PRECAMBRIAN OF THE AFRICAN CONTINENT

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Abstract: Precambrian rocks are exclusively found in the vast shield areas such as the Antarctic and the African Continents. Drastic revision of Precambrian geology in the African Continent has been done in recent years. Current knowledge on Craton and Precambrian orogenic belt, on relationship among Precambrian orogenic belt, continental drift and rift valley, and on two distinct types of structural-metallogenic domains is reviewed in Introduction.

The Association for African Studies, Nagoya University made a start in 1962. Some contributions by the Association to Precambrian studies in Africa have been described: Precambrian anorthosites, chromian phlogopite in Bushveld anorthosite, contact aureole of the Bushveld Complex, palaeomagnetism of Precambrian kimberlites, isotope geochemistry of Precambrian carbonatites, geochronology of the Mozambiquian orogenic belt, and metamorphic and plutonic rocks in the Mozambiquian belt around Machakos, Mgama ridge, Linthipe, Aswan and other areas.

1. Introduction

1.1. Precambrian time

Precambrian time covers almost 90% of the total length of time that has elapsed since the formation of the earth. Until recently, however, this long period of geologic time was among the least known segments of the geologic record.

The actual absence of visible fossils in Precambrian rocks makes it very difficult to correlate rocks of one locality to those of the others or to identify the age of geological formations in different localities. By introducing the radiometric dating methods, reliable age data on minerals and rocks have been accumulated. The Precambrian is now outstanding in availability of a notable number of exact ages, among which the oldest ones are estimated at 3600 million years. The Precambrian rocks are exclusively found in the vast shield areas such as the Antarctic and the African Continents. In the African Continent, their areal distribution amounts to 57% of the whole continent.

Fairly good correlation of Precambrian rocks from one region to another is done throughout the African Continent. HOLMES (1963) wrote vividly this situation of drastic revision of the Precambrian stratigraphy in Africa as follows: "For me, probably the most dramatic and unexpected surprise of a decade packed with

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surprises was the anouncement of the great age of the Bushveld Complex, about 2000 million years, and the consequent realization that the Transvaal Group of strata must be older still.   Until 1901 the Transvaal "System" was correlated on lithological grounds with the Palaeozoic Cape "System".   Then for over half a century the Transvaal "System" was confidently thought to be of late Precambrian age and, lithologically, a typical representative of the Algonkian.   Yet it has turned out to be immensely older than such characteristically Archaean rock sequences as the Grenville of the Canadian Shield and the Svecofennian of the Baltic Shield."

1.2.   Craton and orogenic belt

Almost all Precambrian rocks of the African Continent have been hitherto considered to represent the Precambrian craton.   Radiometric dating has shown that, in addition to large massifs of older material, it includes a network of belts which were not stabilised until early Palaeozoic times.   As shown in Fig. 1, three great massifs of older Precambrian rocks —Kalahari Craton, Congo Craton and West African Craton— remained stable throughout the development of the late Precambrian-early Palaeozoic system of fold-belts (KENNEDY, 1964).
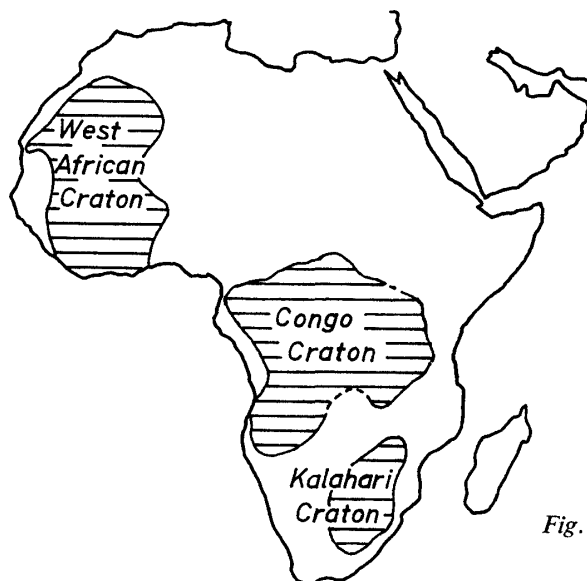

Fig. 1.   Three cratons in the African Continent.

The Kalahari Craton has been subdivided into the Kaapvaal Craton (to the south) and the Rhodesia Craton (to the north). The Limpopo orogenic belt is situated between the Kaapvaal and the Rhodesia Cratons.   The Congo Craton has been subdivided into the Congo Craton proper (in the west) and the Tanganyika Craton (in the east).   Areas presently occupied by a large part of the Western Rift Valley had been situated in an orogenic belt of the Pan African Cycle itself.   With progress of researches on the Precambrian rocks, the distribution areas of Cratons seem to

become gradually smaller (SUWA, 1966a, 1967, 1968; SUWA and YAIRI, 1979).

Recently, time, character, and areal distribution of the Precambrian orogenic cycles in Africa have been confirmed, and the following four orogenic cycles have been recognized (KRÖNER, 1977).

    a.   Limpopo-Liberia Cycle (2700±200 m.y.)

    b.   Eburnian Cycle (2000±200 m.y.)

    c.   Kibaran Cycle (1100±200 m. y.)

    d.   Pan African Cycle (600±200 m. y.)

The Limpopo belt situated between the Kaapvaal Craton and the Rhodesia Craton is a representative orogenic belt of the Limpopo-Liberia cycle. The Ubendian belt and the Kibali-Toro-Buganda belt are the representative orogenic belts of the Eburnian cycle. The Irumide belt and the Kibaran-Burundian-Karagwe Ankolean belt are the representative orogenic belts of the Kibaran cycle. The Mozambiquian, Zambezi, and Damaran belts are the representative orogenic belts of the Pan African cycle (Fig. 2).

A concept of marginal continental accretion has long seemed to be well supported by the tectonic structure of the European and the North American Continents. The picture seen in Africa, however, is certainly not as simple as it appears to be in North America. In the African Continent, younger orogenic belts were built up on a previously consolidated sialic basement.

1.3. Relationship among Precambrian orogenic belt, continental drift and rift valley

It is possible that the pronounced general parallelism between the present coast lines of Equatorial Africa and the West Congolian and Mozambiquian portions of the youngest Precambrian belt, may be due to fracturing along the general strike of the beds at the time of the continental drift rather than to what would appear to be marginal continental accretion.

The extension of the Mozambiquian belt trends nearly in a N–S direction in East Africa, and the interior structure of the belt also takes the same direction in general. Tectonic elongation, interior structure, and less hardness of rocks of the Mozambiquian belt might have controlled the location of the African Rift Valley (MATSUZAWA, 1966).

1.4. Mineral deposits in relation to the structure of the continent

When the major mineral deposits of Africa are considered in relation to the structure of the continent, two distinct types of structural-metallogenic domains are distinguished; older cratons are characterized by the major deposits of gold, platinum, diamond, chromium, asbestos, and iron ore reserves; and younger orogenic belts are characterized by the major deposits of copper, zinc, lead, cobalt, niobium, tungsten, tin, and beryllium (CLIFFORD, 1966).

1.5. Association for African Studies, Nagoya University

In 1962, Nagoya University dispatched the Commission to four countries (Afars

and Issas, Ethiopia, Sudan, Egypt) for field investigations of geology and medical plants. In the same year the Association for African Studies, Nagoya University made a start. Since then, many earth-scientists of Nagoya University have continued their field surveys in several countries (Kenya, Uganda, Rwanda, Burundi, Tanzania, Malawi, South Africa).

In the following sections, some contributions on Precambrian studies done in Africa by the Association for African Studies, Nagoya University will be described (Fig. 3).

2. Precambrian Studies on Kaapvaal Craton (South Africa)

2.1. Anorthosite from Bushveld Complex

The Bushveld Complex in South Africa is an intrusion in the Transvaal System dated at 2050 m.y. In the Bushveld Complex, anorthosite layers occur in the Critical-, Main-, and Upper Zones.

At Dwars River Bridge, Bushveld, anorthosite belonging to the upper part of the Critical Zone occurs as a spectacular alternation of white anorthosite layers (plagioclase adcumulate layers) and black chromite-rich layers (chromite-plagioclase heteradcumulate layers).
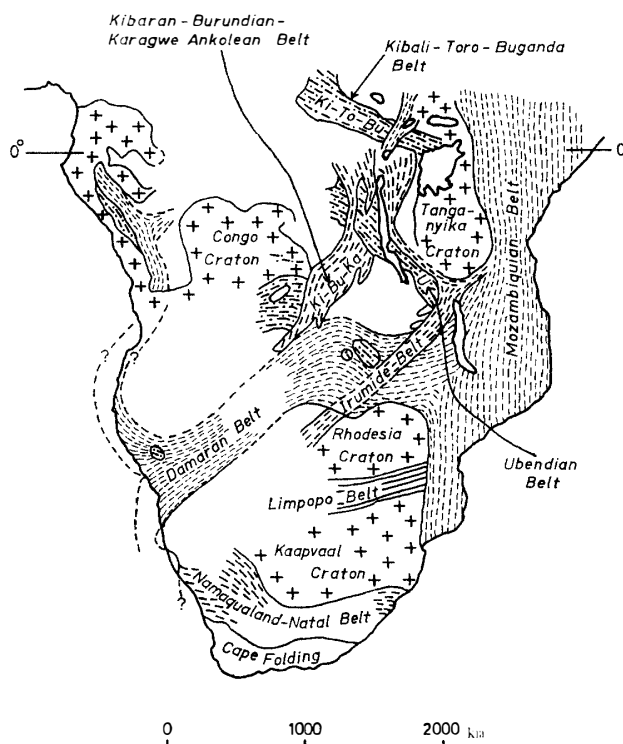

Fig. 2. Cratons and Precambrian orogenic belts in equatorial and southern Africa (Modified from CAHEN and SNELLING, 1966).

Plagioclase grains in both layers are twinned according to the albite-Carlsbad law (40%), pericline law (31%), albite law (25%), and Carlsbad law (3%).

There are at least three varieties of anorthosite of the Precambrian time in view of their different geological and petrological situations.

Bushveld type anorthosite occurs as layers within stratified intrusions developed under stable cratogenic conditions. Adirondack type anorthosite occurs as large independent intrusion with domed roofs. Fiskenaesset type anorthosite forms layered stratiform sheets occurring as conformable layers in granitic gneiss of the oldest Archaean craton.

The emplacement of anorthosites during the Precambrian time may be divided into four periods: 3500 ± 200 m.y. (Fiskenaesset type anorthosite), 2200 ± 300 m.y. (Bushveld type anorthosite), 1500 ± 300 m.y. (Adirondack type anorthosite), and 1200 ± 200 m.y. (Bushveld type anorthosite).

Plagioclases of these varieties of anorthosite have the respective petrographical characteristics exhibiting their different petrogeneses (SUWA, 1975, 1976a, 1976b, 1977, 1978, 1979).

2.2. Chromian phlogopite in Bushveld Anorthosite

At Dwars River Bridge, Bushveld, the adcumulate layer consists of bytownite with small amounts of clinopyroxene, orthopyroxene, chromite and chromian phlogopite, and the heteradcumulate layer consists of chromite and bytownite with small amounts of clinopyroxene, orthopyroxene and chromian phlogopite. These chromian phlogopites contain sizable amounts of $Cr_2O_3(>1\%)$, $FeO(>4\%)$, TiO_2 $(>5\%)$, $K_2O(>9\%)$, $Al_2O_3(>14\%)$ and $MgO(>21\%)$.

Although there are several reports on chromian phlogopites in the rocks of upper mantle origin, this is the first finding of chromian phlogopite in an igneous rock formed in the crustal environment (SUWA and SUZUKI, 1977a).

2.3. Contact aureole of Bushveld Complex

Contact metamorphic rocks occur widely around the Bushveld Complex which is a giant among mafic layered intrusions. Many studies on the contact metamorphism of the Bushveld Complex include petrochemical and petrographical data, but no detailed mineralogical data can be found. SUWA and SUZUKI (1977b) discussed the contact metamorphism of the rocks in the northeastern contact aureole of the Bushveld Complex.

In pelitic hornfels, plagioclases are of sodic oligoclase in lower grade and are of sodic andesine in higher grade. In pelitic-psammitic hornfels, with increase in metamorphic temperature the TiO_2 contents of biotite co-existing with ilmenite increase and the $Na/Na+K$ ratios of muscovite decrease.

In calcareous hornfels, plagioclases are of pure anorthite in higher grade and potassic hastingsite is a characteristic amphibole in higher grade. In basic hornfels, assemblage of actinolite and bytownite with zoisite is characteristic in lower grade.

2.4. Palaeomagnetism of Precambrian kimberlites

Many kimberlite bodies have been emplaced in the African continent since the Precambrian time, particularly during the Cretaceous period. The kimberlite bodies examined are the Premier mine, Montrose pipe, and National pipe of Precambrian time.

The formation of kimberlite is characterized by a deep-seated origin in the upper mantle and a rapid rise through the crust with fast cooling near the surface. Accordingly, the rock's remanent magnetization should have been acquired within a short time and the properties are similar to the thermoremanent magnetization of normal volcanic rocks. The natural remanent magnetization of the Precambrian kimberlites remains stable to both alternating field and thermal demagnetization. The virtual geomagnetic pole-positions derived from the directions of stable remanence of the Precambrian kimberlites can be correlated with palaeomagnetic poles obtained from other Middle-Late Precambrian rocks in Africa (ITO et al., 1977, 1978).

2.5. Isotope geochemistry of Precambrian carbonatites

Many carbonatite bodies have been emplaced in the African continent since the Precambrian time, particularly during the Mesozoic and Cenozoic eras, and current exposures represent a range in depth of consolidation. The carbonatite bodies examined are the Palabora, Spitskop and Premier mine carbonatites of Precambrian time. Carbonatite complexes (Palabora and Spitskop) of subvolcanic-plutonic association show a restricted carbon and oxygen isotopic composition range, and Mesozoic and Cenozoic carbonatite complexes of volcanic and volcanic-subvolcanic association show considerably wider varieties as a result of interaction with atmospheric oxygen and meteoric water during eruption. The Premier mine carbonatite shows a significant enrichment in ^{18}O compared to the subvolcanic type carbonatite (SUWA et al., 1975).

3. Precambrian Studies on Mozambiquian Orogenic Belt

3.1. Geochronology of Mozambiquian belt

Rb-Sr whole-rock ages of 827 m.y. and 766 m.y. are given on the metamorphic rocks in the Taita Hills of southern Kenya and on the granitoid gneiss in the Mbooni Hills of Machakos area, central Kenya, respectively. These ages may indicate either the time of high-grade metamorphism or that of primary emplacement and sedimentation. The low initial $^{87}Sr/^{86}Sr$ ratios of 0.7047 and 0.7041 exclude a possibility that the rocks originated from much older crustal material. The K-Ar mineral ages of about 500 m.y. in the Taita Hills and Mbooni Hills indicate the time of a later thermal event (SHIBATA, 1975; SHIBATA and SUWA, 1979).

The K-Ar age determinations on the Tanzanian igneous and metamorphic rocks are reported by UEDA et al. (1975). The Nyanzian schist near Mwadui may be older
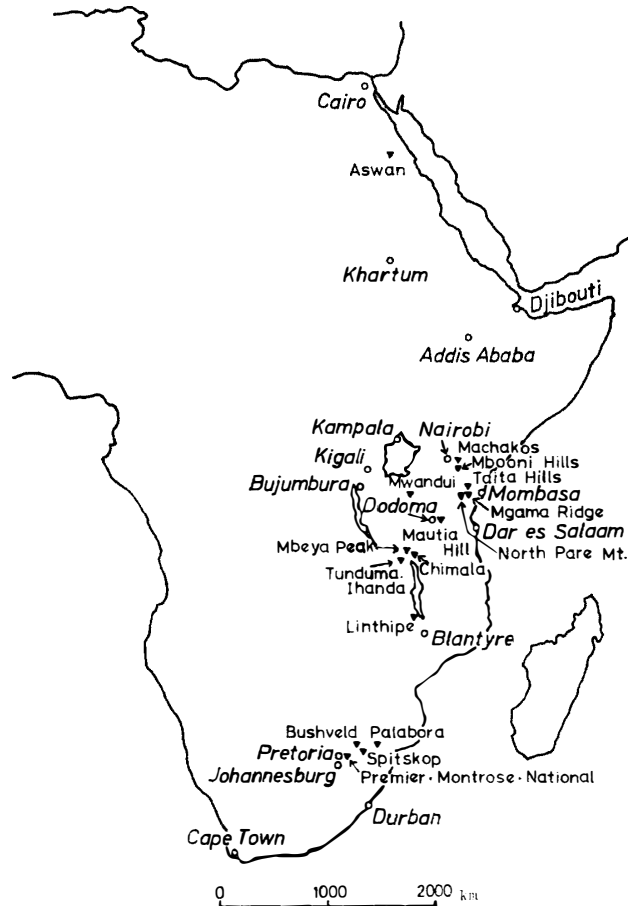
Fig. 3. Map showing localities described in this paper.

than 3150 m.y. and metamorphic and plutonic rocks in the Tanganyika craton represent 2200–2750 m.y. The Ubendian metamorphic rocks represent 1500–1900 m.y. Metamorphic and plutonic rocks at Mautia Hill, Mbeya Peak, Chimala, Ihanda and Tunduma represent 600–750 m.y. These rocks may have been produced in the period of the Eburnian cycle and polymetamorphosed in the period of the Pan African cycle.

3.2. Metamorphic rocks of Machakos area

The area southeast of Machakos is occupied mainly by Precambrian metamorphic rocks constituting part of the Mozambiquian belt of Kenya, mostly belonging to the amphibolite facies of metamorphism (BIYAJIMA *et al.*, 1975; BIYAJIMA, 1976). In this area, three hills of 2000 m above sea level are situated from east to west: Mbooni Hills, Kalama Hills and Muumandu-Mbevo Hills. Detailed geological survey was done in the area of 30 km north-south and 30 km east-west.

The Mbooni Hills is a type locality of the granitoid gneiss. The gneisses around

the Mbooni Hills appear to form a gentle dome structure.   The upper stratigraphic formations which appear to be laid on the granitoid gneiss are represented by the various kinds of paragneisses: pelitic gneiss, semi-pelitic gneiss, psammitic gneiss, tuffaceous semi-pelitic gneiss, calcareous gneiss and amphibolite.   The total thickness of these paragneisses reaches about 6000 metres.   General structural trend of these paragneisses is between north-south and northwest–southeast with westerly dipping except for the nearby area around the domes, where the trend changes into concentric arrangements as clearly seen around the Mbooni and the Uvete domes.   Lineation directions are approximately parallel to the general structural trend of these paragneisses and are plunging to north or northwest at low angles.

Granitoid gneiss is usually homogeneous.   The granitoid gneiss in the Mbooni Hills was formed originally as a granitoid mass, which was subjected to a later metamorphism and transformed into granitoid gneiss (NUREKI et al., 1977).   Considering a low initial $^{87}Sr/^{86}Sr$ ratio, this age (766 m.y.) is interpreted to indicate the time of original emplacement of the granite magma derived from the mantle.   The K–Ar biotite age of 528 m.y. in the Mbooni Hills indicates the time of a later regional metamorphism (SHIBATA and SUWA, 1979).

After our geological survey we noticed that a conspicuous dome structure is found only in the Mbooni Hills, whereas no dome structure occurs in the Kalama Hills or in the Muumandu-Mbevo Hills.   The Kalama Hills consists mainly of psammitic gneiss called "Kalama type sandstone" which is a member of the paragneisses of this area.   The granitoid gneiss occurring in the Muumandu-Mbevo Hills appears to form a concordant sheet in paragneisses.   In petrographical features the granitoid gneisses in the Mbooni Hills and the Muumandu-Mbevo Hills are different from each other.

Between the Mbooni Hills and the Kalama Hills a characteristic belt consisting of the association of pelitic gneiss and basic gneiss occurs continously more than 20km and this pelitic gneiss is composed of kyanite, staurolite, almandine, biotite, muscovite, plagioclase and quartz.   From the Fe/Mg distribution coefficient between coexisting almandine and biotite and from the Ca distribution between coexisting plagioclase and almandine, this pelitic gneiss is considered to have been formed at 570°C–590°C and 6.8 kb.   The ZnO content of staurolite of this pelitic gneiss belonging to kyanite zone amounts to 3.79% in maximum.   The content, however, is considerably variable within the same horizon and even in a small rock specimen. Staurolite inclusion in almandine porphyroblast is rich in FeO and Al_2O_3 and poor in ZnO; staurolite inclusion in muscovite crystal is rich in Al_2O_3 and ZnO and poor in FeO; poikiloblastic staurolite exhibits intermediate properties (INOUE and SUWA, 1979; SUWA et al., 1979 a).

Petrographical and petrochemical features of the granitoid gneisses and Kalama type sandstone from the Machakos area were discussed (MIYAKAWA and SUWA, 1977, 1979), and characteristic occurrences of staurolite in the Kioo kyanite pegma-

tite, Machakos area (MIYAKAWA and SUWA, 1975) and of fuchsite in the Kibingi limestone quarry of Sultan Hamud, southern Machakos area (SHIOZAKI, 1975) were also reported.

3.3. Green garnet from Mgama ridge

Green garnet occurs in the Mozambique metamorphic rocks in southern Kenya and northern Tanzania. Main localities of the green garnet are Mgama ridge, 40 km southwest of Voi, southern Kenya; Namalulu, 100 km south of Arusha, northern Tanzania; and Mikameni, 50 km north-northwest of Tanga, northern Tanzania.

At the Lualenyi mine, Mgama ridge (3°38′S, 38°18′E), calc-silicate gneiss, marble, pelitic-psammitic gneiss, and granitoid gneiss run in a north-northwest direction with northeasterly dipping of 40°. The calc-silicate gneiss consists of scapolite, vanadian diopside, graphite, quartz, and allanite. In this calc-silicate gneiss large porphyroblast called "potato" is found. The "potato" sometimes reaches 2 kg in weight and usually its diameter is 2 to 7 cm. In this "potato", large green garnet occupies the core part and tanzanite crystals usually occur around the large green garnet, and the outermost part is occupied by a reaction zone consisting of scapolite, green garnet, diopside, and vanadian sphene and vanadian magnetite. The marble in some places consists of calcite, graphite, vanadian muscovite, and muscovite, but in other places it consists of calcite, quartz, tanzanite, zoisite, albite, magnesian muscovite, potassium feldspar, vanadian sphene, graphite, vanadian rutile, and secondary goethite. The pelitic–psammitic gneiss is composed of potassium feldspar, quartz, plagioclase, graphite, phlogopite and secondary goethite. The granitoid gneiss consists of potassium feldspar, plagioclase, quartz, white mica, phlogopite with minor amounts of rutile, zircon, graphite, pyrite and secondary graphite.

Scapolite in the calc-silicate gneiss is of 80% meionite molecule and without V_2O_3 and Cr_2O_3. Such properties are the same in scapolite of the reaction zone of the "potato". Vanadian diopside in the calc-silicate gneiss is of $Wo_{50}En_{49}Fs_1$ and has 0.6% V_2O_3, 0.1% Cr_2O_3, 1.6% Al_2O_3, and 0.3% Na_2O, the properties being the same as diopside of the reaction zone of the "potato". Vanadian sphene in the marble contains 0.4% V_2O_3 and 3.1% Al_2O_3 and that in the "potato" 2.0% V_2O_3 and 3.0% Al_2O_3. Vanadian rutile in the marble contains 1.9% V_2O_3. Tanzanite occurs in the marble and in the "potato". Tanzanite in the marble contains 0.7% V_2O_3 and 0.4% Cr_2O_3 and that in the "potato" has 4.3% V_2O_3 and 0.2% Cr_2O_3. Vanadian muscovite in the marble contains 1.9% V_2O_3, 0.7% Cr_2O_3, 7.1% K_2O, and 2.0% Na_2O. Magnesian muscovite in the marble contains 0.1% V_2O_3, 0.1% Cr_2O_3, 2.6% MgO, and 10.6% K_2O. Such special muscovite crystals occur especially in the marble. Graphite occurs widely in the calc-silicate gneiss, marble, and pelitic-psammitic gneiss.

The central part of large green garnet in the "potato" contains 5.7% goldmanite ($Ca_3V_2Si_3O_{12}$) molecule and 94.3% grossular ($Ca_3Al_2Si_3O_{12}$) molecule, while the marginal part of garnet has 20.2% goldmanite molecule and 79.8% grossular mole-

cule.   In the reaction zone of the "potato", green to deep green fine-grained garnet occurs as kelyphitic material in scapolite and diopside.   Deep green kelyphitic garnet in the reaction zone of the "potato" contains 54.5 % goldmanite molecule and 45.5 % grossular molecule.

From the above petrochemical and geological data, it is considered that some salt lakes were widely distributed around southern Kenya and northern Tanzania in a late Precambrian time (ca. 800 m.y. ago) and that calc-silicate gneiss, marble and pelitic-psammitic gneiss were derived originally from the evaporites and their related sediments deposited in the salt lakes.   During the metamorphism the above paragneisses were formed, the green garnet porphyroblasts were produced in the calc-silicate gneiss, and the paragneisses were permeated concordantly or subconcordantly by granitic material, which became the granitoid gneiss through the metamorphic process (SUWA et al., 1979 b).

The North Pare Mountains situated 80 km west of Mgama Ridge is composed of late Precambrian metamorphic rocks belonging to the granulite facies.   Metamorphic rocks of the North Pare Mountains were discussed by MIYAKAWA et al. (1969).

3.4.   Linthipe anorthosite body, Malawi

A large elongate meta-anorthosite body trending NNE stretches for about 30 km around Linthipe (34°8'E, 14°11'S) with a maximum width of 8.3 km.   All contacts appear conformable with the foliation of the charnockitic granulites which completely surround the Linthipe anorthosite body.   The meta-anorthosite is well exposed along the Linthipe River, at Linthipe Quarries, 2 km west and 2.5 km southwest of Linthipe Trading Centre, beneath Linthipe Bridge No. 1 on the main road, and beneath the bridge near Gwenembe admarc, 11 km north of Linthipe Trading Centre.

At these exposures, several kinds of anorthosites and the related rocks are noticed: white anorthosite, white anorthosite with small or moderate amounts of "grey-melanocratic" lens, white anorthosite with considerable amounts of "grey-melanocratic" lens, grey anorthosite, melanocratic anorthosite, concordant garnet bearing melanocratic layer, concordant older amphibolite dyke, discordant younger amphibolite dyke, and brecciated anorthosite.   These anorthosites and related rocks show a beautiful stratification.

The white anorthosite consists mainly of plagioclase with minor amounts of clinopyroxene, amphibole and other minerals.   The grey anorthosite is a white anorthosite with small amounts of grey-melanocratic banding to the unaided eye and is composed of plagioclase, brown hornblende, red brown biotite, ilmenite, augite, with small amounts of apatite and zircon.   The garnet bearing melanocratic layer consists of plagioclase, hypersthene, pyrope garnet, green hornblende and biotite.   The older amphibolite consists of brown amphibole, bytownite, biotite, clino-

pyroxene with minor amounts of orthopyroxene, ilmenite, apatite and garnet. The younger amphibolite consists of brown hornblende, biotite, plagioclase showing a slightly zonal structure, and augite, with minor amounts of ilmenite and apatite.

At present two possibilities are considered for the petrogenesis of the anorthosite body: one is that the anorthosite had intruded as a concordant laccolith and was subsequently recrystallized during a regional metamorphism; the other is that the anorthosite is a product of floatation of plagioclase in magma chambers seated in relatively deep levels, which would account for the stratification of the body and the occurrence of associated charnockitic granulite (SUWA et al., 1979c).

Judging from the modes of occurrence and petrography of the older and younger amphibolite dykes, NUREKI and SUWA (1979) suggested that: (1) Original rocks of the older amphibolite would be intruded into the anorthosite as dykes at a late stage of emplacement of the anorthosite, and subsequently they suffered a high grade regional metamorphism. (2) Long after the metamorphism, fracturing/faulting took place in areas around Linthipe. Dykes of the older amphibolite were often displaced by the faults, and, later, the younger dykes were intruded along the faults. (3) Dykes of the younger amphibolite were subsequently recrystallized by a medium-grade metamorphism.

At one exposure near Tsoyo, 11 km NNE of Linthipe Trading Centre, garnet megacrysts are found in the anorthosite. Immediately around the garnet megacrysts, phlogopite-hypersthene-ilmenite-plagioclase part and pyrope-hypersthene-phlogo-pite-plagioclase part are developed with characteristic texture. In the phlogopite-hypersthene-ilmenite-plagioclase part, phlogopite is of Mg: Fe: Ti$=77.6$: 16.9: 5.5, hypersthene is of Mg: Fe: Ca$=66.1$: 33.4: 0.5 and contains 5.42% Al_2O_3 and 0.17% TiO_2, ilmenite contains 1.95% MgO and 0.11% MnO, and plagioclase is of An: Ab: Or$=69.3$: 30.3: 0.5. In the pyrope-hypersthene-phlogopite-plagioclase part, pyrope is of Mg: Fe: Mn: Ca$=32.8$: 48.3: 1.3: 17.6, hypersthene is of Mg: Fe: Ca$=$ 63.3: 36.1: 0.6 and contains 5.18% Al_2O_3 and 0.16% TiO_2, phlogopite is of Mg: Fe: Ti$=62.5$: 27.1: 10.4, and plagioclase is of An: Ab: Or$=76.1$: 23.6: 0.3. The composition of pyrope megacryst is Mg: Fe: Mn: Ca$=40.5$: 40.4: 0.5: 18.6 (SUWA et al., 1979c).

3.5. Aswan granite, Egypt

In 1962, I visited the Aswan area, Egypt and the optical, X-ray, chemical properties of the potassium feldspars in the Aswan granitic rocks were examined in detail and the potassium feldspars were identified as maximum microcline (SUWA, 1966b).

Acknowledgments

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