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KIMBERLITES IN WESTERN KENYA[1]

by

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(2 figures)

RESUME. - Trois kimberlites ont été récemment découverts au Siaya District (Central Nyanza) du Kenya occidental à la suite d'un programme d'exploration de géophysique aéroportée. Plusieurs puits ont été creusés dans les kimberlites. Aucun diamant n'a été trouvé pendant le lavage des déblais. Les minéraux lourds comprennent : le grenat de composition pyrope-almandin, le diopside chromifère, l'ilménite et la chromite magnésienne, l'orthopyroxène de composition enstatite-bronzite, l'amphibole de composition richtérite-édenite, la magnétite et l'olivine. En comparaison avec les kimberlites sud-africains, les kimberlites kenyans sont pauvres en minéraux satellites. Les diamètres de ceux-ci dépassent rarement 2 mm.

Les trois kimberlites se présentent sous forme de tufs souvent bien stratifiés, d'âge *Crétacé ou Tertiaire.* Probablement beaucoup d'autres kimberlites restent à découvrir dans la région. Leur potentiel économique est discuté.

ABSTRACT. - Recently an airborne geophysical survey with ground follow and drilling indicated the presence of three large kimberlite bodies in the Siaya District (Central Nyanza) of Western Kenya. A bulk sampling programme was set up to assess the diamond content. No diamonds were found. Heavy minerals included pyrope-almandine garnet, chrome-diopside, magnesio-chromite, enstatite-bronzite orthopyroxene, richterite-edenite amphibole, ilmenite, magnetite and olivine. In comparison with Southern African kimberlites, the Kenyan kimberlites are poor in indicator heavy minerals; the latter are almost never larger than 2 mm in diameter.

The kimberlites are tuffaceous and often layered, and not older than Cretaceous. Many other kimberlites probably remain to be discovered in the region and their diamond potential is discussed.

1. - INTRODUCTION

Recently an airborne geophysical survey resulted in the discovery of three large kimberlite pipes in the Siaya District (Central Nyanza) of Western Kenya. The kimberlites occur in an area roughly 50 to 70 kms west to north-west of Kisumu and are intruded into the Archean volcano-sedimentary sequence, which outcrops in the southwestern part of Kenya. A preliminary description of the kimberlites based on core samples of the three diamond drill holes can be found in Ito, Suwa & Winani (1981) and in Ito, Suwa & Segero (1983). This paper presents the results of the work carried out by Kemico Ltd. in view of assessing the diamond content of the kimberlites.

2. - REGIONAL GEOLOGY

The Archean sequence, in which the kimberlites are intruded, forms part of the larger Tanganyika Craton and is of the granite-greenstone type. In Kenya, the Archean outcrops are divided into a northern and southern part by the Kavirondo Rift and its associated Tertiary volcanics (fig. 1). The Kavirondo Rift is transverse on the Gregory Rift and forms part of the extensive East African rift system. The Archean is bounded to the north and east by the Nandi and Siria escarpments, marking the overthrust of the strongly metamorphosed Pan-African Mozambique Belt. In the southern half the Archean is partly covered by subhorizontal strata of lavas and quartzites of Bukoban-Malagarasian age. The Archean rocks are invaded by granites of various age and by numerous smaller intrusives of varied composition. The Archean is divided in two systems : the Nyanzian, the oldest and with volcanics dominant, and the Kavirondian with sediments dominant. From regional mapping a slight discordance is inferred between the two systems, although it has never been observed in outcrop.

1. *Manuscrit reçu, après révision, le 26 janvier 1985.*

2. *Kemico Ltd., Kisumu, Kenya.*

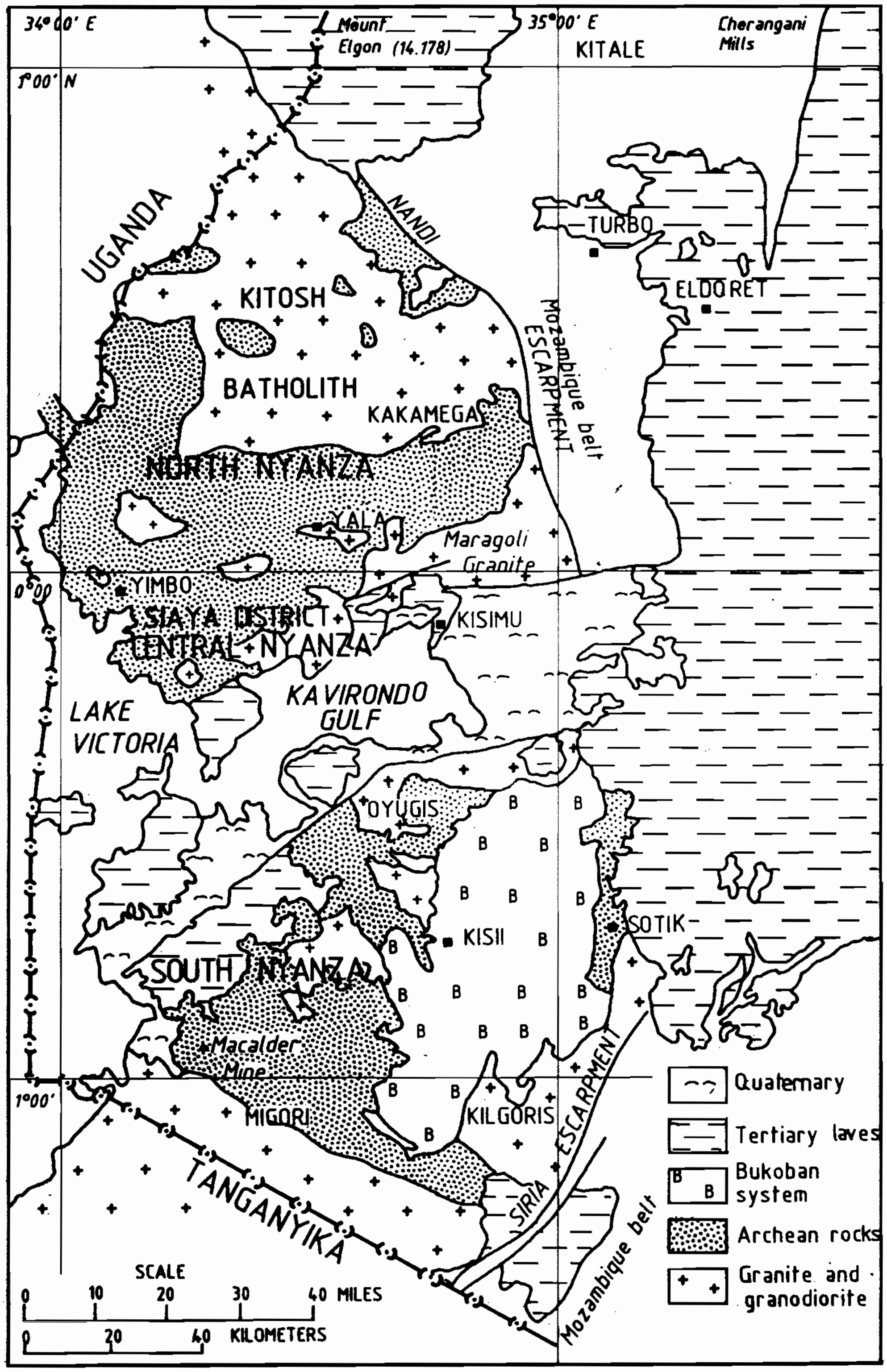

Figure 1. - Geology of Western Kenya (modified after Sanders, 1964).

3. - GEOLOGY OF CENTRAL NYANZA

The three kimberlites occur in the Siaya District of Central Nyanza, 50 to 70 km west to north west of Kisumu. Four units characterize the geology of Central Nyanza (fig. 2) : the Nyanzian volcanics and volcanoclasts, the Kavirondian sediments, the intrusive granites and the Tertiary volcanics.

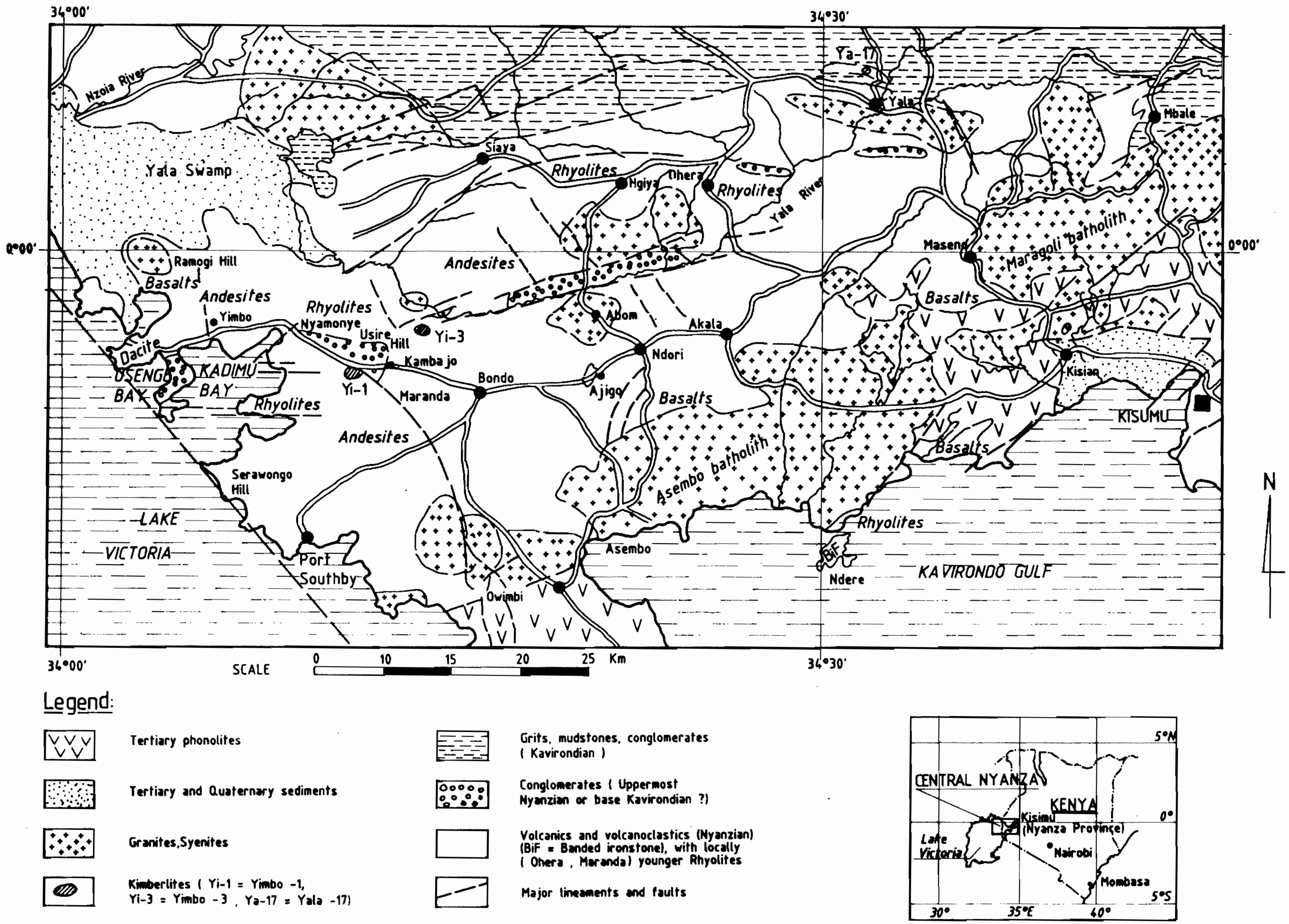

Figure 2. - Geology of Central Nyanza (for the eastern part partly reference has been made to Huddleston, 1954 and Saggerson, 1952).

The Nyanzian system

The rocks belonging to the Nyanzian System are of Archean age. They are moderately metamorphosed in the greenschist facies. From the base upwards the sequence starts with predominantly basaltic lavas, followed by predominantly andesites, and ends with dacitic and rhyolitic lavas and volcanoclasts with lenses of conglomerates and agglomerates. All three kimberlites are intruded in Nyanzian rocks (Hoshino, Yanagi, Suwa & Winani, 1983).

The Kavirondian system

The rocks of the Kavirondian System are of Archean age, but younger than the Nyanzian rocks. They are composed of conglomerates, sandstones and mudstones. (Hoshino, Yanagi, Suwa & Winani, 1983).

Granites

Granites are intruded into the Archean greenstones. The largest outcrop is formed by the Asembo batholith, flanking the Kavirondo Rift. Other stocks occur at Abom, Ajigo, Ngiya, along the Yala River north of Usire Hill and at Ramogi Hill. The latter is associated with nepheline syenite.

Tertiary volcanics

Tertiary volcanics, mainly phonolites, are associated with the Kavirondo Rift. Outcrops can be found around Kisumu and Maseno. North of Kisumu these volcanics are partly covering the Maragoli batholith (Saggerson, 1952).

The Tertiary tectonics related to the opening of the Kavirondo Rift and to the formation of the Mt. Elgon volcano determine the outcrop pattern of the above units in Central and North Nyanza. Near the Kavirondo Gulf and around Mt. Elgon the positive tectonics brought up the deeper parts of intrusive granites, followed inwards by the Nyanzian volcanics with the higher parts (and smaller outcrops) of the granites and with at the center the Kavirondian sediments. Central Nyanza forms the southern half of this tectonic basin.

The structural grain of the Archean rocks in Central Nyanza follows a ENE-WSW direction, turning to E-W near Maseno and Yala. Locally in the Yimbo area the direction can vary from WNW-ESE to E-W. This structural grain resulted in planes of weaknesses in the same direction which have been followed by the Tertiary rift faulting. On Landsat imagery lineaments and faults along a ENE-WSW direction parallel to the Kavirondo Rift predominate, together with the complimentary NNW-SSE faulting, resulting in a block faulting pattern. The three kimberlites are intruded along a line following a steeper NE-SW direction, parallel to some of the Kavirondo Rift faults.

Folds in the Nyanzian rocks are steeper than in the Kavirondian rocks. The contact between the two units could be tectonic as no discordance has been noted in outcrop sofar. Due to the intense faulting and folding it cannot be excluded that the conglomerate lenses in the upper part of the Nyanzian System are in fact, the basal conglomerates of the Kavirondian System.

Two of the kimberlites are intruded in the Yimbo area and are named Yimbo-1 and Yimbo-3. The Yimbo area is characterized by a syncline, formed between the positive movements of the Ramogi Hill intrusive complex to the NW and the Asembo batholith to the SE. In the centre of the Yimbo area a conglomerate lens outcrops surrounded by acid lavas and volcanoclasts. Towards the NW and towards the SE andesites predominate. Close to the contact with the Ramogi Hill intrusive complex and the Asembo batholith basalts outcrop. The axial plane of the syncline seems to be twisted. The direction changes from SW-NE at Usenge Bay to WNW-ESE between Nyamonye and Kambajo, to ENE-WSW at Usire Hill, as reflected in the outcrop pattern of the conglomerates. Around Kadimu Bay important E-W faulting supplements the general block faulting pattern along ENE and NNW. The Yimbo area is bounded towards the southwest by a close set of parallel NW-SE faults with downthrown side towards the SW, easily visible on Usenge Hill and reflected in the direction of the shoreline of Lake Victoria southwest of Serawongo Hill. In fact these NW-SE faults seem to mark the western limit of the Kavirondo Rift.

The third kimberlite, named Yala-17, occurs near Yala and is intruded in a lens of Nyanzian volcanics, surrounded by sedimentary rocks of the Kavirondian System. The Yala region is more humid than the Yimbo area and outcrops are rare due to deep and intense weathering. Faults and structures are more difficult to diagnose. However, the fact that Yala-17 aligns itself with the two other kimberlites 50 km more to the southwest is significant.

Apart from the granites, the Archean Rocks are intruded by smaller diorite stocks and dolerite dykes. The fresh nature of trachyte lavas, outcropping north of Maranda, with no trace of even greeschist metamorphism visible in petrographical slides, seems to point to an acid volcanic phase of much younger age than the Archean rocks. More to the north-east, near Ohera Church, Hoshino, Yanagi, Suwa & Winani (1983) noted the presence of similar rhyolitic intrusives and pyroclastics and concluded a post-Kavirondian age.

4. - KIMBERLITES

The kimberlites are not older than Cretaceous. Layered tuffs are still well preserved, pointing to the relatively limited extent of the erosion of the kimberlite diatreme.

Kimberlite Yimbo-1 occurs just south of the tarmac road between Kambajo and Nyamonye Market. The kimberlite forms a wide circular depression with an outlet to the west towards Kadimu Bay. The depression has a diameter exceeding 1 km. From geophysical ground follow-up data, a kimberlite diameter of 1 km was estimated. The kimberlite is intruded on the boundary between conglomerates to the north and volcanics to the south. The overburden, alluvial silt with basal gravel, averages 5 to 6 m in thickness. Soft weathered kimberlite occurs till a depth of about 15 to 20 m. From 20 m depth onwards the kimberlite becomes harder, although still of a weathered nature. The northern rim of the kimberlite is covered with a 5 m thick laterite duricrust. The kimberlite is vesicular, tuffaceous and often well layered in alternately coarser and finer tuffs. Weathering is intense and most of the original minerals are replaced. Calcite recrystallisation is extensive. Phenocrysts include green mica (phlogopite), pyrite, richterite-edenite amphibole, enstatite-bronzite orthopyroxene and olivine. Garnets and ilmenites are seldom visible in hand specimen. Xenoliths include pyroxenite, dunite, banded ironstone and the various volcanic and volcanoclastic rocks of the Nyanzian System. The dominant clay mineral in the overburden and the weathered kimberlite was shown by X-ray fluorescence and differential thermal analysis to be iron smectite or nontronite. The tuffs are coarser in the southern and western parts of the kimberlite, while kimberlite clay dominates in the northern part.

Kimberlite Yimbo-3 occurs north of the tarmac road Bondo-Yimbo, near Usire Hill, a few kilometres north-east of Yimbo-1. The kimberlite is elliptical in shape, 750 m along the long axis and 500 m along the short axis. The kimberlite is characterised by a topographical flat and a different vegetation pattern. The depth to hard kimberlite is much less on Yimbo-3. On Yimbo-3 hard rock occurs already from 5 to 7 m onwards. This is due to the more intense physical erosion towards Yala River. Relief is more pronounced on the northern side of Usire Hill towards Yala River, than on the southern side. Altitude drops from about 1300 m to 1160 m over only 2500 m on the northern side, while the same altitude drop is spread over about 7000 m on the southern side. The tuffs of Yimbo-3 are similar to the ones of Yimbo-1, showing the same trend of decreasing grain size towards the north. Xenoliths of the surrounding dacitic volcanoclasts are common in the south and centre. Carbonate recrystallisation is extensive and veins with well-crystallized ankerite are visible in the centre pit.

Kimberlite Yala-17 occurs a few kilometres north of Yala town. Geophysical ground follow-up indicated an elliptical conductor, 500 m along its long axis and 400 m along its short axis. The region is densely populated, fertile and intensely cultivated. The kimberlite is deeply weathered. In the pits no fresh kimberlite was encountered. Brown-red laterite clay with light-grey silica concretions occurs till a depth of 11 m. From 11 m onwards a multicoloured laterite clay vaguely displays the original breccia tecture of kimberlite.

5. - HEAVY MINERALS

The kimberlite was excavated in 2.50 x 1.25 m pits, lined with timber. Platforms were timbered in every 3 m and linked by ladders. Ore was hoisted out with buckets and windlass. The ore was piled up in separate heaps of about 3 tonnes, representing 0.5 m of pit depth. The soft kimberlite was treated with footshaker, trommel and rotary washing pan. The rotary washing pan used for the treatment of the soft kimberlite has a diameter of 1.52 m and a designed capacity of 3-5 tonnes/hour. However, the capacity is heavily dependent on the clay content. The ideal mix of feed should be 20 °/o clay-size particles, 50 °/o sand-size particles and 30 °/o pebbles and water. More clay will substantially reduce the capacity. The rotary washing pan is driven by a 5.5. HP diesel engine, making the arms turn with a speed of about 20 turns/minute. The teeth of the arms form a logarithmic spiral and have about 1 cm clearance from the bottom. Final jigging of the different size-fractions was done by hand, the eye examined and the heavy minerals further separated with bromoform, determined and counted in the mineral lab. No diamonds were found.

Overburden, except for the basal gravel, was not treated, because derived from surrounding country rocks. A few heaps of overburden were tested and found to be very poor in kimberlite minerals. Occasionnaly gold grains were found. The clayey and sticky nature of the overburden makes it very difficult to treat.

The most important kimberlitic indicator minerals found in the heavy mineral fraction of the three kimberlites are pyrope-almandine garnets, chrome-diopside, ilmenite, magnesio-chromite, magnetite, green orthopyroxenes (enstatite-bronzite series), amphiboles (richterite-edenite series) and olivine. Samples of these minerals were examined in more detail at the Royal Museum for Central Africa, Tervuren, Belgium, and resulted in the following analysis-results :

Garnets : the garnets are red and of pyrope-almandine composition. The refraction index is N = 1.77 ± 0.005. The X-ray diffraction Debye-Scherrer spectrum shows a = 11.540 Angström. Garnet samples analyzed at Nagoya University (Japan) showed a composition of almandine 47/pyrope 32/grossular 19 ("pyralspite" garnet).

Chrome - diopside : green (darker than orthopyroxenes), with chromium content of 1.4 °/o, and confirmed by X-ray diffraction Debye-Scherrer spectrum.

Magnesio - chromite : black octaedrons, determined by X-ray diffraction Debye-Scherrer spectrum to be a spinel close in composition to (Mg, Fe) (Cr, $Al)_2O_4$.

Ilmenite and magnetites : black shiny grains, one non-magnetic (ilmenite), the other magnetic (magnetite). Chemical analysis shows a high variation in TiO_2 content, probably pointing to the presence of titano-magnetites.

Orthopyroxenes : one sample of enstatite has a refractive index of N_Z = 1.668, corresponding with an orthopyroxene with 5-10 °/o $FeSiO_3$. The X-ray diffraction Debye-Scherrer spectrum shows it to be enstatite. Another sample proved to be enstatite-bronzite after refraction index determination and X-ray diffraction Debye-Schrrer spectrum. The refraction index is N_Z = 1.670 ± 0.005, corresponding to an orthopyroxene of the series enstatite-bronzite containing about 10 °/o $FeSiO_3$ according to the Winchell diagram. Under binocular microscope, enstatite has an olive-green colour, while bronzite is more brownish. Enstatite is much more common than bronzite.

Amphiboles : brown black grains showing distinct cleavage, which in thin section are weakly coloured (green-brown) and slightly pleochroic. The crystals are subautomorphic and often elongated. X-ray diffraction carried out by Geoscience Consulting Unit of Cambridge (England) showed the amphibole to be of the richterite-edenite series.

Olivine : is ubiquitous and highly altered. It was not counted or separeted during the heavy mineral examinations.

No **diamonds** have be found. One **zircon** has been found on Yimbo-1.

Kimberlite indicator minerals are rare. It is estimated from weight measurements during the bulk sampling that the combined content of garnets, diopsides and ilmenites rarely exceeds 100 ppm. Garnets and chrome-diopsides with diameters larger than 2 mm have not been detected. Also most ilmenites, magnesiochromites and magnetites are smaller than 2 mm, but occasionnally grains of 3 mm diameter are present. Sizes of orthopyroxenes and amphiboles range up to 5 mm diameter.

6. - DISCUSSION

Kimberlites are mica peridotites, characterized by two generations of olivine (olivine in the matrix and olivine as xenoliths). However kimberlites defined as such show a great variation in both the relative abundance of their minerals as in their texture. Skinner & Clement (1979) propose a new classification based on the relative abundance of five primary minerals in kimberlite : diopside, monticellite ($CaMgSiO_4$, olivine family), phlogopite, calcite and serpentine. Olivine, being always abundant, is considered of little use in classification. Skinner & Clement (1979) regard minerals formed by deuteric processes as primary constituents, as these processes are a direct consequence of the consolidation of the magma. Following their reasoning, we can classify the Siaya kimberlites as calcite-kimberlites, calcite being mainly of deuteric origin. Intense weathering has resulted in further enrichment of calcite (up to 60 °/o) in the uppermost tuff layers of the diatreme.

Kimberlites can contain diamonds. The relationship of the presence of diamonds to certain mineralogical and chemical characteristics of the host kimberlites is still conjectural. Regional geology seems to indicate that the diamondiferous kimberlites intrude stable Precambrian cratons, mainly composed of competent rocks such as granite and gneiss. These cratons can be covered by younger subhorizontal strata of sediments and volcanics as e.g. the Karroo formations of Southern Arica. Kimberlites are intruded along deep lineaments, fault zones or flexures in the craton.

Known kimberlites in East Africa are not older than Cretaceous, and probably related to the break up of Gondwana and to the initial stages of the Cenozoic East African rift system. Diamondiferous kimberlites (such as the Mwadui pipe), although genetically related to the rifting, only occur in stable cratons at a distance exceeding 200 km from the nearest rift system. Kimberlites originate at a depth of 150-200 km. Pressure and temperature conditions at that depth are compatible with the diamond stability field if the geothermal gradient in the crust is low. Coming nearer to the rift system the geothermal gradient at the time of the kimberlite intrusion was too high to allow the formation and/or the preservation of diamonds.

Kimberlites occurring close to or in a rift system are associated with carbonatites and alkaline complexes. They never contain diamonds. Carbonatite and alkaline complexes are the result of a slow differentiation of an initial basaltic magma and diamonds -if present at the origin-would be resorbed. Examples in East-Africa are Mt. Rungwe in SW-Tanzania and the Mrima Hills south of Mombasa.

The Siaya kimberlites are at least 60 km apart from the nearest carbonatite (Mt Homa), associated with the Kavirondo rift, but a close spatial relationship with carbonatite is not present. The calcite content, high in the upper part of the Siaya kimberlites, decreases rapidly with depth. This seems to prove a deuteric origin of most of the calcite, further enriched by intense weathering.

An explanation for the absence of diamonds in the Siaya kimberlites could be one of the following or both :

- At the time of intrusion the geothermal gradient was too high and the temperature at the depth of origin too high to allow the formation and preservation of diamonds.
- No granite or gneiss xenoliths were noted in the kimberlites, which seems to indicate that the focal point of the diatreme was still in greenstone terrain. The greenstones are tightly folded and fractured, resulting in near-vertical planes of waekness and allowing a significant release of pressure inside the ascending kimberlite magma. Diamonds if present would be resorbed.

Sofar only three kimberlites have been found in the region west of Kisumu. Probably many more are still to be found. Kimberlites intruding large granitic masses, such as the Kitoshi granite, are better diamond targets. But, with intensely fractured and folded greestones never far off, it is much more likely that the ascending kimberlite magma would choose the pathway of lesser pressure resistance offered by the greenstones. We therefore conclude that the diamond potential in the area is limited.

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