Journal of Geological Society of Sri Lanka Vol. 13 (2009), 01-07

POTENTIAL OF GRAPHIC GRANITES OF SRI LANKA AS INDUSTRIAL RAW MATERIALS

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ABSTRACT

Graphic granites are mainly made up of quartz-feldspar intergrowths showing runic writing appearance. In Sri Lanka, these intergrowths are predominantly found either in the marginal or inner parts of sequentially and irregularly zoned granitic pegmatites. They form more than one third of a given pegmatite body and occur as small lenses or pods in granitic gneisses. The aim of this work is to study the possibility of using graphic granites found in feldspar mining sites in industry. The major rock forming minerals of graphic granites are quartz and perthitic feldspar with biotite, hornblende, fluorite and muscovite as accessories. The whole rock chemistry of these granites is identical to that of raw materials used in glass industry. The common impurity found in the studied rocks is iron which occurs below tolerable levels. The melting points of graphic granites are relatively low. As such, use of graphic granites as an alternate raw material could reduce the energy costs of the glass industry. On the other hand, they can even be used for the ceramics industry if the required mineralogical proportions are known.

Keywords: graphic granite, quartz-feldspar intergrowths, ceramic and glass industry

INTRODUCTION

The island of Sri Lanka is endowed with several non-metallic minerals which are being exploited for several local industries. The ceramic industry, mainly based on mineral resources of the country, is export-oriented. However, some ceramic products are also supplied to the local market. The raw materials of this industry are quartz, feldspar, limestone/marble and clay. Mineral-based industries have exploited most of the economic mineral deposits in the world. In this context, it is necessary either to explore new mineral deposits or to exploit the low-grade deposits which have not been exploited as yet.

At present, Sri Lanka has sufficient deposits of quartz, feldspar and limestone/marble for the ceramic industry (Herath, 1998). According to the present consumption and the rate of mining, known quartz and feldspar deposits will be exhausted in a few decades. The other identified deposits may not be exploitable as they are located in natural forests and other restricted areas.

Graphic granites are predominantly associated with granitic pegmatites and can be considered as pure phases of quartz and feldspar. However, accessory amounts of inclusions of mica (mainly phlogopite) are found in some granitic pegmatites. These rocks display runic or cuneiform texture (Figure 1). Fenn (1986) attributes the origin of graphic granite to (i) variable temperature (ii) pressure (iii) composition and (iv) texture to simultaneous growth of quartz and feldspar in a kinetically driven, non-equilibrium situation.

Figure 1: Photograph of graphic granite. Dark coloured runic writing appearance is given by quartz and the lighter coloured ground mass is represented by potassic and sodic feldspars.

Between the cell boundaries, the SiO_2 content of the residual liquid achieves a level of supersaturation that allows quartz to nucleate and grow along with feldspar. Swanson and Fenn (1986) report that subhedral to euhedral quartz grains are normally restricted to volcanic or hyperbyssal plutonic rocks where the quartz phenocrysts develop without any interference from the adjacent grains.

Although graphic granites are present in considerable quantities in Sri Lanka, they are dumped around mining sites of feldspar and quartz. This study is intended to review the salient mineralogical-, geochemical-characteristics and textural features of graphic granites with a view to assessing their economic significance as a raw material in industry.

GENERAL GEOLOGY OF SRI LANKA

Almost 90% of Sri Lanka is underlain by crystalline rocks of Precambrian age. The rest is composed of igneous rocks and Jurassic, Tertiary and Quaternary sedimentary rocks (Figure 2). On the basis of lithology, structure and age, the Precambrian metamorphic rocks can be subdivided into four major litho-tectonic units (Kröner et al., 1991 and Cooray, 1994). They are,

1. Highland Complex (HSWC)
2. Vijayan Complex (VC)
3. Wanni Complex (WC)
4. Kadugannawa Complex (KC)

The igneous rocks found in Sri Lanka are dolerite dykes, granites, pegmatites and carbonatites (Cooray, 1984) that have intruded into Precambrian rocks. Although the pegmatite bodies in the country are not extensive by volume, there are, throughout the island, great number of bodies with a more complex mineralogy (Pitawala, 2001 and 2003).

MODES OF OCCURRENCE OF STUDIED GRAPHIC GRANITES

Graphic granites are mostly found in the marginal parts of granitic pegmatites (Figure 3) which have been intruded into granulite facies rocks in and around Matale District. Some of these pegmatites are relatively large (up to $2000m^2$) elongated or oval-shaped intrusions, consisting of strongly zoned phases. These pegmatites are typical of miarolitic pegmatites found elsewhere in the world (Cerny, 1982 and London, 2005). Graphic granites are also found as small pods or lenses of smaller pegmatite bodies in the high grade metamorphic rocks of the country, specially in granitic gneisses (Figure 3).

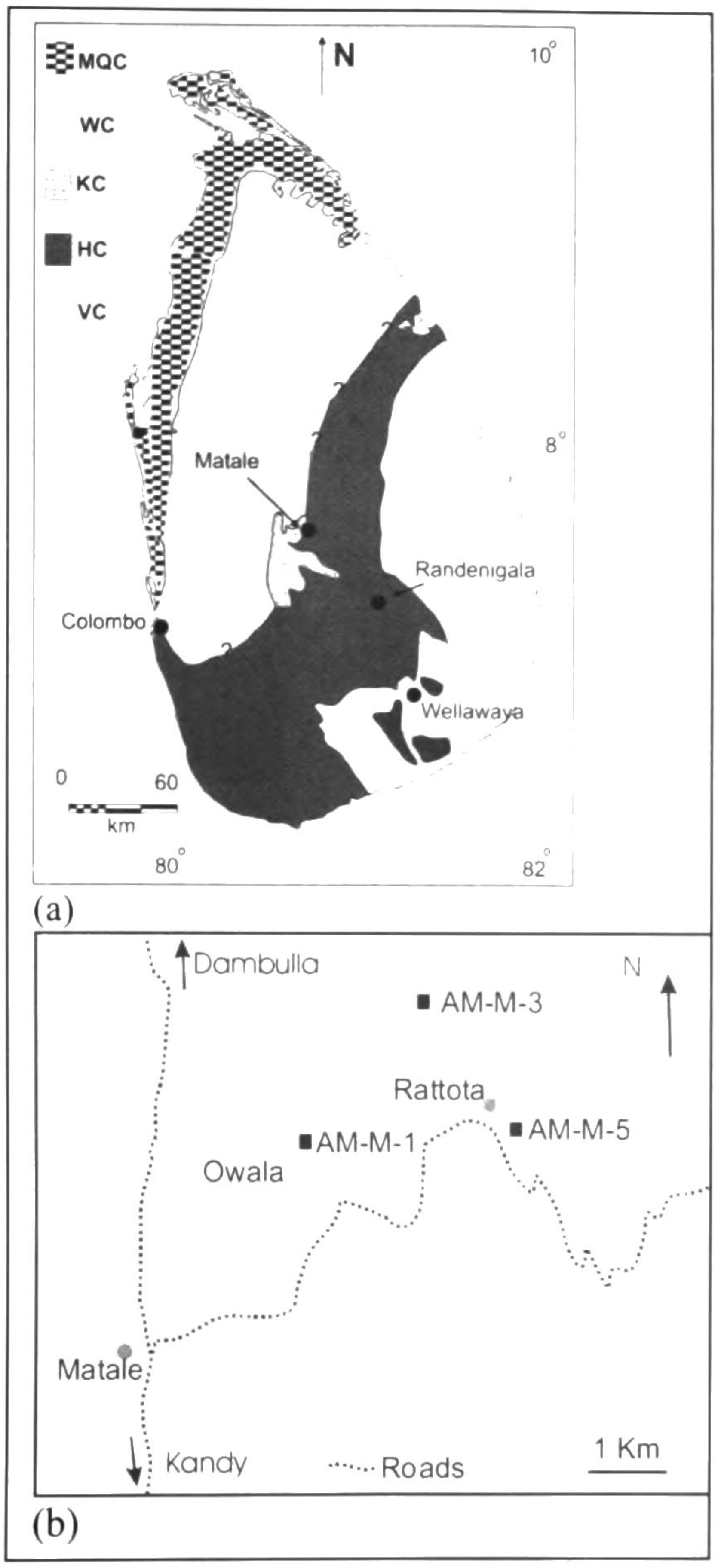

Figure 2: (a) Simplified geological map showing lithological units of Sri Lanka and locations of studied graphic granites. MQC is Miocene to Quaternary Cover; WC is Wanni Complex; KC is Kadugannawa Complex; HC is Highland Complex; VC is Vanni Complex. (b) Sampling sites around the Matale area.

Although the second type is ubiquitous in metamorphic rocks of the country, the extent of the former is high. The size of graphic granite bodies varies widely and the grain sizes increase with the volume of the graphic granite phase. Although the elongated grains show a single direction in hand specimens, different directions can be observed in segments of graphic nature in single exposures. Generally the quartz to feldspar ratio of these rocks does not vary significantly with the locations.

METHODOLOGY

Field investigations were carried out on selected pegmatites in the Matale area in the Central Province and at Randenigala in the Uva Province of Sri Lanka (Figures 2a and 2b). Further, graphic granites associated with granitic gneiss of Monaragala District close to the town of Wellawaya were also selected for the study.

Mineralogical compositions and petrographic studies of each graphic granite were studied using an optical microscope. The chemical analysis of selected samples was done at the Quality Control Laboratory of Holcim (Lanka) Ltd using Thetmo ARL 9800 Oasis simultaneous XRF spectrometer. Melting points of powdered samples of some rocks were determined by heating up to 1100^{0}C for two hours in an electric furnace at the Department of Chemistry, University of Peradeniya.

RESULTS

Petrography of Graphic Granites in Pegmatites

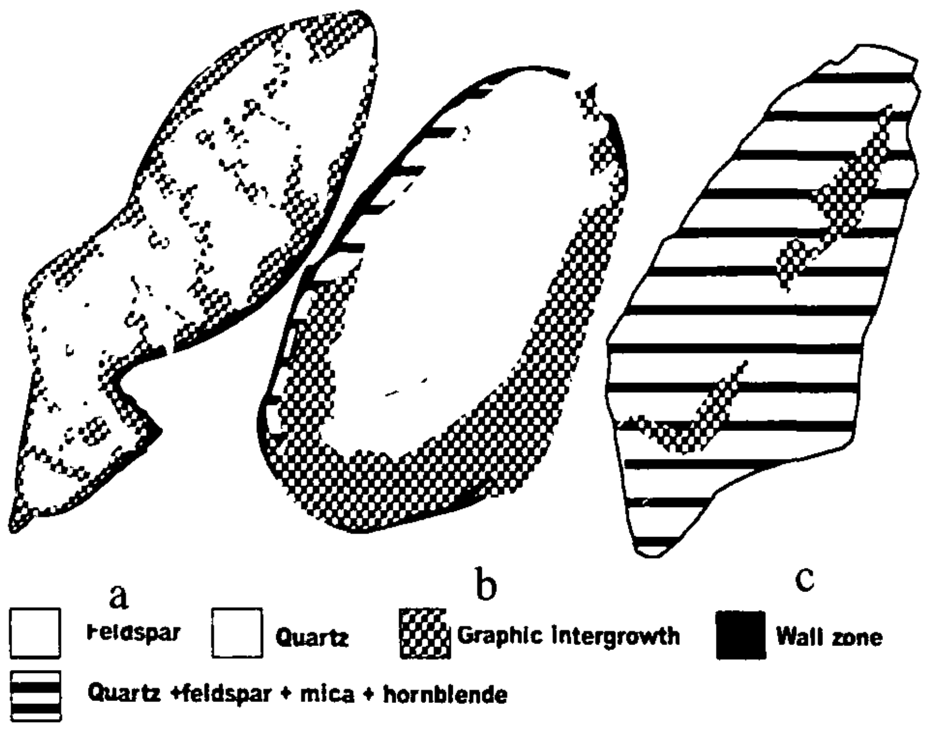

Figure 3: Mode of occurrences of graphic granites in (a) irregularly zoned pegmatite (b) systematically zoned pegmatite and (c) granitic gneiss of Sri Lanka. The size of larger pegmatite bodies (a and b) range from several tens to hundreds square meters. Sizes of graphic granites in granitic gneiss (c) are relatively small and do not exceed 3-5 m^2

A quarry consisting of systematically zoned granitic pegmatites is located at Owala close to Matale-Rattota road (sample- AM-M-1). It is being mined mainly for feldspar. The pegmatite body is about 500m in diameter and is composed mainly of quartz, feldspar and minor amounts of biotite, fluorite and muscovite. Fluorite occurs as small patches whereas biotite is found as cross cutting veins and patches. Graphic intergrowth of the Owala quarry exhibits very coarse-grained texture. The petrographic studies of graphic granites from the quarry show the dominant presence of mesoperthite.

Occurrences of graphic granites in pegmatites were observed about 1km northwards of the Rattota-Gammaduwa road (sample-AM-M-3). They are present as small pods and lenses within the pegmatite body which consists mainly of quartz, feldspar as major mineral constituents with graphic intergrowths. Graphic granites contain perthite (65 %) and quartz (30%) with minor amounts of muscovite. Quartz grains cross cut the exsolution lamellae of the perthitic intergrowths. The host phase of perthite is orthoclase which shows two distinct cleavages and their alterations are not significant. The twin angle of the exsolved phase is about 270^o indicating its andesine composition. Exsolution lamellae occur as veins showing the same optical orientation throughout the thin sections studied.

In another location, graphic granite bodies are found within a pegmatite body at Rattota between 23-24km posts along the Matale-Rattota road (see Figure 2b, sample AM-M-5). It is also strongly zoned and has been exploited for feldspar. The graphic granites in the pegmatite are mainly composed of quartz, mesoperthite and plagioclase. The quartz content is about 30% and most of them show runic appearance. The presence of mesoperthite is defined by the intergrowth of alkali and plagioclase feldspar in approximately equal proportions. Alkali feldspar present here is microcline. Plagioclase is present as irregular patches and its content is about 10%.

Large outcrops of graphic granites are found in a granitic pegmatite close to the Randenigala dam site, along the Victoria-Randenigala road. These outcrops are spread over a few hectares on the surface. The graphic granite consists mainly of microcline perthite and quartz. The quartz content is about 30%. They show runic writing appearance at some places but most places are predominantly coarse-grained. The host phase is microcline which shows distinct cross-hatched twinning. Perthitic lamellae occur as coarse veins and can be classified as string perthite. These strings show the same optic orientation in the thin sections studied.

Graphic Intergrowths in Granitic Gneisses

Occurrences of graphic granites are noted in exposures of granitic gneisses located close to the town of Wellawaya (Figure 2a). Here, graphic

Table 1: Chemical composition of different glass types, some rocks used as raw materials for glass industry and studied graphic granites

Component (wt.%)	soda-lime-silica container glass[1]	electric lamp glass[1]	soda-lime-silica glass tableware[1]	Window glass[2]	Aplite[3]	Nepheline syenite[3]	AM-M-1	AM-W-1	AM-M-3	AM-R-1
SiO_2	72.0	72.40	72.4	72.10	60.5	59.50	73.40	69.80	72.00	73.1
Al_2O_3	2.10	0.80	1.00	1.10	23.0	23.90	14.40	16.60	14.10	14.6
Fe_2O_3	-	0.40	0.10	0.20	0.41	0.08	0.20	0.10	0.20	0.20
CaO	10.20	5.30	8.10	10.20	5.60	0.20	2.01	1.98	2.00	2.11
MgO	-	3.70	0.20	2.60	0.05	-	0.05	0.03	0.06	0.06
Na_2O	14.9	17.40	18.10	13.60	6.10	10.50	5.22	2.31	2.14	5.31
K_2O	-	-	-	-	2.90	5.00	3.10	7.82	8.08	2.98
BaO	-	-	0.20	-	-	-	-	-	-	-
Li_2O	-	-	-	-	-	-	-	-	-	-

1- after Austin (1984), 2- after Kühnel (1996), 3-after Lefond (1983), AM-M-1- Owala, AM-W-1- Wellawaya, AM-M-3- near Rattota-Gammaduwa road and AM-R-1- Randenigala.

granite is associated with granitic gneiss. The grain sizes of the intergrowth are smaller in comparison with those of granitic pegmatites. The rock is mainly composed of quartz and perthite. The quartz content of the studied thin section is about 25%. Most of the grains show runic writing appearance. Perthite content is about 80%. The host phase is orthoclase and the alterations are insignificant. Exsolved phase forms irregular in shaped bodies, often blocky, and plagioclase is often twinned.

Chemical Composition of Graphic Granite

Chemical compositions of four (04) representative samples were obtained. The results are tabulated in Table 1. The major element chemistry of rocks from Rattota, Matale and Randenigala is comparable except for the varying concentrations of Na_2O and K_2O. In contrast, graphic granite collected from Wellawaya, has different chemical compositions. The SiO_2 concentrations (>69 wt.%) of all samples are similar to those of granite. Markedly low concentrations of iron and magnesium of all samples shows that accessory mica and hornblende do not influence the whole rock chemistry to any significant degree.

Results of Melting Point Determinations

In general terms, soda-lime-silica glass manufacture involves melting the required raw material mixture at 1600°C. If raw materials have lower melting points, glass industry can save energy. Therefore, powdered samples were heat treated to determine their melting temperatures. In the trial tests, it was noted that the heated samples did not show any changes below 1000°C. Therefore, observations were carried out on samples heated at or above 1000°C. Powdered graphic granite samples collected from granitic gneiss started to melt at 1000°C and at atmospheric pressure and the process had completely ended on reaching 1050°C. The other samples did not show any alterations at 1000°C. However, they melted partially at 1050°C. When the samples were heated to 1100°C, all samples except the graphic granite from Palletenna had liquidized and formed glass.

DISCUSSION

The grain size of quartz and feldspar in graphic granites varies all studied locations. However, the ratio of quartz to feldspar does not vary significantly. Further, the other minerals found in rocks occur as accessory constituents. Therefore, the mineralogy of different graphic granite samples suggests that they have almost similar chemical compositions. The studied samples also showed that all feldspars were oriented in one direction. However, patchy feldspars that occurred within larger feldspar grains did not show any preferred orientation.

The development mechanism of aligned intergrowth of quartz and feldspar in graphic granite has not yet been clearly understood. Based on the experimental studies, the texture is attributed to simultaneous growth of quartz and feldspar in a kinetically driven non-equilibrium situation (Fenn, 1986, Petersen and Lofgren, 1986). An imbalance between the growth rate of feldspar and the diffusivity of silica in the bulk melt creates a silica enriched boundary layer that in turn may cause the interface to degrade from planar to cellular.

Petrographic studies revealed that all the studied graphic granites were characterized by perthite, which have intermediate compositions in the feldspar group. Formation of perthite may be due to higher growth rate of minerals in a highly viscous melt that is commonly associated with pegmatites. When the growth rate of minerals in the melt increases, the temperature and cooling rate of the system can be lowered, this may lead to the unmixing of K-rich and Na-rich phases from alkali feldspar resulting in perthitic intergrowths as seen in the studied samples.

Lower melting points of studied samples suggest that graphic granites had formed at comparatively lower temperatures. The coarser fraction of minerals in graphic granites may have formed in the presence of abundant fluids. The higher viscosity generated from fluids is favourable to form coarser grains and it is not necessary to have deep seated environments (higher temperature) if a melt has a higher content of fluids. The fine-grained graphic granite in granitic gneiss in the Wellawaya area appears to have formed in a relatively rapid cooling environment and had not derived from a high viscous melt.

Significance of Graphic Granite in Industry

For glass manufacture, the raw materials are heated until they melt and are moulded in the viscous state into their final form. For common glass, appropriate phase diagram is SiO_2- CaO- Na_2O. The ternary eutectic composition of this diagram is 5% CaO, 25% Na_2O and 74% SiO_2 (Figure 4) and the compositions close to this can be used in glass industry, as it will begin to melt at the lowest temperature, saving energy and manufacturing costs (Manning, 1995). Less energy is required to achieve melting temperature, as the latent heat of fusion is lower for that composition.

Great care is taken to consider the minor components of glass, as small amounts of impurities may have a major positive and negative effect on the quality of the finished product. For example, the presence of traces of iron may give a pale green colour, and this can be tolerated in some applications. Some minor components might have beneficial effects on the glass produced. For example, addition of lithium and alumina reduces the temperature required to melt the glass thereby yielding a saving in energy costs. The occurrence of aluminium as an impurity may also be beneficial in reducing the need to add aluminosilicates for the manufacture of certain glass types (Petersen and Lofgren 1986) as well as it helps to improve resistance to weathering. The aluminium concentrations of the studied samples are high but it may not affect the quality of glass products. On the other hand, adding known quantities of quartz or other raw materials in required proportions, different glass types can be produced (see also Table 1).

The trace quantities of iron present in the analysed rocks may not affect the colour of the final products. Therefore, the chemistry of studied samples shows that they can be used as a raw material in glass industry. Their low melting temperatures can be beneficial in the glass industry. However, further analysis on strength testing, thermal expansion and refractive index measurements of the produced glass should be performed prior to utilizing graphic granite as a raw material in glass industry.

Quartz and feldspar intergrowths are generally coarse grained, and therefore the relevant proportions of minerals present in the rock can be estimated by simple petrographic studies. If we know the quartz and feldspar percentages in graphic granites, we can use them directly as a raw material for ceramic industry by adding the deficient mineral (either quartz or feldspar). Further, a simple mechanical process should be developed to separate quartz and feldspar in crushed graphic granites.

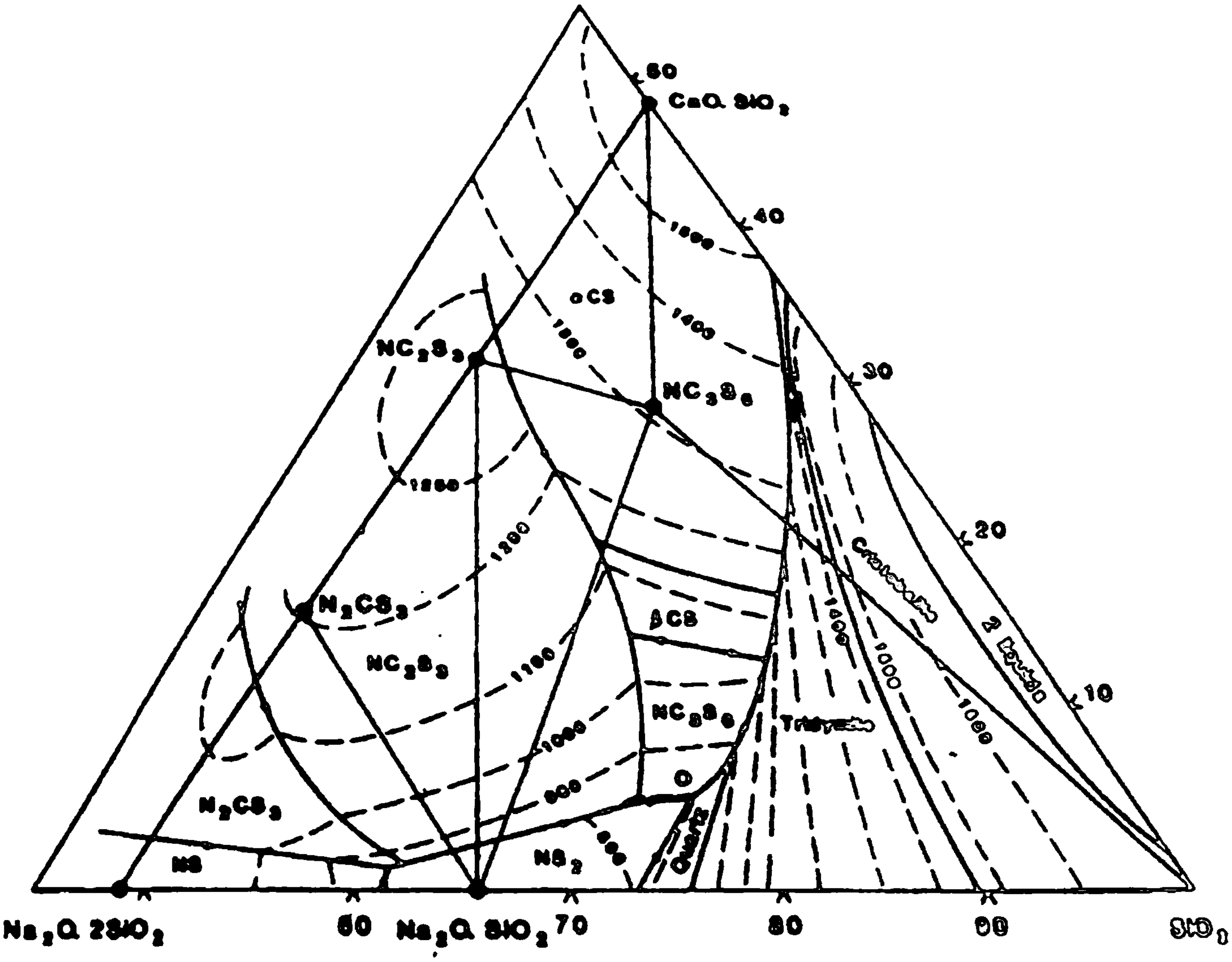

Figure 4: Phase relationships for part of system SiO_2-CaO-Na_2O at atmospheric pressure. Point O is the ternary eutectic, at 725°C. Compositions are expressed as weight percentage.

The extent of graphic intergrowths in Sri Lanka is considerable as granitic pegmatites are ubiquitous throughout the country. However, at present, this important raw material is left in the dumping sites of quartz and feldspar mines. The exposed materials can easily interact with the ionic solutions in the surface water rendering them useless in any future industry. It is, therefore, necessary to store them away from the elements for future industries in Sri Lanka.

ACKNOWLEDGEMENTS

The author thanks A.M.C.S. Amarakoon and P. Samarasinghe for their assistance during the present study. A. Gamage, Holcim (Lanka) Ltd. kindly provided geochemical analysis of graphic granites. The critical reading and helpful comments by Prof. K. Dahanayake and Prof. C. B. Dissanayake have improved the manuscript.

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