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Geology of the Mupamadzi River area

Explanation of degree sheet 1231, SW quarter

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Preface

This report by Mr P Van de Velde and Mr B De Waele describes the geology of an area in the mid-Luangwa Valley in eastern Zambia. The area encompasses parts of the central plateau, the Muchinga Escarpment zone and the Luangwa rift graben. Mesoproterozoic gneisses and granites, with small outcrops of metasedimentary resistors belong to the Irumide terrain and form the western footwall to the Luangwa rift. Sedimentary rocks of the Karoo Supergroup infill the rift valley.

Current economic potential of the area appears to be low. No metalliferous mineralisation has been located and exploitation of any deposit would be difficult because of the inaccessibility of the area. Diamonds have been found in the lamproite pipes in the Kapamba Valley in the south-east of the area, but so far in insufficient amounts to be economically workable.

This report and accompanying map have been edited by a team comprising Mr W J Barclay (British Geological Survey), Mr C Namateba (Principal Geologist, Regional Mapping) and Mr M Njamu (Geologist). Messrs Barclay and Njamu have added a brief summary on the Kapamba lamproites to the sections on the igneous rocks and economic geology of the area (chapters 3 and 6). The map was drawn by Mr T D Tembo, under the supervision of Mr C G Murray (British Geological Survey) and Mr J J Bwalya (Chief Cartographer). The work was carried out by the British Geological Survey as part of a technical assistance programme to the Geological Survey Department. This and the map and report printing were funded by a grant from the European Development Fund of the Commission of the European Communities. The secondment of Messrs Van de Velde and De Waele to the Geological Survey Department was funded by the Flemish Technical Assistance programme V.V.O.B.

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Geology of the Mupamadzi River area

Abstract

The Mupamadzi River area comprises the plateau area in the west, the Muchinga Escarpment zone in the central part and the Luangwa rift valley in the south-east. Most of the plateau area and escarpment zone is underlain by a complex of granites and granite gneisses, with smaller outcrops of meta-sedimentary rocks. The gneisses are subdivided into the Momboshi Group and the Kamangu Group. The Momboshi Group comprises the banded gneisses of the Lukula Formation and the Chifuma Formation. The younger Kamangu Group contains the porphyroblastic Nkala Gneiss and the migmatitic and schistose gneisses of the Tubondo Gneiss. The sparsely distributed metasediments are assigned to the Kanona Group

The Luangwa Valley is underlain by grits and sandstones of Upper Karoo age, into which are intruded sparsely diamondiferous lamproite pipes and dykes.

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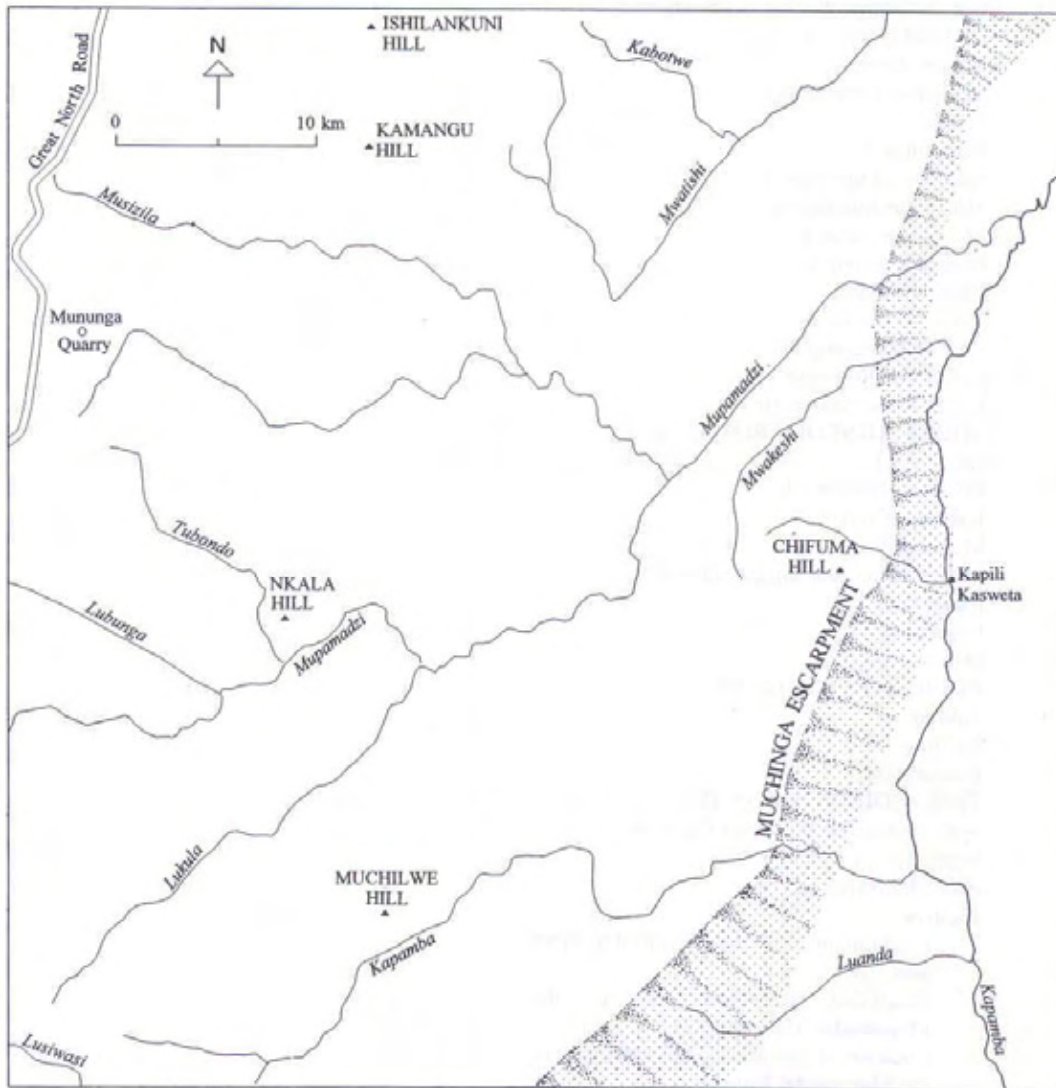


Figure 1. Location map of the Mupamadzi River area

ONE

Introduction

The Mupamadzi River area is located mainly in Northern Province and partly in Central Province. The mapped area is bounded by latitudes 12°30' and 13°00' south and longitudes 31°00' and 31°30' east. Mapping was started by Van de Velde in August 1989, continued by Van de Velde and S C Chisela in June 1992 and completed by Van de Velde and De Waele between June and October 1993. Topographic base maps at 1:50,000 scale, prepared by the Directorate of Overseas Surveys, London, and based on 1:40,000-scale air photographs taken in 1965, were used during the mapping. Reconnaissance geological mapping of the plateau area was carried out by irregularly spaced foot traverse, mainly along stream courses, with an average spacing of 2 to 3km. The geology of the Luangwa Valley section was compiled from reports on the Kapamba diamond prospecting licence area (De Beers, 1973), from air photograph interpretation and from widely spaced foot traverses south of the Kapamba River. The 1:200,000-scale lithological map by Loangwa Concessions Limited (Wright, 1965) and the reports of the Kapamba area (De Beers, 1973) were consulted in preparation for the field work. Air photographs at 1:66,000 and 1:30,000 scales and Landsat satellite images were studied before, during and after field work. Airborne geophysical survey maps of total magnetic intensity and gamma radiation at 1:50,000 scale were also consulted.

Communications

The Great North Road from Kapiri Mposhi to the Tanzania border town of Tunduma passes through the north-west of the area, running parallel to the Zambia - Tanzania railway. There are two small railway sidings at Finkuli and Mununga. Except for the area near the Great North Road and around Mupamadzi primary school, access to the area is generally difficult. A relatively well maintained dirt road gives access to Kalonje school and Mupamadzi school, from where numerous tracks connect the many small villages in the south-west of the

area. Some of these tracks were improved and extended to the east during the field work. Only one poorly maintained dirt track descends into the Luangwa Valley in the north of the area. Farther east, communication routes consist only of a few footpaths and animal trails used by local people for access to the valley. In the valley, a well maintained motorable track connects Mfuwe to Kapili Kasweta game scout camp. Several other tracks were constructed by companies and game scouts, but they are generally overgrown. Mununga quarry and Kalonje pumping station on the Tazama pipeline are the only inhabited areas, with houses at the installations. The Zambia Police has small posts at both locations. Permanent settlements are confined to within a few kilometres of the Great North Road.

Population and agriculture

The area is inhabited by people of the Lala and Bisa tribes, under Chief Mpumba. They live by subsistence farming based on the Chitimene ('slash and burn') system, which leaves large areas covered with secondary bush. The staple crops are maize and millet, supplemented by sweet potatoes, cassava and beans. Few vegetables are grown and there is little livestock. There are some mango, sugar cane and banana plantations near Kamwendo, Isaki and Mukulubwe villages in the Luangwa Valley. There is some game in the area, especially towards the sparsely populated plateau area close to the escarpment (Munyamadzi Game Management Area) and in the Luangwa Valley (South Luangwa National Park).

Climate

A rainy season lasts from November to April, a cool dry season from May to August, and a dry hot period from September to October. Temperatures may rise to 36°C in the hot season, the minimum nightly temperature in the cold season falling to below 8°C. Rainfall varies from year to year, with an annual average of 1300mm. Temperatures are generally higher in the lower ground of the Luangwa Valley. On the plateau, winds blow mainly in an east or south-east direction throughout the year and are often strong in the higher parts.

Soils and vegetation

Plateau soils are leached, pale, sandy loams, the composition of which is dependent on the underlying bedrock. Dambo soils along rivers are leached, grey, sandy loams which grade into quartz sands at the dambo margins. Escarpment Hill soils are skeletal soils found on the Muchinga escarpment. The Lower Valley soils of the Luangwa Valley are brown loams near the escarpment, passing into dark grey calcareous clay. Open woodland of fire-resistant trees (predominantly *Brachystegia - Isoberlinia paniculata*) forms the main vegetation on the plateau. The Chitemene farming system has replaced this with bush scrubland in some places. Open woodland with *Isoberlinia paniculata*, *Brachystegia boehmi* and *Brutalis* is developed on soils overlying granite and gneiss. Dense evergreen forest occurs along the banks of the rivers, where *Raffia* palms grow in profusion. Some relics of *Gallery Forest* remain at the heads of the larger dambos. *Julbernardia - Brachystegia* woodland covers the slopes of the Muchinga Escarpment and the plateau area. *Colophospermum mopane* is the dominant species in the flat-lying parts of the Luangwa Valley. *Adansonia digitata*, *Sclerocarya caffra*, *Combretum imberbe*, *Kigelia africana* and *Acacia albida* are also present (Fanshawe, 1972)

Drainage and topography

The main topographical features are the gently undulating plateau area in the north-west, the Muchinga Escarpment to its east, and the Luangwa Valley in the east. The area lies just to the east of the watershed between the Congo and Zambezi basins. All streams flow into the Luangwa and Zambezi rivers, with the Mupamadzi and Kapamba rivers controlling most of the drainage. The Lusiwasi River crosses the extreme south-west of the area. Many smaller streams which originate near the Muchinga Escarpment become dry before reaching the floor of the Luangwa Valley. A dense, dendritic drainage pattern in the escarpment zone becomes widely spaced, with narrow dambos to the west. The Congo -

Zambezi watershed lies between 1550 and 1600m, sloping gradually to about 1500m on both sides. It is interpreted as a remnant of a mid-Tertiary (pre-Miocene) peneplain that was warped during a period of post-Karoo faulting (Dixey, 1945). The plateau is more deeply incised at its eastern edge above the Muchinga Escarpment. The Luangwa rift valley floor at 700m is the most recent erosion surface. Some isolated, rounded hills of porphyritic gneiss which protrude above the plateau level (Kamangu Hill and Nkala Hill at 1605m, Chikushilika Hill and Chilomo Hill at 1557m and Chifuma Hill) may be remnants of an earlier (Vipya) surface that is well preserved to the east of the Luangwa Valley. Ishilankuni Hill (at 1621m) and Muchilwe Hill are quartzite complexes forming prominent hills above the plateau surface. Some granitic hills (Kabulomo, Chikashi and Mununga) and some quartzite ridges in the north-west also rise above this surface. The transition from undulating plateau to rugged, incised plateau terrain above the Muchinga Escarpment is gradual north of the Mupamadzi River, but abrupt along the Mupamadzi, Momboshi, Chisala, Kapamba and Nchima rivers. The Mupamadzi, which follows a meandering course on the plateau, drops from 1250m to 1000m near Chikashi Hill, and from there lies in a 150m-deep valley until it descends into the Luangwa Valley. The mid-Tertiary surface is abruptly terminated by the Muchinga Escarpment, which drops from 1100m to 750m in the north and from 1250m to 750m in the south.

Previous work

Geologists of Loangwa Concessions Limited carried out the first recorded work in the late 1920's and early 1930's (Guernsey, 1941; Bancroft, 1947). They traversed the area at 0.4km intervals in search of minerals and produced an outcrop map at 1:200,000 scale. Ackermann (1950) and Ackermann and Foster (1960) made a general study of the rocks of the Irumide Belt along the Great North Road, defining the belt as a north-east - trending zone of Precambrian gneisses and metasediments. Ackermann (*op. cit*) described a thick succession of quartzites and schists (the Muva) overlying ancient granitic basement. These rocks were first involved in the Tumbide

orogeny, during which north-trending structures formed, and, following the deposition of the Kalonga Series and Bemba Series, were involved in a second (Irumide) orogeny.

Geology of the Mupamadzi River area

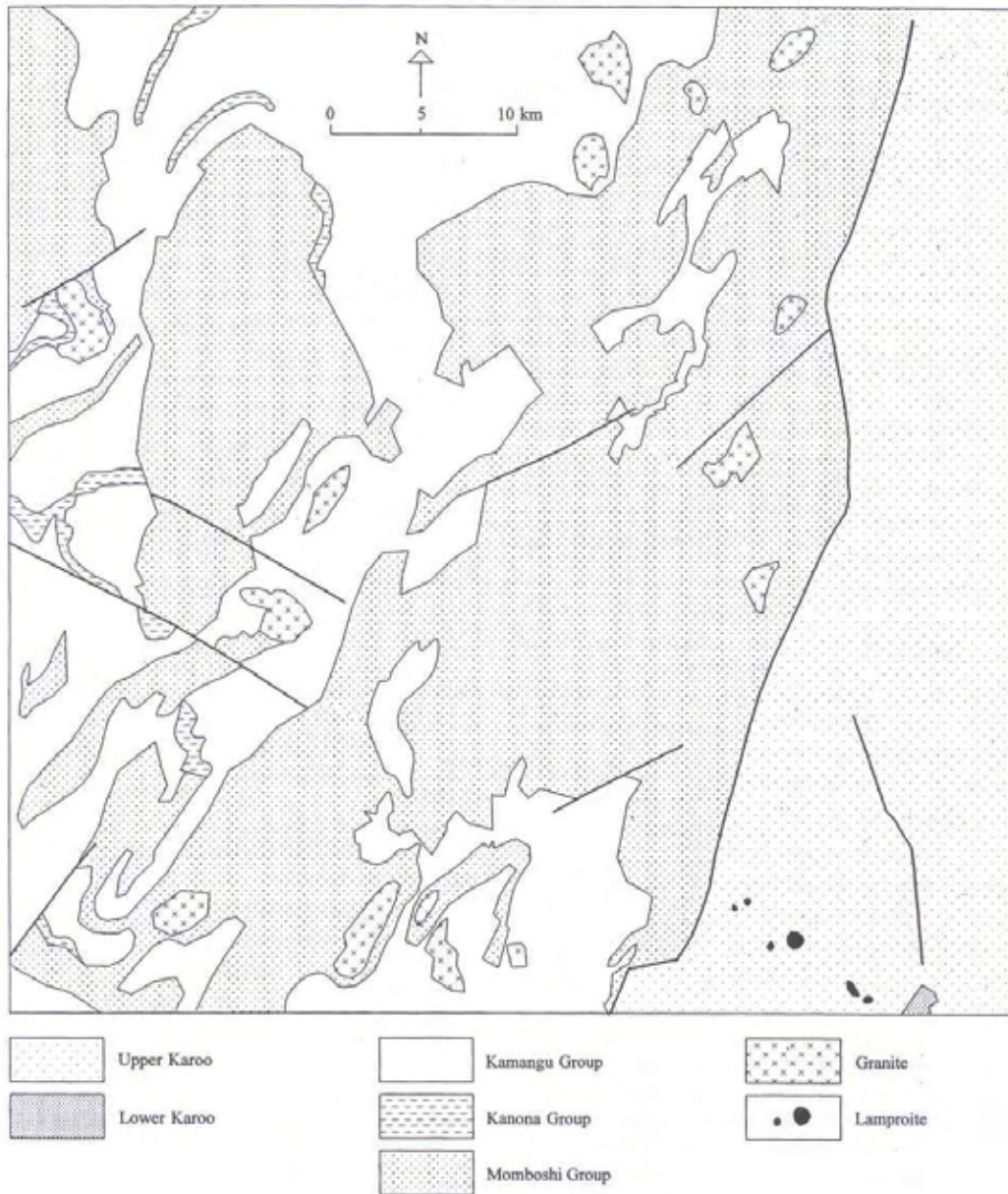


Figure 2. Simplified geological map of the Mupamadzi River area

Chartered Exploration Limited prospected in the area between 1958 and 1963, compiling a provisional geological map at 1:200,000 scale (Wright, 1965). De Beers Prospecting (Zambia) Limited carried out a detailed study of the lamproite pipes and dykes in the Luangwa Valley in the 1960's and early 1970's. The study involved geological mapping and sampling, during which 14 pipes or groups of pipes and dykes were located (De Beers, 1973; Scott-Smith et al., 1986).

Summary of the geology

Most of the plateau area is underlain by a complex of granites and granite gneisses. Smaller outcrops of metasedimentary rocks are present as thin ridges and two large hills (Figure 2). The gneisses are subdivided on lithology and interpretation of the structural data into the Momboshi Group and the Kamangu Group. The Momboshi Group comprises the banded gneisses of the Lukula Gneiss and the Chifuma Gneiss. The younger Kamangu Group contains the porphyroblastic Nkala Gneiss and the migmatitic and schistose gneisses of the Tubondo Gneiss. The Momboshi Group is continuous with the Chibobo Group of the Kanona and Chitambo areas (Cordiner, 1977; in prep.). The gneisses appear to be the product of intense deformation and partial granitisation and anatexis of the metasedimentary sequence. The metasediments are patchily exposed in ridges consisting of micaceous and massive quartzites flanked by softer schists and metasiltstones. These rocks make up the Muchilwe Formation which extends into the adjoining areas and is correlated with the metapelites and quartzites of the Kanona Group (Cordiner, *op. cit.*).

There are several large granite bodies. Two older granites grade texturally and compositionally into the surrounding gneiss. These granites may be considered as the precursors to the banded gneisses of the Momboshi Group, or the product of granitisation of the metasediments of the Muchilwe Formation. The porphyroblastic gneisses of the Nkala Gneiss are the product of deformation of a granite and an important phase of potash metasomatism, probably during or after the main phase of the Irumide orogeny. This event is represented by medium-scale to

very large, tight, isoclinal, north-east - trending folds with steeply dipping axial planes. This pervasive north-east grain cuts an incipient banding and biotite foliation with north-west or east-west strike which is present in the schists and micaceous, banded quartzites. The structural S_1 trend appears to be parallel to sedimentary bedding, which was largely destroyed by the subsequent intense deformation. The major structures are considered to be the result of large-scale recumbent folding on south-east - north-west axes. In the north-west of the area, the metasedimentary rocks wrap around a large, elongated gneiss body of the Momboshi Group, this structure probably resulting from doming (the Nambwa Dome). Crenulation lineation plunges show a radial pattern, reflecting the direction of tectonic transport of the metasediments over the granite gneisses. The youngest granite, the Mununga Granite was affected by one tectonic event; this produced large, tight to open folds with north-south axial trend in the eastern Muchinga Escarpment and many parallel shear zones which increase in numbers and size towards the west where the migmatitic and schistose gneisses of the Tubondo Gneiss. The north-south cleavage and lineations clearly cut the dominant north-east - south-west direction. An important lineation of garnet (L_1) indicates the variance in direction of the shallow axial plunge on the major north-south - trending folds.

The Luangwa Valley is underlain by grits and sandstones of Upper Karoo age, into which are intruded lamproite pipes and dykes. The sedimentary rocks are separated from the Muva-age gneisses and granites by the Karoo rift fault which forms the spectacular Muchinga Escarpment. The pre-Irumide Lubunga and Tubondo faults, with north-west - south-east trend, were probably reactivated during the Pan African orogeny. These faults are part of a strong lineament that extends for over 120km from the west of the area to the Luangwa Valley. Other faults, particularly those on the western margin of the area, are related to doming and shearing. Structurally, the area can be considered as part of the western boundary and tectonic foreland of the Pan African Mozambique Belt, superimposed on the dominant north-east Irumide grain. Steep,

upright, tight folding in the Muchinga Escarpment area represents part of the core zone of the fold belt. Towards the west of the area, there is an increasingly strong lateral component with thrusting and shearing.

Geological history

The area was affected by several major tectono-thermal events. Only the Karoo sedimentary rocks remain unaffected by deformation and metamorphism. The meta-sedimentary rocks originated as shelf deposits. Only part of the sedimentary pile remains, most of its base being granitised and partially melted by anatexis. In contrast to adjacent areas, the volume of remaining metasediment is much reduced in this area. The shelf deposits were shales and sandstones (Muva Supergroup) deposited during the Middle Precambrian (Mesoproterozoic) Lower Muva period. East-west foliation parallel to the original bedding represents an incipient S_1 structure. The presence of remnant flow banding in some of the Mwatishi and Kabotwe granites, also with east-west trend, suggests that granitisation and anatexis of the metasediments could have been syntectonic or post-tectonic in relation to the folding of the metasediments. The geometry of the folding suggests large recumbent or steeply inclined thrust folds.

The folding and granitisation of the metasediments took place at an earlier stage of the Irumide Orogeny, in the late Middle Precambrian. Clear transitional relationships are established between the Mwatishi Granite and the banded biotite gneisses, and between the Kabotwe Granite and the leucocratic gneisses. Clear transitional relationships are also seen between the quartzites and the leucocratic gneisses. The stratigraphic position of the other gneisses of the area remains unclear. They may have formed by intense deformation of S-type granites which formed by anatexis at the base of the metasedimentary pile. Alternatively, they may be the result of plastic deformation of the metasediments at a level above the zone of anatexis.

The main event of the Irumide Orogeny is recorded in the north-east - trending folds which are inclined and thrust to the north-west or

south-east. At an early stage in the orogeny, a porphyritic granite was intruded in lit-par-lit fashion into the banded gneisses of the Momboshi Group. Porphyroblastic growth and feldspathisation took place in the gneisses shortly after folding. The growth of large feldspars destroyed or deflected the north-east - trending biotite foliation which had formed parallel to the axial plane cleavage of the Irumide folds. Doming in the west of the area probably took place slightly later than the main phase of the Irumide folding, perhaps coincident with the intrusion of the Mununga Granite.

In the last phase of folding, major tectonic activity mainly affected the granite and gneiss complex, producing large-scale, upright, tight, double-plunging folds, slightly inclined to the west. In the escarpment zone, the folds have an important effect on outcrop pattern; towards the west, a lateral shear component becomes increasingly important, suggesting increasing distance from the core of the fold belt. Metamorphism in the escarpment zone is limited to amphibolite and greenschist facies, which is of lower grade than the Chipata and Petauke areas to the east. To the west, the prevalence of shear folding and the limitation of the effects of the orogeny outside the shear zones to a weak cleavage in the gneisses and granites suggest that the plateau part of the Mupamadzi River area was the foreland. The folding and shearing with north-south and conjugate directions is considered to be of Pan African age.

The Karoo rocks of the Luangwa Valley were fluvial and lacustrine deposits of a rifted basin (Banks et al., 1995). The rift faults are reactivated older basement faults and movement continued into post-Karoo times, leaving the valley floor some 600m below the plateau. Post-Karoo lamproite pipes and dykes within the Mupamadzi River map area lie between the Lubunga and Tubondo faults. These faults appear to be deep-seated structures, along which the lamproites ascended and metasomatism occurred. Typical meta-somatic mineral assemblages along the Lubunga Fault in the pre-Karoo crystalline complex suggests that lamproite intrusion may have occurred further to the west, in the Muva terrain. There, an amphibolitic, richterite-bearing rock was found

at two localities along the fault.

TWO

Stratigraphy

MESOPROTEROZOIC

The oldest rocks are gneisses, granites and metasediments, which underlie most of the plateau and occupy almost 80 per cent of the map area. They can be assigned a Middle Precambrian, Mesoproterozoic age and are stratigraphically equivalent to the Muva Supergroup. The metasedimentary rocks (the Kanona Group) occupy only small areas. The Momboshi Group has a slightly larger outcrop than the younger granite gneisses of the Kamangu Group. The banded gneisses of the Lukula and Chifuma formations predominate in the eastern Muchinga Escarpment and in the core of the Nambwa Dome in the north-west. The porphyroblastic gneisses of the Nkala Gneiss outcrop in large areas in the north and south. The intensely deformed, sheared, downgraded gneisses are grouped with the Tubondo Gneiss where no apparent relationship to the original lithology can be established.

Momboshi Group

Almost half of the plateau part of the area is underlain by granite gneisses and gneisses of the Momboshi Group, characterised by a strong banding. They outcrop over much of the deeply incised plateau above the Muchinga Escarpment in large, north-south-trending folds with shallow double plunges to the north and south. They also occupy the core and most of the flanks of the Nambwa Dome and outcrop in the south-west of the area in large, open to tight, north-east - trending folds, where they are in contact with the Nkala Gneiss. Two formations are identified on the basis of lithology and mineralogy:- the Lukula Gneiss and the Chifuma Gneiss. Both formations interfinger in the type area of the Momboshi River. The stratigraphic position of the Momboshi Group is unclear. Whilst the relationship and contacts with two older granites suggest a common origin, both the granites and the banded gneisses are the locally granitised and deformed basement to the metasediments of the Kanona Group.

Geology of the Mupamadzi River area

**Numbers refer to specimens in the Department collections*

LUKULA GNEISS

The banded gneisses of the Lukula Gneiss crop out over a large area. In the west, they are mainly in contact with the porphyroblastic gneisses of the Nkala Gneiss in large-scale folds with north-east - trending axes. On the Muchinga Escarpment, they are almost entirely in transitional contact with the leucocratic gneisses of the Chifuma Gneiss. The gneissose bands are commonly thin and folded in tight isoclinal folds with north-east axial trends. The banding of more mafic gneiss and leucocratic gneiss is seen in the tectonic depressions of north-south double-plunging folds. The complete range of textures of the banded gneisses are displayed along the Lukula River, a tributary of the Mupamadzi. The main characteristic of the gneisses is the dark, fine- to medium-grained, biotite-rich matrix. Feldspar is mostly microcline showing typical cross-hatch twinning or 'tartan' albite - pericline intergrowths. Myrmekite, plagioclase - quartz intergrowths are common (10EC 553, 623)*. Texture ranges from fine, laminated and equigranular to porphyritic with phenocrysts of feldspar up to 1.5cm set in a melanocratic matrix. Where sheared, the gneiss has a streaky, banded appearance or is extremely finely laminated and schistose where affected by retrogressive metamorphism. Strain shadows in the quartz, chlorite and chloritoid mineralisation and muscovite inclusions in feldspar are common (10EC 170, 298, 436, 563). The inclusions in the pre-tectonic feldspar (10EC 563) suggest an earlier folding event with the principal stress direction almost perpendicular to the dominant north-east trend. A crenulation cleavage is present locally (10EC 672). The porphyritic gneiss becomes a banded, microcline augen gneiss where sheared and, in extreme cases of shearing, a mylonite (10EC 554). The presence of garnet, andalusite and cordierite indicates middle grade regional metamorphism (10EC 421, 600, 661). Apatite and fluorite occur as accessory minerals in some rocks (10EC 600).

CHIFUMA GNEISS

The leucocratic, banded gneisses of the Chifuma

Gneiss outcrop mainly on the Muchinga Escarpment in the east. The dissected nature of the terrain is due to incision of the rivers down to a level underlain by the banded, strongly foliated gneisses of the Lukula and Chifuma formations. Generally, the rivers have cut steeper, narrower valleys in the outcrop of the Chifuma Gneiss. The gneisses commonly form major ridges which are flanked by leucocratic, foliated gneisses and capped by metadolerite dykes or quartz veins. The type locality of the formation is Chifuma Hill [UA 255 887] which consists of leucocratic gneisses on its flanks and is capped by fine-grained, microgranitic gneiss.

The gneisses of the Chifuma Gneiss are fine- to medium-grained, quartz-rich and feldspathic, with a leucocratic, banded matrix. Some are porphyritic and pegmatitic, and porphyroblastic feldspar growth was seen at a few outcrops. The presence of epidote and clinozoisite indicates a middle-grade metamorphism (10EC 417, 483), as in the Lukula Gneiss. Accessory minerals include calcite (10EC 571), sphene and zircon (10EC 491). The effects of the younger north-south - trending folding are clearly observed in these gneisses. Small, euhedral garnet crystals are commonly oriented along a north-south - trending, shallow plunging mineral lineation. The strongly banded nature is mainly caused by a biotite foliation which was formed during this event. A weaker north-south banding of mica in some areas is commonly folded to a crenulation cleavage by subsequent shearing. Finer grained, microgranitic, equigranular, leucocratic gneisses outcrop in north-south ridges throughout the plateau area. They consist mainly of quartz and feldspar, with variable amounts of biotite and other accessory minerals. They appear to have resulted from the deformation of a fine-grained, leucocratic, syenitic granite or microgranite. In zones of intense, tight folding or in shear zones, the resulting foliation appears less pervasive than in the coarser leucocratic gneisses and granite gneisses. This accounts for the common occurrence of the microgranitic gneiss on steep-sided ridges such as Nkalwe Hill, Fiypishi Hill and Chifuma Hill. No clear age relationship is established between the Lukula Gneiss and the Chifuma Gneiss, but from their gradational contact and similar structure, they are thought to be contemporaneous.

A mesocratic, banded gneiss commonly marks the transition between the leucocratic gneiss and the melanocratic, banded gneiss. The lithological and mineralogical differences between the Lukula and the Chifuma gneisses probably reflects differences in their precursor granites, the Mwatishi and Kabotwe granites respectively. These were the product of granitisation and anatexis of the metasediments of the Muchilwe Formation.

Kanona Group

MUCHILWE FORMATION

The formation consists of intercalated quartzites and schists. Outcrops are confined to a few thin, elongated ridges in the north-west and the Ishilankuni Hill and Muchilwe Hill complexes. Massive and schistose quartzites occupy the higher parts of the ridges, mica schists and metasilstones outcrop on the flanks. The change from pelitic to psammitic rocks is transitional, with progressive coarsening from the former into the latter seen in sections. The quartzite ridges in the north-west are continuous with the larger quartzite ridges, also flanked by schist, of the Kanona Group (Page, 1973). Ishilankuni Hill and Muchilwe Hill are steep hills of complexly folded, interbanded quartzite and schist which stand out as inselbergs above the granite gneisses of the plateau. Large, euhedral garnets occur in the schists near their contact with the gneisses. Rotation of the garnets, chloritisation, and a weak, north-south foliation which post-dated the main, pervasive north-east foliation in the schists indicate at least three tectono-thermal events, including two deformation phases. Near the headwaters of the Musikila and Nkulumashiba rivers, the metasedimentary ridges form an arch over a major dome of granites and gneisses. In the south-west, a dissected quartzite has a north-west - trending arcuate outcrop.

Pelites

The thickness of the pelitic succession is much reduced in comparison to adjacent areas. The schists are red, brown and (locally) greenish grey, fine-grained and have a high content of muscovite and biotite. Only a few are quartz-

rich. In thin section, they are seen to contain iron oxides, sericite (the weathering product of feldspar) and opaque minerals (10EC 22, 23, 30, 314). In some cases, muscovite developed during retrograde metamorphism and forms radiating sheaves which disrupt the schistosity (10EC 320). In the Muchilwe Hill complex, the pelites overlie quartz schists and grade into schistose quartzites. Large garnet porphyroblasts and andalusite crystals developed locally at the contact with the gneisses (10EC 79, 310, 428), indicating middle-grade metamorphic conditions (Turner and Verhoogen, 1960). Retrograde metamorphism produced chloritic schists (10EC 174) and talc or staurolite schists (10EC 561).

Psammites

Three types of quartzite can be distinguished on lithology, relative age and structural setting of those at Muchilwe Hill and Ishilankuni Hill. They are quartzite interbanded with the schists, micaceous, schistose quartzite and massive, recrystallised quartzite.

Interbanded quartzite

This lies at the base of the psammitic succession and consists of quartzite - schist couplet. The bands range from a few centimetres to about 20 to 30cm in thickness. The quartzites have an interlocking fabric in which there is grain flattening locally (10EC 78), with the grains set in a matrix of silica and sericite. The schistose bands consist of muscovite and iron oxide alteration. No sedimentary structures are preserved, but the almost perfect parallelism of the steeply dipping metamorphic banding and an incipient S_1 schistosity or foliation suggests that the banding may reflect sedimentary bedding. The repetitive nature of the quartzite - schist banding may be due to intense, tight isoclinal or recumbent folding, or may be a relic of mud - quartz sand couplets deposited in an unstable shelf environment.

Micaceous quartzite

This is the commonest, but thinnest quartzite. It overlies the interbanded quartzite and is red, strongly banded and micaceous, with magnetite, titanite, hematite and other iron oxide minerals.

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Biotite and muscovite are common, defining the strong, north-east - trending foliation along with grain flattening in the quartz (10EC 103, 255, 511). The quartz is partly recrystallised, which, together with the pervasive foliation, destroyed all sedimentary structures. The micaceous bands are commonly refolded, resulting in a crenulation cleavage. In shear zones, the mica was downgraded to chlorite (10EC 24).

Massive quartzite

Massive, crystalline, medium- to coarse-grained quartzite overlies the micaceous quartzite. It consists almost entirely of recrystallised, saccharoidal quartz. A weak foliation in thin muscovite bands is present in shear zones and areas affected by north-south - trending folding. The quartzite lies in the core of upward facing synforms in the Ishilankuni Hill and Muchilwe Hill complexes. At the former, the quartzite is in faulted contact with the interbanded quartzite. The grain flattening, shadowy extinction and interlocking granular fabric seen in thin section (10EC 332, 319) suggest a complex metamorphic history. Foliated varieties locally contain epidote and clinozoisite in the foliation planes (10EC 635). Some quartzite contains cordierite and andalusite with a pisolitic-like texture, indicating medium metamorphic grade which did not completely obliterate the original sedimentary structure (10EC 514).

Kamangu Group

The Kamangu Group incorporates a wide range of gneissose rocks, the formation of which post-dated the emplacement of the granites which were deformed to produce the banded gneisses of the Momboshi Group. The type locality is a range of several large, rounded hills south of the Mupimbishi River. Two formations are mapped - the Nkala Gneiss which consists of porphyroblastic gneisses and the Tubondo Gneiss which consists of sheared, intensely deformed gneisses produced in north-south shear zones and their conjugate sets, the number of which increases towards the west.

NKALA GNEISS

The gneisses of this formation outcrop over a wide area in the north and south-west. They are

exposed in large, flat outcrops, in grass-covered dambos and in rounded kopjes such as the Kanuma Hills, Chikushilika Hill and Nkala Hill. In the south of the area, rocks of granitic aspect predominate over banded, gneissic rocks. The gneisses are medium-grained and commonly have a marked north-east - trending biotite foliation. Large microcline porphyroblasts up to 10cm long (10EC 307) are set in a matrix of quartz and feldspar. Where sheared, the foliation is crenulated and the porphyroblasts are aligned in the shearing direction or stretched to augen (10EC 554). In some cases, retrograde metamorphism produced chlorite along the crenulated foliation (10EC 436).

The growth of the microcline porphyroblasts deflected or disrupted the biotite foliation and locally destroyed it. It is thus considered to be syn- or post-tectonic in relation to the north-east - trending deformation event, with later north-south folding and subsequent shearing. The Nkala Gneiss resulted from granitic intrusion, perhaps by lit-par-lit injection, into the gneisses of the older Lukula and Chifuma formations. Xenoliths of banded biotite gneiss of the Lukula Gneiss are common, as well as bands and rafts of leucocratic Chifuma Gneiss. Xenoliths and rafts of quartzite and pelite of the Muchilwe Formation are also present.

TUBONDO GNEISS

This comprises the intensely folded and sheared migmatitic and schistose gneisses of the Kamangu Group. Migmatitic, strongly sheared gneisses are common in the western half of the area, schistose, downgraded gneisses are common in the area of the Muchinga Escarpment. The Tubondo River flows through at least two shear zones, providing many outcrops of the migmatitic gneisses [TA 880885]. These show an incipient banding and separation into leucosome and mafic melanosome which did not attain full segregation into amphibolite and felsic bands. They are limited to several north-south shear zones and a few conjugate shears. Limited pyrite and manganese mineralisation occurs in these zones. Ptygmatic folding, second-order steeply plunging folds and microfaulting with mainly sinistral displacement are common.

The schistose gneisses are mainly extremely fine-grained and thinly laminated, with a biotite foliation and schistosity obscuring most of the original gneissic features. The schistosity is pervasive and destroyed all previous foliation planes. Small, euhedral to subhedral garnets lie along a north-south mineral lineation aligned parallel to the shallow dip of the large, north-south - trending folds. In the Lukula and Muchilwe valleys, two minor ridges consist of brown, schistose rock with numerous blue-black, needle-shaped crystals of richterite (10EC 202, 207, 506). The matrix contains amphiboles and remnants of pyroxene (including hypersthene), indicating a basic igneous, intrusive origin. The foliation in these schists is parallel to the transcurrent Lubunga Fault which trends at 115° to 120°. The restricted extent of the outcrops of these rocks supports the view that they are the product of intense deformation of doleritic or gabbroic intrusions. In addition to the richterite, recrystallised, blastomylonitic quartz, large, microcline porphyroblasts (commonly crushed) and sericitised varieties are abundant (10EC 170). A few bands of compact epidosite outcrop in slight ridges in contact with schists of the Muchilwe Formation near the headwaters of the Musizila and Nambwa rivers (10EC 576).

KAROO SUPERGROUP

Sedimentary rocks unaffected by major deformation underlie the fault-bounded, rifted Luangwa Valley, the Muchinga Escarpment forming the footwall of the rift valley (Banks et al., 1995). They consist mainly of sandstones and grits (the Escarpment Grit) of Upper Karoo age, with a small outcrop of Madumabisa Mudstone Formation of Lower Karoo age. These formations occur throughout the Luangwa Valley (Drysdall, 1962; Drysdall and Weller, 1966) and the Luano Valley (Gair, 1959; Brandon, 1977; Smith and Newman, in press).

Lower Karoo Group

A small area in the south is underlain by poorly exposed, greyish red mudstones of the Madumabisa Mudstone Formation.

Upper Karoo Group

Buff, poorly sorted lithic grits and sandstones of the Escarpment Grit underlie most of the Luangwa Valley area. Coarse grits outcrop close to the base of the Muchinga Escarpment, sandstones (the Kapamba Sandstone) outcrop farther east. The grits contain angular to subangular, extraformational clasts of gneiss and granite and intraformational sandstone, mudstone and silicified wood clasts (10EC 682, 688). Roundness of grains and quartz content increases with distance from the escarpment as the grits fine into sandstones (10EC 681, 684, 686). To the east, red and grey, well sorted coarse siltstones, sandstones and conglomerates unconformably overlie the Madumabisa Mudstone. The conglomerates contain rounded quartz pebbles in a fine- to medium-grained, recrystallised matrix and form features above the valley floor level where they are intruded by lamproite pipes. Grey and red mudstones and siltstones are present near the base of the Kapamba Sandstone, the succession overall comprising a coarsening upwards parasequence. The Kapamba Sandstone ranges from an arkose to a quartz-rich arenite. Differential erosion of the interbedded succession of sandstones and mudstones results in parallel ridges and intervening valleys near Kapili Kasweta game camp, the sandstones forming the ridges, the mudstones the valleys.

Three

Igneous rocks

GRANITES

Three granites are distinguished: the Mwatishi and Kabotwe (apparently coeval) and the younger Mununga. Mineralogy, deformation style and geomorphological expression of outcrop are distinguishing characteristics. The Mwatishi and Kabotwe granites outcrop as rounded hills or kopjes, the Mununga Granite has an elongate outcrop on the western edge of the map area. All three granites are surrounded by foliated granites and gneisses of similar composition.

Mwatishi Granite

The Mwatishi Granite outcrops mainly in areas of the banded gneisses of the Lukula Gneiss. It is a medium-grained, biotite-rich microcline granite (10EC 522, 553). Two round hills [UB 320129; UB 251151] on the north-west bank of the Mwatishi River in the north-east of the plateau area provide the type locality. Contacts with the gneisses are commonly gradational, through foliated granite into the gneiss. In part, the granites appear to occupy the core of a dome (the Nambwa Dome) in which intensity of deformation increases outwards towards its edge, the central core area being unaffected. Typical granite weathering produces rounded, exfoliated blocks. Incipient banding strikes mainly east-west or north-west - south-east. There is a north-east - trending cleavage in all the melanocratic granites, commonly accompanied by a weak muscovite mineralisation. Some granites have garnet mineralisation along north-south lineations. One sample (10EC 451) consists of quartz, plagioclase and epidote and has a tonalitic composition.

Kabotwe Granite

The Kabotwe Granite is found mostly in transitional contact with the leucocratic, banded gneisses of the Chifuma Gneiss, but some outcrops have sharp, irregular contacts with the porphyroblastic gneisses of the Nkala Gneiss. A

round hill above the Kabotwe River [UB 173138], a tributary of the Mwatishi, is the type locality. The granite of Chikashi Hill has a gradational contact with mesocratic, banded gneisses of the Lukula Gneiss.

The granite has a leucocratic, quartz- and feldspar-rich matrix, with accessory biotite in larger plates (10EC 504, 526, 544, 552, 663). The original textural banding strikes east-west, but is overprinted by a south-west - trending biotite foliation. A younger north-south trend is expressed by garnet and mica mineralisation.

The Mwatishi and Kabotwe granites were the precursors to the banded gneisses with which they are commonly in contact. The differences between them reflect compositional variations in the parent material from which they were derived by granitisation and partial anatexis of the metasedimentary succession. They are presumed to have been emplaced after the deposition, lithification and metamorphism of the pelites and psammites of the Lower Muva. Correlation with major tectono-thermal events, the structure of the Nambwa Dome, and the role of these older granites are discussed in Chapter 4.

Mununga Granite

The Mununga Granite closely resembles the Kabotwe Granite in composition, but has marked differences in structural pattern. The best exposure is at Tazara's Mununga Quarry [TB 867015]. It outcrops in long, densely wooded, north-south - trending ridges. The granite was affected by only one structural event which produced a weak, north-south - trending cleavage, with little or no mineralogical change. There are numerous xenoliths, particularly of the metasedimentary rocks, and the contact of the granite with all other lithologies (but mostly the porphyroblastic gneisses of the Nkala Gneiss) is clearly an intrusive, igneous one. This granite has no deformed, gneissose equivalent and is therefore younger than the gneisses. Its emplacement appears to have reactivated doming of the overlying cover of gneisses and metasediments.

Metadolerites and amphibolites

Many doleritic dykes occur throughout the area, but particularly in the outcrop of the Momboshi Gneiss. In contrast, there are few if any in the Nambwa Dome and Mununga Granite. The dolerites are fine- to medium-grained and massive, and consist of andesite to labradorite plagioclase laths in a matrix of augite (or actinolite - tremolite and hornblende in the amphibolites; 10EC 572, 670). Some have subophitic texture (10EC 64, 677). Sphene and opaque minerals (mostly magnetite) are common (10EC 484, 633). Chlorite, apatite and hypersthene are accessory minerals (10EC 452, 501, 670). Some coarse-grained varieties (10EC 560) contain aegirine-augite and hypersthene in similar amount to the plagioclase, along with some quartz. The dykes have high magnetic values as a result of high magnetite content.

Field relationships between the dolerites and amphibolites suggest that they have a common intrusive origin. The amphibolites are found only in areas of intense shearing or tight isoclinal folding. In some cases, richterite and cordierite indicate high pressure - low temperature metamorphic conditions (10EC 506). Two phases of basic igneous intrusion can be distinguished on structural grounds. An older suite with north-east trend commonly contains quartz and has a parallel, weak mica foliation. A younger suite, predominantly with north-south trend, but with some dykes parallel to the north-east conjugate shear trend, is less deformed. Some of those in the shear zones have a marked, steeply plunging crenulation cleavage with axes striking 120°.

Lamproites

Five lamproite pipes and dykes comprising part of the Kapamba cluster intrude the Karoo Supergroup in the Luangwa Valley, forming topographic features in the flat valley floor (Scott Smith et al., 1986). Exposure is poor as the intrusions are mostly capped by indurated, recrystallised Karoo sandstones. The dykes and pipes are aligned on a north-north-west trend, their intrusion dated at about 220Ma. Further details are given in Chapter 6. The lamproite is green and medium-grained, with small brown phenocrysts, pseudomorphs of serpentine

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(monticellite) after olivine (10EC 683). Garnet appears to be the only unaltered mineral. Small, rounded quartz pebbles and metamorphic rock fragments occur as inclusions. Scott Smith et al. (1986) note that the pipes are craters filled largely with volcanoclastic tuffs. The topographic features that the pipes make are visible as circular structures on air photographs. There are thirteen other ring structures to the north of the known pipes, but no field confirmation was obtained of their nature. The distribution of the pipes within the Mupamadzi River area appears to be confined by two major lineaments (the Lubunga and Tubondo transcurrent faults) which extend far to the west into the plateau area. The structure of the zone in which they occur is discussed in Chapter 4.

Pegmatites

There are two generations of pegmatites, as with the basic intrusions. They are, however, much less widespread, and appear to occur in concentrations in particular areas. The two suites are markedly different in lithology, mineralisation and metamorphism. The older suite is medium-grained, simple, unzoned, commonly folded, and with a north-east - trending biotite foliation. Locally, deformation of closely spaced pegmatites produced pegmatitic, leucocratic gneisses. An overprinting north-south - trending cleavage is common. The younger suite of pegmatites, commonly mineralized, is apparently related to shearing. They occur mainly in shear zones, aligned north-south or parallel to the conjugate shear directions. These pegmatites are coarser grained and zoned. Their coarse quartz core is surrounded by a zone of coarse, interlocking microcline and quartz (locally reaching economically important dimensions, with large blocks of micas (mainly muscovite) in accessory amount. Tourmaline and beryl are present locally in the outer zone.

Quartz veins

Glassy, brown, tectonised quartz veins occur throughout the area, but are concentrated mainly in the outcrop of the Nkala Gneiss and in shear zones. The veins commonly intrude the gneisses parallel to the axes of the major folds. Wide quartz veins cap hills in the Muchinga range and

Ntwenya Hill. Commonly, the veins act as resistors to erosion, allowing brittle and schistose rocks to form positive topographic features. An example of this is the folded, schistose, garnetiferous, leucocratic gneisses which outcrop on the Mwakeshi - Mupamadzi watershed. Most of the veins are oriented north-south. At Ntwenya Hill, the presence of an axial plane mica foliation in the veins suggests that they belong to an earlier generation. Some veins carry tourmaline and some have beryl mineralisation.

Four

Structure

There is a complex pattern of fold interference produced by successive deformation events in the plateau and escarpment zone. Earlier structures were partly obliterated by later deformation. The dominant north-east structural grain of the area was imposed during the main phase of the Irumide Orogeny (Ackermann and Forster, 1960; Stillman, 1964). Only the Mununga Granite and some of the pegmatites appear to have been unaffected by it. Where the intensity of deformation of the main folding phase was insufficient to destroy the earlier structures, evidence of earlier folding can be detected. The metasedimentary rocks of the Muchilwe Formation were affected by at least three events. The earliest (D_1) produced an east-west to north-west - trending metamorphic banding or (in the quartzites) a muscovite foliation (S_1). Uplift due to anatexis of the metasedimentary sequence and intrusion of the Mwatashi and Kabotwe granites resulted in deflection of the metamorphic banding of the quartzites and schists of the Muchilwe Formation around the Nambwa Dome. The main deformational event (D_2) produced tight, isoclinal folds, commonly overturned towards the north-west, as determined by minor S and Z folds. Chevron-type folds with sub-vertical axial planes in the Lukula and Chifuma gneisses are also attributed to this event. A pervasive north-east - trending schistosity in the schists and a strong muscovite foliation in the quartzites which obliterated all trace of sedimentary bedding (S_0) and other sedimentary structures are also attributed to the main phase of the Irumide Orogeny. A later event (D_3) produced large-scale, upright, tight folds with steep limbs slightly overturned to the west.

A north-south - trending lineation of garnet crystals in the leucocratic gneisses of the Chifuma Gneiss (L_1) is an intersection lineation of the metamorphic banding and the north-south axial plane cleavage. The plunge of this lineation gives an indication of the culmination or depression of the fold axes. The older north-east - trending foliation is very well preserved in depressions. The last structural event to affect

the area was the reactivation of the Lubunga and Tubondo faults and the intrusion of the lamproites.

The plateau area can be divided into two major structural domains. To the west, the main structural imprint is the north-east - trending grain formed during the Irumide event. To the east, closer to the Muchinga Escarpment, a very strong north-south grain locally obliterates the north-east grain. Tight, steep folding produced a pervasive north-south foliation. To the west, progressive increase of shearing produced shear zones. These observations give support to the view that the eastern part of the escarpment zone is a continuation of the Pan African Mozambique Belt and that the western part of the area was its tectonic foreland.

Folding

The rocks of the plateau were intensely folded during at least two tectonic events. Large-scale and mesoscopic folds are common. The polyphase deformation produced complex outcrop patterns in which the detection of individual tectonic stages is difficult.

The east-west banding and metamorphic mica foliation in the quartzites and schists of the Muchilwe Formation are considered to have been formed during the first phase of deformation. Compositional banding in the quartzites may be a remnant of sedimentary bedding. The parallelism of the compositional argillaceous/psammitic banding with the foliation may indicate folding of the sedimentary succession into large, recumbent or steeply overturned folds.

A strong south-east to east-south-east - trending metamorphic banding and foliation cuts the east-west banding in the schists and quartzites, as seen at Muchilwe Hill. This foliation (F_2) is also present in the banded gneisses of the Momboshi Group and the related Mwatishi and Kabotwe granites. It is only locally and weakly developed in the porphyroblastic gneisses, but is found in the richterite-bearing schists along the Lubunga Fault. The geometry of the folding can be deduced from the outcrop pattern of the quartzites in the south-west of the area. Along the Mupamadzi River, just east of Mupamadzi

School, and along the headwaters of the Lukula River, the quartzites form a broad arch with maximum curvature oriented east-south-east, at right angles to the Lubunga Fault. The folds are considered to be large thrust folds with steep plunges to the south-east. The marker quartzites are cut by the faults of the Lubunga Fault system, which are transcurrent faults perpendicular to the thrust. In the north-west of the area, the folds appear to plunge and be directed to the north-west. A relationship can be established with the main north-east - trending Irumide folds and the Nambwa Dome.

The main deformation event was the principal phase of the Irumide Orogeny, which produced large-scale, tight to isoclinal, steeply plunging, north-east trending folds. A strong, distinctive biotite foliation was almost universally developed in the gneisses, as well as a muscovite foliation locally. Many secondary folds and minor folds formed on the limbs of the large-scale, tight folds. These can be seen as the change of vergence of the large folds. In the south-east, the banded gneisses of the Momboshi Group and the porphyroblastic gneisses of the Nkala Gneiss form very large, steeply dipping, north-east - trending folds. Smaller folds with parallel trend and plunge in the Momboshi Group result in rapid alternation of darker and paler, leucocratic gneisses. These Irumide folds are commonly overturned and thrust, either towards the south-east or north-west, the direction of thrusting being dependent on position relative to the Nambwa Dome.

The outcrop pattern of the complexes on Muchilwe Hill and Ishilankuni Hill clearly shows the effect of the north-east - trending folding of the quartzites. Garnet formation at the contact of the gneisses and the schists of the Muchilwe Formation was related to this stage of folding and thrusting.

Folds with north-south axial trends are generally absent from the eastern escarpment zone. Only a local foliation was developed during this event, but a pervasive cleavage cuts the main north-east trend throughout the area. In the east of the Proterozoic outcrop, large, tight folds with north-south - trending axial planes and plunges to the south and north largely determine the outcrop pattern. The upright folds are slightly

overturned towards the west and north-north-west. The direction and amount of plunge is commonly revealed by a mineral lineation of small euhedral garnet crystals. In the escarpment zone, the folds with north-east - trending axial planes are only present in zones which coincide with depressions in the north-south - trending folds caused by the double plunging. The axial plane cleavage is strong in the east, but becomes less penetrative towards the west. The north-south cleavage clearly cuts the north-east - trending biotite or muscovite foliation. Towards the west, shear folding, with the development of closely spaced strain-slip cleavage, is more common. Small-scale folding shows the vergence of the larger north-south or east-north-east - trending shear folds. Ptygmatic folds are common in shear zones in the migmatitic gneisses. In most of the shear zones, the strongly folded and sheared gneisses are cut by faults with mainly sinistral displacement.

Faulting

It is difficult to date most of the faults which affect the gneisses and granites, with many undergoing repeated reactivation. However, some can be related to a particular orogeny and several suites can be distinguished on the basis of their trends. The most important fault trend strikes east-west to north-west, perpendicular to the Irumide fold trend, dissecting the Irumide thrust front. The most important of these faults are the Lubunga and Tubondo faults; the outcrops of these and other faults have been utilised as river courses. Faults with the same trend cut the quartzite ridges in the north-west. These faults are wrench faults, related to north-west or south-east - directed thrusting of the overturned Irumide folds. The Lubunga Fault is an important lineament, visible on the Landsat image, which extends westwards into the adjoining Chitambo area and eastwards into the Karoo outcrop. It marks the southern limit of the post-Karoo lamproite pipes in the Mupamadzi River area, their northern limit marked by the extension of the Tubondo Fault. These faults, with the Luangwa rift and parallel faults in the Karoo outcrop, define a rhombic area. The alignment of the Kapamba lamproite pipes and trend of the feeder dykes lies along the long axis of this rhomboid.

A richterite-bearing schist with strong north-west - trending foliation and mineral lineation lies along the Lubanga Fault. Mineral paragenesis indicates that the schist is a metamorphosed basic intrusive rock, deformed under high pressure/low temperature conditions. Such conditions are not found elsewhere in the area; this rock may therefore be a remnant of an obducted ophiolite sliver. If so, a large vertical component, as well as the transcurrent movement, is indicated.

Other fault sets are related to the younger north-south oriented folding and shearing. With these are many faults with east-north-east and east-south-east trend. Shear zones contain many faults and microfaults. Almost everywhere, the movement sense is sinistral, with a limited amount of horizontal movement. The north-south faults are younger and cut the east-north-east and east-south-east faults.

The Luangwa Valley rift fault has a spectacular geomorphological expression in the Muchinga Escarpment, forming the basin margin to the Karoo sediments. The outcrop of the fault is largely covered by scree, but is well marked on air photographs. A few conjugate faults at 45 to 60° to the main fault cut the banded gneisses. Movement of the fault continued in post-Karoo times.

Doming

The change in direction of the inclination and thrusting of the major Irumide folds is marked in the vicinity of the headwaters of the Musizila [TB 850080] and Nambwa [TB 860030] rivers. This change is also seen in the different directions in the plunge of the crenulation cleavage developed in the micaceous banding in the gneisses, quartzites and schists which form a radial pattern. The foliation in the quartzites dips away from a central area underlain by banded gneisses and foliated granites in the core of the Nambwa Dome. The younger Mununga Granite also lies in the core of the dome. To the east, the slip direction of the Irumide folds is mainly towards the south-east, to the west tectonic transport was to the north-west. Wrench faults have a radial pattern, as can be clearly seen to the north-west of the dome along the Nkulumashiba River. A similar dome can be

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recognised in the interfluvial area between the Mombeshi and Lukula rivers in the south-west of the area.

It appears that the metasedimentary cover acted as a mantle over the dome of granite, which resulted from granitisation and partial melting at the base of the metasedimentary pile. During Irumide folding, when the granites and gneisses were folded into a steeply dipping antiform, the metasedimentary cover was affected by gravity sliding and thrusting. This also accounts for the radial outcrop pattern of the quartzites which form an envelope round the banded gneisses of the Momboshi Group, as well as the presence of the large euhedral garnets aligned in a radial lineation pattern at the boundary between the schists and gneisses.

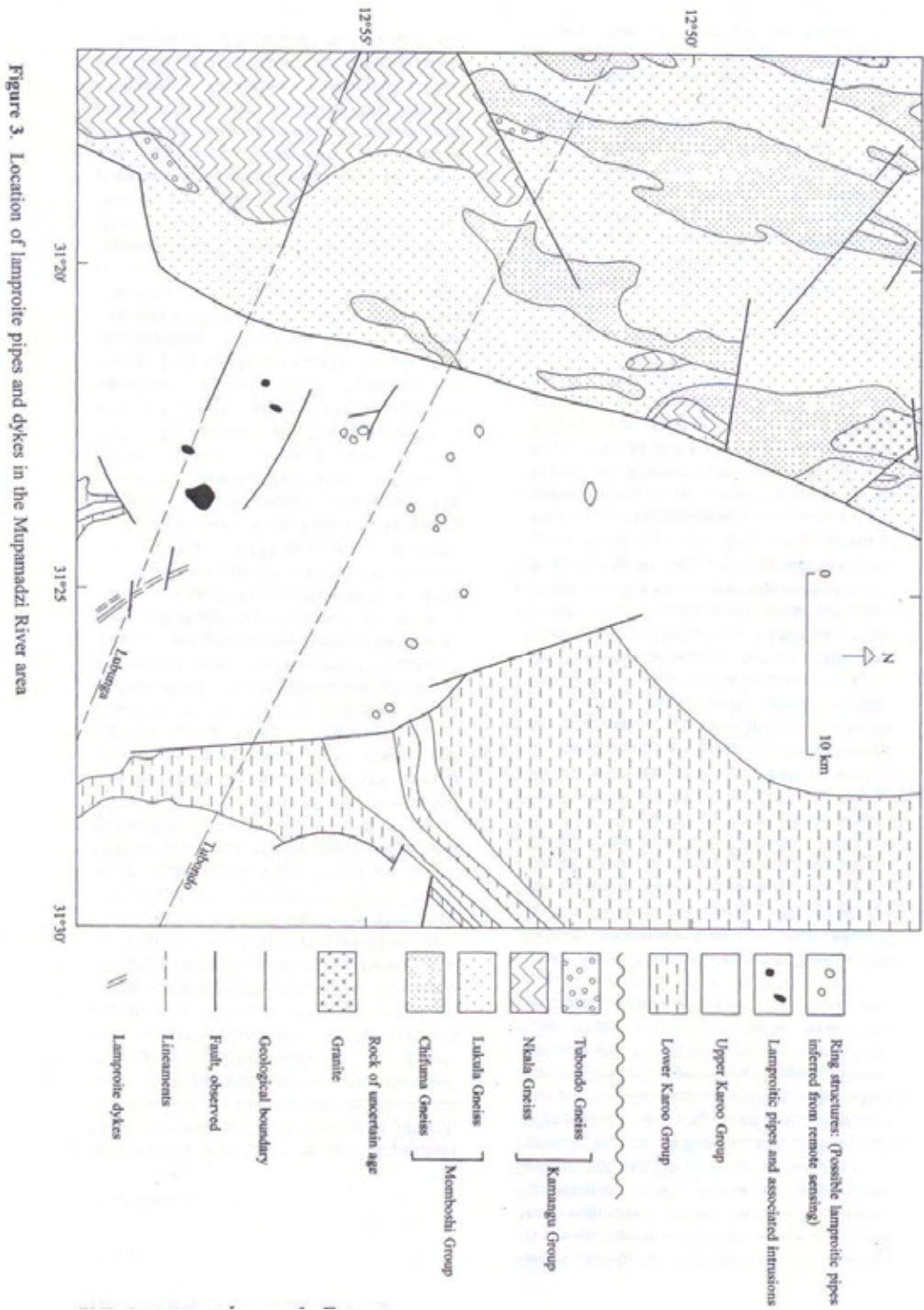


Figure 3. Location of lamproitic pipes and dykes in the Mupamadzi River area

Five

Correlation

Stratigraphic correlation of the Mupamadzi River and adjoining areas is given in Table 1. In the areas to the south-east of the Mupamadzi River area, previous authors described and defined an older complex of highly metamorphosed gneisses as the Mkushi Group (Smith, 1964; Stillman, 1964; Cvetnovic, 1972; Smith and Kerr, 1972; Kerr, 1975). The group was subdivided, except in the Fiwila area, into two formations - the Mkushi Gneiss Formation (gneisses) and the younger Irumi Formation (schists and gneisses). Stillman (1964) did not see a break between the formations in the Musofu River and Mkushi areas, but noted a gradational contact, implying a genetic link between them. In the Serenje area, Mapani and Moore (in press) recognise an older, foliated granite (the Sasa Granite) and classify the gneisses of the Gneiss Group as younger, overlying the schists and quartzites of the Serenje Group. In the area between Serenje and Mupamadzi River, Cordiner (1977) described a series of gneisses, granite gneisses and schists making up the Chibobo Group. A succession of schists and quartzites unconformably overlies the Chibobo Group and was named the Kanona Group (Cordiner, 1977; in prep.). To the north of the Mupamadzi River, Page (1973) divided the gneiss complex into two formations. The Escarpment Gneiss Formation consists of banded granite gneisses and massive amphibolite gneisses; the Mayenze Gneissose Granite Formation appears to be younger. The overlying metasedimentary succession is divided into an older Swankili Formation of metaquartzites and schists and an overlying Chilonga Formation of less deformed quartzites and slates. The Mayenze Formation is thought to be the product of granitisation of the Swankili and Escarpment Gneiss formations (Page, 1973). To the east of the Chilonga Mission area, Mosley and Marten (in press) mapped the Lubanga Gneiss and a paragneiss unit (the Itanga Formation) underlying a metasedimentary succession of metavolcanic rocks, schists and quartzites (the Ibangwe Formation), quartzites, psammitic schists,

amphibolites and metacarbonates (the Kapamba - Sukungule Formation) and pelites and quartzites (the Mansha River Group). Harding (in prep) describes foliated granitic gneisses and migmatites which underlie the metasedimentary Mpala Formation. Mosley (in prep.) differentiates a lower sequence of granites and an overlying unit of higher grade paragneisses and pegmatites (the Lubanga Group). This is overlain by a metasedimentary succession (the Lower and Upper Lubanga formations). The granites are thought to have been formed at least partly by anatexis of the metasedimentary rocks.

A correlation has been established between the Musofu and Kalonga formations of the Mkushi and Musofu River areas, the Kalonga Formation of the Ndabala area, the Serenje Group of the Serenje area and the Kanona Group of the Kanona area (Mapani, 1992). A basal conglomerate at the base of these units is also present in the Kanona Group of the Chitambo Mission area. Kerr (1975) described a metasedimentary succession in the Fiwila Mission area which he correlated with the Kalonga Formation of adjacent areas. Correlation of the metasedimentary rocks of these areas with those of the Mita Hills area (Cvetkovic, 1972) is difficult. The metasedimentary succession in the Chitambo Mission area is the same as that of the Kanona Group in the Kanona area (Cordiner, 1977; in prep). The Swankli and Chilonga formations of the Chilonga Mission area are equivalent to the Kanona group of the Kanona area and to the Musofu and Kalonga formations of the Musofu River, Mkushi and Kapiri Mposhi areas. The Chilonga Formation can be correlated with the Manshya River Group of the Katibunga Mission area (Mosley and Marten, in press).

The Mpala Formation of the Nabwalya area is correlated with the Chilonga and Swankli formations of the Chilonga Mission area and the Mansha River Group of the Katibunga Mission area. Although the metasediments of the Muchilwe Formation in the Mupamadzi River area are of limited extent, they are tentatively correlated with the Mpala formation of the Nabwalya area, the Swankili and Chilonga formations of the Chilonga Mission area and the

Kanona Group of the Chitambo Mission and Kanona areas. The Muchilwe Formation is therefore included in the Kanona Group on the accompanying map legend.

Cordiner (1977) grouped all the gneisses of the Chitambo Mission and Kanona areas as the Chibobo Group. Structural and lithological evidence shows that the porphyritic granite (or porphyroblastic gneiss) of the Kanona and Chitambo Mission areas is younger than the leucocratic and banded gneisses (Mapani, 1992; De Waele, 1997). The Escarpment Gneiss of the Chilonga Mission area is correlated with the Chibobo Group, whereas the Mayenze Gneissose Granite Formation is equivalent to the porphyroblastic gneisses of the Kanona and Chitambo Mission areas. Harding (in prep.) describes lithologies in the Granite Gneiss that are very similar to those of the Chibobo Group, the Escarpment Gneiss Formation and the Mayenze Gneissose Granite. The banded gneisses of the Lukula Gneiss and the leucocratic gneisses of the Chifuma Gneiss of the Mupamadzi River area are equivalent to the gneisses of the Chibobo Group (the coarse porphyroblastic gneisses excluded) and the gneisses of the Escarpment Gneiss Formation. The coarse porphyroblastic gneisses of the Nkala Gneiss correlate with the Mayenze Gneissose Granite of the Chilonga Mission area and the coarse, microcline-porphyroblastic gneiss of the Chibobo Group of the Chitambo Mission area. The gneisses of the Tubondo Gneiss are the result of later deformation of the Momboshi group and have no regional relative.

Table 1. Correlation of the Mupamadzi River area with adjacent areas

GROUP/ SUPERGROUP	Kanona area Cordiner 1971	Chitambo Mission area Cordiner 1971	Chilonga Mission area Page 1973	Nabvalya area Harding 1979	Mupamadzi River area This report
Karoo Supergroup	poorly exposed calcareous shales		grits and sandstones	Chipembele Conglomerate Upper Grit Mufungushi variables Escarpment Grit Madumabisa Mudstone	Escarpment Grit Kapamba Sandstone Madumabisa Mudstone
UNCONFORMITY					
Katanga Supergroup			Bemba Beds		
UNCONFORMITY					
Upper Muva	Kanona Group - quartzites and pelites - quartzites - quartzite and basal conglomerate	Kanona Group - Waka Waka Quartzite - Quartzite - Kipermakanja Quartzite - Nsalu Cave Quartzite - Ikuli Quartzite - Lavushi Conglomerate	Chilonga Formation - upper pelite unit - sandstones, grits and quartzites - massive quartzites - lower pelite unit	Mpala Formation - quartzites and psammitic schists - pelites	Kamangu Group Tubondo Gneiss Nkala Gneiss Kanona Group - psammites - pelites
UNCONFORMITY					
Lower Muva	Chibobo Group coarse porphyroblastic gneiss	Chibobo Group coarse microcline porphyroblastic gneiss	Mayenze gneissose granite formation medium and coarse gneissose granite and coarse porphyroblastic gneissose granite	Granite Gneiss Formation porphyroblastic members	Momboshi Group - Lukula Formation - Chifuma Formation
	Chibobo Group leucocratic gneisses banded gneisses	Chibobo Group granite gneisses banded gneisses	Escarpment Gneiss Formation banded granite gneisses	Granite Gneiss Formation migmatitic and banded gneisses	

Six

Economic Geology

The economic potential of the area is low. No metalliferous mineralisation was located and the exploitation of any workable deposit would be difficult because of the inaccessibility of the area.

The leucocratic gneisses of the Chifuma Gneiss contain small, subhedral to euhedral garnets in many places, particularly in areas in the escarpment zone. Their use would be limited to an abrasive material, and their economic importance diminished by inaccessibility. The granites and gneisses are suitable for road metal. Mununga quarry is the only operational quarry, providing crushed rock for the Tazara railway. Some pegmatites contain beryl and tourmaline, but none of gemstone quality was found. The sands in the river beds of the Luangwa Valley are suitable for building purposes and are exploited by the local community. No uranium mineralisation or radiometric anomalies occur in the Karoo rocks of the area, but further investigation of the Escarpment Grit may be warranted (Money and Prasad, 1977).

Diamond

In a cluster of fourteen lamproite pipes and four dyke systems in the Kapamba Valley (De Beers Prospecting (Zambia) Limited, 1973; Scott Smith et al., 1986), five pipes in the north-west of the cluster (P2, P3, P7, P8 and P9) lie in the Mupamadzi River area. P2 and P3 were discovered by Chartered Exploration Limited in 1961-2, the remainder by De Beers in the 1960's and early 1970's. The pipes were originally classified as kimberlites, but Scott Smith et al. (1986) re-classified them as olivine lamproites on the basis of their petrography, mineral chemistry and whole-rock geo-chemistry. Pipes P2, P3, P8 and P9 form distinct, positive topographic features as a result of silicification and induration of the host Karoo sandstones around the contacts. P7 forms an oval depression. The dykes are mostly highly altered, with local induration of the country rock up to 1 to 2m from their margins.

The pipes are craters filled mainly with tuffs. The geology of the infill is complex, suggesting a range of volcanogenic processes, including pyroclastic flow, fall-out deposition, pulsed pyroclastic activity and reworking. The tuffs contain clasts (typically less than 2cm) of juvenile, commonly altered lapilli, angular grains of quartz and feldspar and some xenoliths of country rock. Euhedral olivine microphenocrysts between 0.25 and 0.5mm in size are set in the fine-grained or glassy groundmass. Olivine macrocrysts are abundant in P2. The grains of quartz and lesser amounts of feldspar (up to 10mm) are xenocrysts derived from fragmentation of the country rock.

P2 is a ring complex of 165,000m² and has yielded 184 small, yellow and brown diamonds totalling 9.4263 carats from 264m³ of material sampled. P3 is 79,300m² and yielded only one diamond of 0.0002 carats from 124m³ of material. P7 is 89,100m² and yielded five diamonds totalling 0.0155 carats from 161m³ of material. P8 is 41,300m² and yielded 13 diamonds totalling 0.0155 carats from 143m³ of material. P9 is 58,400m² and yielded two diamonds totalling 0.15 carats from 178m³ of material.

Watts et al. (1991) comment that the overall grade of the P2 deposits is 0.256 carats per 100 tonnes, with an average size of 0.014 carats, and that whilst it is possible that larger stones exist which would improve the average size, the indications are that the pipe has only a remote chance of being economic. They further note that other lamproite pipes may exist in the area, without the characteristic kimberlite indicator minerals on which prospecting has relied. This suggestion is endorsed by the identification of thirteen further ring structures on the air photographs to the north of the Kapamba cluster (Figure 3). Watts et al. recommend magnetic surveying and investigation of any targets such as these.

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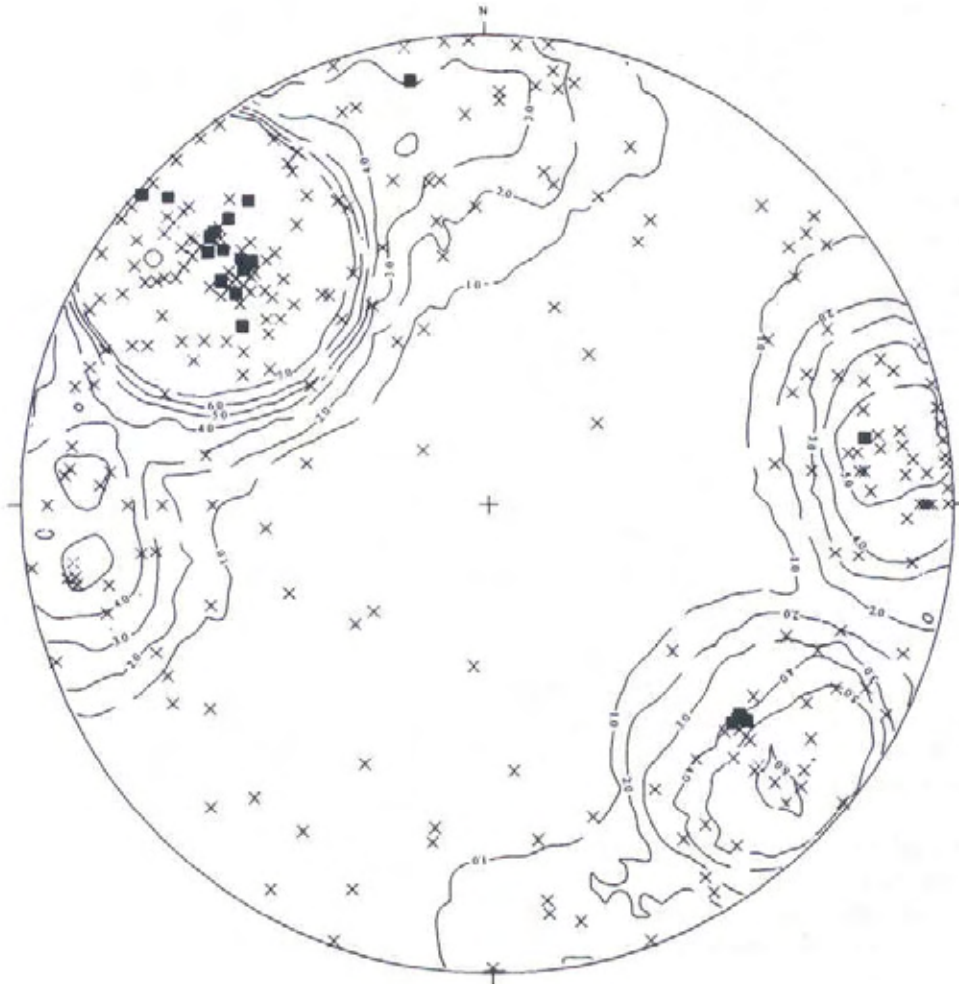
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APPENDIX 1

Stereoplots of small-scale structures in the Mupamadzi River area



- x Banded gneisses
- Porphyroblastic and sheared gneiss

Figure 1. Foliation in Momboshi Group

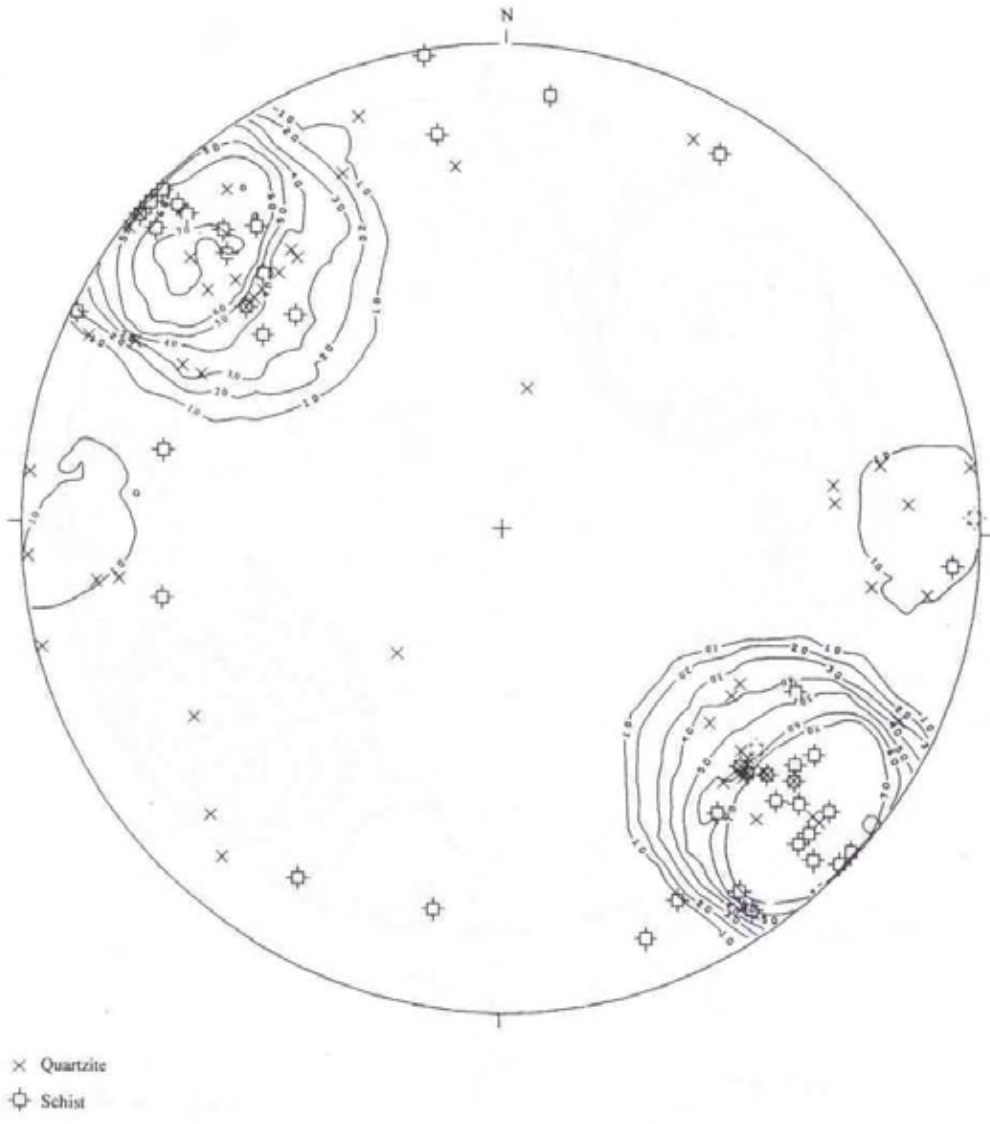
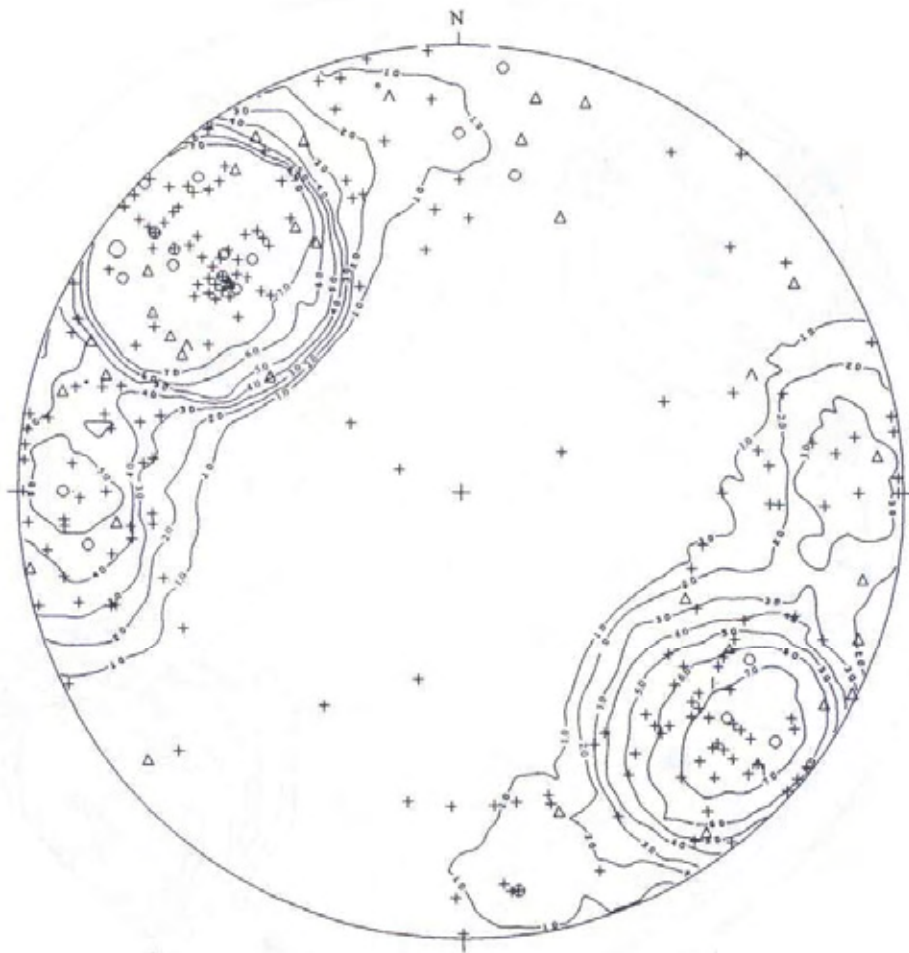
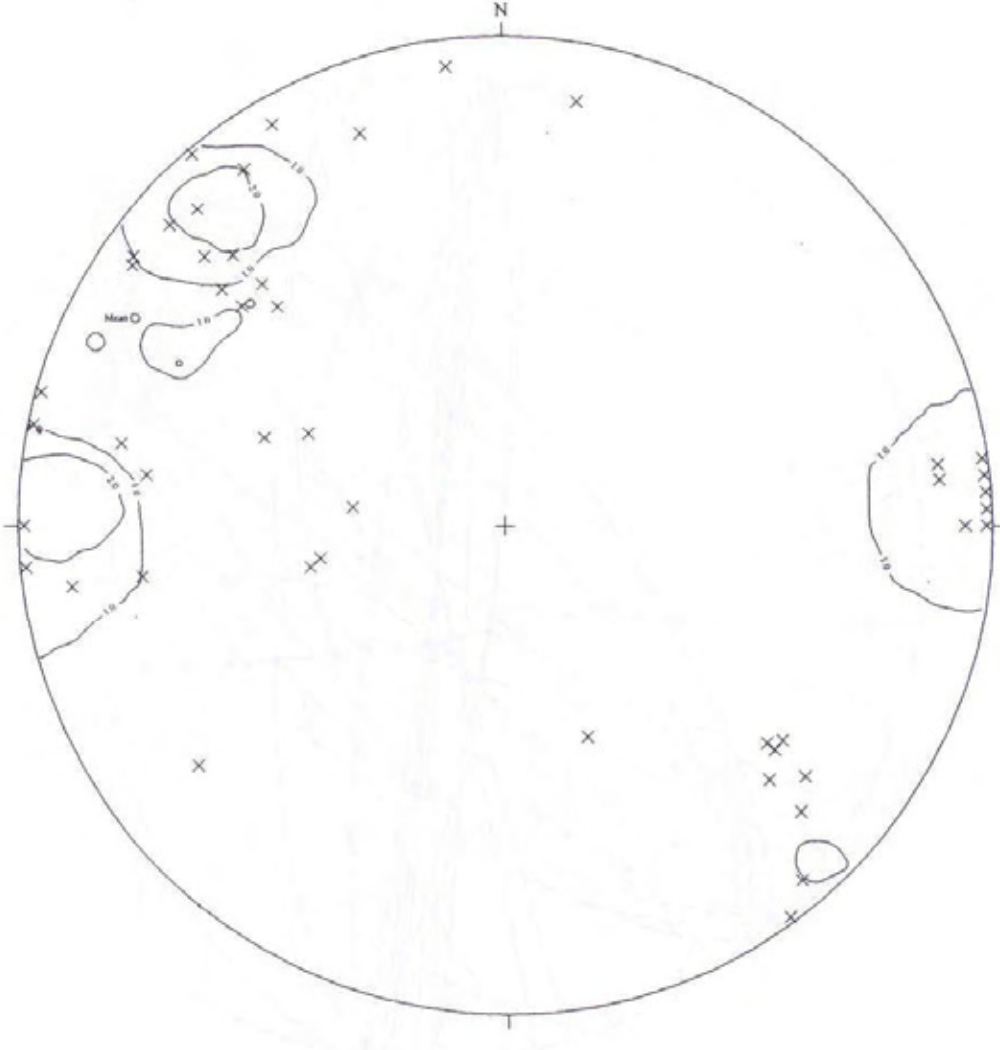


Figure 2. Foliation in Muchilwe Formation



- Δ Augen gneiss
- † Porphyroblastic gneiss
- o Sheared porphyroblastic gneiss

Figure 3. Foliation in Nkala Gneiss



x Migmatitic gneiss

Figure 4. Foliation in Tobondo Gneiss. 49 sample points

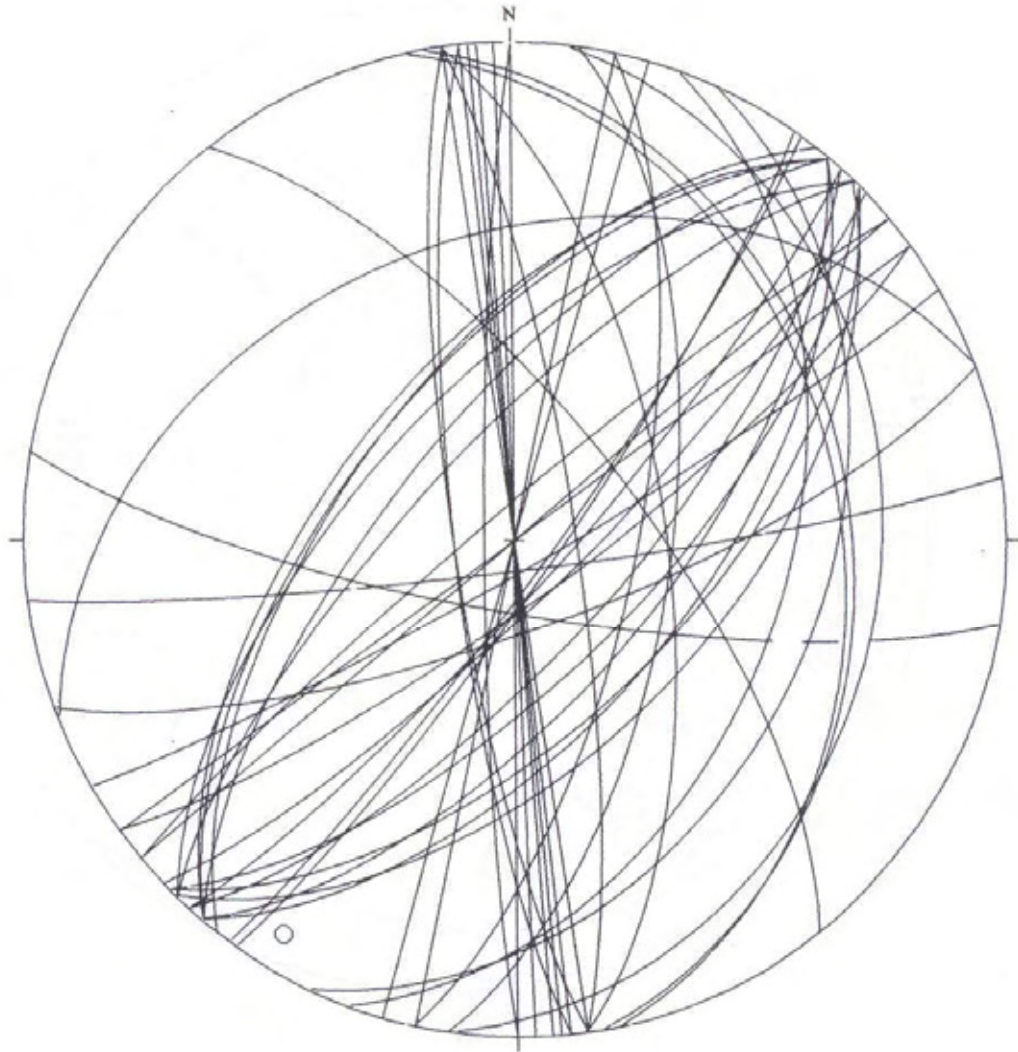
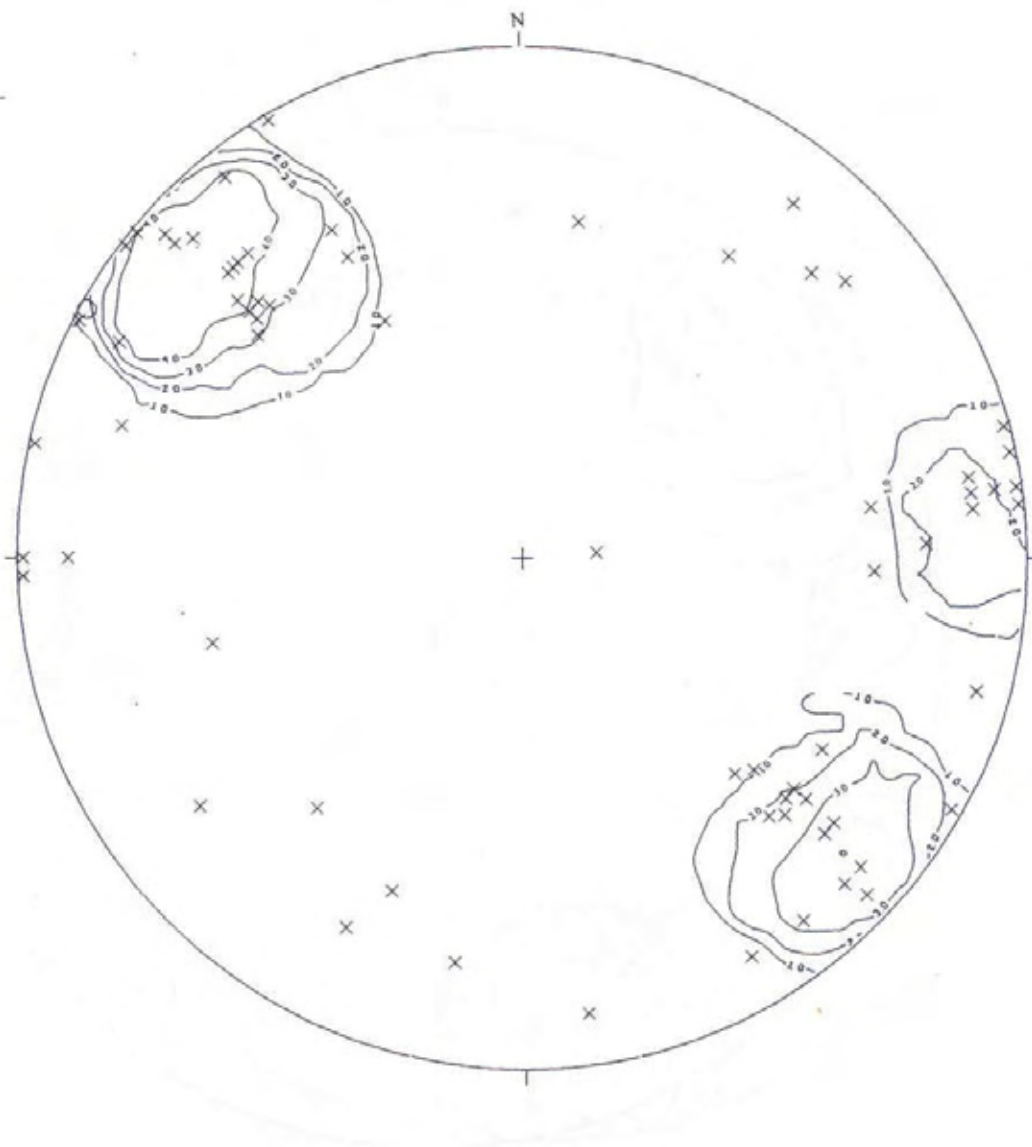
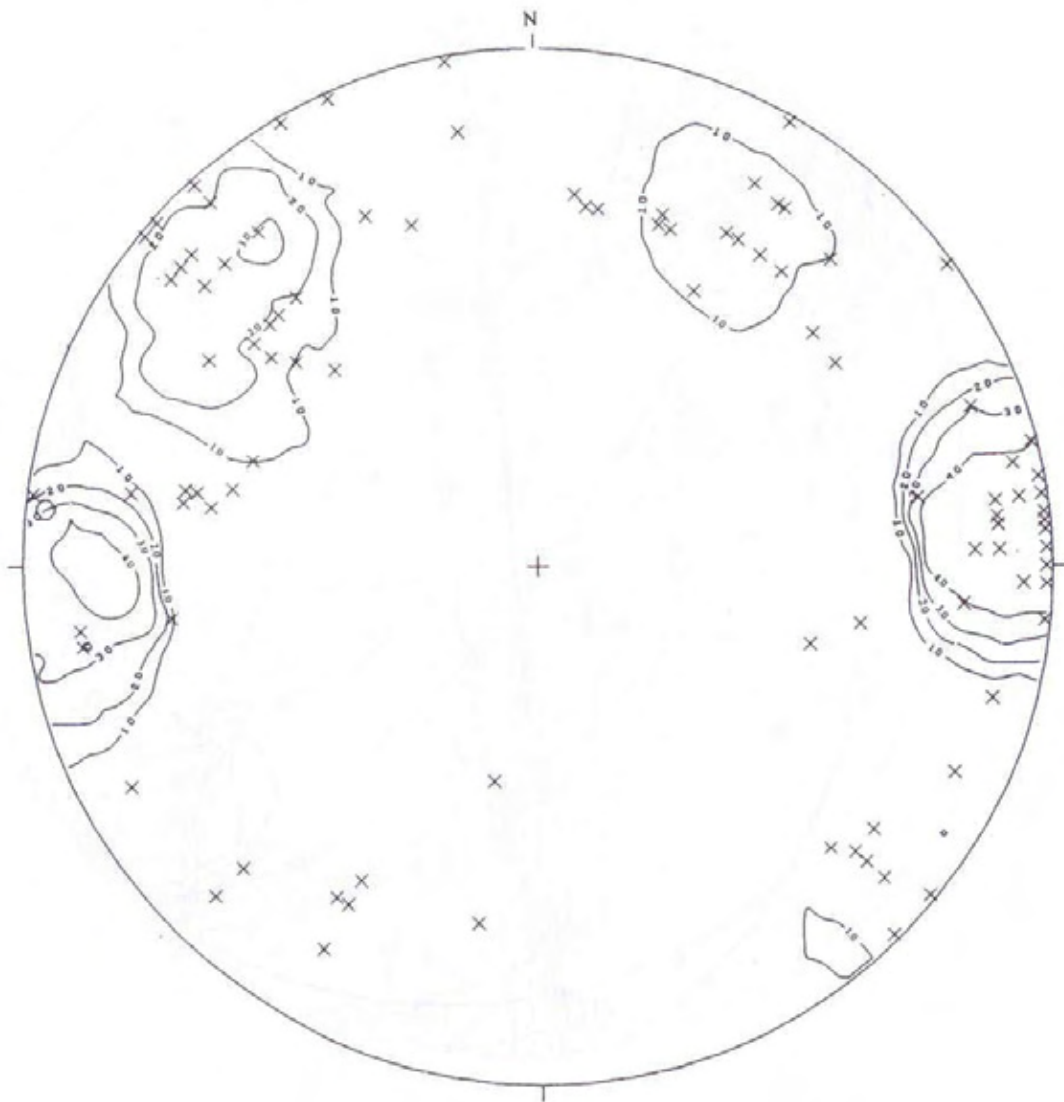


Figure 5. Foliation in migmatite gneiss



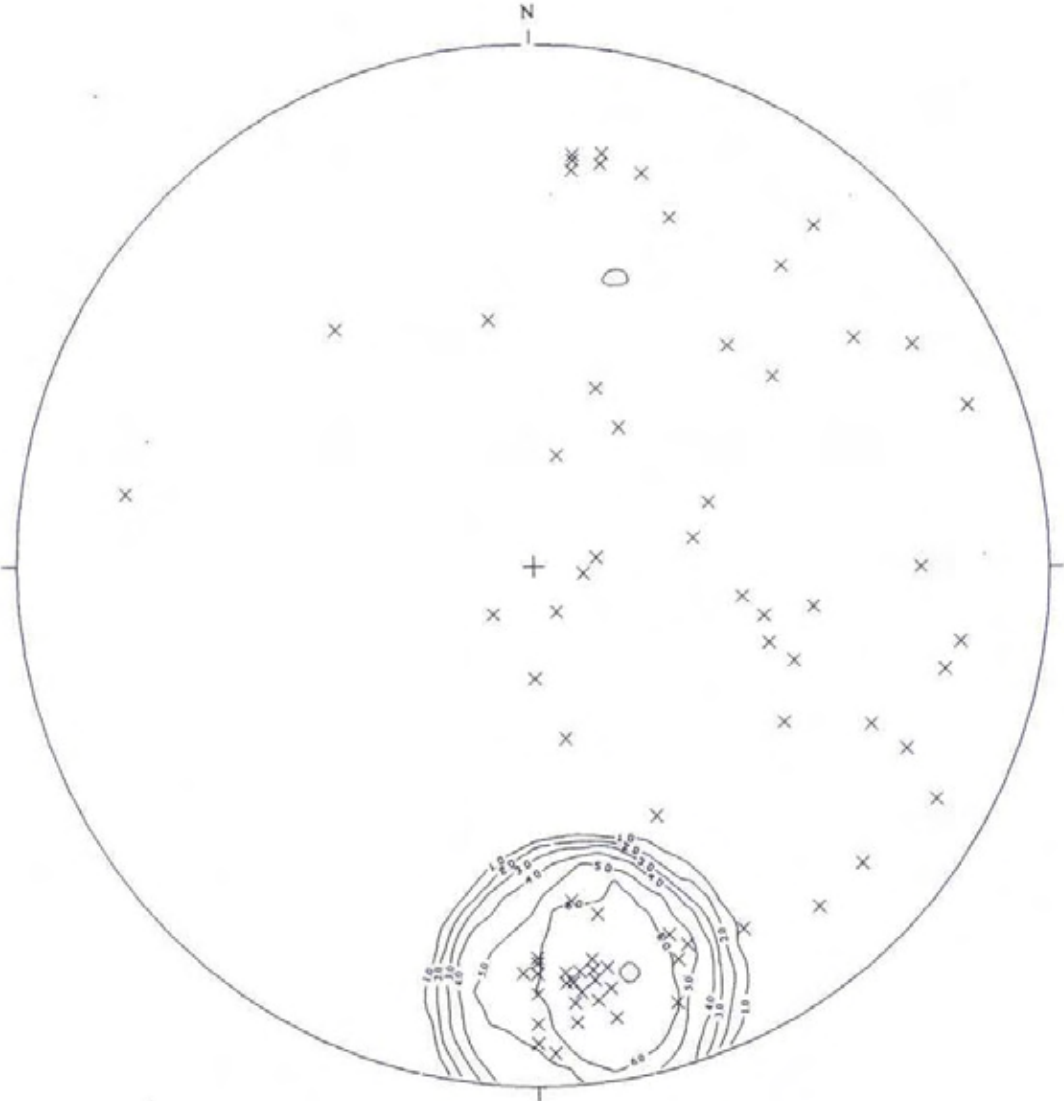
x Dolerite dykes

Figure 6. Orientation of dolerite dykes



x Granites

Figure 7. Foliation in granites



x Lineations

Figure 8. Lineations