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An Overview of the Soutpansberg Sedimentary and Volcanic Rocks

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Volcanic and sedimentary rocks occupy a faulted graben within the previously uplifted and eroded high-grade gneiss terrain of the Limpopo Mobile Belt. The rocks comprise the Soutpansberg Group and represent an important sequence of Proterozoic rocks. Their general geology and volcanology is summarised in this paper.

Key words: Proterozoic, igneous, metamorphic, basalt, sedimentary, pyroclastic, ash-flow, rift.

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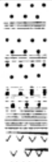
Introduction

Volcanic and sedimentary rocks of the Soutpansberg Group occupy an east-south-east trending graben within the previously uplifted and eroded high-grade gneiss terrain of the Limpopo Mobile Belt. According to Barton (1979) the development of the Soutpansberg group post-dated a sporadic thermal event in the Limpopo gneiss terrain at 1 800±50 Ma. The Soutpansberg volcanics and sediments represent an important, but somewhat neglected group of South African Proterozoic rocks. Their geology and volcanology is described briefly in this paper. Information presented here has been drawn primarily from publications of Barker (1979), Brandl (1981) and the South African Committee of Stratigraphy (SACS) and is supported by field observations in the northern part of the Kruger National Park (KNP). The geology described below includes units and features not necessarily found in the confines of the Kruger National Park. However, this has been done for the sake of completeness.

Table 1

Lithostratigraphy of the Soutpansberg Group as compiled by the South African Committee for Stratigraphy. Slight modifications have been made to the lithostratigraphy as presented by SACS

Formation	Member	Lithology		**Thickness (m)**
Nzhelele	Lukin Quartzite Mutale Tuff Musekwa Basalt		Predominantly white or light-coloured, brown-weathering, laminated quartzitic sandstone with interbedded shale and sandy shale. Lukin Member: white quartzite Alternating reddish, brownish or variegated shale, shaly sandstone, sandstone, and quartzitic sandstone with clay pellets and pellet conglomerate. Locally there are intercalations of tuff (Mutale Tuff Member) or basaltic lavas with interbedded tuff, ignimbrite, sandstone, shale and chert (Musekwa Member)	1 000–2 000
Wyllies Poort Quartzite	Bluebell Conglomerate Devils Gully Basalt		White, pink and light-coloured, medium-grained quartzitic sandstone and purple, brown or reddish coarse-grained sandstone, locally with interbedded pebble washes, grit, conglomerate, shale, mudstone, siltstone and lava Bluebell Conglomerate Member: boulder conglomerate Devils Gully Member: lava, mudstone and siltstone Calcareous rocks at base in one locality	1 000–4 000
Fundudzi			Light-coloured quartzitic sandstone and quartzite and purple, brown or reddish sandstone, locally gritty or conglomeratic with interbedded lava, tuff, agglomerate, shale, sandy shale, and siltstone	0–2 800
Sibasa Basalt			Predominantly basaltic lavas, with interbedded tuff, agglomerate, ignimbrite, quartzite, quartzitic sandstone, grit, conglomerate, shale, mudstone and siltstone	0–3 300
Tshifhefhe			Medium-grained partly feldspathic, quartzitic sandstone with interbedded shale, siltstone and mudstone; or shale with interbedded sandstone or feldspathic quartzitic sandstone, grit and graywacke, arkose, conglomerate, and shale	0–9

General Geology

The Soutpansberg Group consists roughly of equal proportions of volcanic and sedimentary rocks (Jansen 1975; Barker 1979). Detailed mapping of the Soutpansberg rocks has led to the recognition of several important formations which are listed in Table 1 and shown in simplified form on Fig. 1.

The base of the Soutpansberg Group is defined by a very thin, sporadically developed layer of arenaceous sediments. These rocks are referred to as the *Tshifhefhe Formation*. According to Brandl (1981) it attains thicknesses of up to 20 m in the Kruger National Park.

The Tshifhefhe Formation is followed by the much thicker and more extensive *Sibasa Basalt Formation*. The formation comprises a cyclicly erupted sequence of porphyritic to massive tholeiitic basalts with thin, interbedded clastic sedimentary horizons. The petrochemistry of the igneous rocks indicates them to be basaltic with local occurrences of dacites and dacitic pyroclasts. The main development of the Sibasa Formation is along the southern edge of the Soutpansberg where it forms flat to undulating topography overlain by dark fertile soils. It reaches a maximum of 3 300 m in the Sibasa region (Brandl 1981).

The *Fundudzi Formation* conformably overlies the Sibasa volcanics commencing with a thinly bedded shale/siltstone and lithic graywacke succession which grades vertically into a thick succession of orthoquartzites and conglomerates. The sediments were deposited by braided alluvial processes. This formation attains a maximum thickness of 2 800 m in the vicinity of Lake Fundudzi.

The *Wyllies Poort Formation* underlies the major part of the more mountainous ground in the Soutpansberg and has a conformable contact with the underlying Fundudzi Formation (Brandl 1981). The succession is primarily arenaceous and attains a thickness of about 4 000 m in the Thengwe and HaMakuya areas. Cross-bedding measurements suggest palaeocurrent directions from the west, north-west and north. South of the Tshamavudzi fault two thin lava flows are found near the top of the formation. Interbedded lenticular pyroclastic horizons have also been observed in similar positions in the same vicinity.

A lava and pyroclastic to epiclastic transition marks the contact of the *Nzhelele Formation* with the underlying Wyllies Poort Formation. The pyroclastic rocks comprise an assemblage of ash-flows of lapilli and tuff-sized fragments in which small, but consistent grades of syngenetic copper mineralisation have been discovered. The lava at the base of the Nzhelele Formation is most persistent and may be up to 400 m thick. The sediments found in this formation vary between arenaceous and argillaceous. Several layers of pyroclastic rocks are interbedded with the sedimentary rocks.

Petrography

1. Mafic Rocks

Lavas and dolerites of the Soutpansberg succession show textures which vary between aphanitic and porphyritic. Many of the lavas are also amygdaloidal. Porphyritic lavas contain phenocrysts of plagioclase, clinopyroxene and titano-magnetite set in a generally fine grained groundmass of epidote, chlorite, quartz, sericite and leucoxene (Barker 1979). Some rocks are strongly altered and intense epidotization was also noted in parts of the Soutpansberg (see later section).

Plagioclase occurs as euhedral and subhedral ophitic phenocrysts in the fine-grained rocks, large (up to 1 cm) phenocrysts in coarse lavas and intrusives and fine intergrowths in cryptocrystalline rocks (Barker 1979). Groundmass crystals are typically anhedral though alteration commonly makes recognition of groundmass plagioclase difficult.

2. Felsic Rocks

Felsic pyroclastic and lava flows are relatively abundant in the Soutpansberg succession (Barker 1979). Due to extensive alteration, however, pyroclastic rocks yield less petrographic and geochemical data than do the mafic rocks. Many of the pyroclastic rocks show fragmental textures, *e.g.* tricuspate shards typical of ash-flow tuffs. Overall, however, the textures of the pyroclastic rocks show a range of texture suggesting emplacement mechanisms which in all likelihood involved pyroclastic flow, air fall and possibly also base surge.

Alteration and Metamorphism

Alteration and low-grade metamorphism of the Soutpansberg igneous rocks is fairly ubiquitous. Regional metamorphic effects are not that noticeable in the associated sediments. The igneous rocks were examined by Barker (1979) for possible mineral parageneses indicative of a metamorphic condition.

The suite of alteration minerals consist of chlroite, epidote, quartz, sericite, and minor amounts of calcite, leucoxene and actinolite. Pumpellyite has been reported by Stoljan (1974) from basalt sampled near the base of the Soutpansberg volcanics but no paragenesis was given. The identification of pumpellite was by X-Ray diffraction on a mineral separate. All the above minerals are common alteration products of basic igneous rocks. The alteration mineralogy can be seen to have been formed essentially by in-situ alteration of the pre-existing minerals during cooling and post-formational autometasomatism. This is supported by the ubiquitous preservation of pristine igneous-minerals in fresh rocks and the absence of extensive albitisation of the feldspars. It is therefore considered that the alteration reflects essentially isochemical changes and that the bulk-chemical compositions of the ingeous rocks have not been drastically affected, though more mobile elements such as K_2O and Rb have probably undergone some redistribution subsequent to solidification of the rocks.

Table 2

Whole rock analyses of Soutpansberg basalts. NKW 84/1 is from the northern part of Kruger National Park. Other analyses are from Barker (1979) obtained on samples collected outside the park

	NKW 84/1	GC1	GC2	GC3	GC4	GC8	GC9	GC11	GC13	GC14	GC15	GC16
SiO_2	48.9	49.20	49.38	48.88	48.78	52.28	49.53	50.61	48.71	49.47	48.19	48.08
TiO_2	1.39	1.35	1.32	2.23	1.31	.86	.97	1.43	1.49	1.51	1.54	.82
Al_2O_3	14.9	14.30	14.77	13.03	14.09	14.16	13.94	13.98	15.69	14.86	14.87	16.43
Fe_2O_3	12.8	13.11	14.01	17.90	14.22	12.83	12.83	14.16	14.36	14.72	14.28	11.27
MnO	0.17	.20	.20	.25	.28	.21	.21	.17	.16	.16	.17	.14
MgO	6.00	6.50	6.51	4.53	8.37	6.31	5.34	7.28	6.66	6.86	7.12	9.95
CaO	8.66	9.50	9.36	8.51	6.89	7.42	12.06	7.72	7.17	7.17	7.25	8.46
Na_2O	2.60	2.80	2.04	2.18	2.23	2.49	.32	2.05	2.99	2.14	2.33	1.68
K_2O	1.43	.44	.63	.84	.39	.94	.06	.36	.69	.14	.67	.19
P_2O_5	0.14	.26	.23	.37	.26	.23	.38	.26	.31	.29	.28	.21
H_2O^-	.20	.10	.09	.13	.27	.15	.12	.11	.11	.07	.08	.06
H_2O^+	2.41	3.63	3.05	2.53	3.93	3.10	3.99	3.34	2.94	3.88	3.55	3.29
CO_2	.20	.10	.16	.21	.13	.13	.53	.29	.13	.21	1.10	
TOTAL	99.80	101.49	101.75	101.59	101.15	101.11	100.28	101.76	101.41	101.48	101.43	100.58
LOI	2.82											
F	400											
S	130	100	600	1200	100	100	200	100	100	200		
V	250											
Cr	200											
CO	88											
Ni	150											
Cu	202											
Zn	119											
Rb	43											
Sr	77											
Y	18											
Zr	114											
Nb	5											
Ba	670											

TOTAL = OXIDES + H_2O^- H_2O^+ + CO_2 + F + S; Fe_2O_3 represents total iron.

Colour changes are probably some of the most noticeable effects caused by this alteration. Epidotization of the basalts is particularly noticeable in places and results in the occurrences of bright green rocks in which original amygdale structures are well preserved. One consequence of this alteration is that it possibly accounts for references to andesites in the Soutpansberg sequence. Not only do the colours and appearances of the altered rocks show some broad similarities to so called andesites, but the effective masking of original siliceous amygdales would mean that analysis of whole rocks would show increased silica contents more typical of andesites.

Geochemistry

The mafic volcanics of the Soutpansberg Group have previously been described as andesites or basaltic lavas (Du Doit 1939; Truter 1949; Van Eeden, Visser, Van Zyl, Coertze & Wessels 1955). However, due to the generally altered nature of these rocks proper classification has not always been possible on the basis of petrography alone. Early published silicate analyses of Soutpansberg rocks (Van Eeden *et al.* 1955) indicated the presence of basaltic lavas in the succession though use of the term andesite has persisted amongst references to the Soutpansberg lavas (Truter 1949; Van Eeden *et al.* 1955).

More recent geochemical studies of Barker (1979) have however, shown that the mafic lavas of the Soutpansberg consist primarily of tholeiitic basalts. This conclusion has been reaffirmed by more recent analyses of Soutpansberg lavas from within the confines of the Kruger National Park.

Chemical analyses of mafic rocks from the Soutpansberg are listed in Table 2. These analyses show compositions fairly typical of tholeiitic basalts though incompatible elements show enrichment relative to classic tholeiitic basalts. In this respect the Soutpansberg rocks show some similarities to the incompatible enriched basaltic lavas of the northern Karoo province (Bristow & Saggerson 1983). Aside from broad comparisons noted above, the Soutpansberg mafic rocks plot in the tholeiitic field on an AFM diagram (Barker 1979) and show an overall iron-enrichment trend characteristic of tholeiitic rocks (Irvine & Barrager 1971).

Considering the generally altered nature of the Soutpansberg rocks it is possible that more mobile elements may have been redistributed and hence measured abundances do not represent pristine compositions. Both in this study and in that of Barker (1979), altered and epidotized rocks were avoided when selecting samples for analysis. Petrographic work on samples with a reasonably fresh appearance generally indicated the preservation of primary igneous minerals. On this basis Barker (1979) considered that alteration apparent in these rocks was essentially isochemical and argued that the bulk-chemical compositions of the igneous rocks had not been unduly affected.

To test for possible redistribution of elements such as K_2O in the basalts, Barker examined the relationship between the immobile element TiO_2 and

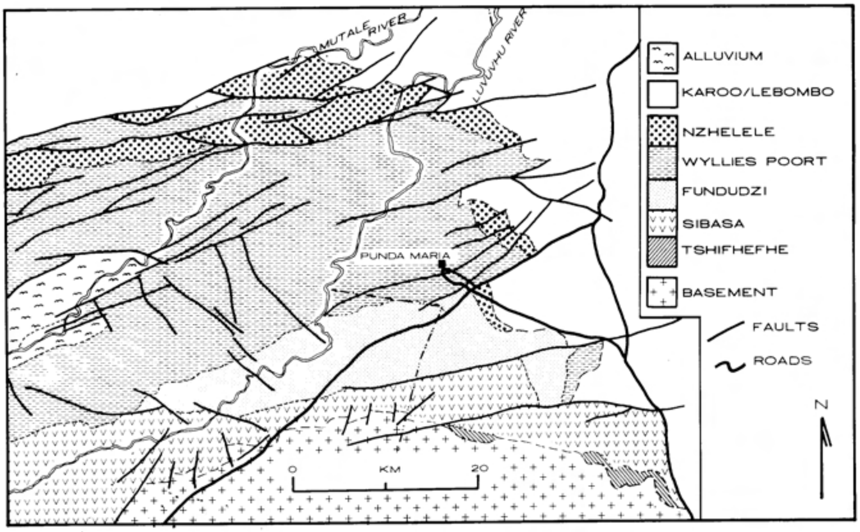


Fig. 1. Simplified geological map of the central and eastern portions of the Soutpansberg region. Note that there is considerably more faulting in the region than is depicted in this figure. (From 1:250 000 2230 Messina Geological Map published by the Department of Mineral and Energy Affairs and Geological Survey of South Africa, 1981).

K_2O. Except for three samples, Barker found that a reasonable correlation exists between these two oxides and thus inferred that no major changes in mobile elements had occurred in lavas and dolerites which on the basis of petrographic examination appeared to be reasonably fresh. Nevertheless, alteration and redistribution of mobile elements cannot be totally discounted in the case of the Soutpansberg lavas.

The felsic rocks of the Soutpansberg have proved more difficult to study in view of their generally altered nature and brecciated (pyroclastic) nature. Limited data presented by Barker (1979) and others suggest that these rocks are predominantly dacitic in composition.

Summary

Studies of the Soutpansberg rocks indicate that the present day rocks were deposited in a series of faulted basins (grabens) trending east-south-east. The strike faulting related to this trend has been active since pre-Transvaal times and the central zone of the Limpopo Mobile region has been continuously rising since the end of the Limpopo era at approximately 2 600 Ma before present. The uplift continued into the Soutpansberg basining period and had an over-riding influence on the shape of the basin and the sediments deposited therein. This is supported by crossbedding measurements which indicate that the source area for the Soutpansberg basin was consistently to the north of the present position of the Soutpansberg sediments. The presence of blue opaline looking quartz grains and occasional granitic gravels in the sediments substantiates this provenance model.

It is envisaged that the initial Soutpansberg basining occurred at approximately 2 100 Ma due to the formation of major east-north-east trending tension faults. These faults were a result of the continuous uplift which had taken place in the Limpopo Mobile belt region over a period of 400 Ma. The faults subsequently tapped basaltic magma from the mantle which was erupted along the east-north-easterly trending fissures and related faults as flood basalts (Sibasa Formation). Sedimentation commenced almost synchronously with the extrusion of the lavas in response to continuing uplift along the northern margin of the basin.

As volcanism died out sediments were carried into the basin by south flowing rivers from the Limpopo highlands to form the Fundudzi and Wyllies Poort Formations. The paucity of preserved overbank-deposits and the unimodal nature of the crossbedding indicates a fairly rapid fluvial flow-regime suggesting continuous uplift of the provenance region during sedimentation. A short period of resurgence of volcanicity was finally terminated by a period of explosive volcanism followed by more fluvial sedimentation (Nzhelele Formation).

A period of pre-Karoo strike-slip faulting took place forming the Siloam lineament and related faults in the basement rocks north of the Soutpansberg (Barker 1979). However, this period was short-lived and there is no evidence to indicate that the Soutpansberg region has been affected by post-Jurassic plate-tectonic movements.

Pre- and syn-Karoo tectonism imprinted a complex fault pattern on the Soutpansberg and surrounding rocks. Major uplift and normal faulting in post-Karoo times resulted in the exposure and erosion of the Soutpansberg Group to its present position and shape.

Possibly one of the most interesting aspects of the Soutpansberg rocks relates to the felsic volcanics. In several instances Barker (1979) describes felsic units characterised by large lateral extent, stretched and welded relict pumice fragments, flow banding and contorted banding. In nearly all cases Barker (1979) cites strong evidence for these rocks being of pryoclastic, ash-flow origin. However, the occurrence of flow banding and contorted flow banding suggests that at some stage in their emplacement these rocks became effectively re-mobilized thus allowing the development of the flow features referred to above. Features described by Barker in many respects mirror those features described in the massive rhyolite flows of the Lebombo (see Bristow & Saggerson 1983; Bristow 1985). The rather unusual volcanology of the Lebombo flows has been interpreted as a function of abnormally high temperature ash-flow type emplacement. Though evidence is presently rather limited it is suggested that some felsic flows described in the Soutpansberg could be additional examples of high temperature ash-flows which show textures characteristic of both conventional ash flows and rhyolite lavas. Apart from differences reflected in the major interbedded sedimentary units found in the Soutpansberg, this Proterozoic succession, as in the case of the Lebombo volcanics, contains an essentially bimodal basalt (mafic) – dacite (felsic) association. The apparent occurrence of possible high temperature ash flows in the Soutpansberg thus once again appears to be linked to a volcanic province in which high heat flow is reflected by the large scale outpouring of basaltic magma.

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