Journal of Geological Society of Sri Lanka Vol. 17 (2015), 113-123
JW Herath Felicitation Volume

IN-SITU OCCURRENCE OF CHRYSOBERYLS FROM YAKKALAMULLA IN SOUTHERN SRI LANKA

C.H.E.R. SIRIWARDANA[1,*], R.R.L. DIAS[2], L.K. SENEVIRATNA[3], W.K.B.N. PRAME[1],
D. DILLIMUNI[4] AND R.L.R. CHANDRAJITH[5]

[1]*Geological Survey and Mines Bureau, No: 569, Epitamulla Road, Pitakotte. Sri Lanka*
[2]*382/4, Sri Nandasara Mawatha, Hokandara North, Sri Lanka*
[3]*No: 188, Dehiwala Road, Maharagama, Sri Lanka*
[4]*Allied Gemmological Institute and Laboratory, Colombo 3, Sri Lanka*
[5]*Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
[*]*Corresponding Author: email: chandawimal@hotmail.com*

ABSTRACT

An in-situ chrysoberyl deposit had been discovered about a century ago at Yakkalamulla near Galle in southern Sri Lanka and that is still being mined for good quality gemstones. Geological, petrographical, chemical and gemological characteristics of this rare chrysoberyl deposit have been studied to constrain the genesis and the gem potential of the terrain. Field geological study is aided with microscopic studies and analysis of gem samples using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES), X-Ray Diffractometry (XRD) and Scanning Electron Microprobe (SEM) tools.

Field geology reveals that the deposit is hosted by granulite-grade metasediments of the Highland Complex, and the chrysoberyl mineralization is associated with a pegmatite that is intruded into garnetbiotite±sillimanite gneiss. The mineralized zone contains tourmaline, garnet, graphite, biotite and greenish feldspar. Well demarcated crystals from the deposit mostly show flat faces with sharp crystal outlines while gem quality stones possess a distinct color change i.e. green in daylight to reddish tint in tungsten light. Higher Cr content (1055-1745 mg/kg) may account for this colour change that is suppressed to a lesser degree by the presence of Fe (0.84% to 0.89%). Cat's eye variety show white to bluish opalescence and chatoyancy (cymophane) and are often cut as cabochons to display the best effect. XRD analyses showed that the presence of quartz as inclusions in chrysoberyl grains whereas SEM analysis showed discontinuities within the grains and the presence of secondary clay fillings in discontinuity planes. Late pegmatitic melt, enriched with Be that occurred from the surrounding aluminous host rock of garnet biotite±sillimanite gneiss, is chemically favorable for the formation of chrysoberyl having excess Al.

Key words: *Chrysoberyl, In-situ gem occurrences, Genesis of gems, Chatoyancy, Highland Complex*

INTRODUCTION

Chrysoberyls, mainly alexandrites and alexandrite cat's eyes of Sri Lanka, have commanded higher values in the world gem market due to their color, quality, chatoyancy and size that are often superior to those from Brazil, Myanmar and Russia. In the past, Galle and Matara districts in Southern Sri Lanka were famous for alexandrites and zircons (locally called "Matara Diamonds", colorless to yellowish gem with an adamantine luster). Alluvial gem beds and low-lying colluvial accumulations have been extensively prospected around Morawaka, Rakwana and Bulutota massifs, Tawalama, Dikkumbura and Neluwa in Southwestern Sri Lanka (Fig.1) and chrysoberyls have been proven to be exceptionally abundant in locations such as Yakkalamulla and Morawaka. However, the source rocks of these gemstones have hardly been prospected (L.K. Senevirathna, personnel comm.).

As shown in the historic records, the Yakkalamulla chrysoberyl deposit had been

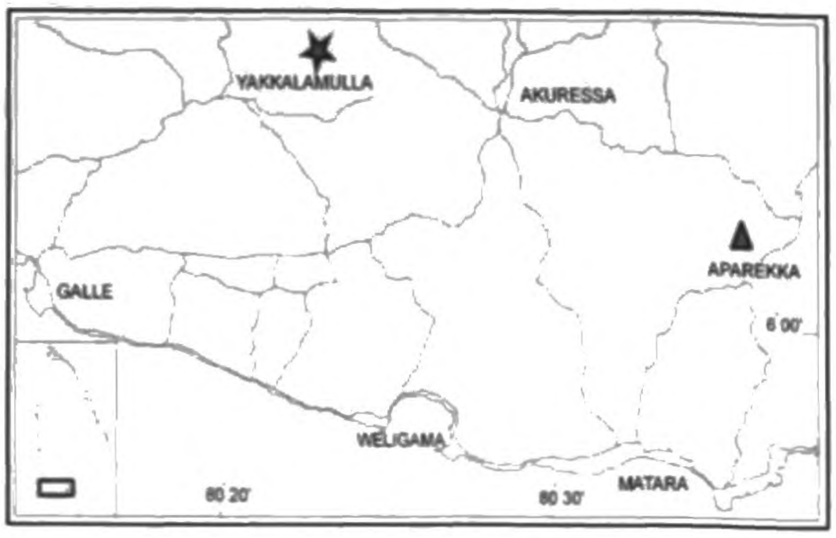

Fig. 1 Location of the Yakkalamulla in-situ chrysoberyl deposit and the main road network in the area (the triangle indicates the Aparekka in-situ corundum occurrence)

discovered in the early 1900(L.K. Senevirathna, personnel comm.). The location had been kept secret by the owners of the land to make sure no outsiders enter the property. Without any exploration for several decades, prospecting was recommenced in 1982. According to the locals, gem mining had been carried out at that time in the marshy land approximately 50 m north of the current mining site which was seasonally used for paddy cultivation. Some chrysoberyls and cat's eyes had been recovered from these paddy fields, but most of the stones were highly fractured. Recently, a gem miner discovered some green lusturous stones while clearing the out flow canal of his paddy field. Consequently, mass scale mining was carried out in the adjacent gravel bed by gem prospectors who found the gem gravel layer (*illam*) extending to the weathered pegmatitic rock. Aim of the present study was to constrain the genesis of the deposit and to ascertain gem potential of the Yakkalamulla area by studying geological, petrographical, chemical and gemological characteristics of this rare chrysoberyl deposit.

LOCATION AND ACCESSIBILITY

The Yakkalamulla chrysoberyl deposit is situated about 150 km from Colombo via Galle in the southern province of Sri Lanka (Fig. 1). The deposit is approachable by a minor jeep track off the rolling hills from Yakkalamulla town. The mining site is located at (80°23'31"E, 6°8'22"N) and is situated in a valley bottom extending to a marshy head stream of a drainage tributary of the Nilwala Ganga, main river in the area. The stream beds of the area are the best prospecting sites with good returns. The area belongs to the wet zone of the country, where a tropical, wet, humid climate is prevalent. Cinnamon, low-country tea and fern-lands occupy the valley slopes with tropical rainforest patches in between.

REGIONAL GEOLOGIC SETTING

Sri Lanka is mostly underlain by Proterozoic high grade metamorphic rocks and the Phanerozoic sediments exclusively to the northwestern coastal region. Based on Nd-model ages, the Precambrian basement is divided into three major lithotectonic units: Highland Complex (HC), Vijayan Complex (VC) and Wanni Complex (WC) (Milisenda et al., 1988; Kröner et al., 1991; Cooray, 1994) (Fig.2). Intensely deformed supracrustal rocks, granitoids and metabasites mostly at granulite grade with an extended crustal history (2-3 Ga) form the HC, as the central belt (Kröner et al., 1991). Most of the charnockitic granitoids of the HC are of igneous origin (Prame, 1997) and were emplaced in the associated supracrustal sequence at various stages of tectonic evolution mostly between 1500-1900 Ma ago (Kröner et al., 1987; Hölzl et al., 1994). The WC is characterized by ortho-gneisses, K-feldspar rich granitoids with subordinate metasediments and the VC mostly comprises of I-type granitoids. Both WC and VC are mostly made up of amphibolite grade rocks with younger Nd-model

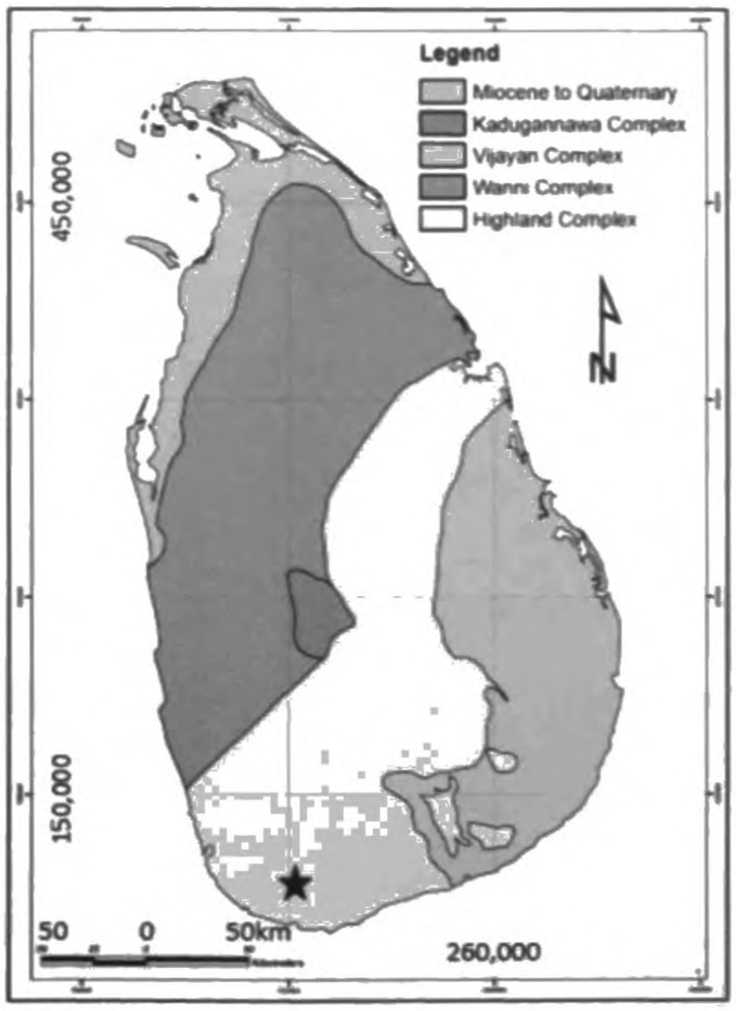

Fig. 2 Major lithotectonic units of Sri Lanka with the Yakkalamulla in situ deposit (red Star) (Geological units after Cooray, 1994)

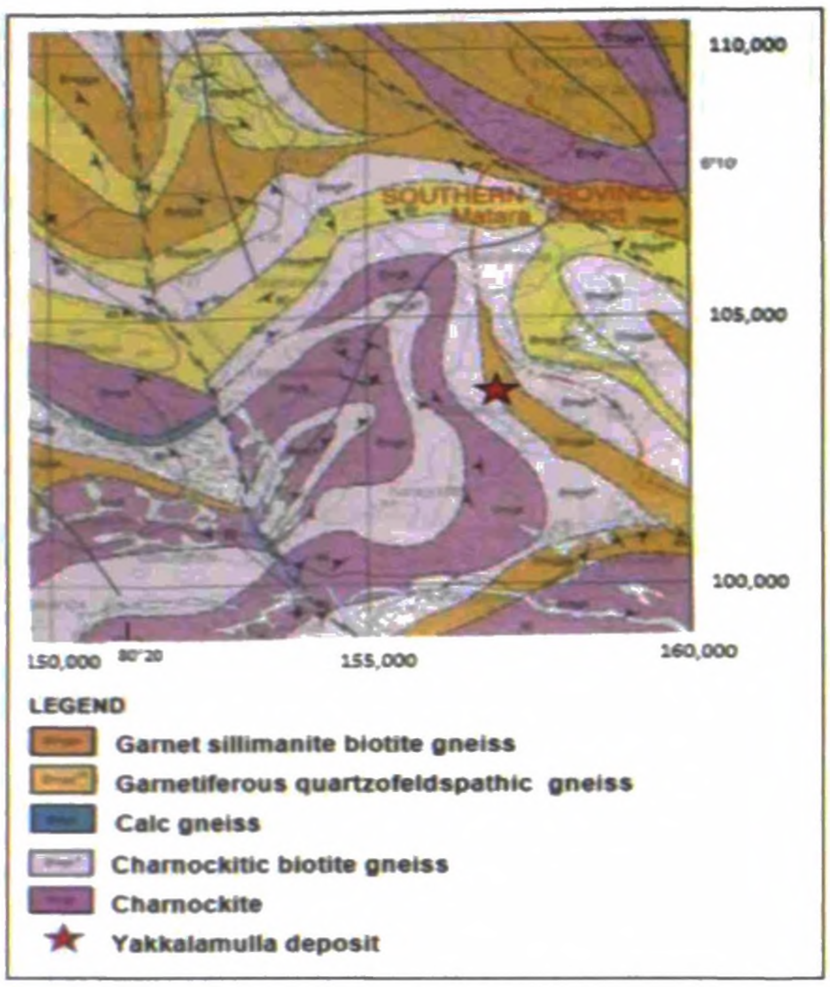

Fig. 3 Regional geology around the Yakkalamulla deposit (From Geological Sheet No. 19: Alutgama- Galle; Scale1:100,000, Geological Survey and Mines Bureau of Sri Lanka, 2000)

ages (1-2Ga) and probably are two distinct crustal units which have been tectonically welded to the HC in the west and east respectively (Kröner et al., 1991).

The Yakkalamulla area is underlain by highly deformed Proterozoic metamorphic rocks belonging to the Highland Complex of Sri Lanka. The rocks consist dominantly of high-grade metasediments and granuliticor-thogneisses. The central and northeastern parts of the HC shows a common occurrence of thick quartzites and carbonates (dolomitic marble and calc-silicate gneisses) suggesting a general correlation with other Palaeo- to Mesoproterozoic shelf sequences.

In the south western part of the HC, where the Yakkalamulla deposit is located, the metasedimentary sequence is dominated by Al-rich, often cordierite bearing locally migmatitic pelitic paragneisses and wollastonite bearing calc gneisses. Garnet-pyroxene geobarometry yields paleopressure estimated from about 7.5 kb in the southwestern (Matara) area to 10 kb in the southeastern HC, displaying a pressure gradient of about 3 kb from the Western HC to Eastern HC (Prame and Ajith Prema, 2014). The Southwestern Highland Complex is magnetically also distinct from the rest of the HC and has a much lower amplitude magnetic character. This southwestern sequence is interpreted as either a facies variant of the main quartzite- carbonate sequence or a part of the separate basin. Regional structure denotes a complex, open to tight refolded system truncated by a set of younger shear zones (Fig. 3). Other Major rock types occurring in the area are charnockite, charnockitic gneisses and garnetiferous quartzo feldspathic rocks. Regional structures run in a NW-SE direction, except for the southeastern edge, where rocks strike in an E-W direction probably due to cross folding.

MATERIALS AND METHODS

A preliminary geological investigation was carried out, in and around the Yakkalamulla chrysoberyl deposit and mineral and rock samples were collected from available exposures. A thin section study was carried out for garnet±sillimanite biotite gneiss rock and an investigation into the mineralogical and gemological properties of the rough and faceted chrysoberyl samples at the Geological survey and Mines Bureau (GSMB) laboratories and at the Allied Gemmological Institute and Laboratory, Sri Lanka. In order to identify the dominant mineral phases in chrysoberyl samples, X-Ray Diffractometry (XRD) analysis was performed at the Industrial Technology Institute Laboratory. XRD spectrum was obtained from powdered chrysoberyl grain using "Rigaku-Ultima IV" XRD and operation conditions were set at 15^0-140^0 with a scan rate of 2°/min.

Major element compositions of chrysoberyls were obtained from atomic absorption spectroscopy while trace elements were measured using Inductively Coupled Plasma-Optical Emission spectroscopy at GSMB analytical laboratory. Scanning Electron Microprobe (SEM) analysis was carried out on rough chrysoberyl grains to investigate the surface morphological characters during which the analyses were performed using Zeiss EVO LS15 equipped with Oxford Instrument X-act EDX detector available at the International Research Center, University of Peradeniya. Gold/Pd coating was applied using SE-76-20'. Sputter Coater to create a continuous conductive

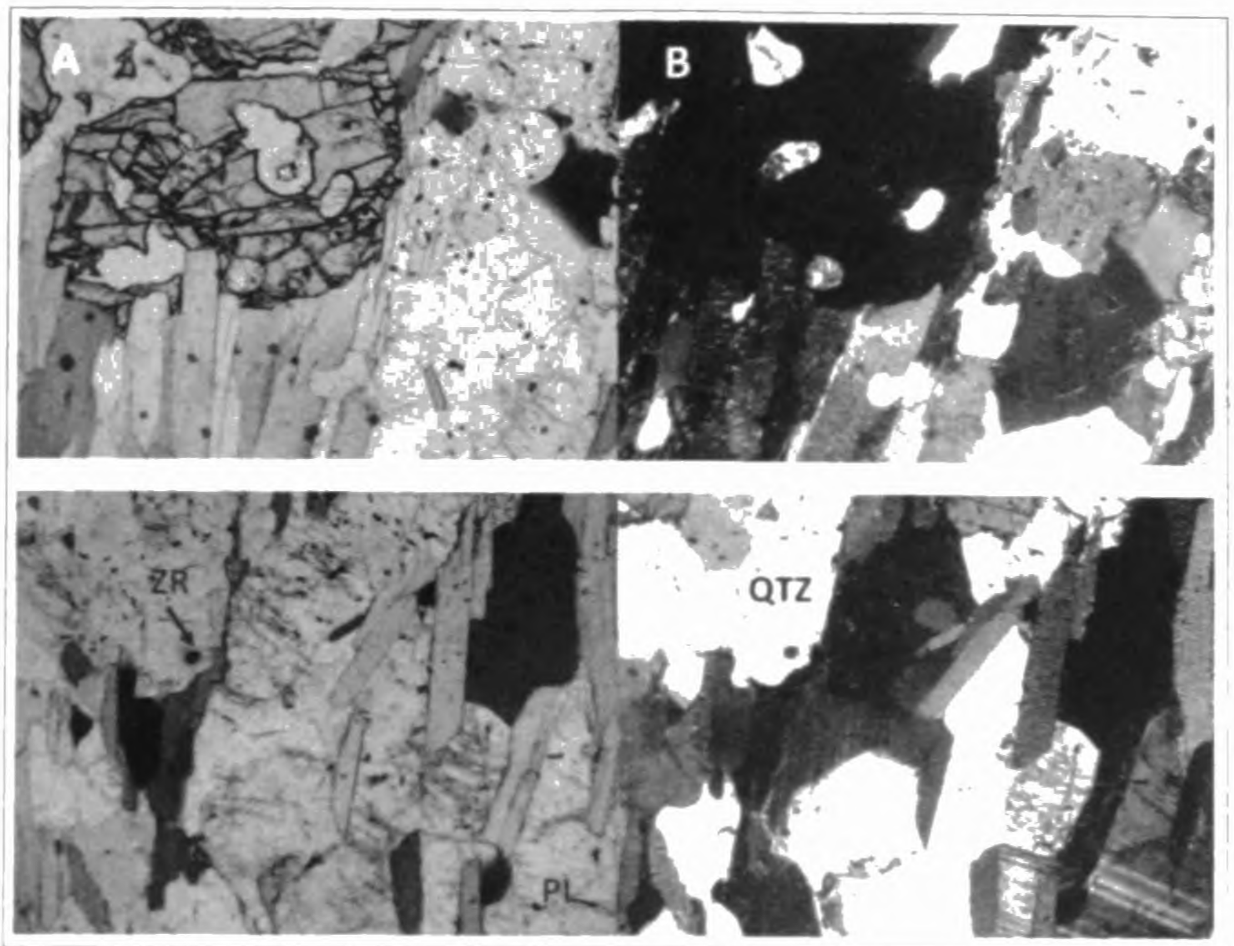

Fig. 4 Photomicrographs of garnet biotite (±sillimanite) gneiss (Magnification- x 10); A and C are views under PPL and B and D are same views under CPL; GT: garnet; BT: biotite; OR: orthoclase; PL: plagioclase; ZR: zircon; QTZ: quartz. Garnet shows no reaction rims and iron ore is rare or nearly absent. Disseminated minor zircons are abundant showing pleochroic halos. Rock shows typical granular texture

media over the grain surface prior to the analyses.

RESULTS AND DISCUSSION

GEOLOGY OF THE YAKKALAMULLA DEPOSIT

The rocks in the Yakkalaumlla area comprise charnockite, charnockitic gneiss, calc gneiss, garnet sillimanite-biotite ±graphite pelitic schist or gneiss, and garnet bearing quartzo-feldspathic rock. Charnockite is the typical hypersthene granite, a massive rock with a green greasy appearance with scattered hypersthene. Charnockitic gneiss is an extensive sequence of charnockite looking grey gneiss usually lacking hypersthene orthopyroxene-bearing mafic layers but including some para-gneissic enclaves commonly as boudinaged forms. Charnockite and charnockitic gneisses have a lower susceptibility for weathering in comparison with other lithologies in the area and generally form positive land forms often occupying hilltops or upslopes. Calcgneiss with scapolite and wollastonite bearing in place, occurs thinly interbanded with charnockitic rocks. Garnetiferous rocks are pale coloured rocks generally containing coarse garnets and they often occupy down slopes or valley bottoms. The rocks are folded into a north easterly trending broad synformal structure which is truncated by a shear zone extending for several tens of kilometers. The Yakkalamulla deposit is located towards the crest region of the synform (Fig. 3).

In the thinly banded garnet biotite (±sillimanite) gneiss to which the host pegmatite was intruded, garnet shows no reaction rims and iron ore is either rare or nearly absent. The rock shows typical granular texture and disseminated minor zircons are abundant showing pleochroic halos (Fig. 4).

PEGMATITE HOST ROCK

The pegmatite contains disseminated coarse biotite flakes, clustered clots of garnet with subordinate black tourmaline and isolated patches of graphite. Garnets and graphite in the pegmatite are probably, derived from the surrounding garnetiferous rock. Feldspar grains have a peculiar greenish color (Fig. 6). The pegmatite is oriented 085°-095°, cross cutting the gneissic rock almost perpendicularly. Garnet biotite gneiss has a general strike varying between 010°-355° with an easterly dipping of 65° to 85° (Fig. 5).

The pegmatite is partially weathered and the width of rock where the main shaft was located is about 2 m wide and gradually thinning out towards the east (Fig. 5 and Fig. 7). The rock is exposed at about 30m in the valley and appears to extend several tens of meters further towards the east in the valley and towards west in the hill slope but critical contacts have been masked by the overburden and exact dimensions are not clear. The direction of the course of pegmatite may vary in its subsurface extension and it could even be branched off in to multiple veins at depth. As a small ion, Be is less incorporated into the silicate lattices during the main phase of

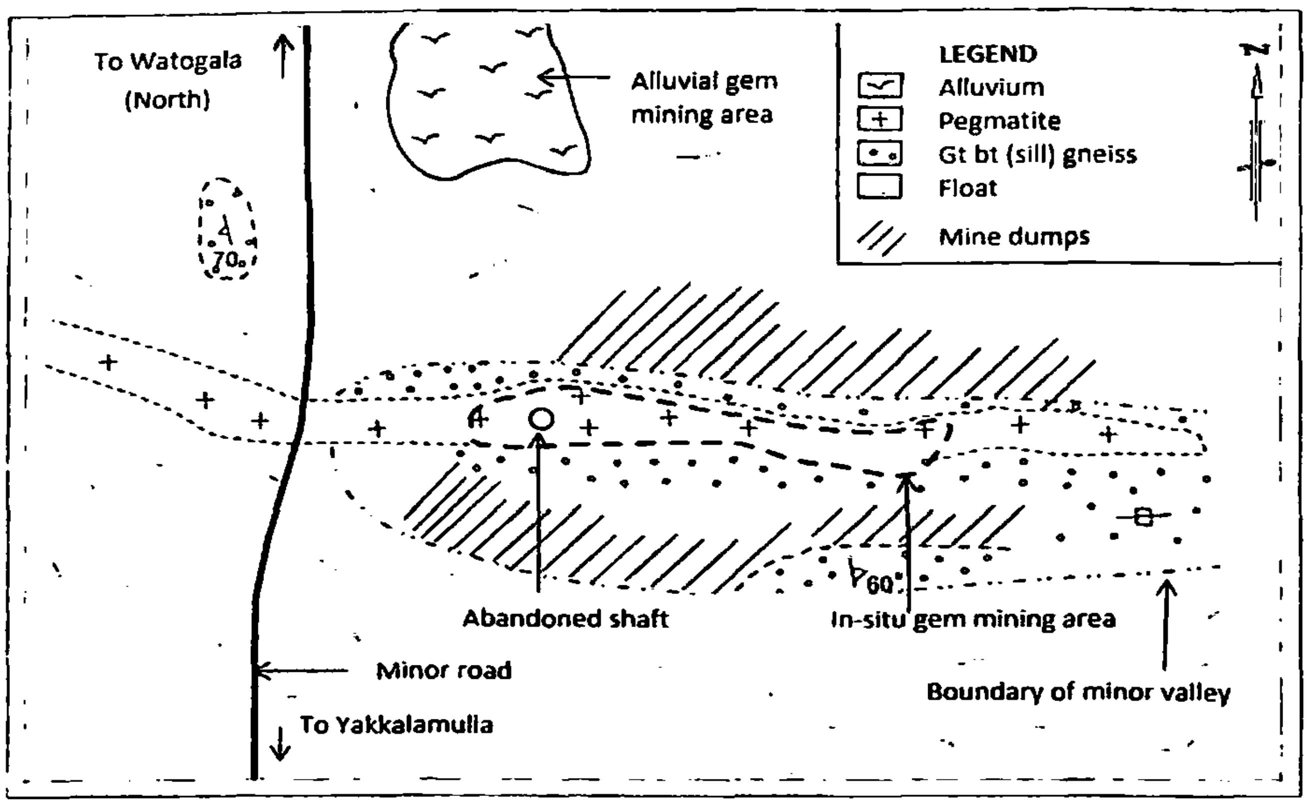

Fig. 5 Sketch map of the Yakkalamulla site (not to scale). Host pegmatite is about 2 m wide near the abandoned shaft and the current in-situ gem mining area extends for about 30 m. The bed rock is partially exposed in a minor valley surrounded by boulder float of lateritized-charnockite and garnetiferusgneiss derivedfrom hill slopes

silicate crystallization and gradually concentrated in late pegmatitic melts. Smaller configuration of the pegmatitic vein available at the Yakkalamulla deposit also do not favor the generation of a wider zone of metasomatic alteration, however, the surrounding aluminous host rock, garnet ±sillimanite biotite gneiss is chemically favorable for chrysoberyl formation having above normal Al.

MINERALOGY AND CHEMISTRY OF CHRYSOBERYLS

MINERALOGICAL CHARACTERISTICS

Chrysoberyl grains collected from the Yakkalamulla deposit display transparent to translucent pale green colored fragments with conchoidal and uneven fractures. Some rough cat's eyes recovered from the mine showed bluish opalescence and chatoyancy (cymophane) (Fig. 8). In some grains, prismatic crystal faces are visible with and the maximum interfacial angle measured on the rotating stage of microscope being 60^0 with the presence of a weak basal cleavage or parting plane.

Chrysoberyls from Yakkamulla deposit showed color change effects as follows: under florescent light similar to daylight the stones appear green and under tungsten lamplight they appear in reddish tint (Fig. 9). This effect is shown in some cat's eye stones as well. Cat's eyes are often cut as cabochons to display the best effect.

Larger transparent fragments show a pleochroism with trichroic colours of bluish green, brownish pink and greenish yellow related to three crystallographic axes under fluorescent light. Hardness of the grains is 8.5 in Moh's scale and the specific gravity is 3.84 (hydrostatic weighing). Maximum refractive index (RI) is 1.75 (compared with methylene iodide RI=1.74) and the interference figure is biaxial positive with large 2V angle. Summary of optical and gemmological properties of chrysoberyls from Yakkalamulla are shown in Table 1. Some chrysoberyls from the Yakkalamulla deposit show three-fold twinning or "trilling" which gives them a pseudohexagonal habit. To display the best 'alexandrite effect' (greatest color change), the 'table' facet (the largest polished surface at the top of a gemstone) of an alexandrite should be oriented as closely as possible to (100)(Liu et al., 1995) (Fig. 10).

XRD ANALYSIS

X-ray Diffractometry (XRD) analysis carried out on one powdered pure chrysoberyl sample (rough stone) has identified two major mineral phases (Fig. 11). The analysis concluded that the sample contained chrysoberyl ($BeAl_2O_4$) as the major chemical component (94.53%) by weight and α-quartz also found as a minor quantity

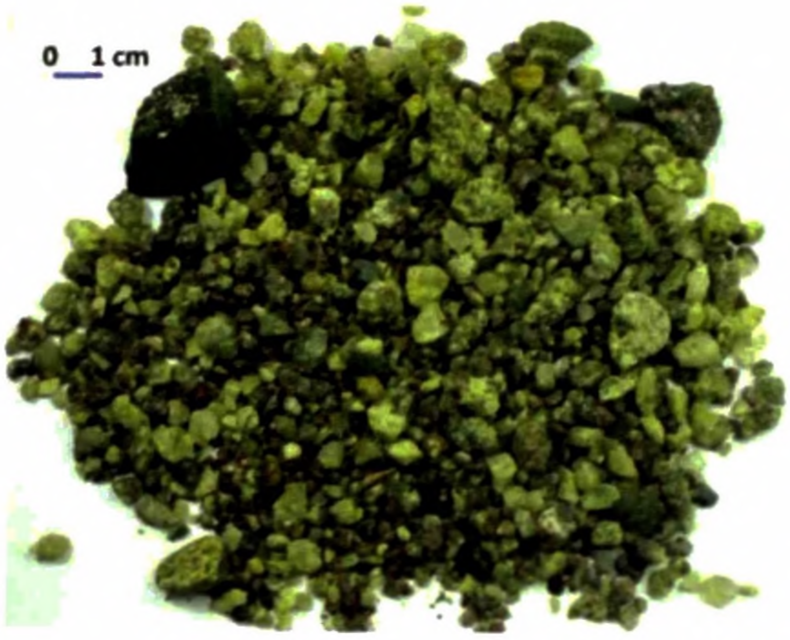

Fig. 6 Crushed pegmatitic material ("illam") showing pink garnets, greenish feldspars and black tourmalines and whitish quartz. Flaky or clotted dark biotite disseminated in places

Fig. 7 Gem mining at Yakkalamulla site. (a) The minor valley where the host pegmatite is exposed; (b) A mined out area; (c) and (d) The mine shaft; (e) mine dumps consisting of pale colored pegmatitic materials; (f) A mechanical shaker used to separate stones

(5.47%). The presence of quartz as inclusions within the chrysoberyl samples of the Yakkaramulla deposit had been confirmed by the microscopic studies as well (Fig. 10).

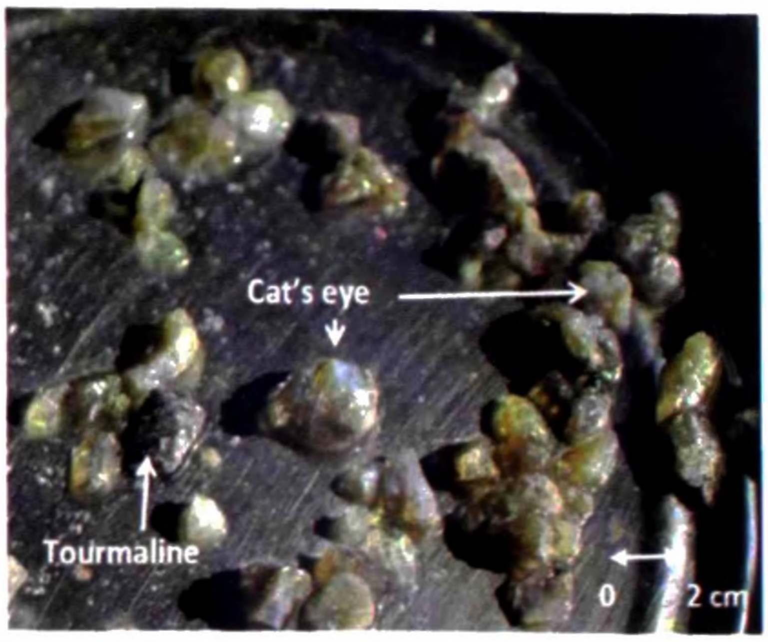

Fig. 8 Rough stones recovered from the mine. Note the bluish opalescence or chatoyancy (cymophane) shown by cat's eyes

SCANNING ELECTRON MICROPROBE (SEM)/ ENERGY DISPERSIVE X-RAY (EDX) ANALYSIS

SEM images of the grain surface characteristics of the rough chrysoberyl grains are shown in Fig. 12 A and B and Fig. 13. Uneven fracture surfaces are generally common in chrysoberyls but some peculiar, rather uncommon, serrated structures are shown in some grains (Fig. 12A). Striated, poorly developed cleavage planes are displayed in Fig. 12 B with scaling along the cleavage. This type of feather- like striations are typical on (001) (Palache et al., 1946).

Thin discontinuous films of secondary minerals are displayed as filled-ins along some discontinuity planes in ure 13. EDX spot analysis of these materials is shown in Fig. 14 with element concentration peaks of Si (10.17%), Al (8.28%), Na (0.6%) and K (0.85%). Visual appearance and the chemistry suggest that the materials may be clay derived from in-situ weathering of the host rock.

CHEMICAL COMPOSITION OF CHRYSOBERYL

Chrysoberyl is an oxide of beryllium and aluminum ($BeAl_2O_4$) while Fe^{3+} is usually present presumably in substitution for Al^{3+} but

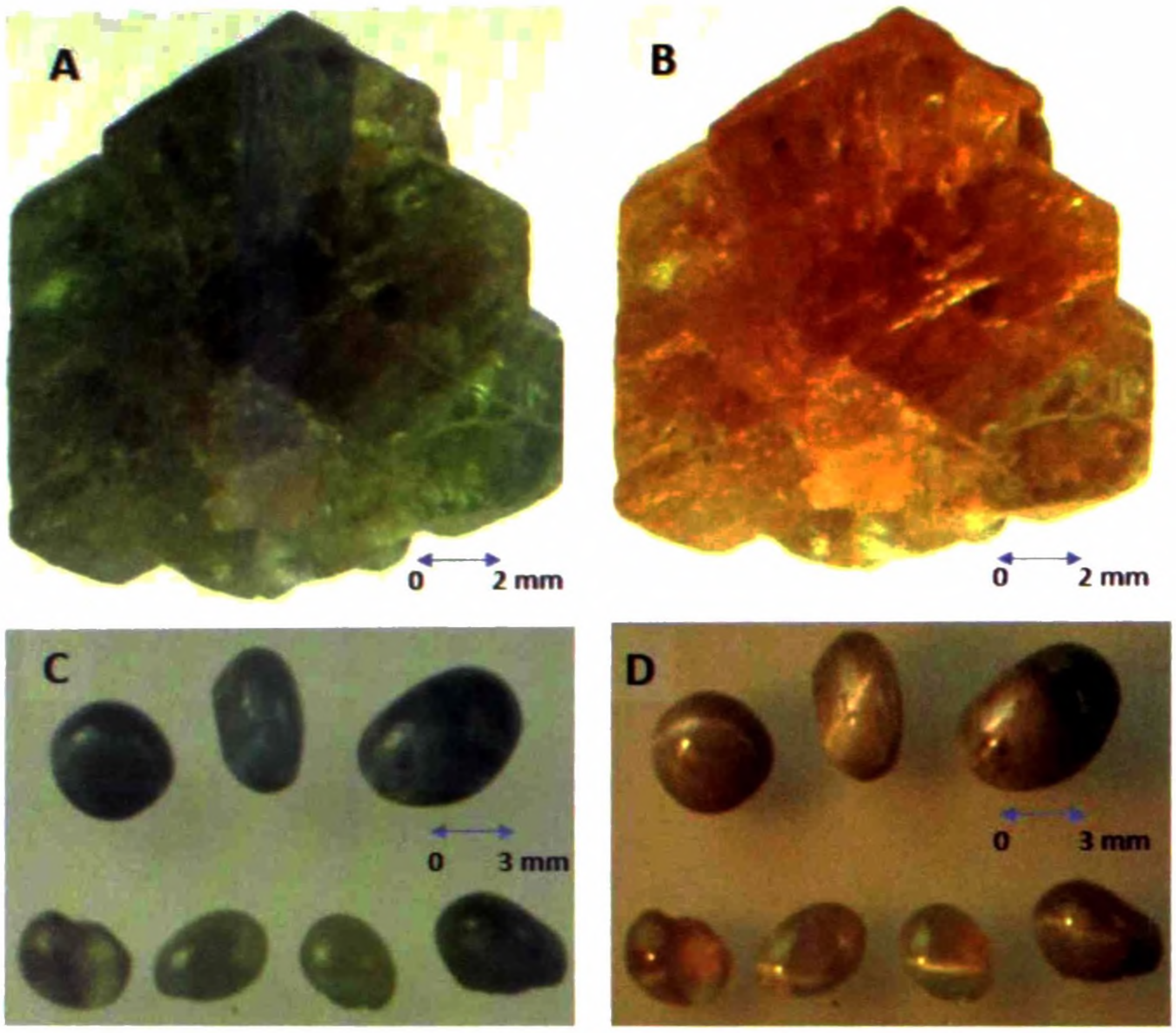

Fig. 9 Chrysoberyls from Yakkamulla deposit. Color change effect of stones under florescent light similar to daylight appear green and under tungsten lamplight they appear in reddish tint. Cat's eye effect is shown in cabochon-cut stones depicted at C & D.

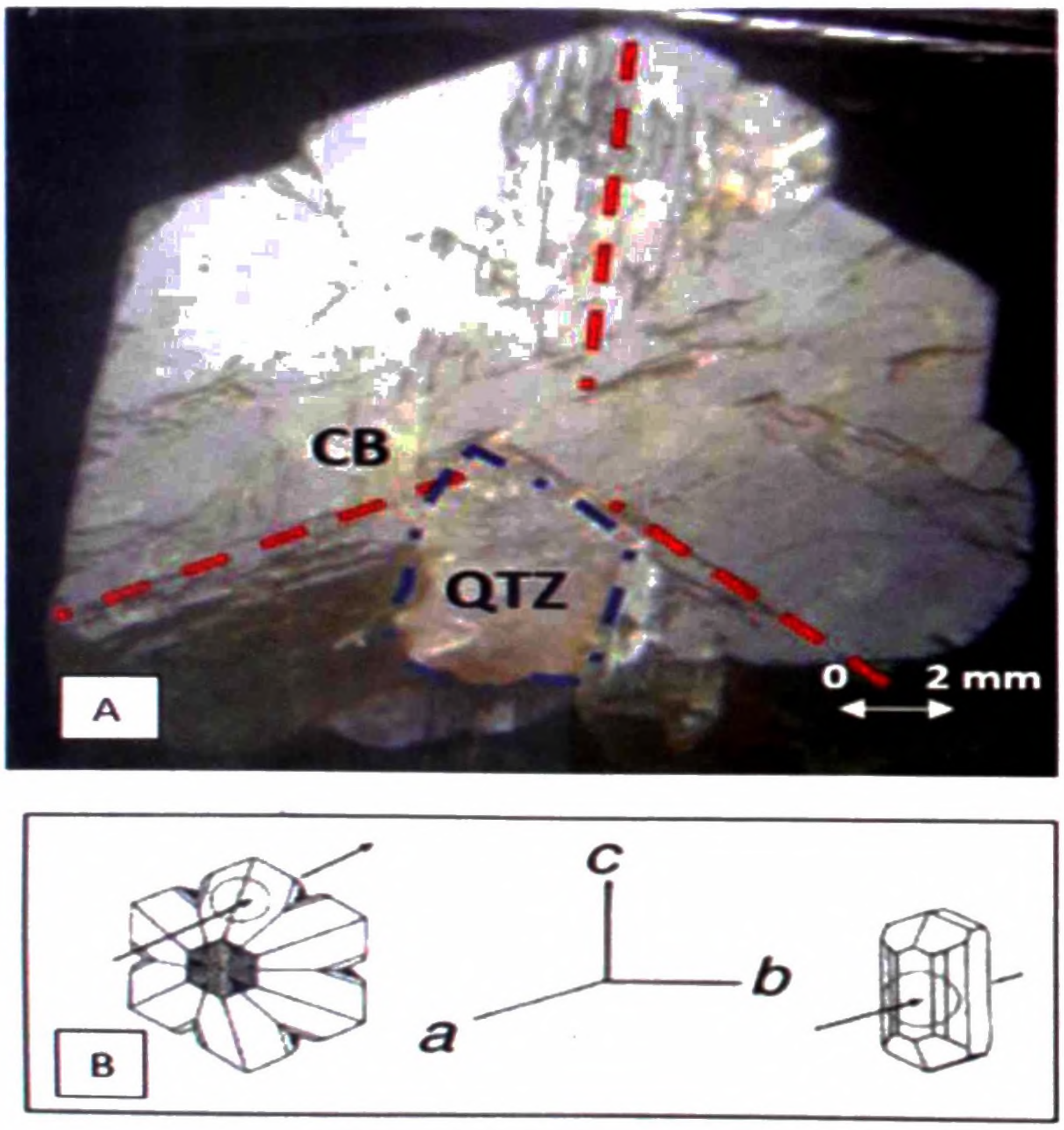

Fig. 10(A) A grain cut perpendicular to [001] and illuminated to show three-fold twinning or trilling which gives a pseudohexagonal habit. Lines representing intersection of ac Plane are shown in red stippled lines. CB: chrysoberyl; QTZ: quartz; Note the quartz inclusion marked in broken blue line. (B) Morphology of twinned and untwinned natural chrysoberyl crystals with crystallographic orientations. Position of the table facet that will display the best colour change is indicated by circles (Liu et al., 1995)

Table 1 Summary of optical and gemological properties of chrysoberyls from Yakkalamulla

Property	Chrysoberyls from Yakkalamulla
Color	Light Green to Bluish green
Color Zoning	No Zoning
Refractive Indices	1.742 – 1.750
Birefringence	0.008
Specific Gravity	3.84 (hydrostatic weighting)
Hardness	8.5
Pleochroism	Strong, in bluish green to green
Fluorescence	
Long-Wave	Reddish Pink
Short-Wave	Inert
Absorption Spectra	Strong Fe absorption line at 444 nm, Weak, Cr line in Yellow
Internal Features	Quartz inclusions, liquid-filled Feathers, trilling, chatoyancy

possibly due to oxidation of Fe^{2+} (Palache et.al., 1946). Minor amount of Cr is present mainly in alexandrite and the colors are possibly due to the presence of Cr and Fe (Palache et.al., 1946). Major and trace element compositions of the Yakkalamulla samples in comparison with the published data are given in Table 2 and trace element composition of the samples is given in Table 3 Comparison of the major elements of chrysoberyls from Yakkalamulla and the other available data suggests that Be and Al contents are generally comparable. However, iron (Fe) content is remarkably low in Yakkalamulla samples, whereas silica content is substantially higher compared to similar samples except for the chrysoberyls from Brazil (#4). From a mineralogical point of view, it was found that quartz is mainly available as a separate mineral phase in the form of coarser inclusions. Therefore, major element composition of Yak2 and Yak3 samples were rescaled as of the Brazil sample. Trace element composition study of the Yakkalamulla samples showed unusually higher Cr contents (1054 to 1755 ppm) compared to other trace elements. It is inferred that the higher Cr contents available in Sri Lankan alexandrites show the beautiful color change, possibly not suppressed by the presence of depleted contents of Fe.

CURRENT STATUS OF MINING AND PROCESSING

The pegmatite has been extensively mined through a narrow open pit dug up during the extraction. The vertical mine shaft had reached a depth of about 18 m. The sides of the pits excavated and the overburden and the weathered pegmatitic material had been subjected to mining and crushing where necessary and washed in gem baskets to separate the heavy fraction (locally called "numbuwa") containing gemstones. Chrysoberyls, the primary target, are handpicked from the heavies that are eye tested for chatoyancy and color change in direct and transmitted light. Both alexandrites and their cat's eyes show this color change possibly due to varying degrees of chromic oxides.

GENESIS

The genesis of the gem minerals in Sri Lanka has been a subject of much debate and diverse origins have been proposed

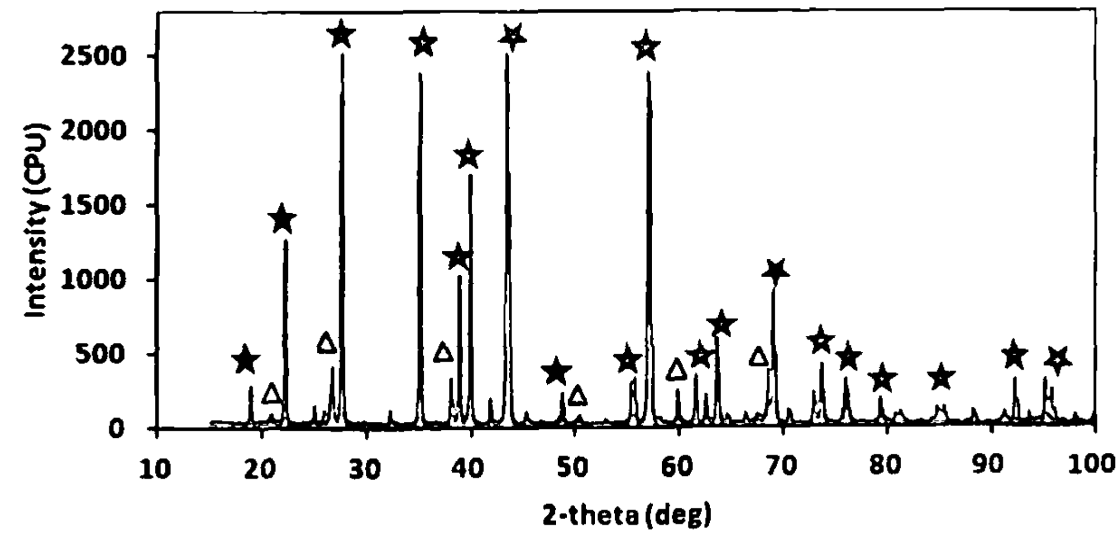

Fig. 11 XRD spectrum of a powdered pure chrysoberyl sample showing chrysoberyl and α-quartz phases. Intensity peaks relevant to chrysoberyl and α-quartz are shown in stars and triangles respectively

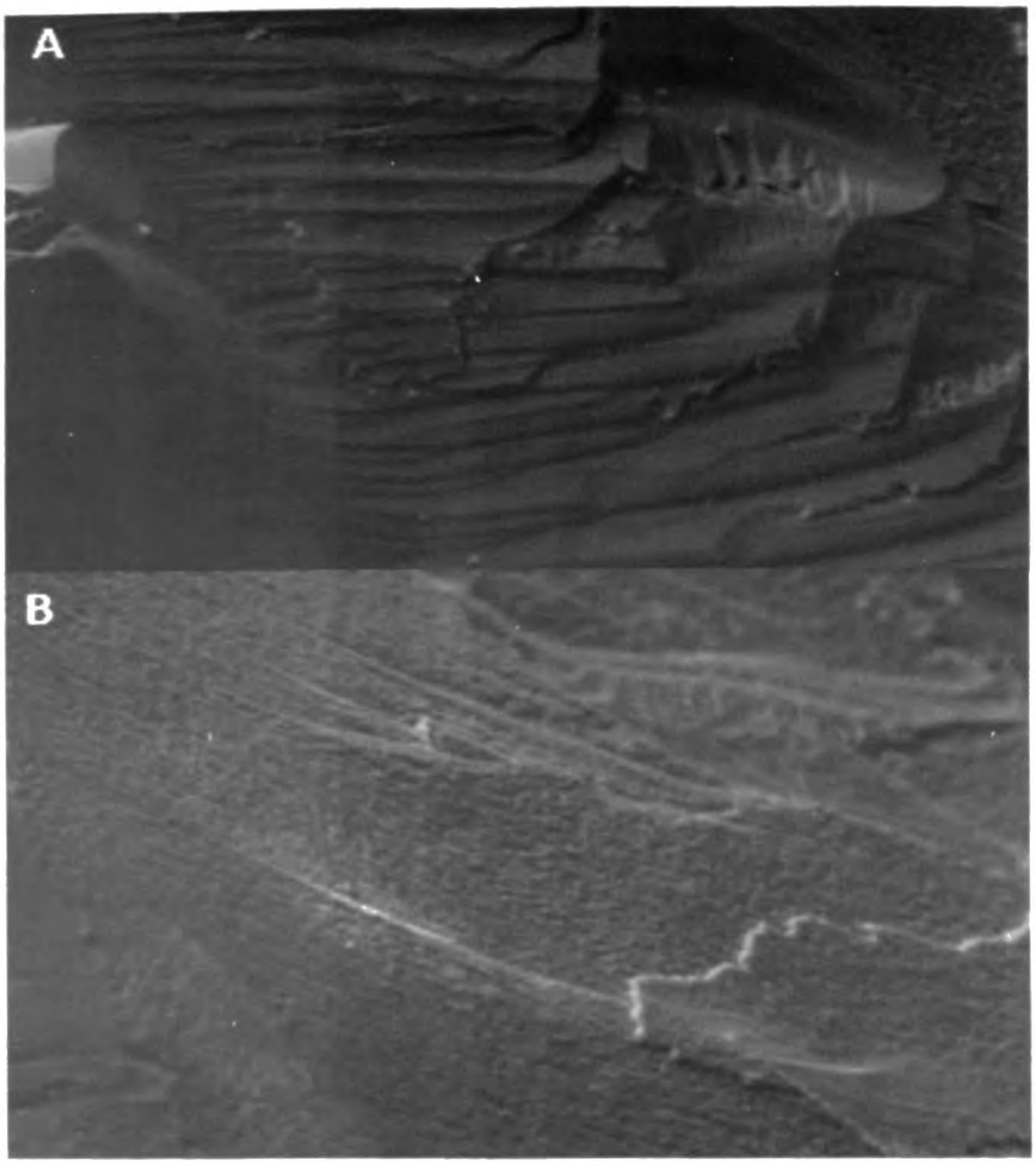

Fig. 12 SEM images of chrysoberyl. (A) Uneven fractures showing serrated structures, (B) Striated, poorly developed cleavage planes with scaling

(Dahanayake et al., 1980; Silva and Siriwardana, 1988; Dissanayake and Rupasinghe, 1995; Almond and Gunatilake, 2001; Fernando et.al., 2001). The primary generation of the gem minerals in the Sri Lankan basement was a polygenetic process; a few mineral grains initially nucleated by isochemical metamorphism may have survived and developed to form gems, but local metasomatism and partial melting were probably more important in the production of the larger gems (Almond and Gunatilake, 2001). In a recent study, Dharmaratne et. al. (2012) found that the corundum mineralization at Thammannawa, near Kataragama was associated with pegmatitic intrusions and mica layers which were formed by a metasomatic process between the pegmatite fluid and the host rock. Although, extensively weathered nature of the mineralization hinders the diagnosis of mineralogy, a metasomatic process could be expected in the Yakkalamulla deposit. Clustered zones of coarse-grained greenish feldspar, biotite, tourmaline, garnet and graphite associated in the mineralization, which are newly formed or recrystallized products of the reaction between the pegmatite and the garnetiferous rock. The occurrence of the chrysoberyl might have een controlled mainly by the localized enrichment of Be in the pegmatite.

The current location is intrinsically a good proven deposit capable of extension along detected directions of the pegmatitic rock by affirmation and investigation for any intelligent entrepreneur. The improper development and abandonment of the mining of this valuable site that can generate good returns, is a misfortune for the land owners and the willing prospectors. Keen understanding of the geology of the prospect and the extension and configuration of the gem bearing pegmatitic veins is required for further development of the mining in the region.

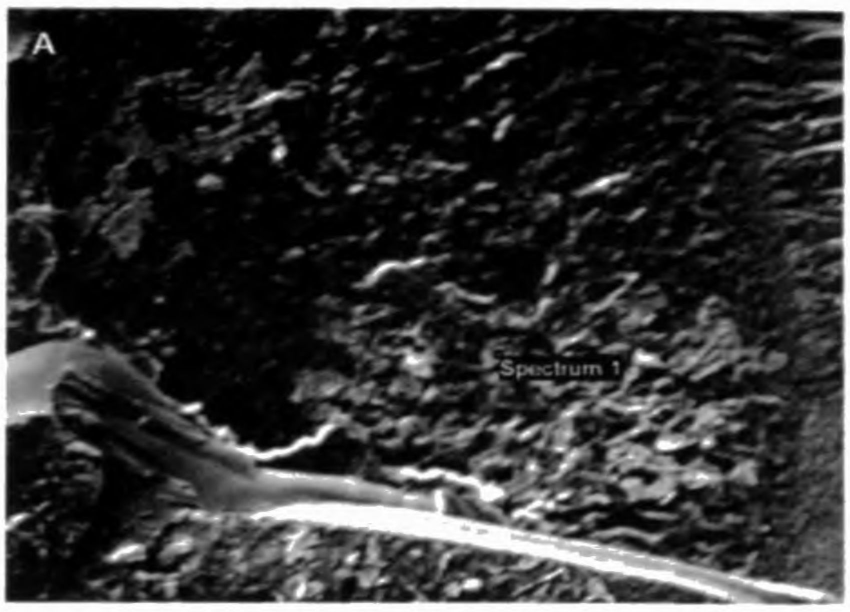

Fig. 13 Secondary minerals are displayed as filled-ins in some discontinuity planes

This might require further scientific exploration using modern technology. Proper procedures in relation to land acquisition, management, security and safety measures have to be adopted by any entrepreneur or prospector.

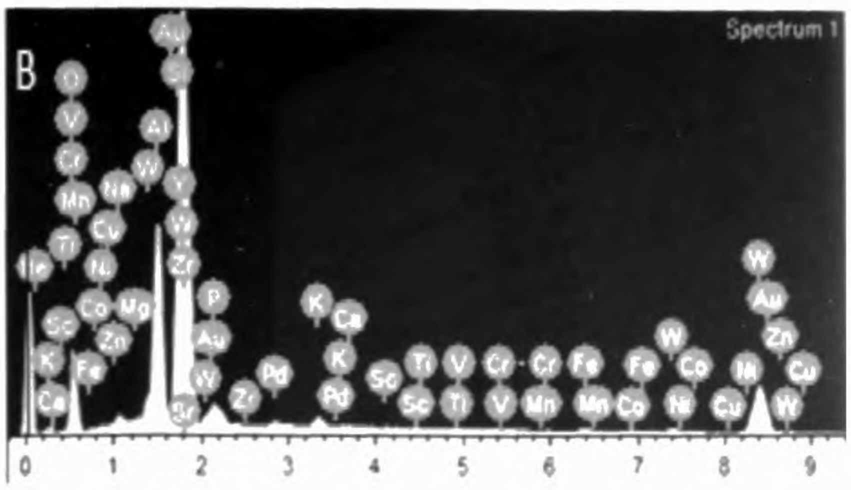

Fig. 14 Spectrum of the spot analysis of secondary minerals showing element concentrations as Si (10.17%), Al (8.28%), Na (0.6%), K (0.85%) and peaks. Note the Au and W peaks derived due to gold coating

SUMMERY AND CONCLUSIONS

Geological, petrographical, chemical and gemological characteristics of a rare, in-situ chrysoberyl deposit located at Yakkalamulla in southern Sri Lanka have been studied. The gem mineralization is hosted by a post-tectonic pegmatite intruded into a garnet biotite ±sillimanite gneiss belonging to the granulite-grade, dominantly meta sedimentary sequence of the Highland Complex. Flat faces with sharp crystal outline sand secondary clay fillings in some discontinuity plains in chrysoberyl crystals suggest in-situ formation of the deposit. Gem quality stones display a distinct color change from green in daylight to red in tungsten light due to higher Cr content (1055-1745 mg/kg) which is virtually not suppressed by the presence of Fe (0.84% to 0.89%). XRD analyses showed that the presence of quartz as minute inclusions in apparently pure chrysoberyls.

So far the deposit has produced substantial quantities of valuable alexandrite and cat's eye varieties. It also envisages remarkable prospects in the remaining pegmatite. Similarly, there is a high potential to locate additional gem- bearing pegmatitic intrusions in this geological setting

Table 2 Comparison of major element composition of the Yakkalamulla chrysoberyl samples with published data

Component (wt. %)	YAK1	YAK2*	YAK3*	1	2	3	4*	5	6
BeO	18.44	16.27	16.03	19.71	17.78	19.15	16.87	18.56	18.80
FeO	-	-	-	-	-	3.60	-	-	-
Al_2O_3	78.69	82.32	82.18	80.29	76.76	76.34	74.85	76.40	74.86
Fe_2O_3	0.85	0.84	0.89	-	6.07		4.06	1.30	3.91
K_2O	0.02	0.03	0.01	-	-	-	-	-	-
TiO_2	0.25	0.37	0.62	-	-	-	-	0.22	-
CaO	0.12	0.08	0.11	-	-	-	2.97	0.48	-
MgO	0.11	0.07	0.13	-	-	-	-	-	0.76
MnO	0.01	0.01	0.01	-	-	-	-	-	-
P_2O_5	0.01	0.01	0.01	-	-	-	-	-	-
SiO_2	1.43	4.57	4.64	-	-	-	5.13	2.24	1.12
LOI	0.00	0.00	0.00	-	-	0.30	0.55	0.40	-
Total	99.92	100.00	100.00	100.00	100.61	99.39	99.30	99.60	99.45

YAK1, YAK2 and YAK3: Yakkalamulla chrysoberyl samples; 1 to 6: published data from Palache et al. (1946); 1: $BeAl_2O_4$; 2: Rivièra du Poste, Quebec; 3: Golden Colorado; 4: Brazil; 5: Bershea Su, Gold Coast, colorless crystal; 6.Bershea Su, Gold Coast, yellow green crystal; X– rescaled after deduction of SiO_2 contents

Table 3 Trace element composition of the Yakkalamulla chrysoberyl samples

Component (ppm)	YAK1	YAK2	YAK3
Cd	3	2	1
Co	5	9	4
Cr	1545	1054	1735
Cu	40	23	68
Mo	12	97	4
Ni	19	22	26
Pb	66	58	57
Zn	59	42	102

by conducting a detailed geological exploration. Along with this deposit, all such resources could provide additional high quality chrysoberyls for future gem market.

ACKNOWLEDGEMENTS

The authors thank Mrs. Y.P.S. Siriwardana, Mr. A.M.M. Ratnayake, Mrs. Priyanka Jayalath, Mr. M.B.U.H.de Silva, Mr. M.P. Priyanga, Mrs. Saman Karunadhipathi, Ms. Nadeeka Gunarathna and Mr. Walter Attanayake for their assistance with this publication. Geological survey and Mines Bureau is acknowledged for providing research facilities and financial assistance in sample analysis.

REFERENCES

Cooray, P.G. (1994) The Precambrian of Sri Lanka: A historical review. Precambrian Research, 66:3-18.

Dahanayake, K., Liyanage, A.N. and Ranasinghe, A.P. (1980) genesis of sedimentary gem deposits in Sri Lanka. Sed. Geol. 25:105-115.

Dharmaratne, P.G.R., Premasiri, H.M.R. and Dillimuni, D. (2012) Sapphires from Tammannawa, Kataragama area, Sri Lanka. Gems and Gemology, 48:(2), 98-107.

Dissanayake, C.B and Rupasinghe, M.S. (1995) Classification of gem deposits of Sri Lanka. Geologie en Mijnbouw, 74:79-98.

Fernando, G.W.A.R., Hauzenberger, C. and Holfmeister, W. (2001) Origin of corundums in Sri Lanka: Evidences from case studies of in-situ deposits. Journal of Geological Society of Sri Lanka, 10:37-47.

Geological Survey and Mines Bureau (2000) Alutgama-Galle geology map, Sheet No. 19: scale 1: 100,000.

Gunatilaka, A. and Almond, D.C. (2001) Serendipity and the Jewels of Serendib: Part 1. The Internal Processes by which a Multi-Species Association of Gem Minerals were Created in Sri Lanka. Journal of Geological Society of Sri Lanka, 10:5-25.

Hölzl, S., Köhler, H., Kröner, A., Jaeckel, P. and Liew, T.C. (1991) Geochronology of the Sri Lanka Basement. In A Kröner (ed.), The Crystalline Crust in Sri Lanka, Part 1. Professional Paper No. 5, Geological Survey Department, Sri Lanka, pp 135-140.

Kröner A., Cooray, P.G. and Vitanage, P.W. (1991) Lithotectonic subdivision of the basement in Sri Lanka In Kröner, A. (ed.) The Crystalline Crust in Sri Lanka, Part 1. Professional Paper No. 5, Geological Survey Department, Sri Lanka, pp 5-21.

Kröner A., Williams, I.S., Compston, W., Baur, N., Vitanage, P.W. and Perera (1987) Zircon ion microprobe dating of high-grade rocks in Sri Lanka. Journal of Geology, 95:771-791.

Liu Y., Shigley, J.E., Fritsch. F. and Hemphil, S. (1995) Relationship between the crystallographic orientation and the alexandrite effect in synthetic alexandrite. Mineralogical Magazine, 59:111-114.

Milisenda, C.C., Liew, T.C., Hofmann, A.W. and Kröner A. (1988) Isotopic mapping of age provinces in Precambrian high-grade terrains: Sri Lanka. Journal of Geology, 96: 608-615.

Palache, C., Berman, H. and Frondel C. (1946) Chrysoberyl - The System of Mineralogy of Dana. J.D. and Dana D.S.Vol.1 (7th Ed.) John Wiley & Sons, Inc. pp 718-721.

Prame, W.K.B.N. (1997) Geochemistry and genesis of granitoid rocks from southern Sri Lanka. Mineralogy and Petrology, 60:245-265.

Prame, W.K.B.N. and Ajith Prema, J. (2014) Geology of charnockitic granulites and calc-silicate granulites from south-southeastern Highland Complex of Sri Lanka: Further constraints for physic-chemical conditions of their metamorphic evolution. Journal of Geological Society of Sri Lanka, 16:170-205.

Silva, K.K.M.W. and Siriwardana, C.H.E.R. (1988) Geology and the origin of the corundum-bearing skarn at Bakamuna, Sri Lanka. Mineral Deposita, 23:186-190.