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Classification of gem deposits of Sri Lanka

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Abstract

Approximately 25% of Sri Lanka's landmass is gem-bearing. Most of the gem deposits are located in restricted zones (approximately 15 000 sq km) within the area occupied by rocks of the Highland/Southwestern Complex. Over 90% of Sri Lanka's gem mining is from secondary placer deposits that can be classified as sedimentary gem deposits of residual, eluvial and alluvial types. Primary or in-situ gem occurrences are located mainly in contact-metamorphic zones comprising of skarn and calcium-rich rocks. Corundum occurrences have also been found in aluminous-rich, silica-deficient metasedimentary formations. Gem minerals that are frequently found in pegmatites within the Highland/Southwestern Complex include corundum, zircon, beryl, quartz varieties, feldspar and chrysoberyl. A special feature of many secondary gem deposits of Sri Lanka is their location on morphotectonically controlled sites.

Introduction

Sri Lanka is known the world over for its vast potential and exquisite varieties of gem minerals. Gem mining in Sri Lanka has a history of over 2000 years and continues unabated even at present. In a recent study of the gem potential of Sri Lanka, the authors (Dissanayake & Rupasinghe 1993) have observed that nearly 25% of Sri Lanka's landmass is gem-bearing. Their study clearly indicates the vast gem potential of Sri Lanka yet to be unearthed. However, in spite of the very long history of gem mining in Sri Lanka, there had been no major study of the gem deposits aimed at their scientific classification.

Among the earliest accounts on the precious gemstones of Sri Lanka is that by Wadia & Fernando (1945). Subsequently several workers dealt with different aspects of the geology and mineralogy of gem deposits of Sri Lanka (Gübelin 1968, Katz 1972, Silva 1976, Dahanayake et al. 1980, Munasinghe & Dissanayake 1981, Rupasinghe & Dissanayake 1984, Dissanayake & Rupasinghe 1993).

The sedimentary gem deposits of Sri Lanka were classified by Dahanayake et al. (1980) into three types, namely residual, eluvial and alluvial formations. Even though sedimentary gem deposits form a major constituent of Sri Lanka's gem resources, later work has shown the importance of other types of gem deposits (Silva & Siriwardena 1988, Mendis et al. 1991, Kumarathilake & Ranasinghe 1992). There is, therefore, a real need to classify all the gem deposits of Sri Lanka on a scientific basis as it would provide background information for future exploration efforts. At present, exploration for gem minerals is based on mere 'hearsay' and chance, and a proper understanding of the nature of the different types of gem deposits is therefore timely. This paper aims at a scientific classification of the gem deposits of Sri Lanka based on their geological occurrence and inferred origin.

Geological setting of gem-bearing terrains

Approximately 90% of Sri Lanka is comprised of metamorphic rocks of Precambrian age. These rocks have been classified in different ways by a number of authors (Adams 1929, Cooray 1984, Vitanage 1985, Kröner 1986). Field work as well as isotopic, geochronological, petrological and geochemical data obtained by a German-Sri Lanka Research Consortium have led

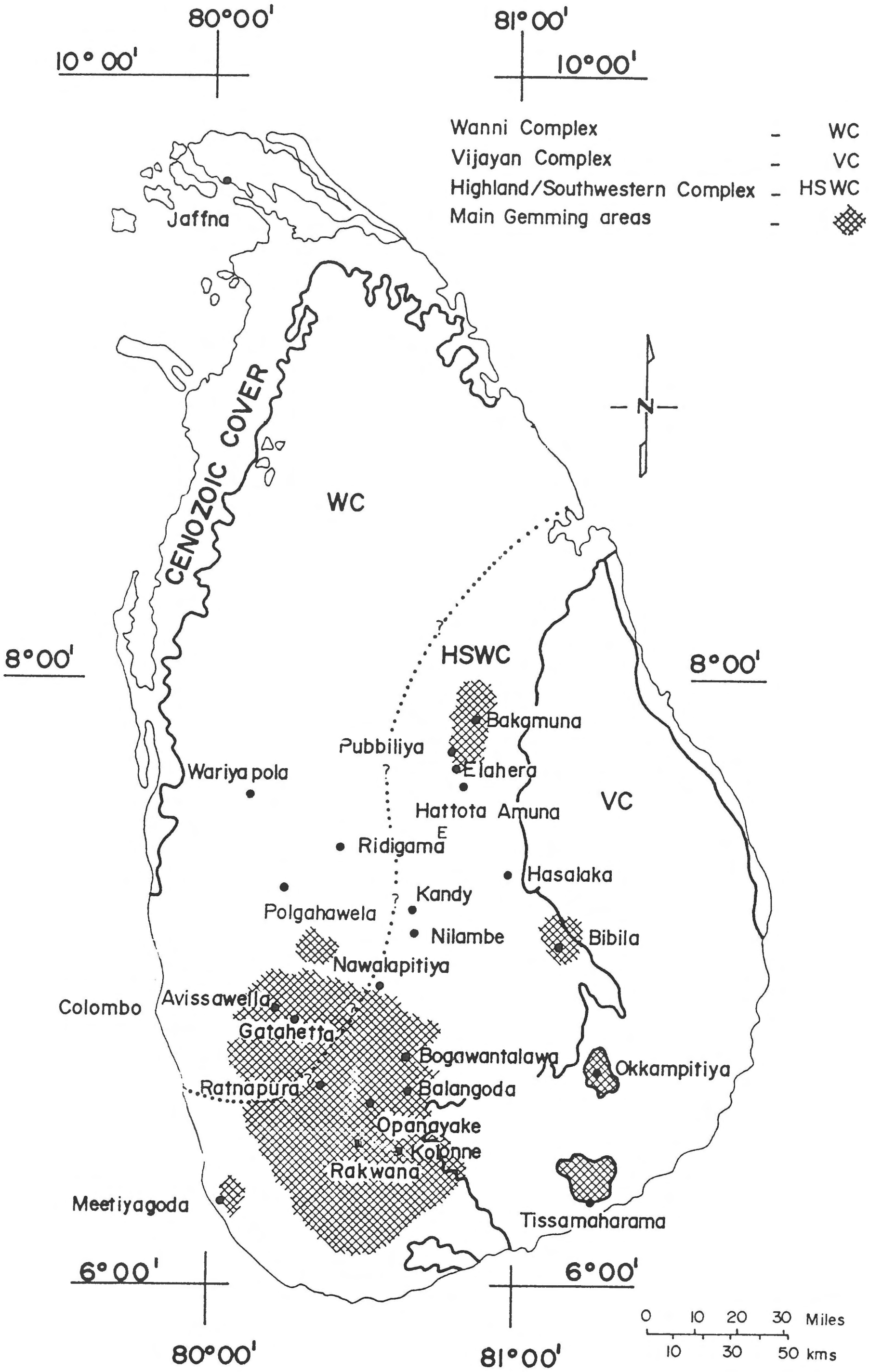

Fig. 1. Simplified and generalized geological map of Sri Lanka showing major lithotectonic units (after Kröner et al. 1991). Note that the boundary between HSWC and WC is still not well defined; the dotted line gives only the proposed boundary.

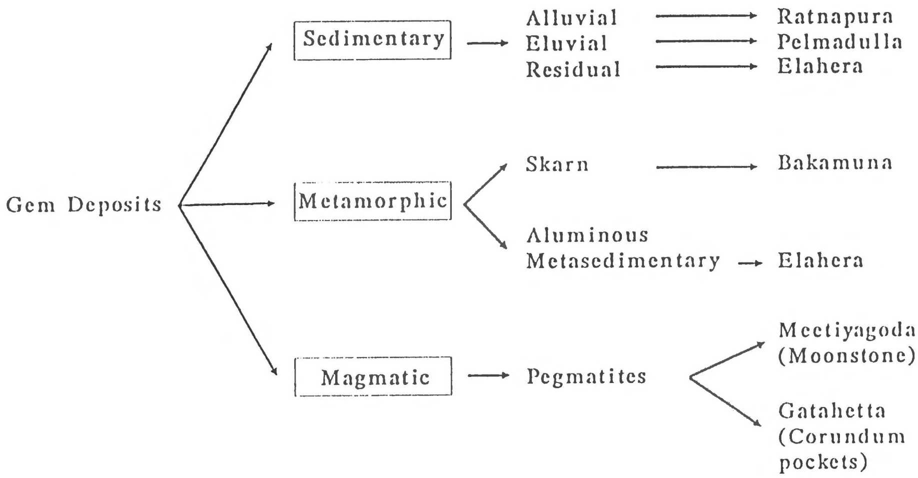

Fig. 2. Classification of gem deposits of Sri Lanka.

to substantial revision of the existing classifications (Kröner et al. 1991). Figure 1 illustrates the new classification of Kröner et al. (1991) which is used in this study. Four lithotectonic units are identified in accordance with the rules set forth in the North American Code of Stratigraphic Nomenclature (Hattin 1991).

Lithotectonic units

The Highland/Southwestern Complex

The Highland/Southwestern Complex (HSWC; Kröner et al. 1991) is the largest unit forming the backbone of the Precambrian rocks of Sri Lanka. Included in it are the supracrustal rocks of the former Highland Series (Group) and Southwestern Group (Cooray 1962, 1984) together with a variety of igneous intrusions of predominantly granitoid composition that now occur as banded gneisses. This is the granulite terrain of Sri Lanka, the prominent rocks present being varieties of granulites, charnockites, quartz-feldspar-garnet-sillimanite-graphite schists, quartzites, marbles and calc-gneisses. Based on field and mineralogical information, Kröner et al. (1991) infer that a significant proportion of the rocks in the Highland/Southwestern Complex is of granitoid origin.

Widespread arrested charnockite formation has been observed in the Central Highland regions in the districts of Colombo, Kurunegala and Galle (Hansen et al. 1987).

The most important observation is that most of the gem deposits of Sri Lanka occur within the Highland/Southwestern Complex. This complex, which has calciphyres, charnockites and cordierite-bearing gneisses, contains abundant sedimentary gem deposits such as those at Ratnapura, Avissawella, Balangoda and Rakwana.

The source rocks of the gem minerals in the sedimentary gem deposits are still a subject of much debate. Among probable source rocks that are mentioned are skarns, marbles, pegmatites, garnetiferous gneisses and contact rocks of charnockites. Recent research (Mendis et al. 1993) appears to indicate calcium-rich rocks as being important source rocks for gemstones of Sri Lanka. Charnockites may be considered important as a heat source for contact metamorphism of limestone and aluminous sediments.

The Vijayan Complex

The Vijayan Complex (VC) consists of biotite-hornblende gneisses and scattered bands of metasediments and charnockitic gneisses. Small plutons of granites and acid charnockites also occur close to the east coast (Jayawardena & Carswell 1976). A prominent feature in the area is the NW-trending suite of dolerite dykes. Milisenda et al. (1991) have described the gneissose granitoids of the Vijayan Complex as having compositions ranging from tonalite to leucogranite. Kröner et al. (1991), commenting on the fact that the Vijayan rocks have not experienced granulite facies metamorphism, interpret the charnockitic bodies occurring within the Vijayan domain as tectonic klippen and/or unfolded or intersliced fragments of rocks of the Highland/Southwestern Complex, similar to the Kataragama klippe of which the derivation from the latter complex has been established.

The Wanni Complex

The Wanni Complex (WC) includes the rocks of the former Western Vijayan Complex and consists of a suite of granitoid gneisses, charnockitic gneisses and granites. Recent work by Milisenda et al. (1994) has shown that there is a large diversity of amphibolite to granulite-facies rocks such as metasediments of predominantly pelitic to semipelitic composition. The depositional age of the Wanni Complex metasediments is yet unknown, but age data obtained from detrital zircons from metapelites show that the Wanni Complex is younger than the Highland/Southwestern Complex. The boundary between the Wanni Complex and the Highland/Southwestern Complex is poorly defined.

Scheme of classification of gem deposits

Figure 2 shows the classification scheme of the gem deposits of Sri Lanka. The scheme follows the accepted petrological classification of the main three rock types and the genesis of the deposits therefore forms the basis of the classification. In addition a special category which could be denoted as structurally controlled deposits can be considered. Gem deposits very often occur in exploitable structures within metamorphic formations and these have been found to be common in the Highland/Southwestern Complex. A further advantage of a genetic classification of gem deposits lies in its predictive value. Contact-metamorphic zones associated with calcium-rich rocks for example are likely loci for gem deposits and identification of such features thus helps in locating target areas for detailed exploration.

Sedimentary gem deposits

Dahanayake et al. (1980) have classified the sedimentary gem deposits in Sri Lanka in three types, namely (a) residual, (b) eluvial, and (c) alluvial. This classification has genetic inferences and hence is of predictive value. It is therefore proposed to adhere to this classification. The reader is referred to the original paper of Dahanayake et al. (1980) and only a brief outline of the different types of sedimentary gem deposits indicated in Fig. 2 is given here. The localities mentioned are shown in Fig. 1.

Residual gem deposits

These deposits are represented by beds containing gem minerals mostly deposited in-situ and are found at depths ranging from a few centimeters to about 10 meters below the surface. The deposits are generally found on flood-plains of rivers and streams and the source of the gem minerals is located nearby. The residual gem deposits are characterized by layers of alternating sands, clays and laterites containing angular rock fragments. Such residual deposits are very common in the Elahera gem field.

Eluvial gem deposits

Hillslopes often expose gem-bearing layers of the eluvial type. Depending on the location with respect to the topography of the hill slopes and the flat areas incised by valleys, the eluvial deposits often pass imperceptibly into the alluvial deposits described below.

Alluvial gem deposits

Alluvial gem deposits are by far the most prevalent and are characteristic of the main Ratnapura gem field. They can reach depths of 25 meters and may even have more than one gem-bearing layer (illam). The alluvial gem deposits generally lie in old stream terraces and flood plains and are characterized by well-rounded heavy minerals indicating their provenance. The gem-bearing beds in alluvial deposits are invariably heterogeneous and show different shapes and sizes. The presence of a gem-bearing layer in one pit may not necessarily be an indication of its presence in an adjacent gem pit. Figure 3 illustrates a geological section of gem beds in an alluvial gem deposit in the Ratnapura gem field. Figure 4 shows a photograph of such a deposit.

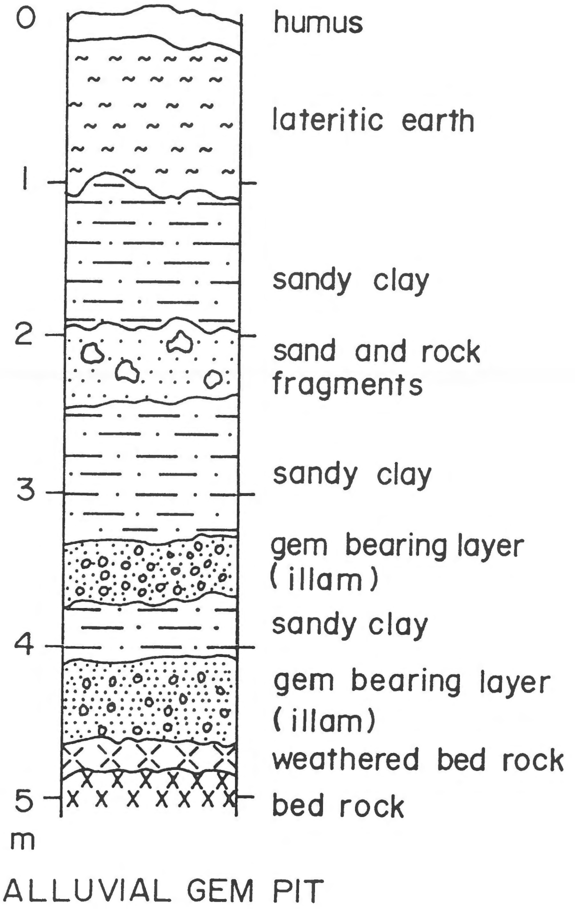

Fig. 3. Lithological column of an alluvial gem deposit in the Ratnapura gem field.

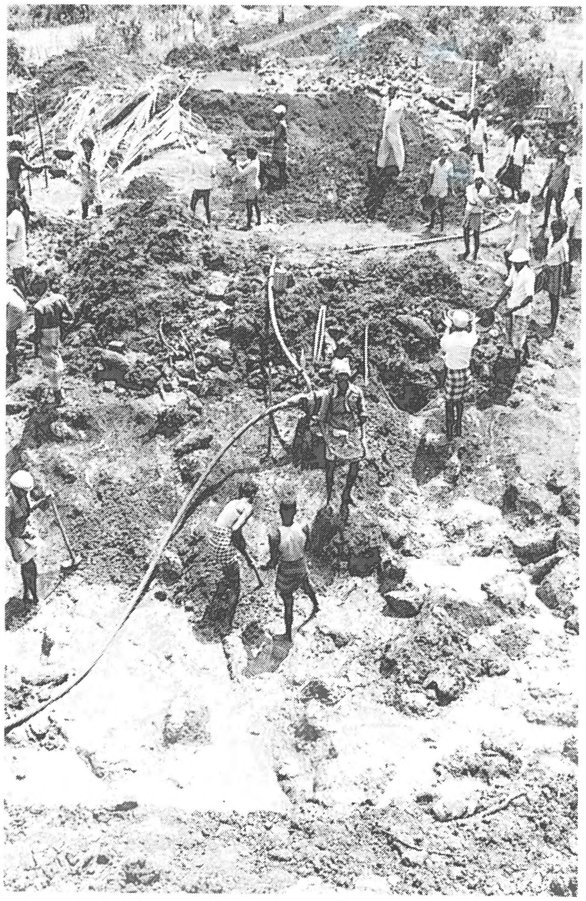

Fig. 4. Typical alluvial gem deposits in the Ratnapura gem field.

Mineralogy of the sedimentary gem deposits

Gem mining in Sri Lanka is almost entirely confined to the sedimentary deposits except for a few minerals such as moonstones and topaz that are mined from pegmatite deposits. The sedimentary gem deposits are abundant in the gem fields of the Ratnapura, Elahera, Rakwana, Balangoda, Opanayake, Hasalaka, Bibile, Passara, Okkampitiya and Deniyaya areas. Mineralogically the sedimentary gem deposits of Sri Lanka contain a wide variety of gemstones and these include corundum, zircon, spinel, chrysoberyl, garnet, beryl, tourmaline, topaz, sillimanite and cordierite.

Rupasinghe et al. (1993) carried out a detailed study of over 200 samples obtained from alluvial gem deposits located on a granulite basement in Sri Lanka and showed the potential use of indicator minerals in gem exploration. Geikielite, sphene and davidite, monazite, scapolite, spinels and garnets and salite in stream sediments were found to be suitable for further investigation as indicator minerals of gem deposits.

Careful mineral analyses in stream sediments provide the necessary information on the mineralogy of gem fields, particularly in cases where there is a good mineralogical correlation between the stream sediment and the gem deposit. Rupasinghe & Dissanayake (1984) showed that Sri Lanka's gem-bearing stream sediments contain high amounts of rare-earth elements with the light rare-earth elements being particularly enriched. Rare minerals such as fergusonite, gadolinite, samarskite and niobian rutile are also considered as potential indicators of gem minerals (Rupashinghe et al. 1993). Many of these indicator minerals, which may escape detection in the field, merit detailed investigation in the laboratory.

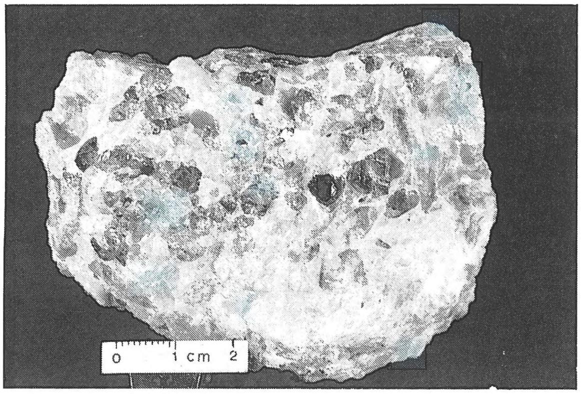

Fig. 5. Gem quality spinel in Precambrian marble in the vicinity of Kandy.

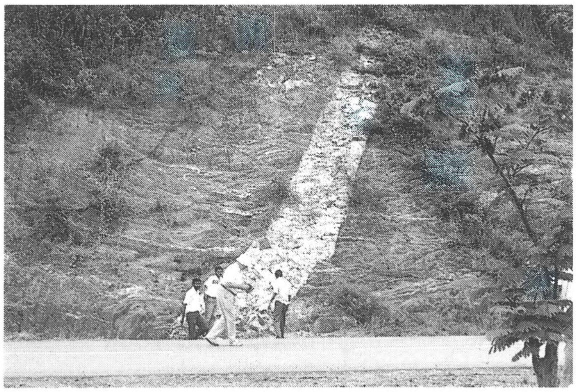

Fig. 6. Example of a pegmatite north of Kandy.

Metamorphic gem deposits

Classified under this heading are all primary gem deposits that have a metamorphic genesis. In view of the fact that 90% of Sri Lanka's rocks are of the high-grade metamorphic type, it is conceivable that a metamorphic parentage could be attributed to many of Sri Lanka's gem deposits. The intense tropical weathering decomposed and disintegrated these gem-bearing host rocks of the Highland/Southwestern Complex and yielded the secondary gem deposits in river sediments.

Several workers have studied the origin of the primary gem deposits of Sri Lanka. Katz (1972), following his study on the cordierite gneisses from the southwest of Sri Lanka, suggested that the Ratnapura-type gem deposits are derived mainly from cordierite gneisses. Munasinghe & Dissanayake (1981) showed that cordierite is more likely to represent a product of an intermediate stage of a desilication process culminating in the formation of corundum. They presumed that the desilication process had been caused by the contact-metamorphic effects of charnockite and other basic intrusions such as diopside-rich dykes and sills, and had affected aluminous metasediments. Rupasinghe & Dissanayake (1985) elaborated on this premise and emphasized the possible role of charnockites in the genesis of gem minerals. More recent work, however, points towards calcium-rich rocks such as skarns as being important in the origin of corundum-bearing gem deposits (Mendis et al. 1993).

Skarn and calcium-rich rock type

Several field investigations by the authors and their colleagues have highlighted the role of calcium-rich bedrock as a source for gem minerals within the metamorphic terrain of Sri Lanka. The presence of pure CO_2 inclusions in corundum from four localities in Sri Lanka, including the Ratnapura district, points to the role of CO_2 and reflects the carbonate-rich environment as being favourable for the occurrence of sapphire, ruby and spinel (De Maesschalck & Oen 1989). The high density of these primary inclusions, 1.05 g/cm^3, was considered compatible with the formation of corundum under granulite-facies metamorphism.

Silva & Siriwardena (1988) carried out field and laboratory studies in a corundum-bearing skarn deposit at Bakamuna near Elahera. They concluded that the skarn body was formed by the reaction of pegmatitic fluids with marble. Hydraulic fracturing of the rock with simultaneous increase in CO_2 pressure and dedolomitization had made the rock permeable to the fluids which reacted with the marble in stages:

$$\text{fluid I} + \text{marble} \longrightarrow \text{scapolite} + \text{corundum} + MgCO_3 + CO_2 \quad (1)$$

With increasing Mg-activity in the fluids, scapolite and corundum become unstable, resulting in the reactions:

$$MgCO_3 + \text{corundum} \longrightarrow \text{spinel} + CO_2 \ (2),$$
$$\text{fluid I} + MgCO_3 + \text{spinel} + \text{scapolite} \rightarrow \text{phlogopite} + \text{fluid II}.$$

The action of the Al-enriched fluid II on the fresh marble through a reaction analogous to reaction (1)

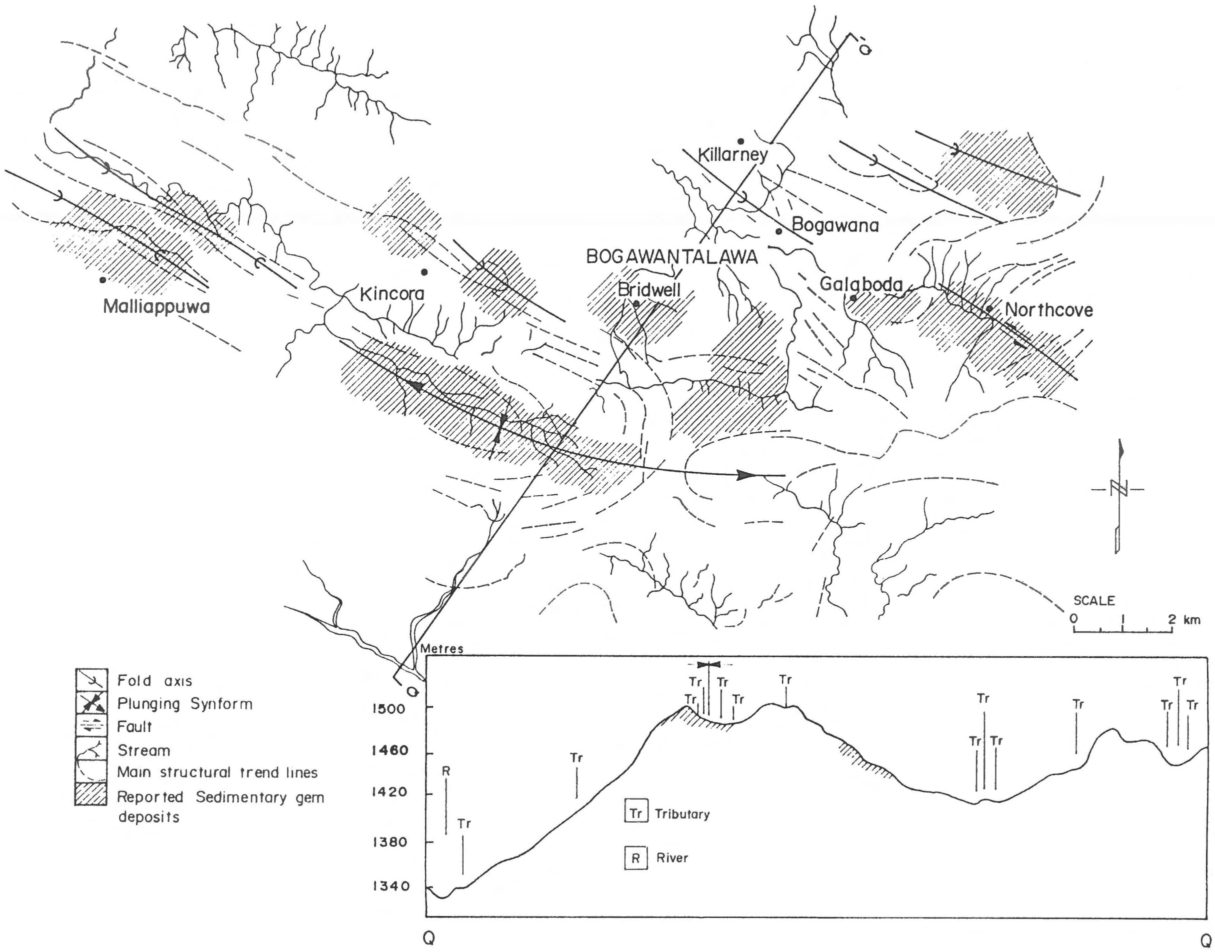

Fig. 7. Structurally controlled sedimentary gem deposits in the Bogawantalawa area. The rocks are high-grade metamorphics of Precambrian age, mostly charnockites and metasediments.

caused the precipitation of increased quantities of corundum.

Cooray (1984) cited the occurrences of spinel and corundum in skarns formed at the contact of intrusive granite and marble in the Elahera area. Wadia & Fernando (1945) had recorded a similar occurrence of corundum and spinel at the contact of marble and syenite at Ohiya, while Hänni & Gunawardene (1982) noted the occurrence of ferroaxinite that was typically formed by pegmatitic action on calcareous rocks. Garnets are also of very common occurrence in calcareous rock types in Sri Lanka.

Figure 5 shows an example of gem quality spinel. There is now ample evidence that skarn and calcium-rich rocks are good host rocks for gem minerals. Exploration efforts should therefore be concentrated on localities of metasomatically altered carbonate and Ca-rich rocks within the granulite belt.

Aluminous metasedimentary type

The abundant aluminous metasedimentary rocks within the Highland/Southwestern Complex are characterised by a chemistry appropriate for the formation of corundum and other aluminous gem minerals. Katz (1986), in his review of the geology of the gemstones of Sri Lanka, noted the following theories that had been proposed for the origin of gemstones in high-grade metamorphic terrains:

(a) the isochemical metamorphism of an originally highly aluminous, silica-deficient parent (e.g. bauxite, anorthosite),
(b) desilication of aluminium-bearing rocks by nearby mafic intrusions,
(c) metasomatism and partial melting.

Munasinghe & Dissanayake (1981) and Rupasinghe & Dissanayake (1985) have suggested that

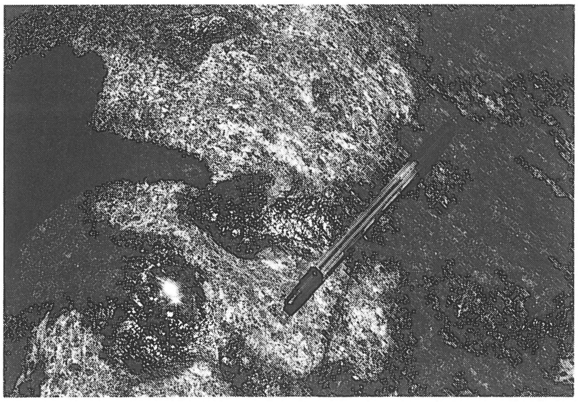

Fig. 8. Gem quality garnet in a structurally controlled primary deposit near Elahera (ballpoint pen for scale).

charnockitic rocks which generally occur in regions of crustal thickening as in the Highland/Southwesten Complex play a key role in the formation of gem minerals. They contend that contact-metamorphic effects of charnockitic plutonic activity on highly aluminous metasediments result in the formation of an assemblage of gem minerals such as sapphirine, cordierite, spinel, ruby and corundum.

Katz (1986) however suggested that such a mode of origin is applicable only locally, and proposed an origin related to granulite-facies regional metamorphism involving CO_2 flooding, purging of H_2O-rich fluids, and partial melting. He further suggested that the gem deposits of Sri Lanka are probably part of a Precambrian Gondwanaland granulite-facies gem province that includes India, Madagascar and Antarctica.

Corundum in a biotite-sillimanite gneiss from near Polgahawela was studied by Cooray & Kumarapeli (1960), who ascribed its origin to re-crystallization and metamorphic differentiation with formation of alumina-rich, silica-poor bands in a semi-pelitic gneiss. A similar occurrence of in-situ corundum had been recorded by Coomaraswamy as far back as 1903, near Kandy.

Gem deposits of pegmatitic origin

Pegmatites are also considered as a source for gem minerals. One of the best known gem deposits in pegmatite is the Meetiyagoda moonstone deposit. Spencer (1930) described this deposit as a pegmatite vein cross-cutting metamorphic rock. Recent field investigations by Malley (1989) showed a mineralogical composition at depth of approximately 50% clay, 40% feldspar, 5% quartz, smoky quartz and opaline silica, and traces of sulphides (mostly marcasite) and tourmaline.

Pegmatites also contain gem minerals such as beryl, chrysoberyl and zircon. Rupasinghe et al. (1984) have commented on these deposits, which may have originated by reaction of Be and halogen-rich fluids with country rocks to form beryl and chrysoberyl. In the Avissawella and Gatahetta gem-bearing areas, Kumaratilake & Ranasinghe (1992) discovered corundum-bearing gem pockets having the appearance of pegmatites. In addition to corundum, other minerals as tourmaline, quartz, phlogopite and pyrite were also found in the gem pockets. Beryl and chrysoberyl have been found from a pegmatite in the Buttala area (Geol. Surv. Adm. Report 1968). Another sought-after gem mineral, zircon, is also occasionally found in pegmatites and it is of interest to note that the Balangoda zircon-rich granite is in fact a very large pegmatite (Cooray 1984).

At Kolonne adjacent to the main Ratnapura gem field, large blue corundum crystals have been found in diopside-bearing pegmatites (Gunaratne 1976).

Pegmatites are also known to be rich sources for rare-earth elements. The presence of significant quantities of rare-earth elements in some Sri Lankan pegmatites indicates a magmatic derivation as anatectic partial melts of the quartz veins and pegmatites. Fluorine-rich minerals such as topaz, fluorite and tourmaline have been found in secondary gem deposits of the main Elahera gem field (Silva 1976, Dissanayake et al. 1992); this highlights the potential of halogen geochemistry as a tool for tracing magmatic gem deposits.

Figure 6 shows a pegmatite near Kandy.

Structurally controlled gem deposits

The location of many gem deposits, both primary and secondary, is subject to structural control; this is revealed by aerial photograph investigations of gem-bearing terrains. The Highland/Southwestern Complex in which most of Sri Lanka's gem deposits are found, has been subject to intense metamorphism and deformation resulting in a tectonic terrain criss-crossed by faults, folds, lineaments, fractures etc. Recent work by Mendis et al. (1993) indicates that residual corundum deposits are generally located in axial plane areas of tight, doubly plunging synclinoria and anticlinoria, where marbles and pegmatites are observed. Such residual deposits occur at sites of heavy structural disturbances such as discontinuities, faults, folds, joints, lensing and necking zones, if marbles and/or pegmatites are present.

Figure 7 illustrates typical structurally controlled sedimentary gem deposits in the Bogawantalawa area.

Recent investigation and the past experience of miners reveal that gems are not found everywhere even within gem mining regions. Structural elements which control the course of streams and rivers have a marked influence on the deposition of heavy minerals. Mendis et al. (1993) observed that very high concentrations of rare-earth elements and other economically useful elements also tend to be controlled by faults and fractures. Fault zones are probable loci for pegmatite intrusions and structural mapping could therefore be a useful tool in gem exploration.

Figure 8 shows a structurally controlled primary occurrence of garnet.

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