CHAPTER 3

PETROGRAPHY OF ROCK TYPES AND FIELD RELATIONS OF THE UMKONDO GROUP IN EASTERN ZIMBABWE

3.0 Introduction

In the Umkondo type area, Archean basement granites and gneisses are the oldest rocks and are overlain by a sequence of metasedimentary strata of the Umkondo group that are at least 800 m thick (Mukwakwami *et al.*, 2001). Umkondo dolerites intrude Archean basement and the overlying Umkondo strata as both dykes and sills, although the sills are far more widespread. North northeast trending dykes of the Mutare swarm also intrude the Umkondo strata and Archean basement. Description of rocks of the Zimbabwe facies is based on outcrop and detailed thin section study, while that of the Mozambique facies is partially based on field observations made during an Honours class field excursion organised by the Department of Geology (1999) and on literature. Mapping was done in an area around Nhedziwa Business Centre (Fig. 1.3) to elaborate the field relationships of rock units of the Zimbabwe facies.

Rocks of the Mozambique facies are and discussed briefly in this and subsequent chapters. Rock types and field relations of the Zimbabwe facies are described and discussed in detail in this chapter. Cross sections that are based on the geological map of Watson (1969) have been made to illustrate the field relations of different rock units.

3.1 Archean basement Rocks

3.1.1 Basement Complex Granites

Basement Complex granites generally occur to the west and below the Zimbabwe facies metasedimentary rocks. The oldest granitoids documented in eastern Zimbabwe have a Rb-Sr whole rock age of 2.97 Ga (Vail and Dodson, 1969) and occur to the north of Nyanga (Fig. 1.7). Schmidt Mumm *et al.* (1994) obtained U-Pb zircon ages of 2742 ± 3 Ma and 2522 ± 36 Ma for tonalities and K-rich granites that intrude the Mutare greenstone belt (Fig. 5.22). The most common variety of granite that occurs in eastern Zimbabwe is white to pink in colour, massive, coarse-grained, and often porphyritic. Mafic enclaves that probably represent mafic xenoliths occur in places (Grid. Ref.: 459905, 7835875) in the porphyritic granite and define a fabric that dips steeply towards north. The granites are cut by fractures that are in places filled by sphene-bearing epidote-quartz veins that range from sub-millimetre to a centimetre in width (chapter 4). White quartz and pegmatite veins with variable attitudes and widths ranging from a sub-millimetre scale to a metre wide also cut the granites. Gneisses predate the porphyritic granite and occur in association with the greenstone belt remnants, i.e. the metaironstone unit near Chitimani school (Fig. 1.10).

The major constituent minerals in the granite are subhedral quartz, plagioclase and K-feldspar. Mafic minerals (biotite and hornblende), and accessory apatite and sphene make up less than 5% of the rock. Sericite and lesser quantities of epidote replace plagioclase along twin and cleavage planes and grain boundaries. The granites are commonly porphyritic, with euhedral phenocrysts of simple-twinned plagioclase laths that are up to 3 cm in size (Fig. 3.1). The plagioclase laths are preferentially orientated and define a sub-vertical primary igneous fabric that trends east-northeast in the vicinity of Chiramba School (Fig. 1.3).

Fig. 3.1. Porphyritic granite with euhedral plagioclase phenocrysts that define a steeply dipping, east-northeast trending primary layering. Grid Ref.: 459105, 7835904.

3.1.2 Metaironstone

Metaironstone crops out on a small hill that occurs near the southwestern corner of the map (Fig. 1.10). The rock is banded consisting of alternating quartz-rich layers and layers that are rich in iron-oxides and grunerite (Fig. 3.2). The metaironstone is strongly deformed and metamorphosed and is cut by a massive sub-horizontal dolerite sill (Fig. 1.10) that is undeformed and very weakly metamorphosed. The sill that also intrudes granites is probably of Umkondo age since the sill is petrographically similar to known Umkondo sills in the area. The metaironstone is presumably of Archean age and is probably a banded ironstone.

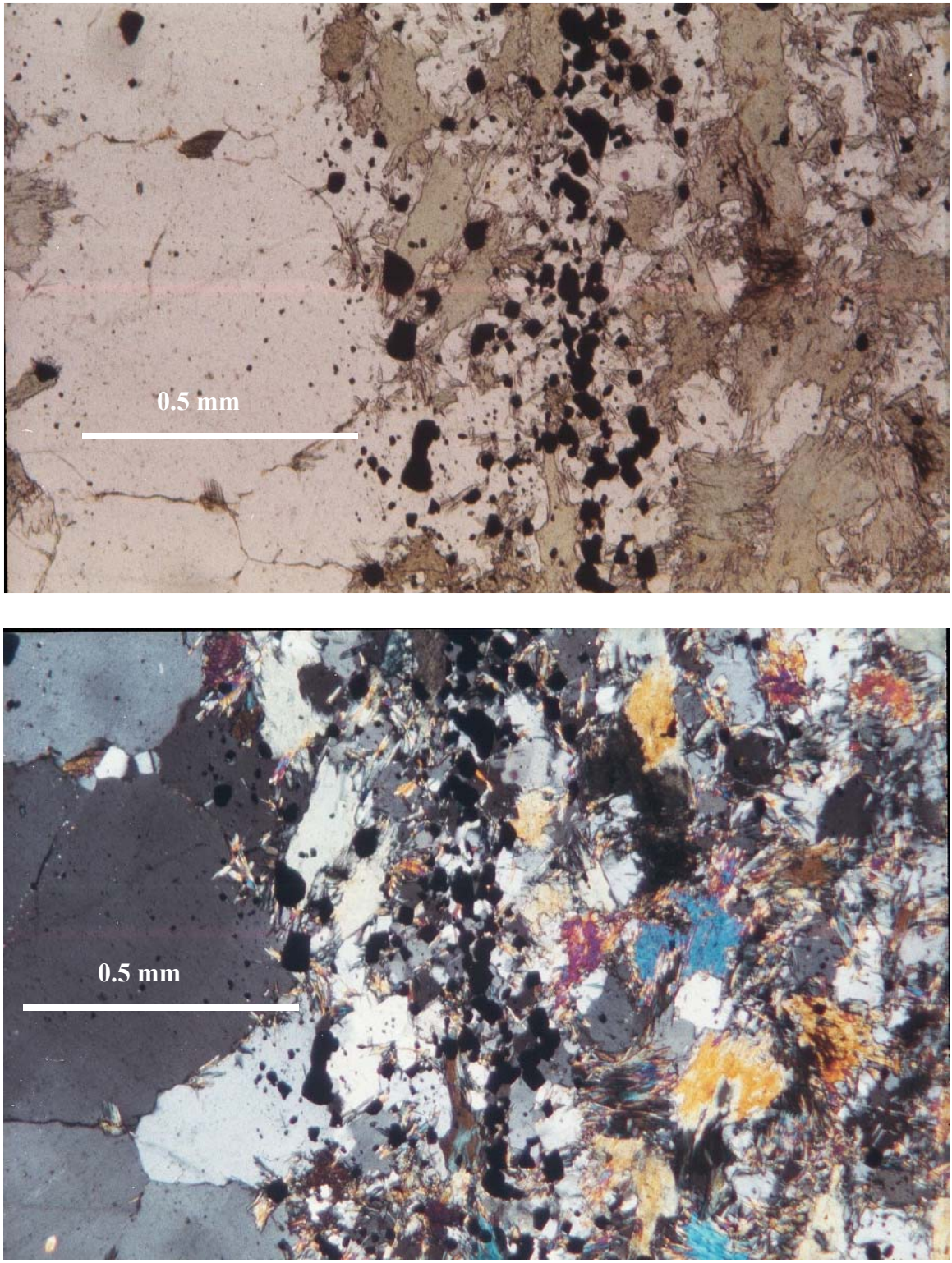

Fig. 3.2. Banding in metaironstone defined by alternating quartz-rich layers and grunerite-magnetite layers. Top photograph – plane polarised light, Bottom photograph - crossed polars. Sample JM0149; Grid Ref.: 451850, 7832660.

3.1.3 Amphibolite Dykes

Amphibolite dykes in the mapped area trend between east and east northeast (Fig. 1.10) and represent deformed and metamorphosed dolerite dykes that were emplaced along pre-existing fractures (chapter 7). The emplacement of these dykes predates the Umkondo and Mashonaland igneous events since Mashonaland dykes are undeformed and weakly metamorphosed. The dykes are possibly Archean in age and may be comparable to amphibolite dykes that were deformed with the Shamvaian sediments and predate the Magondi orogeny (section 2.7.3) in the Chinhoyi area (Fig. 1.1). The dykes consist of relict clinopyroxene and plagioclase; and secondary hornblende, actinolite, quartz, and chlorite. Clinozoisite and sericite occur as alteration products of plagioclase.

3.2 Mozambique Facies

Rocks of the Mozambique facies flank the Zimbabwe facies to the east and crop out in areas bordering with neighbouring Mozambique (Figs. 1.3 and 1.7). Psammites, slates, chlorite- and quartz-mica schists of the Mozambique facies structurally overlie the Mozambique quartzofeldspathic gneisses. The contact between the Mozambique facies and the Mozambique basement gneisses is a sheared contact and the evidence for this tectonic contact is further discussed chapter 5.

3.3 Rocks of the Zimbabwe Facies, Umkondo Group

The Zimbabwe facies, which makes up most of the exposures of the Umkondo group in eastern Zimbabwe, consists of relatively undeformed, weakly to non-metamorphosed sub-horizontal strata. The metasedimentary strata comprise of a pebbly basal arkose that is succeeded by shallow marine stromatolitic limestone, chert, argillaceous rock and cross-bedded upper arkose (Fig. 3.3) that possibly record deposition in fluvial and deltaic environments. The upper arkose unit is interbedded and capped by Umkondo basalts

(Fig.3.4). The stratigraphic sequence (Fig. 3.4) is basically uniform throughout the Zimbabwe facies of the Umkondo group, and individual formations within the group can be traced the entire length of the preserved basin. The beds are sub-horizontal to gently dipping throughout the Zimbabwe facies from Chipinge in the south through Chimanimani to Nyanga in the north (Figs. 5.7a-e).

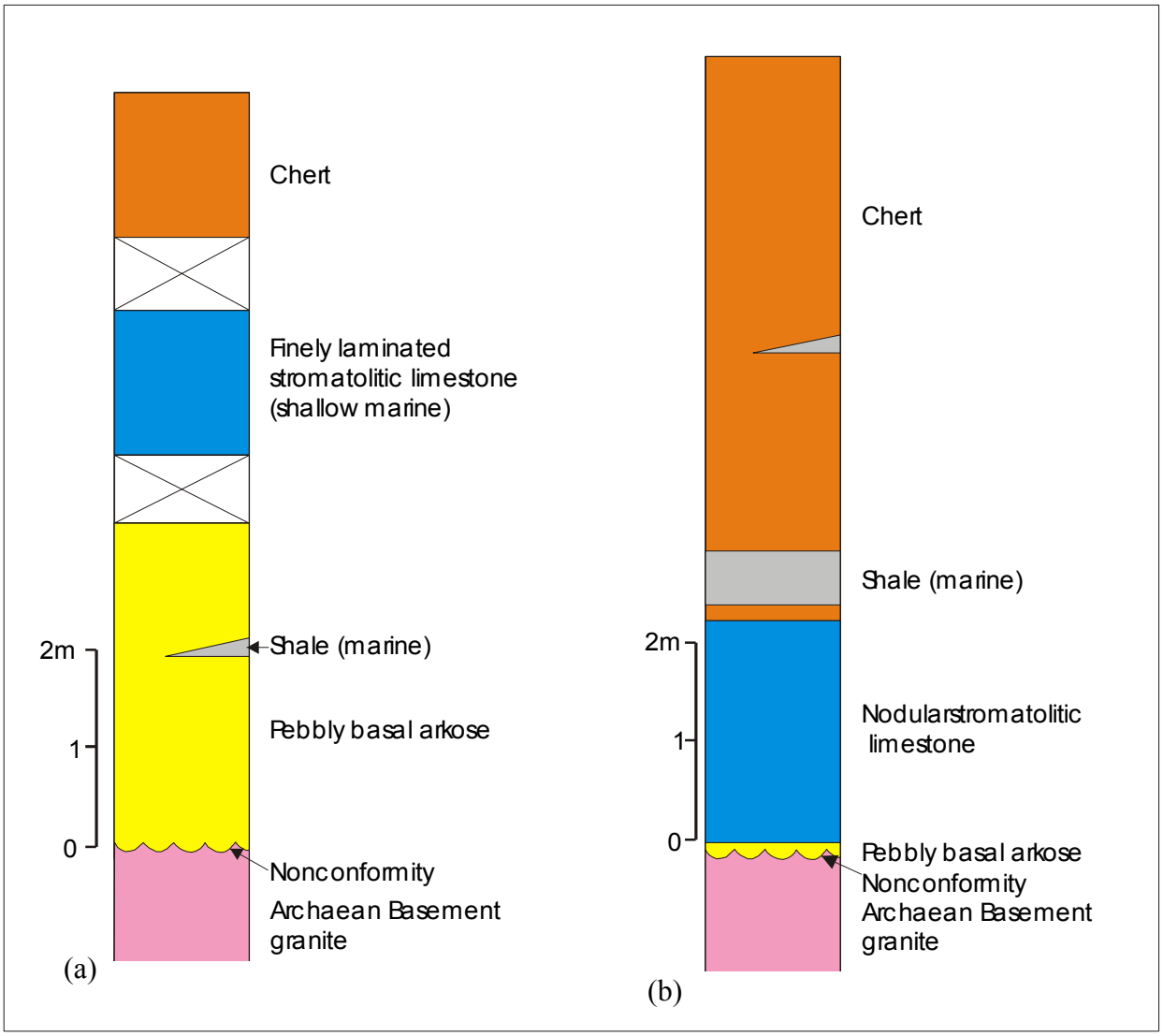

Fig.3.3. Stratigraphic log from (a) a hill section west-northwest of Hot Springs (Grid Ref.: 432707, 7831387) and (b) from a hill section south-southeast of Hot Springs (Grid Ref.: 446960, 7818693). Basal arkose overlies 20 cm wide layer of weathered granite (b). The sequence shown in a and b is basically uniform throughout the Zimbabwe facies of the Umkondo group, and individual formations within the group can be traced the entire length of the preserved basin.

3.3.1 Pebbly Basal Arkose

The pebbly basal arkose is reddish to pink in colour and predominantly consists of angular to sub-angular, poorly sorted grains of quartz, plagioclase and K-feldspar that vary from 0.5 – 30 mm in size. Silica is the dominant cement as well as minor chlorite, calcite and epidote. The arkose is characterised by a matrix-supported conglomerate in places at the base (Fig.3.3b) with angular to sub-angular gravel to pebble size clasts of quartz embedded in a matrix of arkosic composition. Individual beds exhibit graded bedding and there is a general fining upward sequence. Ripple marks with wavelengths of up to 5 cm occur in basal pebbly arkose to the west-northwest of Hot Springs (Grid. Ref.: 432707, 7831387). A few ripple marks (Table 3.1), which are exposed on one surface over an area of 3 m^2, are asymmetrical and indicate a palaeocurrent direction that is from south-southwest to north-northeast.

Authigenic orthoclase and microcline feldspar, chlorite, calcite and minor oxides also occur in very small quantities. Silica is the dominant cement and some minor calcite, chlorite and epidote. Quartz and feldspar content are at least 50% and 40% respectively in the arkoses and K-feldspar is the dorminant feldspar. Calcite and epidote replace plagioclase along twin planes and grain boundaries. Deformation lamellae and sub-grains occur in some quartz grains.

Pebbly basal arkose forms the lowest horizon along the western occurrences of the Umkondo group throughout the Zimbabwe facies. The arkose unit occurs as a continuous, sub-horizontal horizon that rarely exceeds 20 m in thickness and overlies undeformed Archean basement granites, e.g. east and south of Charamba School in the mapped area (Fig. 1.10). The pebbly basal arkose unit possibly marks the initial stages of sedimentation. The thicknesses of the arkose unit to the east and south of Chiramba School (Fig. 1.10) do not vary significantly and the beds are parallel to the granite/arkose contact. Lack of discontinuity at the contact and the persistence of these arkose horizons suggest that the arkose is authochtonous with respect to the Archean basement granites, and hence the contact is a nonconformity. The composition of the arkose is similar to that

of the underlying granite and the sub-angular nature of the detrital grains and high feldspar content may suggest that the arkose was derived from weathering of the underlying granite *in situ* as suggested by some previous workers (Watson, 1969; Stocklmayer, 1978). In one locality (Grid Ref.: 446960, 7818693), the unit overlies a matrix derived from weathering of the underlying granite. The matrix comprises euhedral to subhedral grains of quartz and feldspars with white material in the interstices. A matrix of weathered granite that occurs at the contact (Fig.3.3) shows that the contact is at least locally a nonconformity. Alternatively, deposition and lithification may have occurred very close to the provenance. These facts further suggest that the Zimbabwe facies is authochtonous.

3.3.2 Stromatolitic Limestone

Limestones are medium-grey in colour, finely laminated with convex upward, stromatolite domes (Fig.3.5), that have wavelengths ranging from 5-10 cm and amplitudes of 2-8 cm. The limestone contains at least 90% calcite and small quantities of detrital angular quartz grains and oxides. Nodular limestone occurs on a hill, about 6km south-southeast of Hot Springs (Grid Ref.: 432707, 7831387).

Stromatolitic limestones conformably overlie basal arkoses. The thicknesses of limestone horizons do not exceed 15 m and occur as lenses that pinch out along strike. The strike extent of these horizons in the mapped area is less than a kilometre (Fig. 1.10). The lenses are a primary sedimentary feature since there are no discontinuities below and above the limestone to suggest structural truncation of the horizon. Moreover, the stromatolites observed throughout the Zimbabwe facies are undeformed and always show an upward younging direction, which further favours a sedimentary origin for the lenses. The limestones contain approximately 20% silica (Watson, 1969) and are therefore of no economic significance.

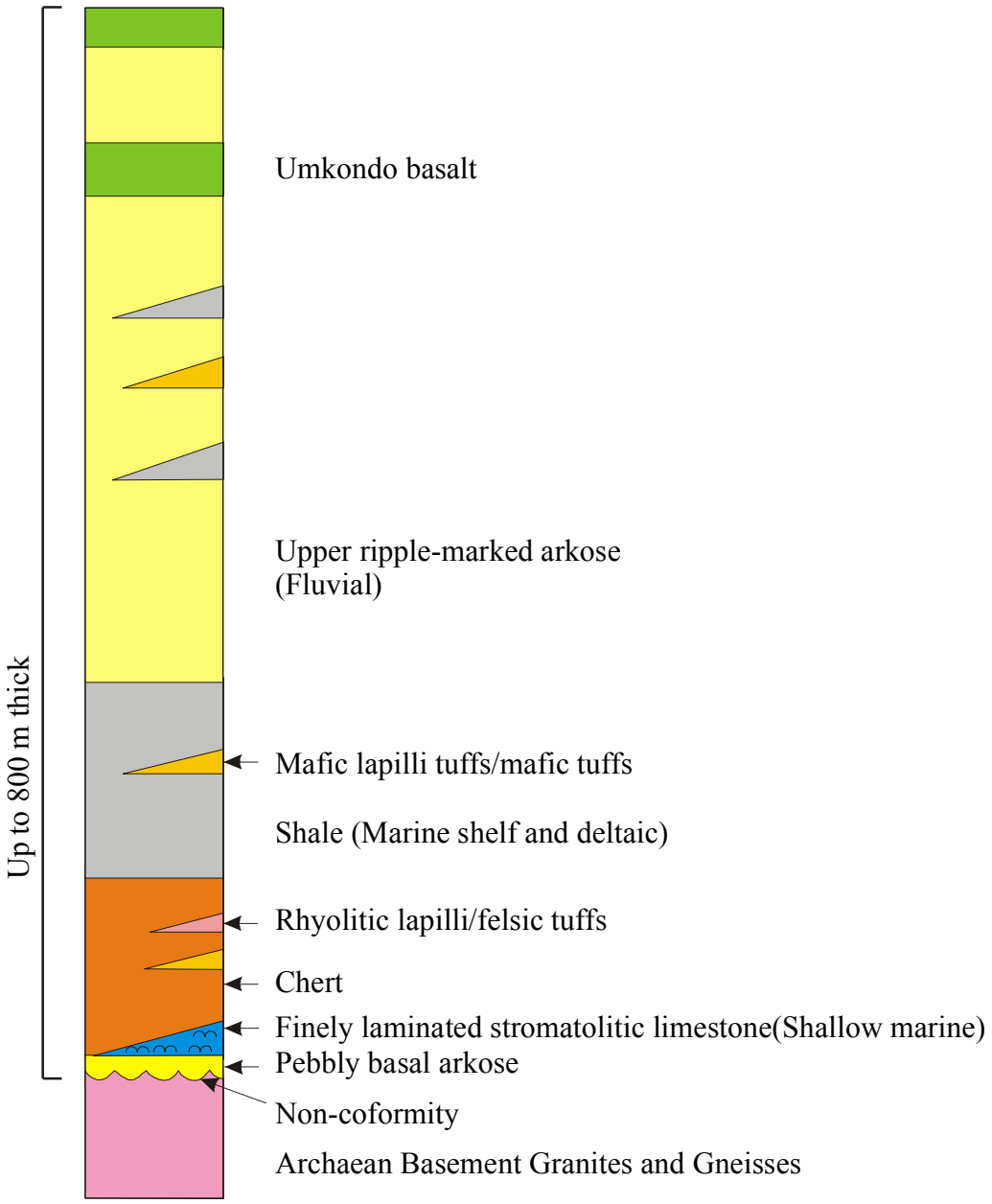

Fig.3.4. Stratigraphic column showing the major rock types of the Zimbabwe facies of the Umkondo group in eastern Zimbabwe. Shallow-marine stromatolitic limestones and cherts succeed a pebbly basal arkose unit that unconformably overlies Archean basement granites. Deltaic and fluvial shale and the cross-bedded upper arkose unit record deposition in fluvial and deltaic environments.

Fig.3.5. Low amplitude stromatolites in a limestone boulder. The stromatolites from outcrops of a limestone that overlies the pebbly basal arkose unit show an upward younging direction. Grid Ref.: 439358, 7832748.

3.3.3 Banded Cherts

The chert unit shows layering that is defined by colour variations. The layering is defined by alternating pale green layers and light pink-grey layers in one chert variety or medium red-brown layers alternating with light pink-grey layers in another chert variety. The former is by far the most common variety. The chert is composed of microcrystalline quartz and secondary epidote and chlorite that were introduced through circulation of hydrothermal fluids. Epidote patches that cut primary layering in chert to the south southwest of Hot Springs (Grid Ref.: 446995, 7818693) are evidence of hydrothermal alteration in cherts, and hence the Zimbabwe facies (chapter 4). Primary layering is well preserved in cherts. The thicknesses of individual bands vary from a sub-millimetre scale to 5 mm and do not vary significantly along strike in undeformed chert. Layering in undeformed chert is parallel to the bedding in the underlying pebbly basal arkose. These

observations strongly suggest that the layering in the chert is likely to be primary sedimentary layering. However, the primary layering is in places obliterated by a secondary foliation where the cherts are deformed, e.g. to the east and northeast of Chiramba School (Fig. 1.10). Individual layers are not continuous on a scale of a metre in deformed chert (section 5.5.2).

The chert unit is part of the basal formation (Watson, 1969; Stocklmayer, 1978). In the mapped area, undeformed chert units have a maximum width of at least 100 m and occur on a north-facing scarp to the south of Chiramba School (Fig. 1.10). The chert horizon conformably overlies lenses of limestone and the basal pebbly arkose and is interbedded with lenses of weathered, finely laminated mafic tuffs (Grid Ref.: 454455, 7830057) and felsic lapilli tuffs (Grid Ref.: 435491, 7833026). A horizon of stromatolitic limestone is interbedded with the chert unit to the south of Chiramba School (Fig. 1.10). Deformed cherts occur at Mutsago hill as well as to the south and west of this hill (Fig. 1.10). These are foliated and the structure in the cherts is described in detail in section 5.5.2).

3.3.4 Shales and Slates

Shale and slate units are very fine-grained and medium grey in colour, although shales are dark black in places where they are graphitic. Observed minerals under microscope include quartz and plagioclase, epidote, chlorite and an opaque mineral. Shales and slates do not occur in the mapped area.

Shales are poorly exposed along roads in the steep north-facing hill slope, about 7 km north of Cashel (Grid. Ref.: 475200, 7847330). Graphitic shales are rare and occur as less than 5 cm thick layers interbedded with non-graphitic shales. Irregular planar surfaces that are sub-vertical cross cut bedding in shales and were filled with silt to sand-size grains that were lithified. These cracks are therefore likely to represent desiccation cracks rather than joints. Beds are shallowly dipping with variable dip directions (Fig. 5.7e).

Shale and slate horizons conformably overlie cherts and have been intruded by dolerite sills (Fig. 3.17). Lenses of slate 5 to 15 cm thick are intercalated with the upper arkose unit to the south of Cashel (Grid. Ref.: 479972, 7835436). Shales also overlie Archean basement granites to the north of Cashel (Grid. Ref.: 475225, 7847480). The granite/metapelite contact is irregular and the overlying bedding is sub-parallel to the contact. The absence of cleavage and deformation in granite immediately below the contact suggests that the irregular nature of the contact does not reflect folding, but was an erosion surface on to which the sediments were deposited and compacted. The contact is presumably an unconformity. A 20 cm wide layer of silicified shale, which extends for about 2 m along strike, occurs at the contact and contains sub-millimetre wide, 5-10 cm long white quartz veinlets that are parallel to bedding and the contact. The silicification that resulted in the formation of the quartz vein-bearing layer is a localised feature.

3.3.5 Upper Arkose

The upper arkose is white-grey in colour, massive, moderately sorted and predominantly composed of quartz, plagioclase and K-feldspar with minor hornblende, biotite and opaque minerals. Feldspars constitute 35% of all the minerals and K-feldspar is the dominant feldspar. Silica is the dominant cement along with minor chlorite. Trough cross beds and ripple-marks observed in a single bed that crops out to the south of Cashel (Table 3.1; Grid Ref.: 479983, 7835224), show a southwest to northeast palaeocurrent direction. North of Nyanga town (Grid Ref.: 475821, 8010947), a good exposure of about a hundred square metres of planar cross-bedded upper arkose was used to deduce the palaeocurrent direction. The topsets are sub-horizontal and there is therefore no need to restore the beds to their original horizontal positions. The palaeocurrent direction, given by the dip direction of shallowly dipping foresets, is from north northwest to south southeast (Fig.3.11). The palaeocurrents are interpreted to reflect the palaeoslope and indicate the provenance direction (Tucker, 1991). Pyrite-bearing upper arkose, which contains up to 30% epidote occurs south of Cashel (Grid Ref.: 479972, 7835436). The abundance of epidote at this locality (Grid Ref.: 479972, 7835436) in the upper arkose

unit reflects hydrothermal alteration (chapter 4). There is a possibility that epidote in the rock is a product of pseudomorphic replacement of plagioclase grains since there is little plagioclase in this arkose.

3.3.6 Mafic Lapilli Tuffs and Mafic Tuffs

Previous workers in the area have not documented the occurrence of pyroclastic volcanic rocks in the Umkondo group. Tuffs are highly altered and occur as thin, weathered horizons on a scale of a few centimetres to a few metres that are interbedded with banded cherts (Fig.3.6) and the Upper Arkose unit of the Zimbabwe facies. The mafic tuffs cannot be easily distinguished from argillaceous rocks in the field.

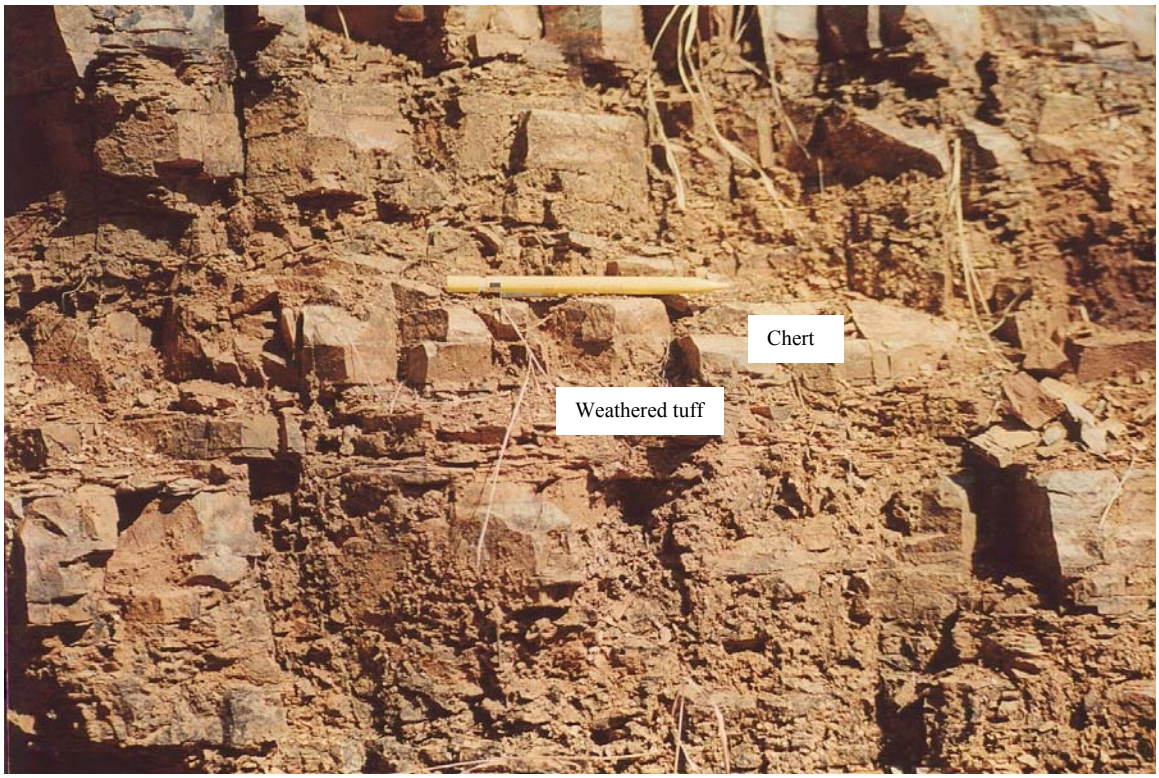

Fig.3.6. Banded chert interbedded with horizons of mafic tuff. The tuff horizons are finely laminated and strongly weathered, while the chert horizons have resisted weathering. Grid Ref.: 454455, 7830057.

Mafic lapilli tuffs are medium grey to dark grey-black rocks with up to 4 mm-wide spherical lapilli embedded in a fine-grained matrix of similar mineralogical composition (Fig. 3.8). The primary minerals have been replaced mainly by secondary epidote, chlorite, actinolite, prehnite, pumpellyite, analcite and quartz. The matrix and lapilli in a tuff occurring north-northeast of Birchenough Bridge (Grid Ref.: 445109, 7810104) are predominantly composed of epidote, chlorite, prehnite and sericite, and minor plagioclase, prehnite, oxides and quartz (Fig. 3.8). Sericite grows around the lapilli suggesting that the sericite is secondary. The observed mineral assemblage is indicative of a mafic protolith. Some dark material observed in thin section possibly represents some glass before deformation and alteration. Flattened lapilli occur in a very fine-grained tuff to the north on Nyanga (Figs.3.7 and 4.4). The lapilli are spherical to ellipsoidal in shape and have variable diameters that range from 2-4 cm (Fig. 3.7). The lapilli coalesce to form linear structures and could be mistaken for trace fossils in the field. The lapilli have a mineralogy that is similar to the matrix, i.e. predominantly epidote, chlorite, actinolite and minor detrital quartz.

Fine-grained white-yellowish mafic tuff that is interlayered with thin chert beds crops out on the Nyanga-Ruwangwe road near Ruwangwe police station (Fig. 1.7; Grid Ref.: 474277, 8056126). The mafic tuff is predominantly composed of epidote, chlorite, actinolite and plagioclase; and minor euhedral quartz, and some accessory sphene. Rock-forming minerals are secondary since they define secondary anastomosing layering. The mineralogical composition suggests that the precursor to this rock is a mafic tuff. The beds are interbedded with chert horizons. In the mapped area, horizons of mafic tuffs are up to 2 m wide (Grid Ref.: 454455, 7830057).

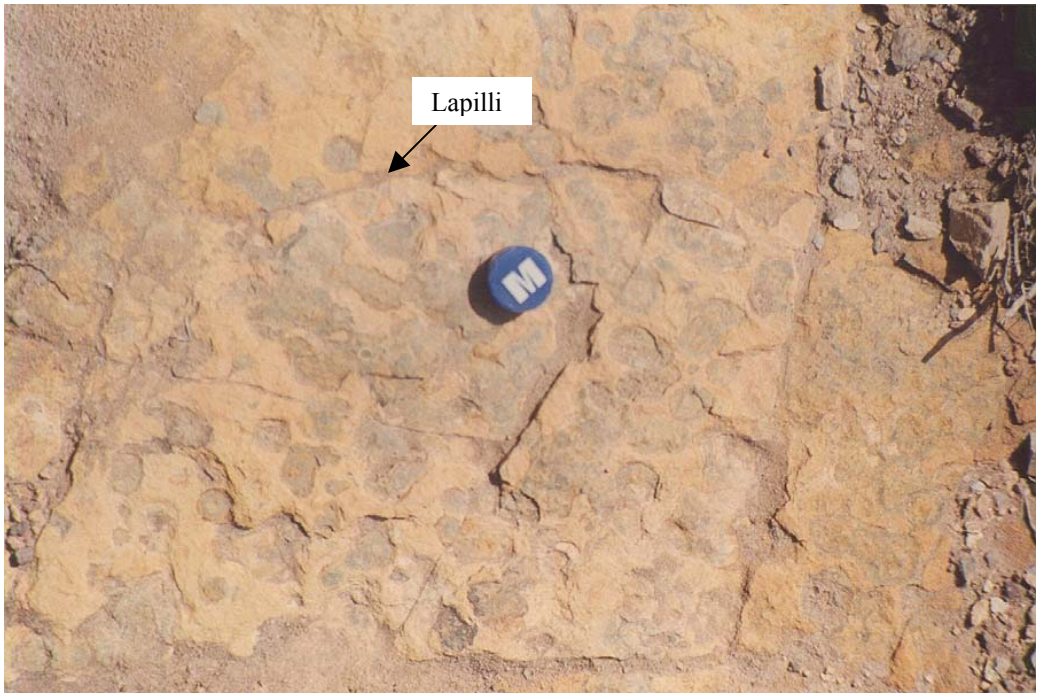

Fig.3.7. Flattened spherical to ellipsoidal structures in a very fine grained, light grey rock. The structures have variable diameters ranging from 2 to 4 mm. The spherical structures coalesce to form linear structures near the centre of the photograph that could be mistaken for trace fossils in the field. The lapilli have a mineralogy that is similar to the matrix, i.e. predominantly epidote, chlorite, actinolite and minor detrital quartz. Grid Ref.: 476148, 8019207.

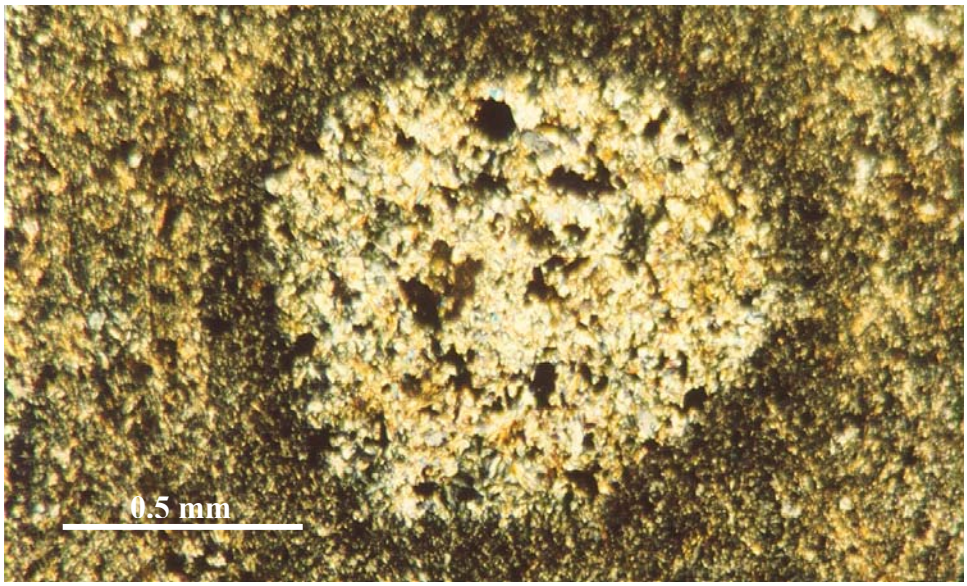

Fig.3.8. Spherical lapilli in a matrix of similar composition, i.e. predominantly epidote, plagioclase, chlorite, prehnite and some grains of quartz. The dark material around the lapilli possibly represent glass before alteration. Crossed polars. Sample JM 0111, Grid Ref.: 445109, 7810104.

3.3.7 Rhyolitic Lapilli Tuff

Rhyolitic lapilli tuff is light pink in colour and spotted when fresh. Spherical lapilli that are up to 4 mm wide occur in a fine-grained matrix of similar mineralogical composition (Fig.3.9), which comprises predominantly of quartz and laths of plagioclase and K-feldspar, minor quantities of chlorite and epidote, and accessory sphene. The lapilli have resorbed boundaries possibly reflecting reaction of the early-solidified lapilli with the melt.

A rhyolitic tuff unit was observed at one locality that occurs some 10 km west-northwest of Hot Springs (Grid Ref.: 435491, 7833026). The tuff occurs as lenses that are about two-metre wide and are interbedded with chert horizons.

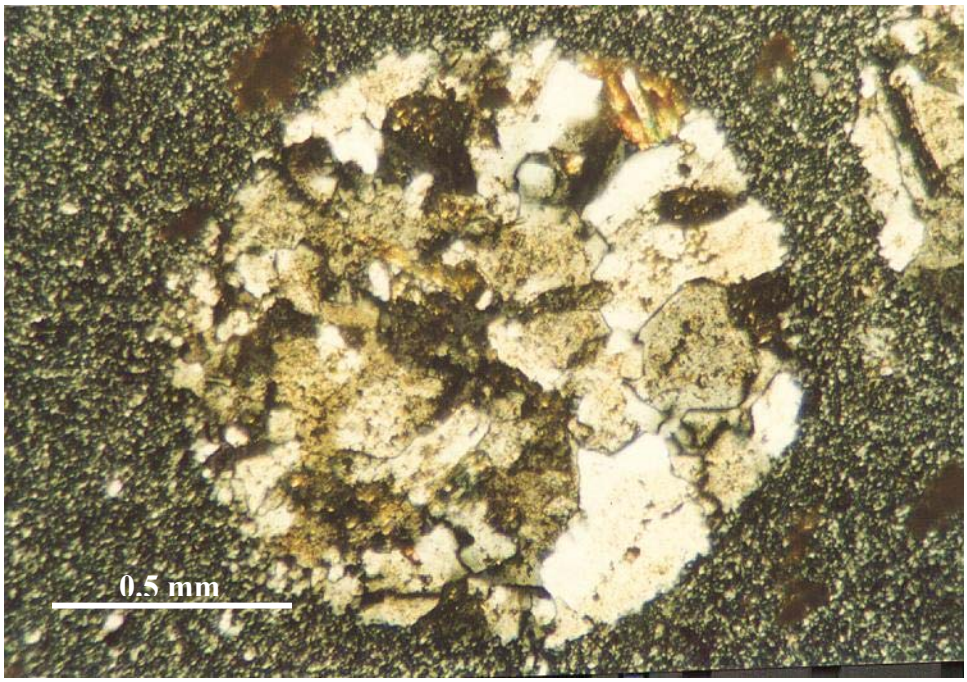

Fig.3.9. Rhyolitic tuff with spherical lapilli that have resorbed margins. The lapilli are composed of quartz, plagioclase, K-feldspar, epidote and sphene, and occur in a fine grained-matrix of similar composition. Occasional laths of plagioclase and oxides also occur in the matrix. Crossed polars. Sample JM0209; Grid Ref.: 435491, 7833026.

3.3.8 Umkondo Basalt

Umkondo basalts are generally fine-grained dark green or purplish-brown in colour. The purplish-brown colour is due to iron oxide staining (Munyanyiwa, 1999). Dark green basalts are porphyritic and are composed of phenocrysts of plagioclase laths and clinopyroxene that occur in a matrix of mainly plagioclase and clinopyroxene, and minor opaque minerals. Secondary minerals include chlorite and actinolite that replace clinopyroxene, and epidote that replaces plagioclase. The pinkish-brown basalt exhibits an amygdaloidal texture and vitrophyric texture in which crystals of plagioclase and clinopyroxene are set in a glassy matrix (Fig. 3.10). The amygdales include quartz, pumpellyite, prehnite and minor epidote. Secondary chlorite occurs on the edges of the amygdales. Sericite and epidote occur as pseudomorphs after plagioclase.

Basalts crop out in small areas that are 4–20 km^2 in extent over a distance of more than 80 km, which suggest that they originally covered a large part of the present extent of the Umkondo group as flood basalts (Munyanyiwa, 1999). An estimated maximum thickness of 200 m has been reported for Umkondo basalts (Allsopp *et al.*, 1989). The basalts are intercalated with- and conformably overlie the upper arkose (Mukwakwami *et al.*, 2001). In the Odzi River on the downstream side of the bridge (Grid. Ref.: 442834, 7819648), good exposures of basalts show floor tops that dip shallowly towards the southeast. The floor tops are cracked and have very fine glassy material. Randomly oriented chilled mafic dykes that occur on a centimetre scale to 10 cm wide have intruded the basalts. The dykes have been gently folded and the fold axes are randomly oriented.

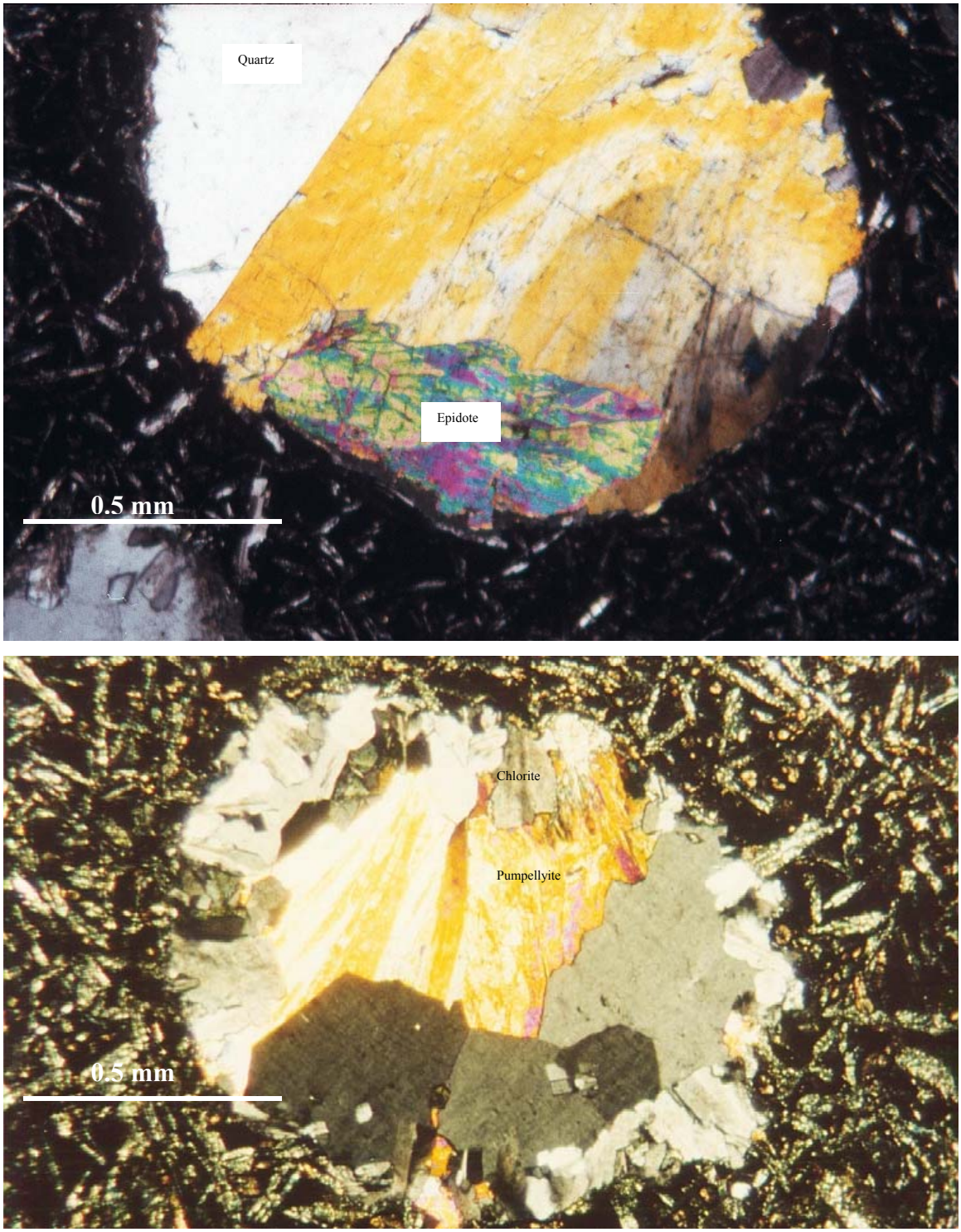

Fig.3.10. Hypocrystalline Umkondo basalt showing amygdaloidal and vitrophyric textures. The amygdales this microphotograph include pumpellyite, quartz and minor epidote, while chlorite occurs on the margin of the amygdale assemblage. Plagioclase and small crystals of clinopyroxene are set in a glass matrix. Crossed polars. Sample JM0115, Grid Ref.: 442699, 7825648.

3.4 Depositional Environment for Umkondo Sediments

There is no evidence of fault-controlled deposition in the entire Umkondo Basin, which would be characterised by coarse-grained boulder-supported conglomerates near the edge of the basin that gradually get finer towards the centre of the depocentre. The flat nature of the contact between the Zimbabwe Basement granites and the Zimbabwe facies (Fig. Fig. 3.17) is consistent with a peneplained surface that developed prior to deposition of the Umkondo strata. It is plausible to suggest that deposition of the Umkondo group occurred in an epicontinental basin on a flat, peneplained surface developed on the Zimbabwe Archean craton.

Pebbly basal arkoses and cross-bedded upper arkose record deposition in a fluvial environment. The palaeocurrent data (Table 3.1) are insufficient for regional interpretation. A unimodal north northwest to south southeast palaeocurrent direction with a large dispersion probably reflects a high sinuosity or an alluvial fan (Fig.3.11; Tucker, 1991). Stromatolitic limestones were deposited in a shallow marine environment, while deposition of the shales took place in a low energy environment, possibly deltaic. The arkoses are compositionally and texturally immature, consisting of poorly to moderately sorted angular to sub-angular grains, which suggest that the depocentre was probably very close to the provenance. The composition of the detrital grains characterised by the presence of abundant felsic minerals and minor mafic minerals suggests that the detrital grains were wholly derived from a predominantly granitoid terrane, i.e. the Archean Basement Complex greenstone-granite terrane. Mafic tuffs and mafic lapilli tuffs that are interbedded with Umkondo sediments record input of pyroclastic material into the Umkondo basin, which may reflect explosive volcanic activity that was contemporaneous with sedimentation. Basalts that are geochemically similar to Umkondo dolerites conformably overlie Umkondo sediments and record the occurrence of a mafic magmatic event that was penecontemporaneous with sedimentation in the Umkondo Basin. Rhyolitic lapilli tuffs possibly represent the most evolved magmas associated with the Umkondo Mafic Igneous event.

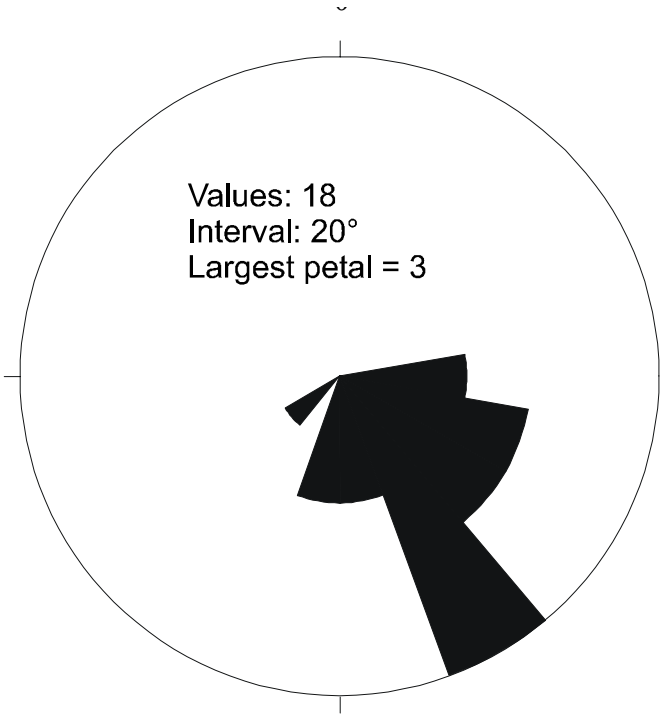

Fig.3.11. Palaeocurrent pattern obtained from cross beds in the Upper Arkose unit north of Nyanga town (Grid Ref.: 475821, 8010947). The palaeocurrent is from north northwest to south southeast. Unimodal pattern with a large scatter possibly indicate a high sinuosity river or alluvial fan.

Table 3.1. Summary of palaeocurrent data from two units of the Zimbabwe facies.

Grid Reference	Stratigraphic Unit	Feature Observed	Number of Observations	Palaeocurrent Direction
432707, 7831387	Pebbly basal arkose	Asymmetrical ripple marks	2	SSW to NNE
479983, 7835224	Upper arkose	Trough cross beds and ripple-marks	2	SW to NE
475821, 8010947	Upper arkose	planar cross-beds	18	NNW to SSE

3.5 Dolerites

Dolerites intrude Archean basement granite and the overlying Zimbabwe facies metasedimentary strata in the Chimanimani and Chipinge area to the south and in the Nyanga area to the north as both dykes and sills, although the sills are far more widespread (Mukwakwami *et al.*, 2001). Dolerites have chilled margins and contain

xenoliths of granite near the granite/dolerite contacts, which shows that the contact is intrusive.

3.5.1 Dolerite Dykes – South of Mutare Town

The majority of dolerite dykes that intrude metasedimentary rocks of the Umkondo group and the Archean basement granites are generally medium to coarse grained, massive and weakly metamorphosed. The weakly metamorphosed dykes define two dominant trends (chapter 7), but exhibit textures and mineralogy that do not vary significantly. Wilson *et al.* (1987) classified the approximately north- and east trending dykes as the Mutare and Limpopo swarms respectively. Mineralogically, the dykes predominantly consist of primary plagioclase and clinopyroxene (diopside), minor quartz and accessory sphene, rutile and apatite. Actinolite, biotite, chlorite and epidote are the common metamorphic minerals in the dykes (chapter 4). Relict igneous textures in dolerites include ophitic (Fig.3.12) and granophyric textures (Fig. 3.13). Sub-vertical flow banding defined by alignment of plagioclase feldspars occurs in some dykes and the banding trends parallel to the dykes (Grid Ref.: 490800, 7793860).

Dolerite dykes are by far more widespread in the Archean granite terrane, possibly owing to the competent nature of the granites relative to the metasedimentary rocks. The dykes are fairly straight and sub-vertical to vertical, and show two dominant trends (chapter 7). The less altered dykes, i.e. the Mutare swarm of Wilson *et al.* (1987), were subdivided into six subgroups on the basis of their geochemistry (section 2.9.2), despite their petrographical and textural similarities. A post-Umkondo mafic igneous event is indicated by the occurrence of one metre-wide, very fine grained dolerite dykes trending north and west-northwest that intrude an Umkondo sill in the Umvumvumvu River near the bridge (Fig. 3.14; Grid Ref.: 461724, 7840425). The relationships between the dykes and the sills are discussed in detail in chapter 7.

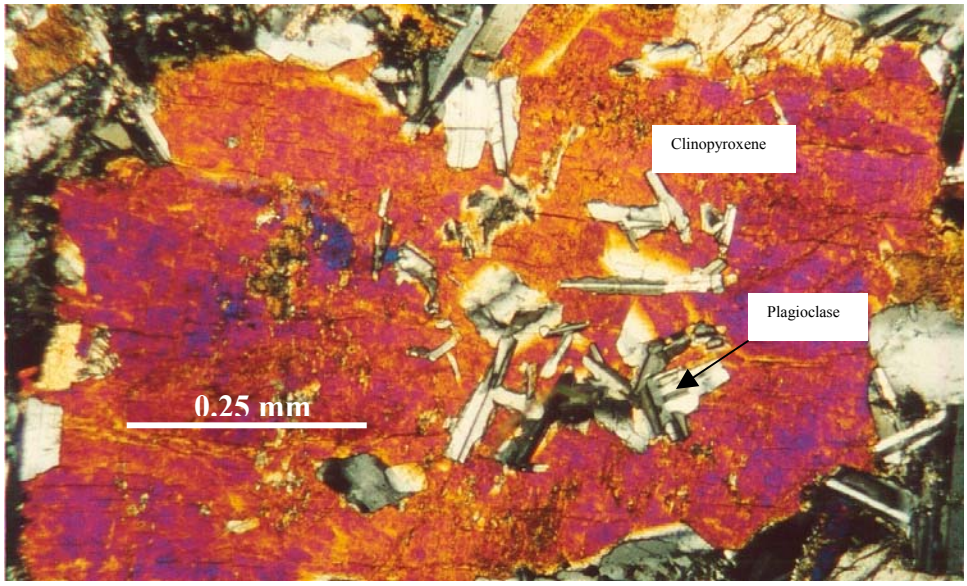

Fig.3.12. Igneous textures are preserved in dolerite dykes including an ophitic texture in which many plagioclase crystals are enclosed by a single clinopyroxene crystal. Crossed polars. Sample JM0110, Grid Ref.: 436702, 7800301.

3.5.2. Umkondo Dolerite Sills

Umkondo dolerite sills are generally dark grey-black in colour, coarse grained and are gabbroic in places (Fig. 1.10). Individual sills have variable thicknesses that can be up to 350 m and can be traced for some tens of kilometres along strike (Fig. 3.18). The dolerites are predominantly composed of primary clinopyroxene and plagioclase of andesine to labradorite composition, minor quantities of orthopyroxene, magnetite and quartz. Accessory sphene, apatite, ilmenite, and rutile also occur in the dolerites. Secondary minerals include biotite, actinolite, chlorite and prehnite. Ophitic and granophyric textures are common igneous textures that are preserved in the sills.

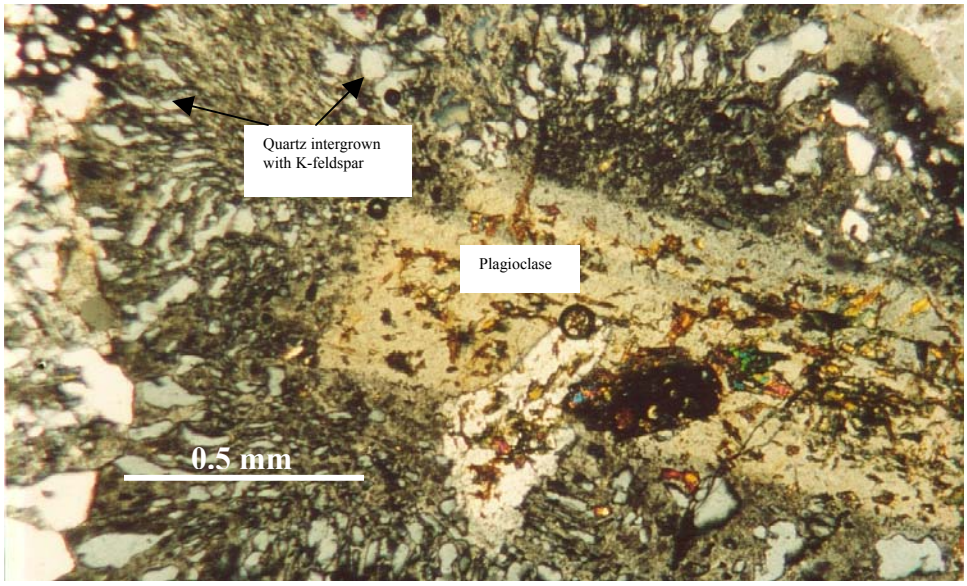

Fig.3.13. Granophyric texture resulting from co-crystallisation of quartz and K-feldspar at the eutectic point in late magmatic fluids. Quartz intergrown with alkali feldspar is arranged about euhedral plagioclase crystal. Crossed polars. Sample JM0125, Grid Ref.: 480387, 7832272

Fig.3.14. An aphyric post-Umkondo dolerite dyke that intruded an Umkondo sill suggests the occurrence of a post-Umkondo mafic magmatic event. The sill is flanked by epidote-quartz veins on either side along the dyke margins. Grid Ref.: 461724, 7840425.

3.5.3 Granophyres

Granophyres either occur as mesocratic or melanocratic gabbroic units in the roof regions of some Umkondo sills. An approximately 30 m wide mesocratic granophyre unit occurs in the roof region of the Tandaai sill (Fig. 1.3) that has a width of approximately 100 m. The Tandaai sill shows some vertical compositional variation that is depicted by progressive increase of modal quartz and alkali-feldspar from the bottom to the top of the sill. Quartz content increases from about 3% at the bottom of the sill to about 10-15 % at the top. Thus the dolerite sills grade into the granophyres. The progressive increase in silica from the bottom to the top of the Tandaai sill possibly reflects tholeiitic magma that differentiated and solidified from the base upward (McBirney, 1984). Important processes of differentiation possibly included flow segregation, gas streaming and filter pressing (McBirney, 1984; Hall, 1992). Mineralogically, the granophyre consists of primary clinopyroxene, albitic plagioclase, biotite, and granophyric intergrowths of quartz and alkali feldspar that possibly resulted from simultaneous crystallization of quartz and K-feldspar at the eutectic point (Turner and Verhoogen, 1960; Barker, 1970; Lofgren, 1974; Cox *et al.*, 1979; Best, 1982). Quartz intergrown with K-feldspar occurs around plagioclase (Fig.3.13), which suggests that the granophyric intergrowths probably formed by interaction of the early-formed plagioclase with late magmatic fluids that were more sodic and silica rich (Barker, 1970; Best, 1982; Hyndman, 1985). Sphene and rutile also occur as accessory minerals.

Melanocratic granophyres occur as lenses of coarse-grained rocks of gabbroic composition near the roof regions of sills to the north and east of Mutsago Hill (Figs. 1.10 & 3.15). The gabbroic rocks are characterised by the occurrence of coarse-grained pegmatitic segregations that have irregular shapes and are up to a metre wide (sample JM0109, Fig. 1.6; and sample JM0138, Fig. 1.7). Pegmatitic patches were probably formed by differentiation through filter pressing and segregation of late magmatic fluids into dilational fractures in the partly crystallized gabbroic mush (McBirney, 1984) and are interpreted to represent true differentiates of Umkondo dolerites. The pegmatitic segregations have similar mineralogical compositions to the felsic granophyres.

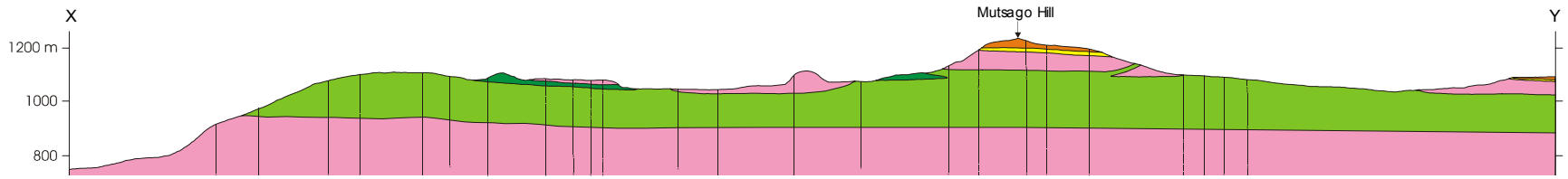

Fig. 3.15. Cross section from X to Y (Fig. 1.10) showing a sub-horizontal Umkondo sill that intruded Archean basement granite. Gabbroic granophyres occur as lenses in the roof region of the sill.

3.6 Peperite

Along one well-exposed sill margin in a road cut some 59.5 kilometres along the Wengezi-Chimanimani road (Grid Ref.: 469675, 7803150), an approximately 4 m-wide zone of peperite occurs. The zone consists of randomly oriented dolerite fragments that are intermingled with sediment fragments. Many sediment clasts are plastically deformed and folded into open folds that are randomly oriented (Fig 3.16). The randomly oriented folds are interpreted to indicate absence of a remote stress field during deformation of the sediments. The matrix around these plastically deformed clasts is not penetratively deformed. Some sediment clasts were stretched, to form boudins, in a direction parallel to the bedding and then folded about a sub-vertical fold axial surface. Presumably, these folds were formed due to upward migration of fluids resulting in up doming and formation of antiformal structures.

The rock consists of euhedral biotite porphyroblasts, sericite, plagioclase, clinopyroxene, actinolite, chlorite, epidote, quartz, finely and uniformly disseminated magnetite and accessory sphene and rutile. Chlorite replaces biotite and the feldspars in sediments are corroded due to interaction with the magma. Light pink patches that have a vein appearance occur in the peperite. The patches have widths that are up to a centimetre and lengths that are up to 5 cm. These patches have a granitic composition i.e. predominantly plagioclase, K-feldspar and euhedral to subhedral biotite and quartz (Fig. 3.17); and are interpreted to represent anatexis of some arkose clasts that were incorporated in the sill at the time of emplacement.

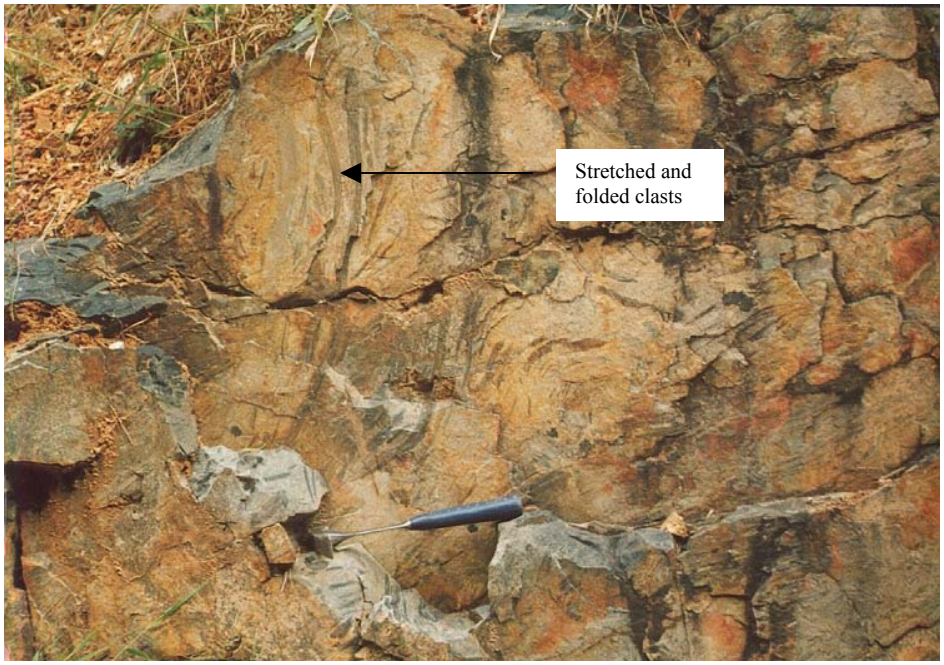

Fig. 3.16. Plastically deformed sediment clasts folded into randomly oriented open folds in a peperite that occurs along a sill margin, which suggests absence of a remote stress field during deformation. The occurrence of the peperite suggests that Umkondo sills were emplaced before Umkondo sediments were completely lithified (Hanson *et al.*, 1998b). Grid Ref.: 469675, 7803150.

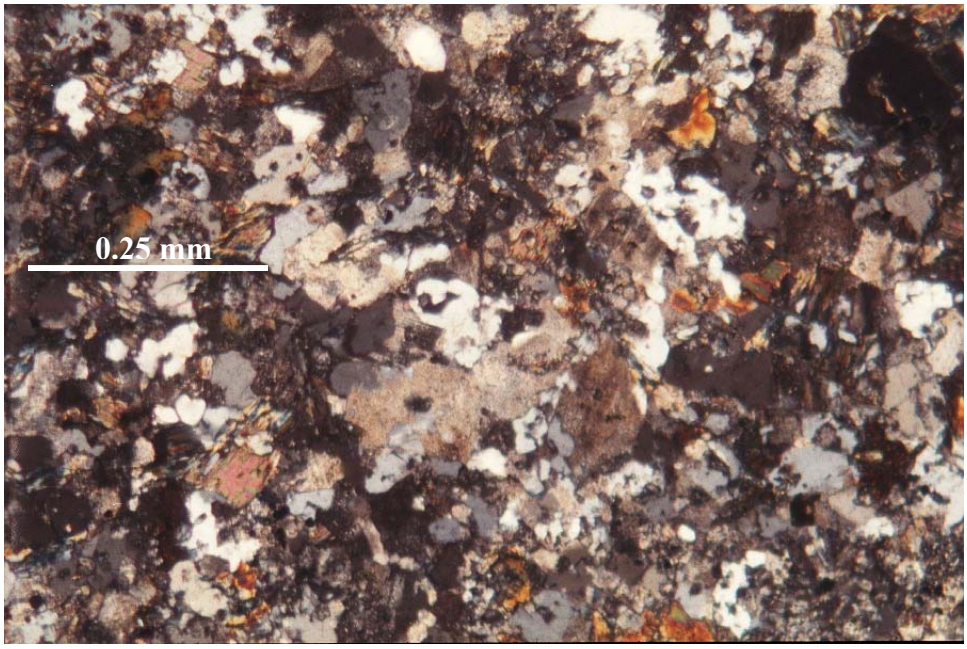

Fig. 3.17. Pink patches that occur in peperite predominantly consist of plagioclase and quartz and minor K-feldpar and biotite. These patches are possibly a product of anatexis of the siltstone during emplacement of the sill. Crossed polars. Sample JM0107, Grid Ref.: 469675, 7803150.

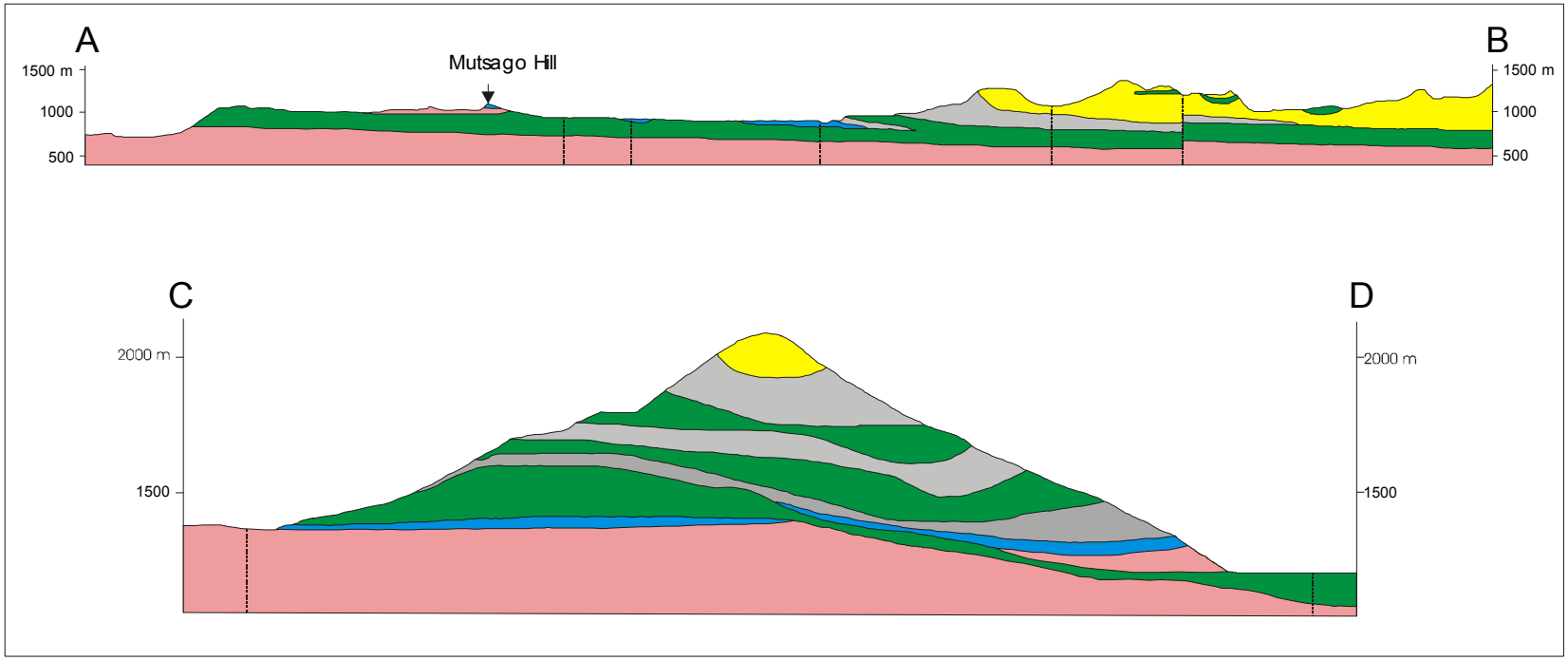

Fig. 3.18 Sections along lines A-B and C-D (Fig. 1.3). Umkondo sills have variable thicknesses along strike and transgress the Archean basement granite/Zimbabwe facies contact bedding. The Basement Archean granite/Zimbabwe facies contact is a non-conformity and generally sub-horizontal.

3.7 Discussion and Conclusions

The sedimentary sequence (Fig 3.4) is basically uniform throughout the Zimbabwe facies of the Umkondo group, and individual formations within the group can be traced the entire length of the preserved basin. The lateral persistence of these strata over a distance of 390 km in eastern Zimbabwe probably suggests deposition in a single north-south trending basin with a minimum dimension on the order of 400 km. Sharp differences in metamorphic grade and intensity of deformation between the Mozambique- and Zimbabwe facies (chapters 4 and 5) are interpreted to reflect tectonic juxtaposition rather than evidence for different depositional ages. Thus rocks of the Mozambique facies represent the strongly deformed and highly metamorphosed equivalent of the Zimbabwe facies. The entire Umkondo group was deposited nonconformably in a flat peneplained surface on the east side of the Kalahari Craton and the Zimbabwe facies of the group is autochthonous at a large-scale (chapter 5). The sedimentary strata of the Umkondo group were deposited in fluvial to shallow marine environments and record the presence of a major epicontinental basin in this part of southern Africa. The palaeocurrent data, based on 3 measurements from 2 units of the Zimbabwe facies (Table 3.1), obtained in this study are not sufficient to define any basinal geometry on a regional scale. There is excellent potential for a detailed sedimentological study.

The presence of peperites that have plastically deformed clasts indicates that the Umkondo dolerite sills intruded while at least some of the host Umkondo sediments were still wet and poorly consolidated. Tuffs that are interbedded with metasedimentary rocks of the Zimbabwe facies record input of pyroclastic material into the Umkondo basin, and reflect explosive volcanic activity related to the Umkondo igneous event. Basalts that are geochemically similar to Umkondo dolerites are conformably interbedded (Fig.3.4) with the Upper Arkose unit of the Zimbabwe facies and the palaeomagnetic direction in Umkondo dolerites is indistinguishable from that of the overlying basalts (McElhinny, 1966). These facts suggest that widespread 1100 Ma Umkondo Province mafic magmatism was penecontemporaneous with or immediately followed sedimentation in

the Umkondo basin of eastern Zimbabwe in a continental environment. However, the palaeogeography of the Umkondo basin remains unclear.