosilicate ($CaB_2Si_2O_8$) which crystallises in the orthorhombic system as prismatic crystals similar to topaz in habit. It is

generally pale coloured or colourless, with light yellows, pinks and very light brown common. SG is 3.00 with RI of 1.630-1.636 and a hardness of Moh 7. Danburite also fluoresces under UV radiation. Good quality material has been found in gravels in Ratnapura, Rakwana, Bulutota and Morawaka and it was initially misidentified as high quality yellow sapphire.

Dumortierite is an exceptionally rare but valuable gemstone. It is an Al borosilicate ($Al_{27}B_4Si_{12}O_{69}(OH)_3$ which crystallises in the orthorhombic system. It has an SG of 3.41, RI of 1.686-1.723 and hardness of Moh 7. Colours are generally pale with violets, pale pinks and brown common and Sri Lankan material is also renowned for its transparency. It has been reported from gravels in the Ratnapura area.

Phenakite is a rare Be silicate (Be_2SiO_4 with very few trace constituents and crystallises in the trigonal system forming lenticular rhombohedral crystals. It has an SG of 2.79-3.00, RI of 1.654-1.670 and a hardness of Moh 7.8-8. It is generally colourless although pale green-blues, yellows and pinks are reported. Sri Lanka is well known for the large, clear, and facettable crystals found in the gravels in the Horana-Matugama region.

Axinite is a Ca Al borosilicate containing some Fe and Mn in its structure replacing Ca and has the general formula $(Ca, Fe, Mn)_3Al_2(BO_3)(SiO_4O_{12})$-(OH). It crystallises in the triclinic system, forming wedge shaped crystals with an SG of 3.27-3.29, RI of 1.685-1.675 and a hardness of Moh 7. It is strongly pleochroic. The substitution of Fe and Mn causes some variation in these properties and results in a range of colours from blues and violets through to reddish brown, although some crystals with low Fe and Mn are colourless. Gem material is found around Horana, Matugama, Rakwana and Haputale.

Sphene is a Ca Ti silicate ($CaTiSiO_5$), usually containing some Fe, Th and rare earth elements as well, which crystallises in the monoclinic system producing distinctive wedge shaped crystals. It has an SG of 3.45- 3.52, RI of 1.885-2.050 and a hardness of Moh 5.5. Colours are variable but are dominantly yellows, greens and browns and the minerals is also pleochroic (trichoric) along the three crystal axes. Although is low hardness diminishes its value as a gem, quality sphene is worked from both in situ deposits at Amarawewa and alluvial gravels at Kartagama, Morawaka and Galle in southern Sri Lanka.

Ekanite is a rare mineral and seldom used as a gemstone although Sri Lanka does produce some of the best quality material in the world. It is a Ca Th silicate ($Ca_2ThSi_8O_{20}$) which was first discovered in Ratnapura in 1953. It has an SG of 3.28, RI of 1.596 and a hardness of Moh 6-6.5 although lower values have been reported. Colours are usually drab greens, yellows and browns. Its is a radioactive phase and is usually found in a metamict state due to radiation damage to the crystal structure. Ekanite is found in Ratnapura, Eheliyagoda, Rakwana and the Passara-Lunugala-Buttala region.

Sapphirine is rapidly becoming a highly sought after gem with demand far out stripping supply. Its is an Mg Al silicate ($Mg_7Al_{18}Si_3O_{40}$) which crystallises in the monoclinic system. SG is 3.40-3.58, RI 1.705-1.711 and hardness Moh 7.5. Colours are pinkish browns and the mineral is strongly pleochroic. In Sri Lanka, a deposit has recently been discovered near Kolonne, near Embilipitiya and is producing some good quality material although large stones are rare.

Serendibite is an extremely rare gemstone. It is a Ca Mg Al borosilicate ($Ca_2(Mg, Al)_6(Si,Al,B)_6O_{20}$ which has many similar optical and physical properties to sapphirine leading to confusion between the two. It crystallises in the triclinic system, has an SG of 3.42, and RI of 1.710-1.706 and a hardness of Moh 7. Colours are dominantly purples, blues and pale yellows. It has been reported from Gangapitiya near Kandy, associated with moonstone in a specific association with diopside, green spinel and scapolite.

Fluorite is simply a fluoride of calcium (CaF_2) which contains trace amounts of Y and Ce substituting for Ca. It crystallises in the cubic system, has an SG of 3.18-3.25, and RI of 1.433 and a hardness of only Moh 4. It occurs in a wide range of colours and as a colourless stone. Despite being a comparatively soft mineral it is cut and polished as a semi-precious stone. Good fluorite is found at Kolonne and Rakwana, worked from in situ deposits.

Peridot is the gem version of the mineral olivine and is a simple Mg, Fe silicate ($(Mg, Fe)_2SiO_4$, there being complete solid solution between the Mg and Fe end members (fosterite-fayalite). It crystallises in the orthorhombic system, has an SG of 3.3-3.4, RI 1.65 -1.69 and hardness of Moh 6.5-7, these properties increasing with increasing Fe content. Colours are typically pale olive greens and good stones are generally cut as

a tabular crystal or "en cabachon". Good peridot has been recorded from around Ratnapura.

Wollastonite is a simple Ca silicate (Ca SiO_3) and crystallises in the monoclinic system and has an SG of 2.9, RI 1.61-1.63 and hardness of Moh 4.5-5. Good crystals are rare but several yellow-brown facettable pieces have been found in southern Sri Lanka. It can also be distinguished by its fluorescence under UV light.

Rutile is simply Ti dioxide (TiO_2) and can contain small amounts of Nb, Ta and Fe. It crystallises in the tetragonal system and has an SG of 4.23, RI 2.62-2.90 and hardness of Moh 6-6.5. Although rare, translucent red-brown crystals can be found and worked as gemstones. Some green varieties are known, the colour imparted by Cr. Rutile is widespread in the Sri Lankan gem fields but gem quality material is rare.

Monazite is a rare earth and Th-bearing phosphate (La, Ce, Nd, Th)PO_4 and is highly radioactive when it contains Th. Very rare red-brown translucent crystals are found in alluvial gravels in Sri Lanka but are generally not sought by any body other than mineral collectors. Material from Sri Lanka is monoclinic, has and SG of 5.25, RI 1.797-1.845 and a hardness of Moh 6.

A1.5 Gem Resources

Sri Lanka has the highest density of gem deposits in relation to its landmass in the world and production of gems dominates its export earnings from minerals. However, despite this neither government nor private organisations have carried out much scientific investigation, mapping or appraisal of the country's gem potential. In the early 1990's the Institute of Fundamental Studies (IFS) in Kandy instigated a systematic survey, using 500 samples of the gem mineral potential of south-central Sri Lanka (Dissanayake & Rupasinghe, 1993). The work was funded by the IFS and by the Sri Lankan Export Development Board (SLEDB). Based upon the results of this sampling and follow up mineralogical work a set of 4 key criteria were established to categorise the gem mineral potential of south central Sri Lanka. The key criteria defined were:

i) Lithology and Topography
ii) Drainage Density
iii) Presence of Alluvium

iv) Heavy Mineral Concentrations

These are described below.

A1.5.1 Gemstone Indicators

i) Lithology and Topography: The Highland Group of rock is highly conducive to the formation of gem minerals but this potential also requires the interplay of a suitable topography to mobilise the gems from their source rocks and to concentrate the gems into alluvial deposits. In particular flat lying river valleys with wide, meandering water courses favours the formation of alluvial gem deposits.

ii) Drainage Density: A well-developed fluvial network is essential for the weathering, transport and concentration of gemstones into alluvial deposits. The central and southern regions of Sri Lanka have a well-developed radial drainage network and high rainfall values.

iii) Presence of Alluvium: Areas that show extensive development and thickness of alluvial deposits such as floodplains and valley floors have a high potential for concentrations of gem minerals.

iv) Heavy Mineral Concentrations: The presence of other heavy minerals in the alluvium is one of the best indicators for gem potential. In particular the appearance of zircon, spinel and garnet are particularly indicative as they have very similar densities and hardness to gem minerals proper. Studies of the samples suggested that at least 25% of the alluvium needs to be composed of heavy minerals for the area to be prospective (ie. showing potential for mining).

A1.5.2 Classification of Gem-bearing Potential in Sri Lanka

Based on the results of the sampling and application of the criteria above a 5-fold classification was devised to categorise the gem bearing potential of the area, ranging from a "No Deposits" class up to a "Highly Probable" class. The distribution of these groups is illustrated in Figure 2, which clearly outlines the 3 main gemfields, centred on Ratnapura-Rakwana; Buttala and Elahera.

Based upon the dataset and samples collected by the study described above several authors have attempted to refine the resource map and also define specific mineral indicators for the gem fields. In addition, many of the samples have been analysed by

geochemical means to investigate correlation's between gem distribution and the bulk chemical composition of the alluvium within which they are located. Statistical methods, using factor and discriminant analysis have shown a good correlation between certain elements and ratios of elements (Rare Earth Elements (REE) are Li, F, Rb/Sr, Zr, Nb, Y, K and Ba – need full names) and areas of high gem potential (Fernando, Rupasinghe & Dissanayake, 1996; Dissanayake et. al., 1994; Gamage et. al., 1992).

Studies of the associated accessory and indicator minerals in the gem fields have reinforced the close association between gem deposits and the presence of other "heavy" resistate phases. New phases, in addition to zircon, spinel and garnet, were identified including salitic pyroxene, monazite, davidite, sphene, Ca-scapolite, ilmenite and low grade corundum (Rupasinghe, Dissanayake & Mendis, 1994; Rupasinghe, Senaratne & Dissanayake, 1986).

The relative lack of official sanction and support for a formal survey of the gem potential of Sri Lanka may reflect a deliberate policy on the part of the government to maintain the gem mining industry as essentially a cottage industry supporting a large proportion of the rural population, in many cases augmenting income from agriculture. Such a philosophy has certainly restricted the commercial over-development and more mechanised mining of resources in Sri Lanka (Gunaratne & Dissanayake, 1995; Ariyaratna, 1993).