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PETROGRAPHY AND GEOCHEMISTRY OF GRANITOID ROCKS IN THE NORTHERN PART OF TETE PROVINCE, MOZAMBIQUE

by
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The crystalline basement in the northern part of Tete Province, NW Mozambique, is largely composed of various Mesoproterozoic granitoids, with Neoproterozoic to Ordovician granitoids occurring to a smaller areal extent. These granitic rocks are divided into several types on the basis of petrography, texture, geophysical signature, chemical composition, and age. Most granitoids belong to the 1.2–1.0 Ga age group and are related to the Grenvillian Orogeny. The largest massives belong to the Furancungo Suite (~8300 km^2), Cassacatiza Suite (~5700 km^2), Serra Danvura granitoids (~4700 km^2), Castanho Granite (~3400 km^2) and Rio Capoche Granite (~2600 km^2), which all are composed of different magmatic phases. The Ordovician 0.50–0.47 Ga intrusions belong to post-Pan-African magmatism. Some intrusions have undergone Pan-African (c. 0.53 Ga) metamorphism.

Certain massives have specific textural characteristics. The extensive Cassacatiza Suite shares a parallel, ENE structural grain with the neighbouring supracrustal rocks of the Fíngoè Supergroup and is cut by the NW trending Furancungo Suite in the northeast. The charnockitic c. 1.05 Ga Castanho Granite has spatial and mutual relationships with the contiguous Tete Gabbro-Anorthosite Suite. The Mussata granitoids near the Tete Suite are mylonitized due to the allochthonous nature of the latter.

Most of the Mesoproterozoic as well as the post-Pan-African granitoids in the northern part of Tete Province are ferroan, and alkalic to calc-alkalic in composition. They classify from quartz syenites and quartz monzonites to granites; tonalites are rare and lacking amongst the post-Pan-African granitoids. The aluminium saturation index varies from metaluminous to slightly peraluminous. The ferroan intrusions suggest an extensional tectonic regime. The absence of S-type granitoids indicates that sedimentary rocks did not dominate in the source regions. The post-Pan-African granites usually have higher La and Ce contents than the older granitoids.

Key words (GeoRef Thesaurus AGI): granites, granodiorites, quartz monzonite, quartz syenite, chemical composition, classification, Proterozoic, Mesoproterozoic, Phanerozoic, Tete, Mozambique.

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INTRODUCTION

Tete Province in northwestern Mozambique may be geologically divided into three main areas: (1) the Mesoproterozoic "West Gondwana" basement, which has undergone the Kibaran orogeny in the north with minor "East Gondwana" assemblages in the northeastern corner; (2) the Archaean Zimbabwe craton with Proterozoic cover sequences in south; and (3) the Phanerozoic graben-type sediments of the Zambezi rift (parallel to Cahora Bassa Lake) between these basement areas (e.g. Shackleton 1994, Rogers *et al.* 1995, Grantham *et al.* 2003, GTK Consortium 2006). Two-thirds of the first-mentioned area – the subject and thesis of this article – is composed of Mesoproterozoic (-Ordovician) granitoids (Fig. 1). Thus, knowledge of plutonic rocks is crucial in understanding the crustal evolution in the northern part of Tete Province.

Between 1980 and 1984, Hunting Geology and Geophysics Limited initiated a new phase of geological investigations (Hunting 1984) in Tete Province, carrying out a comprehensive mineral exploration and reconnaissance geological mapping project under the aegis of the Mozambican government. Approximately at the same time, the French BRGM (Bureau de Recherches Géologiques et Minières) surveyed the northern part of Mozambique, resulting in the publishing of a geological map at the scale 1:1 000 000 that provided new insights in the geology of the Tete area (Pinna *et al.* 1986, 1987). However, the most updated mapping of the region was made during 2002–2006 within an extensive geological mapping project, *Mineral Resource Management Capacity Building Project, Republic of Mozambique, Component 2: Geological Infrastructure Development Programme, Geological Mapping LOT 2*, executed by Geological Survey of Finland (GTK) and financed by WB/NDF. The project produced new 1:250 000 scale geological maps with explanations (GTK Consortium 2006) from Tete Province.

The present paper summarizes petrographic and geochemical observations of the granitic rocks situated north of Cahora Bassa Lake and the Zambezi River, in the northern part of Tete Province (Fig. 1). All locations presented in figures and appendices are in UTM coordinates (WGS 84). Please note that in the study area reference is made to the 36S.

REGIONAL GEOLOGICAL SETTING

From a geodynamic point of view it is generally accepted that the crystalline basement of Mozambique is composed of three major lithospheric plates or terranes[1] that have collided and amalgamated during the Pan-African Orogenic Cycle. Prior to amalgamation, each terrane was characterised by an individual and specific geodynamic development. These terranes are called East Gondwana, West Gondwana and South Gondwana (e.g. Shackleton 1994, Grantham *et al.* 2003, Rogers *et al.* 1995, and references therein).

The crystalline basement of northern Tete Province belongs (in addition to West Gondwana) mainly to a smaller structural element called the Tete-Chipata Belt, which formed during the Grenvillian orogenic cycle (~1.1–1.0 Ga) (see Westerhof 2006, Westerhof *et al.* 2008a). The belt is bounded by the W-E trending Sanângoè Shear Zone (SSZ), which roughly follows Cahora Bassa Lake in the south, by a thrust front or pseudo-suture between the East and West Gondwana terranes in the east, and by the Mwembeshi Dislocation in the northwest, in Zam-

[1] The term "terrane" is used to indicate a tectonic unit of variable size, i.e., a lithospheric plate, a plate fragment or sliver or a tectonic mass such as a "nappe". "Terrain", on the other hand, is a generic term, broadly similar to "area".

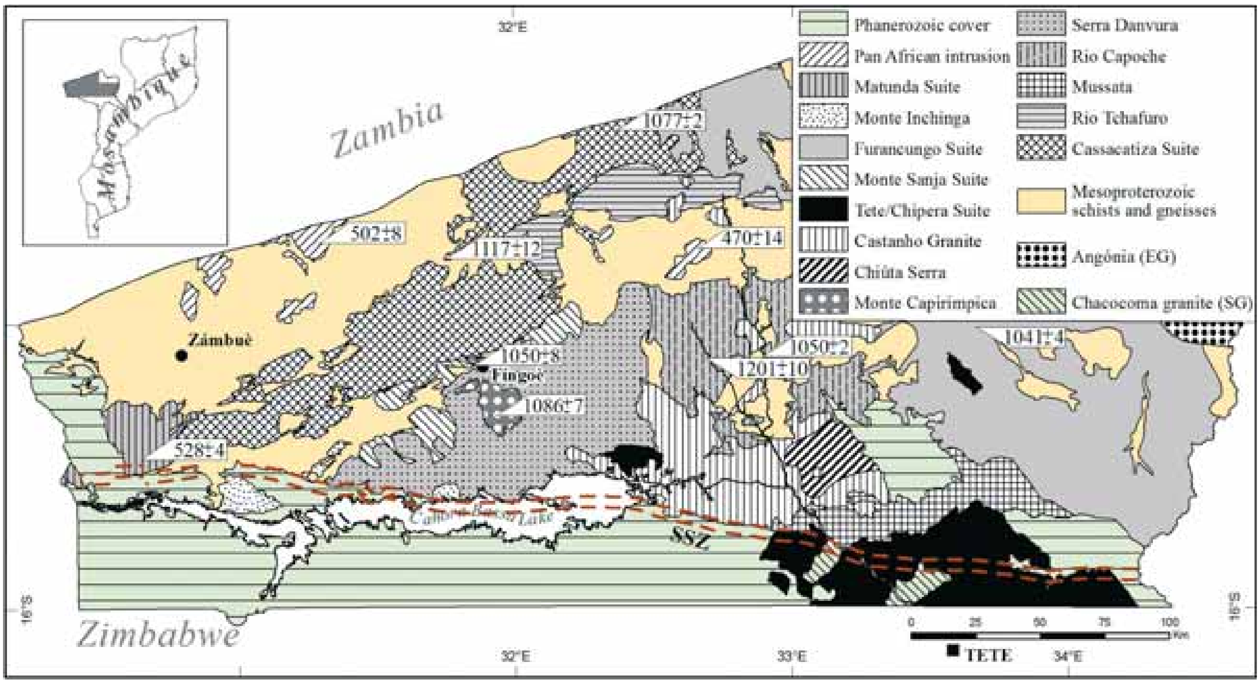

Fig. 1. Simplified geological map of the northern part of Tete Province showing the locations of the most voluminous granitoids with corresponding U–Pb ages in Ma. The U–Pb age obtained in Matunda Suite refers to Pan-African metamorphism. The Sanângoè Shear Zone (SSZ) is marked as a red broken double line. Note that the town of Tete is situated in the SE corner of the figure and that a small portion (behind the legend) in the NE corner was not included in the present study. The map is drawn after the GTK Consortium (2006).

bia. Being located close to a triple junction between the Irumide belt, the Zambezi segment of the Zambezi-Lufilian-Damara belt and the Mozambique belt, the basement geology of the northern Tete Province is very complex (Westerhof *et al.* 2008a, and references therein).

New geochronological data by the GTK Consortium show that all granitoids in the northern part of Tete Province are younger than the ~1.3 Ga Fíngoè Supergroup and other supracrustal rocks of the region (Mänttäri *et al.* 2006, Mänttäri 2008). Most granitoids of the region are 1.2–1.0 Ga old and related to the Grenvillian orogenic cycle, culminating in the formation of the Rodinia Supercontinent. The youngest granite intrusions belong to post-Pan-African magmatism, 0.50–0.47 Ga in age (Fig. 1). Mafic dykes several kilometres long, Neoproterozoic and Karoo in age, locally cut the granitoids.

Many of the granitoids form impressive and well-exposed, 100–300 m high *kopjes* (Fig. 2). Between the granitoid batholiths there occur either various Mesoproterozoic supracrustal rock units or granitoids. The central part of the study area is characterised by WSW-ENE trending metavolcanic and sedimentary rocks of the Fíngoè Supergroup. Arkosic metasediments of the Zâmbuè Supergroup dominate the northwestern corner of the area, while granulitic gneisses of the Chidzolomondo, and Cazula and Mualadzi Groups prevail in the northeastern part of Tete Province (GTK Consortium 2006).

Fig. 2. Granitic kopjes in Tete Province near the Zambian border, 40 km NE of the Fíngoè village.

GROUPING OF GRANITOIDS

Principles

Structural and fabric features, chemical and mineralogical composition, geophysical signature, and U–Pb age determinations of granitic rocks allow the distinction of several granitoid groups in the northern Tete Province (Table 1). Compared to the "old" unit names defined by Hunting (1984), the new names defined for various granitic units are also shown in Table 1.

One of the main problems with the newly defined granitoid (and metamorphic) units is to find names that meet the rules of stratigraphic (and lithodemic) nomenclature. The previous criteria "pre-/post-Fíngoè" (Hunting 1984) to define major granitoid groups in Tete Province were based on observed/interpreted field relationships with supracrustal rocks of the Fíngoè Supergroup. However, granites should be interpreted and grouped on the basis of age and the role they played during the geodynamic evolution of the region. For instance, the "pre-Fíngoè Granites" sensu Hunting (1984), between the Zâmbuè and Fíngoè sequences, now defined as the Cassacatiza Suite, could represent a syn- to late-orogenic Grenvillian "*stitching pluton*". They may have been emplaced at the site of an accretionary suture between the terrestrial "Zâmbuè terrane" in the north and the volcano-sedimentary Fíngoè belt in the south, and were probably derived by anatexis from a deeper crustal level.

These examples underscore the need to understand the role and time of emplacement of granitoids in the geodynamic evolution of the region. Furthermore, there is no justification for naming the

Table 1. The proposed names for granitoids in the northern part of Tete Province. The U–Pb ages are after Mänttäri (2008).

Eon/Era	U-Pb age in Ma	Granitoids (supracrustal rocks in italic)	Old name (e.g. Hunting 1984)
Phane-rozoic	470±14	Macanga granite	
	502±8	Sinda Suite	Sinda Granite
Neo-proterozoic		Cassenga Leucogranite	
		Monte Tarai granite	
		Monte Inchinga granite	SW part of pre-Fíngoè Granites
	528±4, metamorphic/ (~0.8 Ga magmatic?)	Matunda Suite	SW part of Zámbuè Group
Meso-proterozoic		Boesi granite	
		Marirongoe granite	
	1041±4	Furancungo Suite	Desaranhama Granite
		Messambe quartz monzonite	
		Mussata Granite, mylonitic	Southernmost part of Luia Group
	1050±8	Monte Sanja Suite	Bulk of post-Fingoè Granites
	1050±2	Castanho Granite	Granito Castanho
	1086±7	Monte Capirimpica Granite	Small part of post-Fingoè Granites
		Serra Danvura granitoids*	Southern part of Pre-Fíngoè Granites
	1077±2, 1117±12	Cassacatiza Suite	Northern part of pre-Fíngoè Granites Granites
	1201±10	Rio Capoche Granite*	
		Rio Tchafuro Granite	NE part of pre-Fingoè Granites
		Chiúta Serra Granite	
		Supracrustal rocks:	
		Mualadzi Group	*ENE extension of Fingoè Group*
	~1.3 Ga	*Fíngoè Supergroup*	*Fíngoè Group*
		Zámbuè Supergroup	*Zámbuè Group*
		Cazula Group	*Parts of Angónia Group and Luia Group*
		Chidzolomondo Group	*NE part of Luia Group*
		Rio Messeze Suite (ortho- *and paragneisses)*	

*) Note that "Monte Capingo granite" reported by Mäkitie et al. (2006) is here divided into Serra Danvura granitoids and Rio Capoche Granite.

different groups with numbered map codes, which automatically imply some chronological order – as was done in the maps of Hunting (1984) and the BRGM 1:1 000 000 scale geological map (Pinna *et al.* 1987).

Borges (1937) introduced the term “granito castanho” (brown granite) to describe certain granitic rocks with distinctive field characteristics, widespread in the central Tete Province. Later work by Assunção *et al.* (1956a, 1956b) showed that some, but not all, of these rocks belong to the charnockite series (Le Maitre 1989). In this study, the name “Castanho Granite” is proposed for this specific granitoid type. As a matter of fact, a significant proportion of observed rock types have syenitic, monzonitic and monzodioritic compositions and not all are characterised by the presence of pyroxene, as assumed by Assunção *et al.* (1956a, 1956b).

The extensive Cassacatiza Suite (~5700 km^2), Furancungo Suite (~8300 km^2), Serra Danvura granitoids (~4700 km^2) and Rio Capoche Granite (~2600 km^2) each comprise different mappable granitic phases. Some granitoids with a smaller areal extent (<500 km^2) may also locally display notable differences in modal composition. There are also a few small granitoid areas (occurrence <20 km^2) not shown in Fig. 1. These include the Rio Messeze orthogneisses, Messambe quartz monzonite, Monte Tarai Granite, Cassanga Leucogranite and Monte Macanga Granite. In the following chapter, the granitoids of the northern Tete Province are described from the oldest to the youngest.

PETROGRAPHY

Rio Messeze orthogneisses

The Rio Messeze gneisses occur about 40 km east of the village of Fíngoè, where tonalitic orthogneisses have undergone polyphase deformation and are cut by granite dykes of different age (Fig. 3). The rock is moderately to weakly banded, with polyphase fold structures and variable structural trends. Elongated mafic inclusions as well as porphyroblastic K-feldspar grains occur in places.

The tonalitic composition of the gneiss is interesting because the granitoids in the northern part of Tete Province are mostly granitic in composition. The tonalitic rocks resemble “TTG assemblages” more than any other granitoids in the area. Dominant minerals of the orthogneiss are plagioclase and quartz, with subordinate biotite, hornblende, K-feldspar and epidote.

Fig. 3. Polyphase deformation in the Rio Messeze tonalitic gneiss east of the Chipungo village (0421927/ 8327571). The scale bar is 14 cm.

Chiúta Serra Granite

The Chiúta Serra (meta)Granite occurring about 75 km north of the town of Tete is characterized by, and partly delineated on the basis of a strongly dominant relief, expressed by mountain ridges and chains of major *kopjes* or *inselbergs*. Another mapping criterion for the Chiúta Serra Granite is its distinctive, high Th-K signature, which contrasts sharply with neighbouring lithological units.

The average rock type is a grey to brownish grey (colour depending on biotite and garnet content), coarse-grained, inequigranular, occasionally very coarsely porphyritic biotite granite, typically with variable garnet content. This granite may contain small mafic xenoliths or larger (dm to metre scale), dark grey, retrograde amphibolite enclaves. Migmatitic metasediments, possibly belonging to the Chidzolomondo Group, occur in the inner parts of the main Chiúta Serra Granite body.

The contact relations seem to favour an older age than Rio Capoche granitoids dated at ~1201 Ma. As a consequence, the Chiúta Serra granitoids are regarded as the oldest plutonic rocks in the northern part of Tete Province, possibly equal in age to the Rio Messeze orthogneisses.

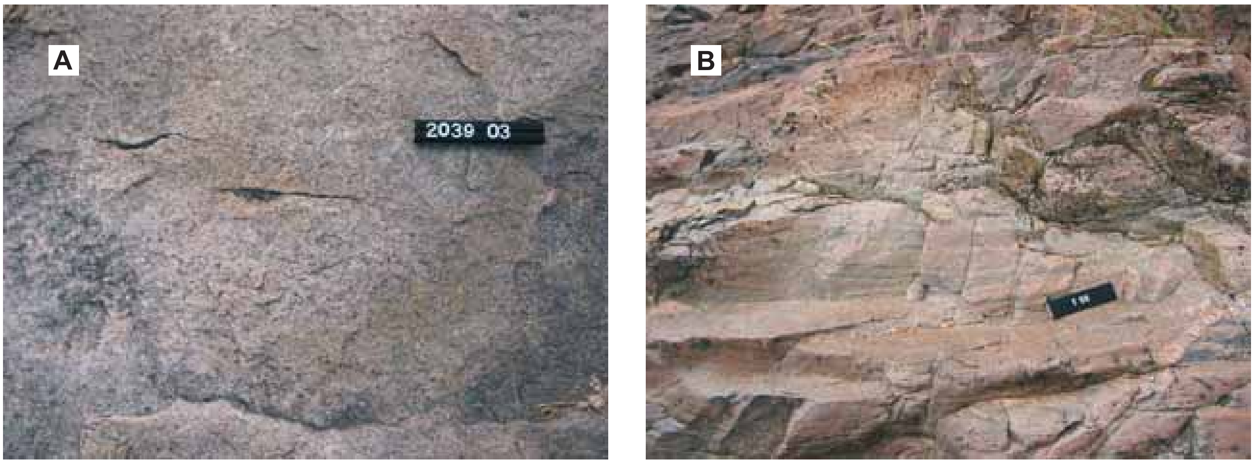

Fig. 4. Rio Capoche granitoids. (A) Relatively homogeneous granite containing K-feldspar phenocrysts. NW of Monte Nhanjo (0519390/ 8322890), (B) Granitic orthogneiss. The U–Pb zircon age obtained from a sample of this outcrop is ~1.2 Ga. Rio Capoche bridge (0468284/ 8326745). The scale bar is 12 cm.

Rio Tchafuro Granite

The Rio Tchafuro granitoids are spatially restricted to a large W-E directed section along the main road from Tete to the Zambian border in the north. The average rock type is light grey to pinkish grey, inequigranular to porphyritic, biotite-bearing granodiorite, in places tonalite and granite. The grain size is variable, ranging from fine to (locally) very coarse. The finer-grained varieties are typically more equigranular. Locally, a magmatic flow structure is indicated by an incipient alignment of K-feldspar phenocrysts.

Evidence of mixing of different granitoid magma batches and migmatisation can be observed in several outcrops. Where various "leucosome" generations are involved, the contacts between rock parts range from sharp to diffuse.

Rio Capoche Granite

The Rio Capoche granitoids represent an extended family of biotite granites and granodiorites located 100 km NW of the town of Tete. The average rock type in the NW part of the Rio Capoche batholith consists of a (light) grey to pinkish and brownish grey, medium- to coarse-grained, inequigranular and locally porphyritic biotite granite (Fig. 4A). The biotite content is variable, but mostly low to very low. Gneissic types also occur locally (Fig. 4B).

A pink to reddish grey, fine-grained, equigranular quartz-feldspar rock (with accessory biotite) is believed to represent large granitized enclaves of metasediments. These meta-arkositic rocks occur in the western parts of the Rio Capoche batholith.

Cassacatiza Suite

The Cassacatiza Suite, one of the spatially largest granitoids in the northern part of Tete Province, is dominated by porphyritic biotite-hornblende granite, often deformed and flattened in the NE direction. The rocks of the Cassacatiza Suite range in composition from granite to granodiorite, but quartz monzonites and quartz syenites also locally occur. The following lithological varieties are defined: (1) megacrystic, deformed granite and granodiorite, (2) coarse-grained, mesocratic granite and (3) medium-grained, gneissic granite.

In the first type, the average size of alkali feldspar phenocrysts is 1–5 cm, but roundish megacrysts up to 8–10 cm in diameter have also been observed (Fig. 5A). Owing to the mesocratic composition, the second type (Fig. 5B) has a lower potassium signature on radiometric maps compared with porphyritic varieties of the Suite. The third type, even macroscopically rather isotropic, may show a foliation and extensive sericitisation of plagioclase, with large white mica inclusions implying metamorphic overprinting.

The Cassacatiza granitoids are usually clearly intrusive into the supracrustal rocks of the Zâmbuè and Fíngoè Supergroups. However, in the western part of the Suite, some foliated variations of these granitoids are locally difficult to distinguish from granitized meta-arkoses of the Zâmbuè Supergroup.

Serra Danvura granitoids

The Serra Danvura granitoids occupy an area of 50 x 130 km on the northern side of Cahora Bassa Lake, to the south of the supracrustal rocks of the Fíngoè Supergroup (Fig. 1). These granitoids represent an assemblage of coarse- to medium-grained biotite-hornblende granites (Fig. 6A), quartz monzonites (Fig. 6B) and quartz syenites. Their colour varies from pinkish to dark greenish brown and texture from equigranular to porphyritic and undeformed to weakly deformed. Quartz monzonites and quartz syenites form large, individual intrusions, particularly to the south of the village of Fíngoè. However, most of the Serra Danvura rocks are true granites in the classification of Streckeisen (1976).

Porphyritic granites characterise the western parts of the Serra Danvura batholite and are composed of abundant K-feldspar phenocrysts, 1–3 cm in size. The granitic rocks situated in the eastern part of the Serra Danvura batholite are usually foliated and have a smaller grain size than those in the west.

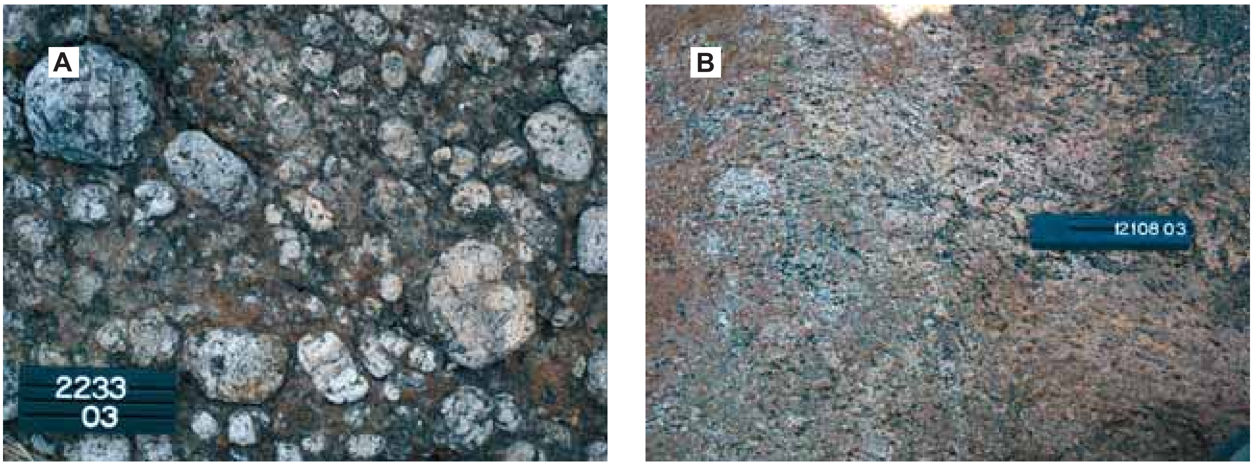

Fig. 5. Granitoids of the Cassacatiza Suite. (A) Alkali feldspar megacrysts in biotite granite. South of Monte Dómué (0431280/ 8414628), (B) Foliated, slightly mesocratic, quartz monzonitic granitoid. Monte Chipalava (0289834/ 8317326). The scale bars are 8 cm and 14 cm.

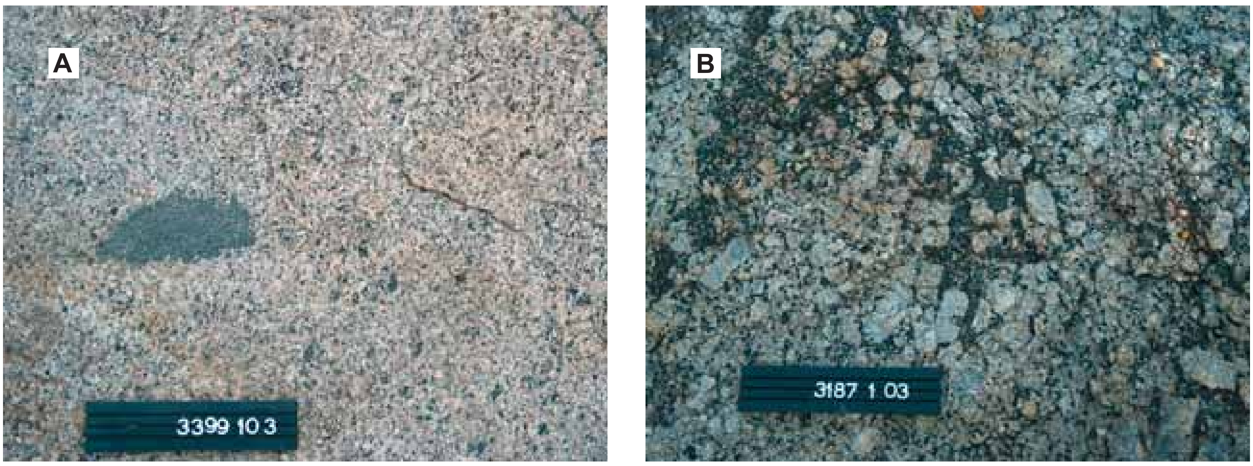

Fig. 6. Serra Danvura granitoids. (A) Weakly deformed hornblende-biotite granite with fine-grained, mafic enclave. Western part of the batholith (0345807/ 8288337), (B) Grain size variation in almost undeformed, porphyritic quartz monzonite(-syenite). 25 km south of the village of Fingoè (0378550/ 8299448). The scale bar is 14 cm.

Monte Capirimpica granite

The Monte Capirimpica granite occupies a mountainous area of over 400 km^2, a few kilometres south of the village of Fíngoè. Detailed studies have shown that this area with a strong radiometric signature is occupied by (1) almost undeformed, coarse-grained and equigranular hornblende-biotite granite (~75% of the total area) and (2) medium-grained aplitic granite (~25%). The aplite occurs as irregular elongated patches, streaks and dykes, up to 30 m in breadth.

Castanho Granite

In outcrops, the Castanho Granite typically appears as massive bodies, which are usually porphyritic in texture (Fig. 7A). However, the fresh, non-weathered rock often has a thin weathered "skin". Boulders are typically rounded due to the effects of onion-type exfoliation. The non-weathered rock ranges in colour from (dark) brown to dark grey, even to dark green (e.g. along the old road southwest from Songo). Weathering "skins" also have a range of colours: they are mostly brown to grey, but sometimes also light grey to white, in sharp contrast to the dark colours of fresh rock. Locally, the rocks may comprise xenoliths (Fig. 7B). The larger massifs of the Castanho Granite are generally irregular in shape and/or roughly conformable with country rock structures.

The Castanho Granite is composed of variable amounts of quartz, alkali feldspar, plagioclase, orthopyroxene, augite, biotite and hornblende, with opaque minerals. The composition ranges from true granite and quartz syenite to granodiorite and from quartz monzonite to (quartz-)monzodiorite. Locally, the rock is nearly totally devoid of Fe-Mg silicates and composed almost entirely of quartz, feldspars and opaque minerals (e.g. some of the dark green types near the Cahora Bassa dam). These types resemble the dark anorthosites and gabbros of the Tete Gabbro-Anorthosite Suite. The charnockitic type of the Castanho Granite is often associated with gabbro and locally with granulite, and may form a "bimodal suite" with the extensive Tete Gabbro-Anorthosite Suite (see Westerhof *et al.* 2008b). The Castanho Granite and gabbros of the Tete Suite have similar ages (c. 1.05 Ga) (Mänttäri 2008).

Monte Sanja Suite

The Monte Sanja Suite forms an over 120 km long and locally up to 35 km wide, NE-SW trending zone of weakly deformed, pinkish or grey biotite-hornblende granite intrusions near the village of

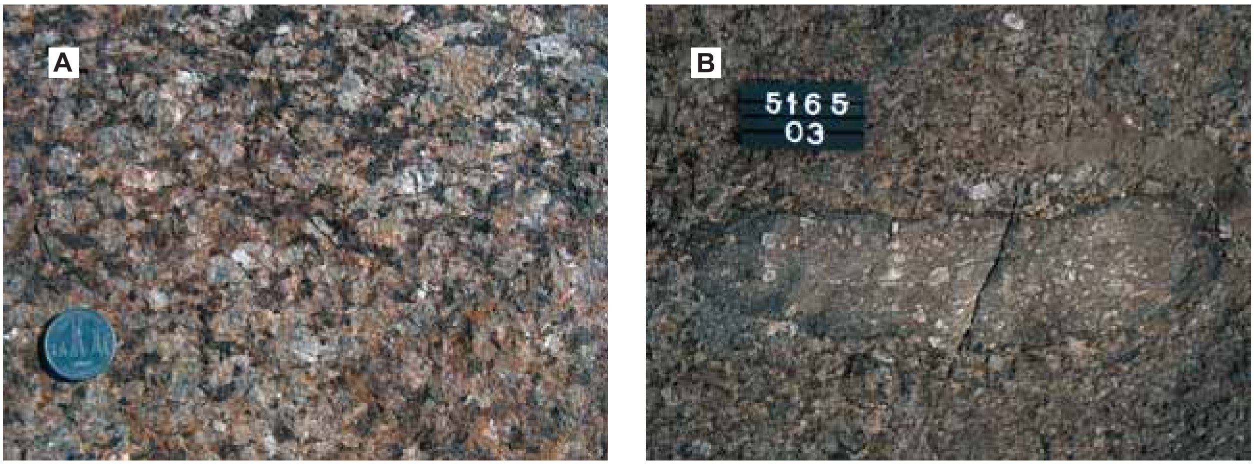

Fig. 7. Castanho Granites. (A) Dark brownish quartz monzonitic granitoid, west of the village of Shigoncho (0401151/ 8351329), (B) Examples of locally abundant, small mafic xenoliths in Castanho Granite, south of Serra Chiúta (0529366/ 8277532). The diameter of the coin is 3 cm, the scale bar is 8 cm.

Fíngoè. These rocks are intrusive to the supracrustal sequences of the Fíngoè Supergroup. Two units occur in the Suite: (1) granite, granodiorite and quartz diorite and (2) quartz monzonite, diorite and tonalite. The latter types are found near Fíngoè.

The granitic rocks of the Suite often form conical, round-topped hills and sugar-loafs interspersed among steep valleys, often resulting in a spectacular high-relief topography. This topographic feature and stronger radiometric signature distinguishes the Monte Sanja Suite granitoids from the surrounding and slightly older granitoids of the Rio Capoche and Cassacatiza Suite. The Monte Sanja rocks locally comprise darker and more mafic enclaves than is typical for the other studied granitoids (Fig. 8).

Fig. 8. Large dioritic xenoliths in Monte Sanja Suite granite, NE of Serra Mezeze (03672939/ 8320902). Note quartz-filled en-échelon fault gashes in xenolith, which do not continue in the granitic host rock. The scale bar is 14 cm.

Mussata Granite

The Mussata granitoids and associated mylonites have been named after the locality of Mussata, situated near the Zambezi River, NW of the town of Tete. Field observations are restricted to a single N-S section along the road to Zambia and to a section south of the village of Songo. The Mussata granitoids are partly remaining below the allochthonous Tete Gabbro-Anorthosite Suite and are mylonitized there (GTK Consortium 2006, Westerhof *et al.* 2008b). Due to deformation, an augen gneiss texture is occasionally found (Fig. 9A).

The Mussata granitoids occur in a 15 km wide belt, stretching north of, and parallel to the Tete Suite, with which it has tectonic contact. Subhorizontal mylonites of the granitoids were mapped in the past as undifferentiated "quartz-feldspathic gneisses" (Hunting 1984), a suitable descriptive term in many cases, which hides, however, the tectonic origin of the "gneissic" fabric (Fig. 9B).

The majority of field observations on these granitoids were carried out on variably mylonitised types, and undeformed relics have been encountered in only a few locations. The latter refer to a light grey to pinkish grey, weathering to light yellowish brown, coarse-grained, generally porphyritic biotite-granite, having K-feldspar phenocrysts and a variable biotite content.

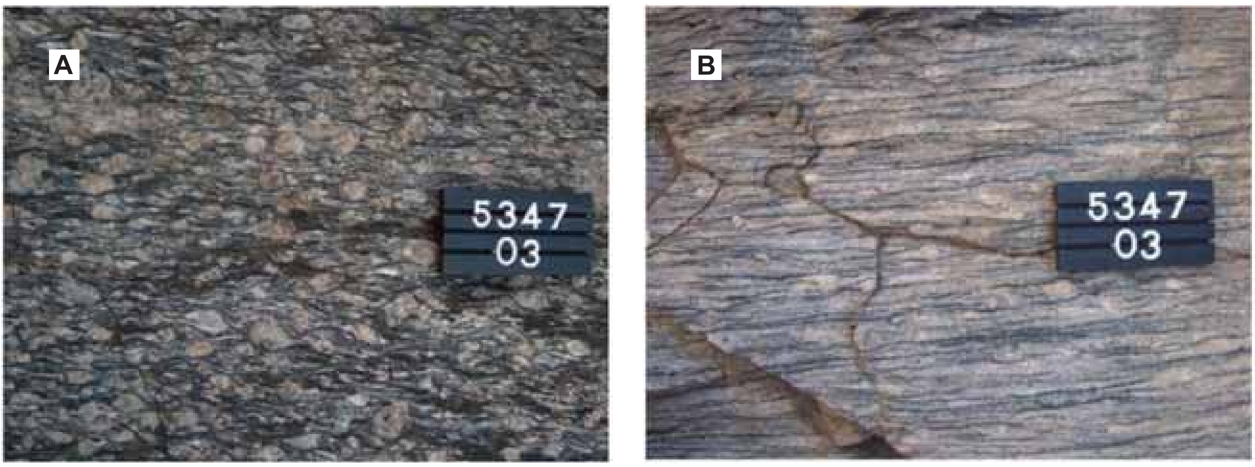

Fig. 9. Examples of the mylonitic fabric in the Mussata Granite. (A) Mylonitic augen gneiss. The higher biotite content has resulted in thick foliation planes wrapping around feldspar porphyroclasts, (B) Ultramylonite. Biotite has neocrystallized into white mica. Feldspar grains are ground and recrystallised into fine quartz-feldspar laminae, with occasional relics of feldspar porphyroclasts. East of Serra Dzunsa (0482376/ 8265619). The scale bar is 8 cm.

Messambe quartz monzonite

Porphyritic quartz monzonite intrusions within the large Serra Danvura pluton near the village of Fíngoè occupy areas up to 50 km^2 in size. They form small, rounded and generally well exposed hills along the main road to the east of Fíngoè, and differ from the surrounding rocks by their higher K-Th-U signatures on radiometric maps.

Weathered surface of the Messambe quartz monzonite is brownish grey, while fresh surfaces have a dark brown colour. Texturally, these weakly deformed rocks are porphyritic; K-feldspar phenocrysts locally exceed 3–4 cm in size. Parallel alignment of potassium feldspar crystals observed in places may indicate magmatic flow. The dominant minerals are K-feldspar, plagioclase and hornblende with subordinate quartz, biotite and locally pyroxene.

Furancungo Suite

The Furancungo Suite, forming an extensive batholith in the northeastern part of studied area, is composed of non-foliated to foliated hornblende biotite granite and minor quartz monzonite(-syenite). It comprises the Desaranhama Granite (main component) and in its southern and eastern peripheries some smaller plutons of somewhat different lithologies. The latter include the Rio Ponfi Quartz monzonite(-monzodiorite), the Nacoco Granite and the Monte Dezenza Granite (GTK Consortium 2006). The Furancungo Suite forms a NNW-SSE directed, elongated massif (250 x 80 km) continuing into Malawi in the SE and into Zambia in the NW. The Furancungo rocks crosscut the Cassacatica Suite granitoids. Moderate to high relief landforms, dissected by numerous fault-related gorges, characterise the central parts of the Furancungo Suite.

The Desanharama Granite is principally composed of a non-foliated to moderately foliated, pinkish grey, coarse, porphyritic biotite granite with K-feldspar phenocrysts, 1.5–3 cm in diameter. The phenocrysts are in places mantled by white plagioclase. Small mafic enclaves are locally common. The granite becomes deformed in its eastern arcuate periphery, where the main rock type is very coarse-grained, biotite bearing, K-feldspar porphyritic, often veined granite gneiss or augen gneiss (Fig. 10).

Fig. 10. Close-up photo of deformed Desaranhama Granite. North of Monte Cangangunde (0636780/ 8339956). The scale bar is 14 cm.

Marirongoe Granite

The Marirongoe Granite forms a roundish pluton by the Fíngoè-Zâmbuè road 50 km west of Fíngoè village. It has a unique feature compared to other granitoids: owing to numerous pegmatites, it is selectively quarried in tens of open pits for “blue sky” mineral (aquamarine) and topaz. The Marirongoe granite is grey, medium-grained and usually weakly foliated biotite granite with only subordinate hornblende, and locally epidote. Texturally, it is mostly even-grained, but some porphyritic varieties also exist, occasionally with *rapakivi* textures. Some of the even-grained types resemble granitized quartz-feldspar gneisses.

Matunda Suite

The Matunda Suite is situated in the Zumbo area, in the western corner of Tete Province, where it is bound by the Zâmbuè Supergroup in the north, by the Cassacatiza Suite in the east and by the Fíngoè Supergroup in the south. The Suite comprises biotite- and hornblende-bearing granite gneisses, interlayered felsic and mafic gneisses and isolated metagabbro and metadiabase bodies, locally cut by a swarm of wide pegmatite dykes.

The Matunda Suite forms a domal structure, in the south, where it is outlined by regional scale circular landscape morphology. On radiometric images the Matunda Suite is dominated by K, with less U, resulting in light blue to cyan colours in the ternary radiometric image. A radiometric U–Pb determination indicates a Pan-African metamorphic age (c. 0.53 Ga) for these gneisses (Mänttäri 2008). However, zircons in these gneisses also comprise cores, indicating a c. 0.8 Ga thermotectonic event.

Monte Inchinga granite

The Monte Inchinga granite, named after the mountain, comprises several plutons on the northern shore of Cahora Bassa Lake. Because these granites have intruded at and near the E-W trending Sanangoè Shear Zone (SSZ) (Fig. 1), they are probably Neoproterozoic to late Pan-African in age. The SSZ is a Pan-African transpressional fault zone (Westerhof *et al.* 2008a). The Monte Inchinga granites are light grey to pinkish grey, medium- to coarse-grained biotite hornblende microcline granites with a distinct porphyritic texture (Fig. 11A).

Sinda Suite

Several bodies of porphyritic granite have intruded metasediments of the Zâmbuè Supergroup in the northwestern margin of Tete Province and form a voluminous, early Palaeozoic Sinda Suite c. 0.50 Ga in age. Described firstly on the Zambian side by Phillips (1957, 1965), these generally undeformed intrusive rocks belong to the last stages of Pan-African magmatism and, together with the Macanga granite, represent the youngest granites in the study area.

The Sinda Suite granites are light pinkish or yellowish brown, coarse-grained, porphyritic microcline granites (Fig. 11B) with euhedral K-feldspar phenocrysts (0.5–2 cm in size). They usually have a high radiometric K-U-Th signature. Thin crosscutting granitic dykes or veins are usually fine- to mediumgrained.

Macanga granite

Eight granite intrusions, from 3 to 10–20 km in diameter, crosscut the older Precambrian crystalline basement in the northern part of study area on both sides of the main road from the town of Tete to Cassacatiza, a border post to Zambia. Their high to very high Th-U-K radiometric signatures (Fig. 12), and the fact that they cluster in a relatively small area, differentiate them from other representatives of the "late-Precambrian group" *sensu* Hunting (1984), justifying the definition of a separate family of granitoid intrusions.

A typical example of the Macanga granite, a large NE-elongated body (Fig. 12B) is a pink to light grey in colour, medium-grained and massive biotite granite. Semi-angular enclaves of light grey quartz-feldspar rock (supposedly belonging to the Chidzolomondo Group) are common in the granite. Coarse pegmatite bodies, typically with magnetite, have intruded the granite.

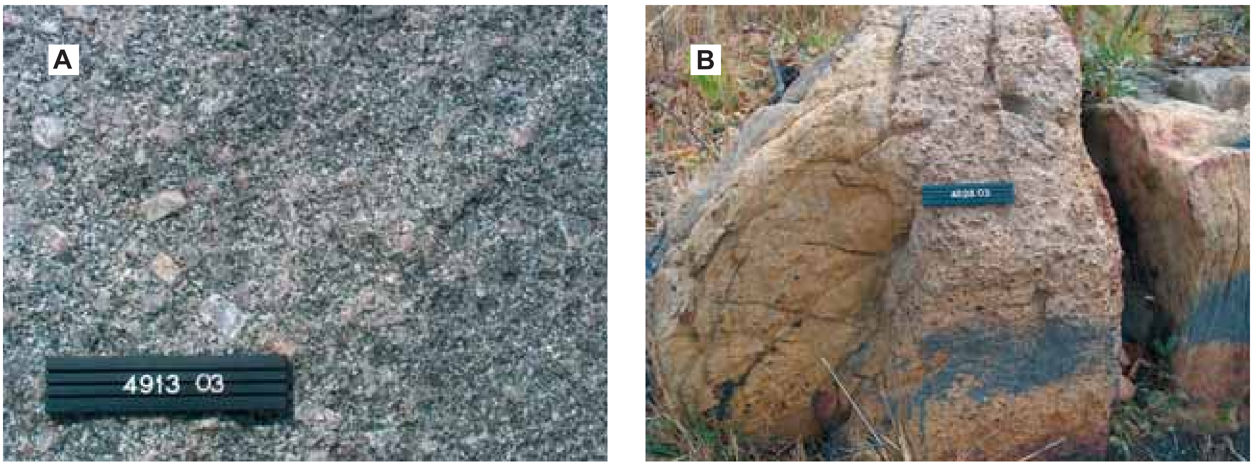

Fig. 11. Neoproterozoic-Cambrian intrusives. (A) Close-up photo of porphyritic Monte Inchinga granite. Rio Tongoé (0260292/ 8285447). (B) A dyke of coarse-grained, porphyritic Sinda Suite granite has intruded light brown, weakly banded meta-arkose of the Metamboa Formation of the Zâmbuè Supergroup. North of Monte Luala (0314716/ 8365524). The scale bar is 14 cm.

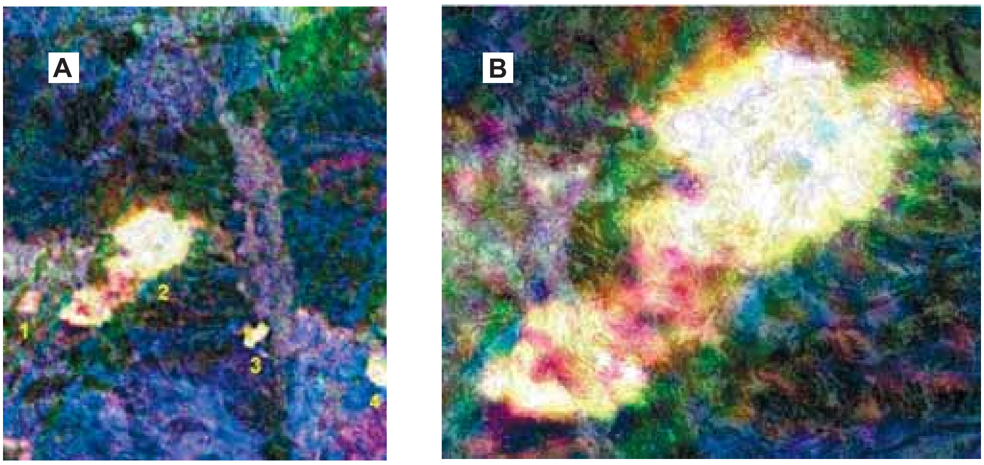

Fig. 12. (A) High to very high Th-U-K radiometric signature in four (1–4) Macanga granite intrusions. 100 km NW of the town of Tete. (B) Note the crescent-shaped landscape features in the southern half of body No. 2, thought to reflect successive injections of magma sheets along the SW margin of the northern core. The width of the area in (B) is 24 km.

Other granitoids

In addition to the granitoids described here, some small granite areas can also be distinguished. For example, the Neoproterozoic Monte Tarai Granite, which forms a one kilometre wide and several kilometres long mountain chain in the Chidzolomondo gneisses, occurs near the Zambian border, on the eastern side of the Luatize River. According to Hunting (1984), quartz-feldspar porphyries are especially common in these remote mountains. The other granitoids with small extent are the Boesi granite, the Monte Dómue granite and the Cassenga Leucogranite (GTK Consortium 2006).

GEOCHEMISTRY

Introduction

Chemical whole rock analyses (55 in total) have been used to classify the granitoid rocks and to evaluate crustal evolution in the northern part of Tete Province (Figs 13–16 and Appendix 1). The Fe# symbol, which occurs in the text of the geochemistry chapters and in Appendix 1, represents Fe_2O_3t / (Fe_2O_3t+MgO). The chemical composition of selected minerals of these granitoids is presented in Appendix 2.

Analytical procedures

Major and some trace element (V, Zr, La, Ce, Ba, Sr, Rb, Y, Nb, Th) concentrations were analysed by XRF from pressed powder pellets in the Chemical Laboratory of Geological Survey of Finland. The mineral analyses were carried out from polished thin sections using a Cameca SX100 electron microprobe at GTK.

Chemical characteristics of the rocks

According to the classification of Middlemost (1994) and Streckeisen and Le Maitre (1979), most granitoids are granites (Figs 13A, B). Their aluminium saturation index varies from metaluminous to slightly peraluminous (Fig. 13C). In general, most granitoids are geochemically alkalic to calc-alkalic and have ferroan affinities (Figs 13D, E). The petrographically distinguished phases in the Rio Capoche Granite, Serra Danvura granitoids, Cassacatiza Suite and Furancungo Suite predictably show scatter and poor correlation in the diagrams (Figs 13–15). Notably, most of the Mesoproterozoic granite analyses plot in the field of post-collisional granites according to the classification of Pearce (1996, Figure 3) (see also Fig. 14). A more detailed description of sampled and analysed units is given in the following.

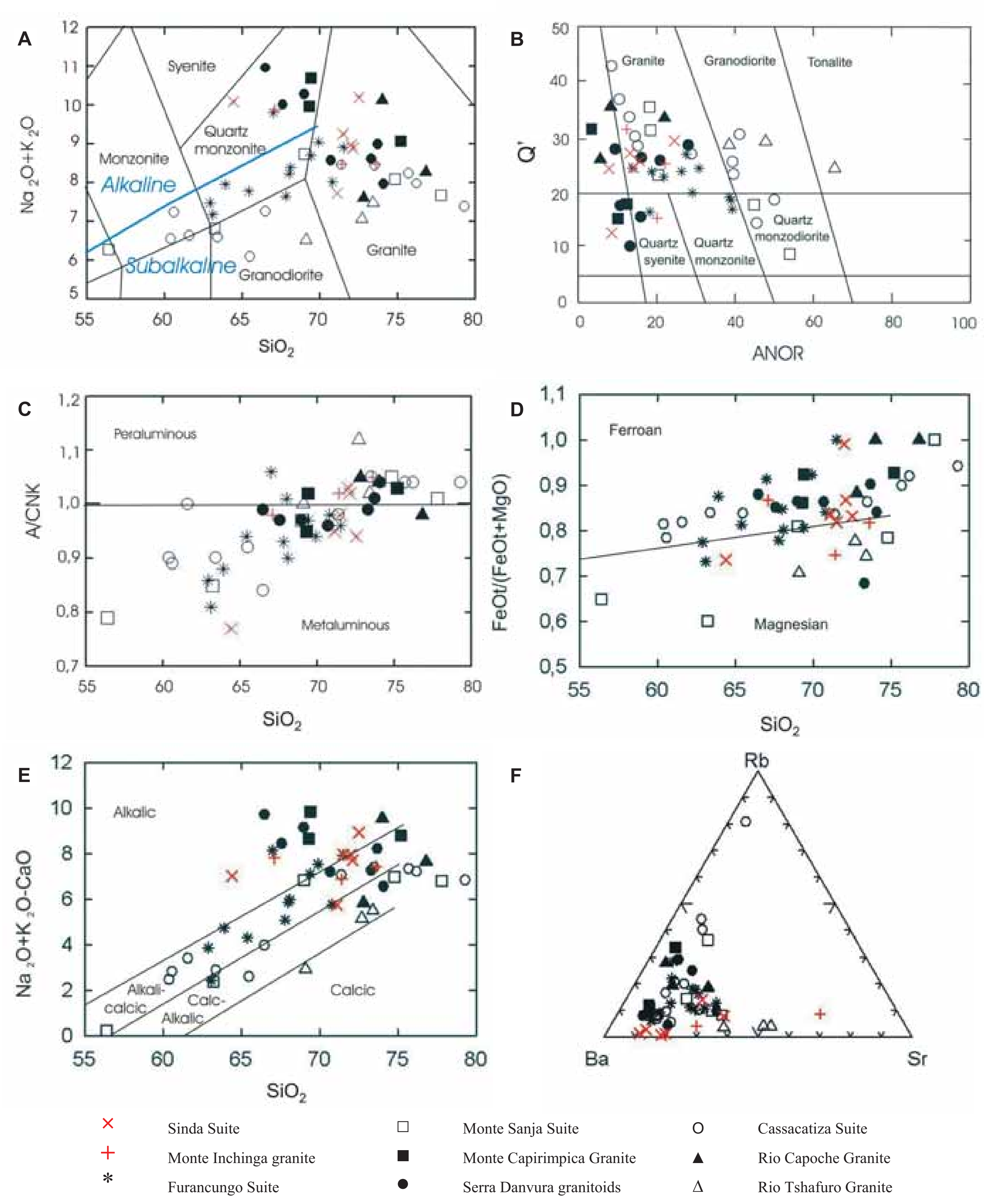

Fig. 13. Classification diagrams for the granitoids. (A) (Na_2O+K_2O) vs. SiO_2 (TAS) diagram of Middlemost (1994). The blue line separating alkaline and subalkaline fields is after Le Bas *et al.* (1986), (B) Q' vs. ANOR diagram of Streckeisen and Le Maitre (1979), (C) the aluminium saturation index A/CNK (Shand 1947), (D) FeOt/(FeOt+MgO) vs. SiO_2 diagram of Frost *et al.* (2001), (E) Na_2O+K_2O-CaO vs. SiO_2 diagram of Frost *et al.* (2001) and (F) Ba-Rb-Sr diagram.

Rio Tchafuro Granite

The three analyses of Rio Tchafuro granitoids plot as subalkaline, peraluminous granites, granodiorites and tonalites and differ in their chemical characteristics from other major Mesoproterozoic plutonic rocks within the northern part of Tete Province (Figs 13A–C). The low Rb/Ba and Rb/Sr ratios also clearly separate these samples from other granitoids, as does the lower Fe# (0.71–0.78, see Appendix 1). The Rb content of Rio Tchafuro rocks is low (~43 ppm), while the Sr content is high (~530 ppm) in comparison to the other studied Mesoproterozoic granitoids.

Rio Capoche Granite

The analyzed samples classify the Rio Capoche granitoids as sub-alkaline and ferroan (Figs 13A, D). Two samples have features of alkali-feldspar granites (Figs 13A, B). Their Rb-Sr-Ba ratios plot in the central part of the spectrum that stretches from the Ba apex to the Rb apex, defined by the other studied Mesoproterozoic granitoids (Fig. 13F). Two analyses have MgO contents below the detection limit and refer to very high Fe/Mg, as does the third analysed sample with Fe# 0.88 (Appendix 1).

Cassacatiza Suite

The SiO_2 content of the Cassacatiza Suite ranges between 60.4–79.3 wt.%; this refers to intermediate and felsic compositions (Appendix 1). The lack of lower silica values is also verified in field observations by the absence of mafic rock types such as diorite and gabbro amongst the granitoids. However, titanium is partly enriched (up to 1.5 wt.% TiO_2) in the Cassacatiza rocks.

Chemical and molar norm compositions show that the Cassacatiza granitoids form a continuous differentiation trend from quartz monzodiorite to granite (Figs 13A, B). However, some quartz monzonites(-syenites) were observed by modal composition without chemical analyses. Thus, a monzonitic trend also seems to characterize the granitoids of the Cassacatiza Suite. All analysed samples are subalkaline and most are metaluminous (Figs 13A, C). On the AFM diagram of Irvine and Baragar (1971) the granitoids plot in the calc-alkaline field, while the rocks with a lower SiO_2 content straddle the boundary between the calc-alkaline and tholeiitic fields, indicating moderately ferriferous compositions (Fe# >0.80, Appendix 1).

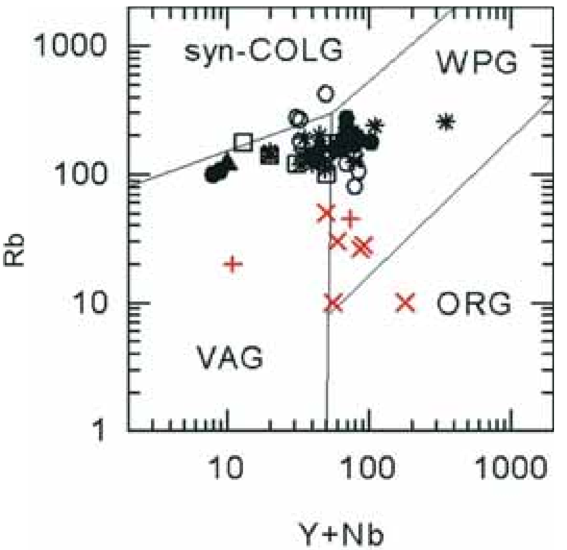

Fig. 14. LogRb vs. Log(Y+Nb) diagram of Pearce *et al.* (1984), where syn-COLG = syn-collisional granites, WPG = within plate granites, VAG = volcanic arc granites, ORG = ocean ridge granites. Symbols as in Figure 13.

On the Rb-Sr-Ba ternary diagram a group of analyses close to the Ba apex (high Ba/Rb ratio) is separated from the rest of the Cassacatiza data (Fig. 13F). This group of high Ba/Rb is equal to the low silica content Cassacatiza granitoids (SiO_2 <65.5 wt.%) and represents quartz monzodiorite members (Appendix 1). A low Sr/Ba can be expected for the monzonitic series.

On Harker diagrams, a reasonably distinct fractionation trend can be seen when SiO_2 is plotted against TiO_2, Al_2O_3, Fe_2O_3t, K_2O, CaO, P_2O_5 and Zr, despite a gap in SiO_2 values from 66.5 to 71.4 wt.% (some are shown in Figure 15). This gap may indicate that the entire Cassacatiza Suite is not cogenetic, though the gap may also result from insufficient data.

Serra Danvura granitoids

The range of SiO_2 contents of these granitoids, from 66.5 to 74.1 wt.%, manifests the differentiation from quartz syenite to granite in the Na_2O+K_2O vs. SiO_2 and Q' vs. ANOR classification diagrams (Fig. 13A, B). The analytical values straddle the boundary between the alkaline and subalkaline fields (Fig. 13A) and the composition is between per- and metaluminous (Fig. 13C). The Na_2O, K_2O and Zr contents of the Serra Danvura granitoids are locally elevated – a slight alkalinity and syenitic characters separate these granitoids from all other granitoids, except the Monte Capirimpica Granite.

On Rb vs. Y+Nb diagram (Fig. 14), which separates different geotectonic settings, the Serra Danvura granitoids plot very similarly to other Mesoproterozoic granitoids of the northern Tete Province; around the boundary line of *volcanic arc* and *within plate granites*.

Monte Capirimpica Granite

The analyses of these granites plot as alkali feldspar granites and quartz syenites (Figs 13A, B). They are transitional between alkaline and subalkaline affinities and on the aluminium saturation diagram transitional between met- and peraluminous rocks (Figs 13A, C). The low Sr/Ba is compatible with syenitic rocks (see Fig. 13F). Together with the Serra Danvura granitoids, the Monte Capirimpica granites are the most alkaline of all granitoids in the northern Tete Province.

Castanho Granite

In Fig. 16, the chemical analyses from Castanho Granite, Tete Gabbro-Anorthosite Suite and Chipera Gabbro have been plotted together to test their possible spatial and temporal relationship (Anorthosite-Mangerite-Charnockite-Granite Complexes). Two analyses (shown in Appendix 1) of the Castanho Granite classify them as felsic rocks (Fig. 16), which are also strongly ferrugineous (Fe# 0.85–0.90) and have elevated Zr contents (~520 ppm). In many discrimination diagrams the gabbroic analyses of the Castanho Granite plot in the same field as the gabbros of the Tete Suite (GTK Consortium 2006, Westerhof *et al.* 2008a). They all are subalkaline tholeiites. The Castanho Granite analyses together with the analyses of the Tete Suite form an arcuate line resembling a magmatic differentiation/fractionation trend on the CaO-MgO-Al_2O_3 diagram (Westerhof *et al.* 2008a, Fig. 6).

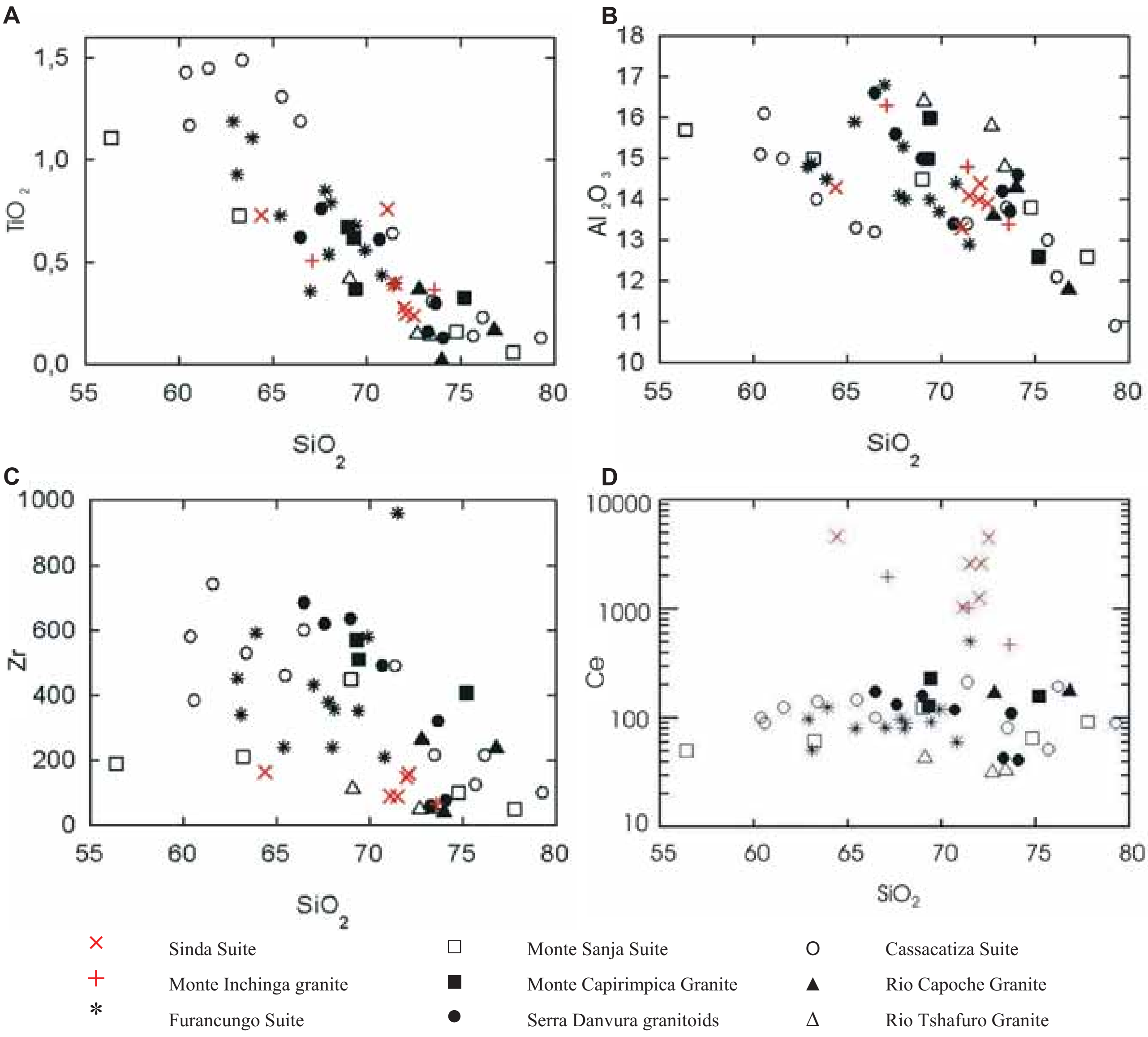

Fig. 15. Selected Harker diagrams for the granitoids.

Monte Sanja Suite

The analysed Monte Sanja samples have a wide range of SiO_2 contents (56.4–77.8 wt.%, Appendix 1), which according to the classification of Streckeisen and Le Maitre (1979) corresponds with quartz-monzodiorites and granites. The whole series is subalkaline to calc-alkaline (Figs 13A, E). Monzodioritic rocks are clearly metaluminous, while granites straddle between the fields of met- and peraluminous rocks (Fig. 13C). In a ternary Rb-Sr-Ba diagram (Fig. 13F), Monte Sanja granitoids indicate moderately high Ba/Rb and Ba/Sr, approximately similar to other Mesoproterozic granitoids of the northern part of Tete Province, save Rio Tchafuro granitoids, which have distinctly low Rb/Sr and Rb/Ba.

In general, the geochemistry of the Monte Sanja Suite granitoids is similar to the Cassacatiza Suite, but the clear calc-alkalinity of the Monte Sanja Suite strongly differs from the tholeiitic character of the latter.

Furancungo Suite

The SiO_2 content of Furancungo granitoids ranges from 62.9 to 72.5 wt.%, forming a differentiation trend from granite to quartz monzonite and quartz syenite, and referring to a K-enriched magma series (Figs 13A, B). The total alkali content is reasonably high (7–10 wt.%, Appendix 1), but the granitoids still plot in the subalkaline field in the diagram (Fig. 13A).

These most metaluminous rocks have high Fe/Mg ratios (Fe# 0.73–0.92, Appendix 1), which can also be seen in the AFM diagram, where the analyses plot on the boundary between the calc-alkaline and tholeiitic fields. Moreover, the Mg and Zr contents of the Furancungo granitoids vary notably at a given SiO_2 (Fig. 15C). The Rb vs. Y+Nb ratios refer to a *volcanic arc* to *within-plate* environment (Fig. 14).

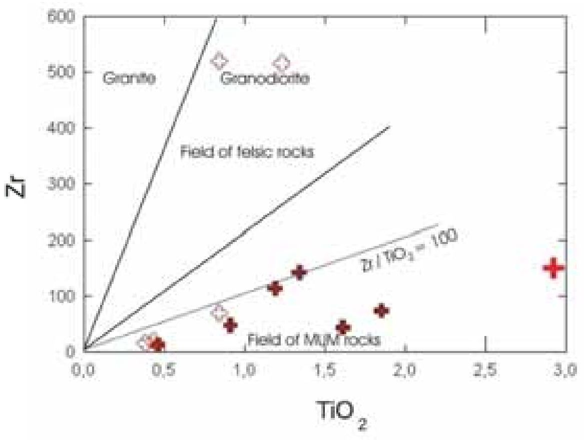

Fig. 16. Chemical Zr vs.TiO2 diagram of Winchester and Floyd (1977) for classification and for comparison with the Castanho Granites, Tete Suite gabbroic rocks and Chipera Gabbro. Open crosses are Castanho Granite samples, brown crosses are gabbro samples from the Tete Suite and the red cross refers to a sample of Chipera Gabbro nearby. MUM = mafic and ultramafic.

Monte Inchinga granite

Three analyses were carried out from these obviously Neoproterozoic granitoids. The SiO_2 content of the analysed samples ranges from 67.1 to 73.6 wt.%. Cerium concentrations are elevated (up to 1985 ppm), but Rb and Zr contents are low, often below the detection limit (Fig. 15D, Appendix 1). The tectonic diagram shown in Fig. 14 also supports the idea that these rocks are not *syn-collisional*.

Sinda Suite

These Pan-African granitoids plot in alkalic to alkali-calcic fields in Fig. 13E. The analysed Sinda Suite samples have a relative small range of SiO_2 contents (67.1–73.6 wt.%). They are also characterized by a higher V content and a lower Rb content than the Mesoproterozoic granitoids (Appendix 1). Moreover, Ce and La are clearly elevated, having concentrations between 1000–4600 ppm (Fig. 15D) and 75–255 ppm, respectively. In the tectonic diagram of Figure 14, the Sinda Suite granites are clearly distinguished form the Mesoproterozoic granitoids, showing characteristics of *within-plate* granites.

Mineral chemistry

The microprobe analyses of minerals (see Appendix 2) have focused on charnockitic rocks of the study area.

The Fe/(Fe+Mg) of the Castanho Granite charnockites orthopyroxene ranges from 0.79 to 0.87, and that of clinopyroxene from 0.78 to 0.84. The relatively low Al_2O_3 content (~0.5 wt.%) of these orthopyroxenes, compared to orthopyroxenes of the supracrustal Chidzolomondo granulite gneisses nearby, indicates magmatic crystallization (see e.g. McFarlane *et al.* 2003).

Although macroscopically the Rio Capoche intrusions locally resemble Castanho Granite rocks, their orthopyroxene does not have a high Fe/(Fe+Mg), which is common in pyroxenes of the Castanho Granite samples. This suggests that the mineralogy of Rio Capoche intrusions is metamorphic while the pyroxenes of the Castanho Granite rocks are of magmatic origin.

The amphibole of the quartz syenitic types of Castanho Granite has very high Fe/(Fe+Mg), up to 0.95 (FeOt 31.2 wt.%, MgO 0.9 wt.%). In some amphiboles TiO_2 can be ~2.7 wt.% and Na_2O ~2.3 wt.%. However, the amphibole in the granites, *sensu stricto*, of Castanho Granite is generally hastingsitic with Fe/(Fe+Mg) in the range of 0.78–0.85. Biotite of the Castanho Granite is relative rich in iron, Fe/(Fe+Mg) ranging from 0.64 to 0.77. Locally in the granites, biotite may contain up to 4 wt.% fluorine and almost 5 wt.% TiO_2 (Appendix 2).

In the NE part of Monte Sanja Suite, the hornblende of the granites locally has a somewhat elevated Na_2O content (~1.9 wt.%) and biotite may have a F content up to 3.1 wt.%. However, the Mg-Fe silicates of the Monte Sanja Suite are not as ferroan as those of the Castanho Granite (Appendix 2).

In the contact area of the Matunba Suite and Cassacatiza Suite, near Monte Sumba in the western part of Tete Province, hornblende of the foliated quartz syenite has a very high Fe/Mg ratio, over 0.9 (FeOt 32.3 wt.%, MgO 0.9 wt.%, see Appendix 2). Lower values of Fe/Mg can be expected in minerals of metamorphic origin. Accordingly, these syenitic rocks with a high Fe/Mg ratio should be placed in the Cassacatiza Suite rather than in the Matunda Suite, which has undergone Pan-African metamorphism. Amphibole of the Cassacatiza Suite quartz syenite, at Monte Chipalava, also has a very high Fe/Mg ratio (Appendix 2).

DISCUSSION

Based on the diverse data collected during 2002–2005, we considered that the identified granitoid units should be provisionally named after a type locality (Fig. 1 and Table 1). As a consequence, more than a dozen granitoid suites or related assemblages have been identified. The differentiation between these igneous suites is based on age, geophysical signature, geochemistry and field and laboratory observations.

The studied basement is part of the larger Tete-Chipata Belt (Westerhof *et al.* 2008a). The bulk of the granitic rocks has a “Grenville” age between 1.20 and 1.04 Ga. Data on older basement granitoids or Ubendian rocks (De Waele *et al.* 2003) in the Tete-Chipata Belt are restricted to a dating from the Zambian side of the border (Cox *et al.* 2002). The undated Rio Messeze orthogneisses (Fig. 3) may be equivalent to the latter. The origin of granite boulders found in the ~1.3 Ga Fíngoè Supergroup conglomerates (Hunting 1984, GTK Consortium 2006) in Tete Province remains unknown.

Geochemically, the presently studied Mesoproteroic ferroan granitoids suggest an extensional tectonic regime (see Frost *et al.* 2001) in the Tete-Chipata Belt. However, there are regional differences; the Serra Danvura granitoids in the south comprise relative high alkalies (Na_2O+K_2O, in total 8–11 wt.%) while the Cassacatica Suite in the north has higher iron and magnesium contents than the former. The absence of S-type granitoids in northern part of Tete Province indicates that sedimentary rocks did not dominate in the source areas.

The charnockitic Castanho Granite, associated with Tete Gabbro-Anorthosite Suite, may be the result of melting of a previously dehydrated lower crust. This would explain the occurrence of the Castanho Granite charnockites adjacent to the Chidzolomondo granulites. Depending on the composition of the lower crust, the charnockitic melts may acquire a range of compositions, further widened by potential crustal contamination during ascent. In conclusion, the anorthosites of Tete Suite and associated charnockite intrusions are not co-magmatic but are derived from coexisting melts, and slight differences in emplacement age may therefore exist (Westerhof *et al.* 2008b).

The older, c. 0.8 Ga zircons found in the c. 0.53 Ga Matunda granite gneisses may reflect the Rodinia Supercontinent breakdown event and/or formation of juvenile crust during post-Grenville Neoproterozoic extensional phase. Notably, the large ultramafic-mafic Atchiza Suite in the western part of Tete Province has the same age, c. 0.86 Ga (Mänttäri 2008), supporting a distinct Neoproterozoic thermotectonic event.

The Matunda granite gneisses resemble rocks reported from Zambia and Zimbabwe by Goscombe *et al.* (2000) and Johnson and Oliver (2004). The formation of the Pan-African metamorphic c. 0.53 Ga Matunda gneisses possibly corresponded with the collision and amalgamation of the West and South Gondwana Terranes – as interpreted for near gneisses by Goscombe *et al.* (2000) and Johnson and Oliver (2004). The same thermotectonic event is indicated by the coeval emplacement of Monte Inchinga granitic plutons within or adjacent to the Pan-African Sanângoè Shear Zone. Finally, some of the post-Pan-African granite intrusions (e.g. the Sinda Suite) were emplaced in this collage of terranes as "stitching plutons". However, the post-Pan-African c. 0.47 Ga Macanga granite may also manifest west-vergent subduction of East Gondwana, followed by amalgamation and possible crustal thickening (GTK Consortium 2006). In the Tete area this (pseudo-)suture of East and West Gondwana is believed to correspond to the contact between the Desaranhama Granite and the NW-SE trending Angónia Group (Fig. 1).

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Appendix 1.

Chemical composition of the granitoids from the northern part of Tete Province. The intrusion group, rock type, sample number and coordinates are given. b.d. = below detection limit. Detection limits were 0.033 wt% for MgO and 0.014 wt% for P_2O_5.

	Rio Tchafuro Granite			Rio Capoche Granite			Cassacatiza Suite											Serra Danvura granitoids	
	Tonalite	Grano-diorite	Grano-diorite	Granite	Granite	Granite	Quartz monzo-diorite	Quartz monzo-diorite	Granite gneiss	Grano-diorite	Grano-diorite	Granite	Granite	Granite	Granite	Granite	Granite	Quartz syenite	Quartz syenite
SiO_2 wt%	69.1	72.7	73.4	72.8	74.0	76.8	60.4	60.6	61.6	63.4	65.5	66.5	71.4	73.5	75.7	76.2	79.3	66.5	67.6
TiO_2	0.42	0.15	0.14	0.37	0.02	0.17	1.43	1.17	1.45	1.49	1.31	1.19	0.64	0.31	0.14	0.23	0.13	0.62	0.76
Al_2O_3	16.4	15.8	14.8	13.6	14.3	11.8	15.1	16.1	15.0	14.0	13.3	13.2	13.4	13.8	13.0	12.1	10.9	16.6	15.6
Fe_2O_3t	2.50	1.53	1.33	2.93	0.60	1.87	9.18	7.51	8.62	8.05	7.78	6.62	3.41	2.07	1.42	2.06	1.28	2.97	3.14
MnO	0.04	0.04	0.03	0.04	0.01	0.02	0.18	0.12	0.15	0.15	0.13	0.12	0.06	0.07	0.05	0.03	0.03	0.07	0.09
MgO	1.04	0.44	0.46	0.39	b.d.	b.d.	2.10	2.08	1.92	1.55	1.51	0.91	0.67	0.33	0.16	0.18	0.08	0.41	0.55
CaO	3.60	1.92	2.00	1.77	0.59	0.64	4.09	4.43	3.24	3.73	3.50	3.31	1.41	1.06	0.92	0.78	0.57	1.26	1.58
Na_2O	4.99	5.37	4.87	2.77	2.99	3.31	3.85	3.87	3.44	2.86	2.63	3.34	3.39	3.65	3.39	2.86	2.58	4.72	4.35
K_2O	1.53	1.70	2.61	4.83	7.14	4.97	2.70	3.37	3.19	3.74	3.46	3.93	5.07	4.79	4.85	5.12	4.81	6.24	5.66
P_2O_5	0.12	0.05	0.04	0.11	0.06	b.d.	0.54	0.37	0.57	0.60	0.39	0.45	0.25	0.07	0.04	0.05	0.03	0.10	0.19
Total	99.74	99.7	99.68	99.61	99.71	99.58	99.57	99.62	99.18	99.57	99.51	99.57	99.7	99.65	99.67	99.61	99.71	99.49	99.52
A/CNK	1.00	1.12	1.02	1.05	1.04	0.98	0.90	0.89	1.00	0.90	0.92	0.84	0.98	1.05	1.04	1.04	1.04	0.99	0.97
Fe#	0.71	0.78	0.74	0.88			0.81	0.78	0.82	0.84	0.84	0.88	0.84	0.86	0.90	0.92	0.94	0.88	0.85
V ppm	57	b.d.	b.d	b.d.	b.d.	b.d.	120	146	130	130	150	100	60	b.d.	b.d.	b.d.	b.d.	40	46
Zr	112	50	53	264	40	237	580	384	742	530	460	600	490	216	125	215	100	685	619
La	b.d.	b.d.	b.d	70	b.d.	72	50	30	57	60	56	40	90	53	b.d.	63	30	73	52
Ce	43	32	33	168	b.d.	175	100	90	125	140	146	100	210	81	51	193	90	173	132
Ba	443	543	770	579	370	428	1110	924	1240	1110	623	1200	740	786	287	315	70	1634	1579
Sr	528	585	481	107	160	40	280	375	218	230	158	210	140	130	60	79	30	170	184
Rb	39	46	44	164	120	180	80	146	105	140	194	120	230	180	273	263	420	155	169
Y	b.d.	b.d.	b.d	35	10	67	60	39	57	60	57	50	50	33	18	24	50	46	62
Nb	b.d.	b.d.	b.d	10	b.d.	18	20	15	28	20	26	20	20	b.d.	13	9	b.d.	18	18
Th	b.d.	b.d.	b.d	27	b.d.	19	b.d.	12	b.d.	b.d.	11	b.d.	20	12	24	59	30	12	b.d.
Sample	5066	5074	5059	2034-03	2217	5007	14069	2227	8015	7185	4946	2007-03	2001-03	11101	11099	3469	8623	3193	3191
Easting	442158	438889	444763	519584	469299	470212	371625	436738	314125	333114	268312	431190	429232	320733	319624	357157	386330	383934	382921
Northing	8390845	8396983	8385516	8319614	8326609	8346427	8336184	8416363	8306826	8337533	8295442	8414422	8414154	8300488	8302233	8334762	8309898	8287162	8288883

Appendix 1.
Continues.

	Serra Danvura granitoids					Monte Capirimpica Granite			Castanho Granite		Monte Sanja Suite					Furancungo Suite			
	Quartz syenite	Granite	Granite	Granite	Granite	Granite	Granite	Granite	Quartz monzonite	Granite	Quartz monzo-diorite	Quartz monzo-diorite	Granite	Granite	Granite	Quartz monzonite	Quartz monzonite	Quartz syenite	Granite
SiO_2 wt%	69.0	70.7	73.3	73.7	74.1	69.3	69.4	75.2	59.9	65.1	56.4	63.2	69.0	74.8	77.8	62.9	63.1	63.9	65.4
TiO_2	0.67	0.61	0.16	0.30	0.13	0.62	0.37	0.33	1.23	0.84	1.11	0.73	0.67	0.16	0.06	1.19	0.93	1.11	0.73
Al_2O_3	15.0	13.4	14.2	13.7	14.6	15.0	16.0	12.6	15.7	15.2	15.7	15.0	14.5	13.8	12.6	14.8	14.9	14.5	15.9
Fe_2O_3t	2.72	4.01	1.27	1.83	1.10	2.72	2.06	1.90	9.20	6.08	8.68	5.41	3.48	1.27	0.62	7.13	6.18	7.42	4.93
MnO	0.07	0.08	0.04	0.04	0.05	0.07	0.06	0.04	0.15	0.09	0.15	0.09	0.07	0.02	0.03	0.09	0.09	0.11	0.07
MgO	0.43	0.64	0.59	0.20	0.21	0.44	0.17	0.15	1.17	0.56	4.71	3.61	0.82	0.35	b.d.	2.08	2.27	1.06	1.14
CaO	1.16	1.39	1.36	0.79	1.42	1.34	0.85	0.30	4.01	2.90	6.06	4.46	1.91	1.13	0.89	3.63	4.75	3.22	3.49
Na_2O	3.93	3.85	4.64	4.18	4.97	4.48	4.68	3.38	4.71	3.87	3.56	3.67	3.53	4.10	4.42	4.51	3.41	3.60	3.91
K_2O	6.36	4.72	3.97	4.81	3.00	5.49	6.01	5.70	3.25	4.77	2.72	3.15	5.21	4.00	3.26	2.97	3.77	4.35	3.88
P_2O_5	0.17	0.19	0.05	0.15	0.02	0.15	0.03	0.05	0.35	0.28	0.45	0.17	0.24	0.04	0.02	0.31	0.22	0.34	0.21
Total	99.51	99.59	99.58	99.7	99.6	99.61	99.63	99.65	99.67	99.69	99.54	99.49	99.43	99.67	99.7	99.61	99.62	99.61	99.66
A/CNK	0.97	0.96	0.99	1.01	1.04	0.95	1.02	1.03	0.85	0.90	0.79	0.85	0.97	1.05	1.01	0.86	0.81	0.88	0.94
Fe#	0.86	0.86	0.68	0.90	0.84	0.86	0.92	0.93	0.89	0.92	0.65	0.60	0.81	0.78		0.77	0.73	0.88	0.81
V ppm	36	52	b.d.	b.d.	b.d.	30	b.d.	b.d.	117	60	210	96.1	65	b.d.	b.d.	155	117	99	70
Zr	635	491	60	320	75	570	510	408	516	520	190	210	448	102	50	452	341	592	240
La	72	33	b.d.	40	b.d.	60	120	76	34	40	b.d.	29	52	b.d.	35	36	b.d.	55	40
Ce	158	118	43	110	41	130	230	160	85	90	50	61	125	66	92	97	51	125	80
Ba	1268	419	1781	570	651	1190	930	366	904	950	980	740	1585	815	134	636	624	723	780
Sr	142	116	430	90	353	140	100	39	212	200	580	370	260	241	43	280	328	155	290
Rb	185	177	99	270	106	160	140	205	63	120	140	120	172	176	101	110	140	126	120
Y	51	79	8	50	9	50	30	55	67	50	20	23	47	13	41	36	33	60	40
Nb	15	25	b.d.	20	b.d.	10	10	18	25	20	b.d.	8	13	b.d.	9	13	b.d.	19	b.d.
Th	b.d.	12	b.d.	40	b.d.	10	10	22	b.d.	b.d.	b.d.	11.2	12	10	41	b.d.	13	b.d.	b.d.
Sample	3214	3399	3933	7213	9131	13032	8631	2254	6054	2096	8030	4054	3016	4313	4329	7014	34420	10130	2147
Easting	384063	345807	429105	392272	425249	384685	386662	432635	506180	547321	324445	376230	351049	398568	401269	651907	498546	544246	585697
Northing	8286652	8288337	8313451	8324577	8320051	8304453	8314543	8416448	8335716	8327619	8292172	8321297	8314750	8328068	8331735	8305648	8407294	8342217	8305457

Appendix 1.
Continues.

	Furancungo Suite								Monte Ichinga granite			Sinda Suite					
	Granite	Granite	Granite	Granite	Granite	Granite	Granite	Ortho-gneiss	Quartz syenite	Granite	Granite	Quartz syenite	Granite	Granite	Granite	Granite	Granite
SiO_2 wt%	67.0	67.8	68.0	68.1	69.4	69.9	70.8	71.5	67.1	71.4	73.6	64.4	71.1	71.5	72.0	72.1	72.5
TiO_2	0.36	0.85	0.54	0.79	0.68	0.56	0.44	0.40	0.51	0.39	0.37	0.73	0.76	0.40	0.28	0.25	0.24
Al_2O_3	16.8	14.1	15.3	14.0	14.0	13.7	14.4	12.9	16.3	14.8	13.4	14.3	13.3	14.1	14.0	14.4	13.9
Fe_2O_3t	3.47	4.94	4.15	4.52	4.03	4.30	3.06	4.57	2.92	2.06	2.05	4.09	3.75	2.15	3.07	2.08	0.74
MnO	0.05	0.08	0.04	0.07	0.06	0.07	0.05	0.08	0.05	0.03	0.05	0.07	0.05	0.03	0.07	0.03	0.02
MgO	0.33	1.41	0.75	1.12	0.97	0.36	0.58	b.d.	0.45	0.70	0.46	1.47	0.74	0.48	0.03	0.32	0.15
CaO	1.68	2.58	2.39	2.42	1.60	1.52	2.27	0.99	2.08	1.61	1.05	3.09	1.99	1.31	1.04	1.18	1.27
Na_2O	3.89	3.89	3.26	3.77	3.72	3.54	3.41	3.53	3.96	4.28	3.09	3.70	3.61	3.58	3.53	4.14	2.60
K_2O	5.92	3.76	4.98	4.62	4.98	5.51	4.61	5.38	5.92	4.20	5.38	6.39	4.12	5.68	5.45	4.75	7.59
P_2O_5	0.08	0.23	0.20	0.20	0.17	0.16	0.13	0.05	0.23	0.14	0.11	0.64	0.19	0.15	0.04	0.10	0.13
Total	99.58	99.64	99.61	99.61	99.61	99.62	99.75	99.4	99.52	99.61	99.56	98.88	99.61	99.38	99.51	99.35	99.14
A/CNK	1.06	0.93	1.01	0.90	0.97	0.94	0.98	0.96	0.98	1.02	1.05	0.77	0.95	0.98	1.03	1.02	0.94
Fe#	0.91	0.78	0.85	0.80	0.81	0.92	0.84		0.87	0.75	0.82	0.74	0.84	0.82	0.99	0.87	0.83
V ppm	b.d.	91	60	94	68	40	40	b.d.	343	190	255	480	430	240	570	220	182
Zr	432	379	240	358	353	580	210	960	b.d.	b.d.	66	164	90	90	148	160	b.d.
La	b.d.	b.d.	40	b.d.	39	50	30	218	71	70	134	321	160	180	256	200	76
Ce	82	98	80	90	92	120	60	502	1985	1020	468	4610	1030	2600	1268	2610	4523
Ba	1617	740	1200	653	696	730	570	575	340	400	134	1850	220	900	205	740	1153
Sr	240	247	210	219	221	120	210	74	140	180	345	230	90	130	126	180	259
Rb	120	124	140	190	202	240	150	257	20	b.d.	45	26	50	30	28	10	10
Y	24	36	20	28	34	90	20	261	11	b.d.	26	42	30	30	65	80	17
Nb	9	12	b.d.	7	11	20	b.d.	87	b.d.	20	48	45	20	30	27	100	39
Th	b.d.	16	b.d.	14	14	10	b.d.	17	b.d.	b.d.	11	4	b.d.	b.d.	b.d.	20	b.d.
Sample	6125	7048	2125	7050	7052	2297	2132	6305	9174	8090	34211	4167	3534	4493	1578	2450	4728
Easting	566515	644214	565323	653140	654629	571960	565266	648685	369001	324079	277357	356283	279060	316851	297488	463515	270362
Northing	8314094	8317461	8306412	8325063	8324965	8338805	8300760	8307370	8275637	8293286	8269877	8394459	8344885	8371018	8336545	8369012	8363176

Appendix 2.
Representative chemical composition of minerals in the granitoid rocks. Analyses are made by Cameca Camebax SX100 microprobe in the Geological Survey of Finland. Granitoid group, rock type, observation number and coordinates of the samples are given. Mineral abbreviations are after Kretz (1983). nd = below detection limit. Conditions of analysis were: voltage = 15kV, intensity of beam current = 25nA, beam diameter = 5 µm.

	Rio Capoche Granite Pyroxene granitoid				Rio Capoche Granite Pyroxene granitoid				Cassacatiza Suite Quartz monzonite			Cassacatiza S. Quartz syenite	Castanho Granite Pyroxene granite				Castanho Granite Pyroxene granitoid			
	Opx	Cpx	Bt	Pl	Opx	Cpx	Hbl	Pl	Opx	Bt	Pl	Hbl	Opx	Hbl	Bt	Pl	Opx	Cpx	Hbl	Pl
SiO_2 wt%	52.44	52.49	37.32	61.22	48.25	50.02	41.24	61.09	49.65	35.40	59.91	38.58	48.81	41.94	35.65	60.86	48.39	49.93	40.56	62.10
TiO_2	0.12	0.22	4.80	0.04	0.08	0.12	1.84	nd	0.10	4.47	nd	2.19	0.11	2.24	4.93	0.01	0.09	0.19	2.16	nd
Al_2O_3	0.50	1.11	13.35	23.84	0.31	0.82	9.31	22.95	0.43	13.03	23.69	8.61	0.42	9.03	13.16	24.18	0.42	1.24	9.92	22.35
FeOt	23.55	9.55	13.00	0.17	39.26	19.17	23.84	0.11	31.79	22.63	0.05	31.44	35.43	21.33	22.80	0.12	37.66	18.61	22.43	0.07
MnO	0.74	0.33	0.06	nd	1.00	0.48	0.22	0.01	1.59	0.14	nd	1.01	1.21	0.29	0.08	0.01	1.62	0.80	0.38	nd
MgO	21.35	13.68	15.78	nd	9.13	7.63	6.24	nd	14.03	8.95	nd	0.75	11.84	7.89	8.72	nd	9.79	7.89	6.38	nd
CaO	0.83	21.40	0.01	5.65	0.89	20.18	10.63	5.57	1.03	0.06	6.35	9.55	0.90	10.70	0.03	5.70	0.83	19.53	10.50	4.85
Na_2O	nd	0.42	nd	7.72	0.01	0.31	1.32	8.55	nd	0.06	8.05	2.10	0.01	1.59	0.02	8.06	0.05	0.54	1.78	8.93
K_2O	0.01	nd	9.52	0.63	0.02	0.02	1.43	0.28	0.01	9.37	0.25	1.48	0.01	1.19	9.47	0.43	0.03	0.02	1.63	0.36
P_2O_5	0.01	nd	0.03	0.02	0.03	0.03	0.01	0.03	0.01	0.22	0.01	0.01	0.02	0.01	0.02	0.03	0.01	0.02	0.02	0.01
BaO	0.02	0.03	0.80	0.01	0.01	0.01	0.06	0.02	0.01	0.25	0.01	0.04	0.01	0.03	0.06	0.02	nd	0.02	0.07	0.03
F	0.16	0.11	1.22	0.04	0.11	0.09	0.53	0.03	0.07	0.35	0.02	0.50	0.03	0.38	0.56	0.03	0.12	0.08	0.97	0.02
Total	99.74	99.34	95.89	99.34	99.10	98.87	96.65	98.63	98.73	94.93	98.34	96.27	98.81	96.61	95.50	99.46	99.04	98.94	96.82	98.82
Sample	25434				5184				14069			12108	6038				2435			
Easting	8316623				8326208				8336184			8317326	8327661				8377781			
Northing	455254				481781				371625			289834	487372				430083			

	Castanho Granite Quartz syenite			Castanho Granite Pyroxene granitoid			Castanho Granite Pyroxene granite					Castanho Granite Pyroxene granite			Monte Sanja Suite Granite			Matunda Suite (Cassacatiza?) Quartz syenite
	Hbl1	Hbl2	Bt	Opx	Hbl	Pl	Opx	Cpx	Hbl	Bt	Pl	Opx	Hbl	Bt	Hbl	Bt	Pl	Hbl
SiO_2 wt%	38.90	39.52	33.29	48.12	41.78	64.20	51.46	51.42	49.83	37.70	54.26	47.78	42.90	37.65	44.15	36.86	51.04	38.99
TiO_2	1.31	2.46	3.66	0.06	1.39	nd	0.10	0.40	0.81	4.37	0.02	0.21	1.66	3.61	1.49	3.35	0.11	1.83
Al_2O_3	9.98	9.29	13.83	0.18	8.33	21.46	0.52	1.63	5.35	13.21	28.35	0.40	7.76	11.56	7.22	12.36	0.80	8.03
FeOt	31.22	29.26	32.50	39.84	24.23	0.05	26.98	9.53	11.21	14.49	0.07	38.02	19.82	18.39	16.39	15.55	12.73	32.29
MnO	0.60	0.30	0.29	0.68	0.15	nd	0.66	0.25	0.15	0.05	0.01	1.20	0.30	0.06	0.48	0.11	0.87	0.88
MgO	0.90	2.09	1.20	9.34	6.64	nd	18.51	13.02	15.55	14.48	nd	9.82	9.44	13.06	11.88	14.13	11.24	0.94
CaO	10.30	10.15	0.14	0.71	10.57	3.19	0.55	21.51	11.55	0.06	10.67	1.13	10.81	0.02	10.75	0.02	20.16	9.56
Na_2O	1.53	1.51	nd	nd	1.46	10.34	0.03	0.34	0.72	0.07	5.22	0.01	1.99	0.06	1.87	0.03	0.54	1.79
K_2O	1.41	1.67	8.18	0.01	1.11	0.13	0.01	0.06	0.47	9.36	0.11	nd	1.36	9.62	1.05	9.60	0.02	1.38
P_2O_5	0.01	0.03	0.05	0.01	0.02	0.00	0.01	0.02	0.03	0.03	0.04	nd	0.03	0.01	nd	nd	0.06	0.01
BaO	0.02	0.06	0.20	0.01	0.03	0.03	nd	nd	0.01	0.30	0.00	0.02	0.02	0.27	0.07	0.09	0.02	0.03
F	0.44	0.53	0.75	0.10	0.31	0.01	0.06	0.06	0.36	1.10	0.03	nd	2.06	3.97	1.50	3.09	0.03	0.33
Total	96.63	96.87	94.10	99.08	96.00	99.40	98.88	98.25	96.02	95.23	98.78	98.58	98.16	98.29	96.85	95.18	97.62	96.03
Sample	5310			2060			8587					5314			3105			7298
Easting	8286180			8327693			8311544					8275965			8348987			8308145
Northing	511200			523316			478359					474268			419620			259567