New Chemical Analyses of the Suurberg Volcanic Rocks and Their Significance in Relation to Mesozoic Volcanism in Southern Africa

Volcanic rocks are found associated with several of the late Mesozoic basins of southern South Africa.[1,2] Bentonites are known from Plettenberg Bay[2] and, according to an unconfirmed report, they are also found in the Worcester Basin, while vitric tuffs have been recorded from east of Oudtshoorn. The most extensive occurrences, however, are those of the Suurberg Group, which crops out sporadically around the margins of the Algoa Basin (Fig. 1). These rocks were first described by Rogers, in 1905,[3] and have more recently been the subject of an MSc thesis by Hill.[4] The latter has shown that the Suurberg Group overlies the Palaeozoic rocks of the Cape and lower Karoo Supergroups with considerable angular discordance, and has expressed the view that the succeeding Uitenhage Group is conformable upon the volcanic sequence. The basis for this view is inconclusive, as no satisfactory exposure of a sedimentary contact is known, but field mapping does not indicate any major structural discontinuity between the two groups. The fluviatile sediments of the lower part of the Uitenhage Group are of approximately Late Jurassic and/or Early Cretaceous age,[5] but the available palaeontological data do not permit a more precise determination.

Hill[4] presented chemical analyses of tuffs, lavas and an intrusive sheet, concluding that the tuffs are rhyolitic and the lavas basaltic, with an absence of igneous rocks of intermediate composition. A closer examination of his data reveals inconsistent features, however. The analyses of the tuffs are quite unlike those normally considered typical of magmatic rocks, with normative Q values ranging between 45 and 63%, normative ab/an ratios of 0.3 to 7.4, and $(FeO + Fe_2O_3)/MgO$ ratios of between 0.74 and 4.4. Typical rhyolites have CIPW norms with up to 35% of Q and ab/an ratios greater than 6.0 and have $(FeO + Fe_2O_3)/MgO$ ratios greater than 5.0.

Analytical results

As part of a broader investigation of Mesozoic volcanism in Southern Africa, we have collected and analysed several specimens of lava and of tuff from localities within the Algoa Basin in order to resolve some of the questions posed by Hill's results. Analyses of three tuffs and five lavas are presented in Table 1. Because the lavas are all highly amygdaloidal, an important aspect of our sample preparation was the removal by hand-picking of vesicle-filling materials before final crushing. This approach was adopted because there is no simple way of establishing unequivocally whether the vesicle-filling materials are primary or secondary. Furthermore, our experience with basalts of the Drakensberg Group indicates that removal of vesicle-filling minerals prior to analysis results in relatively minor changes in bulk rock composition compared with possible intraflow variations.

The analyses of the lavas indicate that they range from basalt to ferrolatite in composition. The basalts are tholeiitic and compositionally indistinguishable from the basalts of the Lesotho Formation of the Drakensberg Group (unpublished data). The presence of more evolved lavas (W-3 and WM-9) of intermediate composition is significant as they have not been reported from the Suurberg Group before.

Examination of Table 1 reveals that two of the tuffs (WM-7 and WM-8) display low values for Na_2O and slightly high SiO_2 values when compared with typical rhyolitic lavas, while WM-2 has an unexceptional, igneous chemistry. Many of the quartz grains in the tuffs are seen to be highly strained or polycrystalline, and it is probable that a proportion of these are xenocrystic, derived from the Palaeozoic wall-rocks, or detrital, having been mixed with the tuff during reworking in a sedimentary environment. This interpretation accounts for the high silica values characteristic of Hill's analyses and of some of our own. It might be noted here that Hill's identification of the rhyolitic tuffs as ignimbrites is questionable; the planar fabric noted in some thin sections is probably a reflection of bedding (grains and glass shards resting with their long axes horizontal) and a degree of normal compaction, not of welding compaction.[6] Several blocks collected from Beyer's Vlei Outspan were cut perpendicular to bedding plane and polished, revealing abundant small-scale bedding, made conspicuous by the mudstone laminae. In many cases, the lamination was highly disrupted, possibly a result of the boiling of pore-waters as overlying lava flows were emplaced. This process may also have led to sufficient mobilization of the tuffaceous sediment for the latter to have become fluidized, leading to the intrusive relationships seen in the outcrops on Beyer's Vlei Outspan. Alternatively, these intrusions may have resulted from the near-surface emplacement of fluidized pyroclastics directly from a deeper magmatic source, an interpretation which we prefer. If we are correct, any foreign quartz grains in the intrusive tuffs are xenocrystic, rather than detrital.

Discussion

In order to assess the significance of the Suurberg volcanism within the general framework of Mesozoic igneous activity in Southern Africa, it is necessary to know the age of these rocks. The available data have recently been summarized[5] and are both inadequate and ambiguous. References in the literature to dates of '80 to 90 m.y.', 'early Upper Cretaceous' (sic) and 'less than 100 m.y.' are apparently all based on a misreport of a conventional whole-rock K/Ar age determination of 162 ± 7 Myr (Middle Jurassic).[5] The sample used was 'a single sample of basalt from near the western boundary of the farm Tyger Kop'.[5] We have searched this area and found the outcrops to be poor and the rocks highly weathered. We saw no material which we would regard as sufficiently fresh to justify radiometric dating, particularly by conventional K/Ar methods, and are sceptical of the significance of any age which might be obtained by this

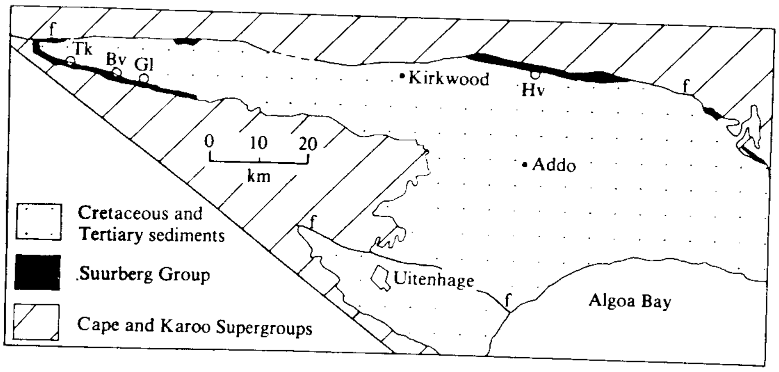

Fig. 1. The Algoa Basin showing distribution of the Suurberg Group. Tk, Tyger Kop; Bv, Beyer's Vlei Outspan; Gl, Gorie Laaghte; Hv, Honeyvale.

means. Moreover, our experience with basalt lavas from the Drakensberg Group has shown that even when fresh samples are dated by conventional K/Ar methods and the results compared with those obtained by the $^{40}Ar/^{36}Ar$ isochron technique, differences of as much as 20 Myr are common (unpublished data). In short, we do not regard the available data as reliable.

The association of basalts with volumetrically significant intermediate and silicic lavas and pyroclastics is characteristic of the igneous activity which accompanied the rifting and breakup of Gondwanaland and the formation of the new continental margin around Southern Africa. A good example of this type of volcanism is provided by the basalt-latite-quartz latite suite (the Kaoko Group) of Namibia, which was erupted during the separation of South America from Africa in the early Cretaceous.[7] The basalt-dacite-rhyolite Lebombo suite of Natal (located along the Lebombo-Nuanetsi-Lupata lineament[8]) was also extruded during a time of faulting and crustal thinning[9] which was possibly related to the breakaway of East Gondwanaland from West Gondwanaland in the Early and Middle Jurassic, although the details and timing of this event are not well known.[10,11]

Many authors[12] have, in the past, accepted a direct correlation between the Suurberg Volcanic Group and the Lower and Middle Jurassic[13,14] basalts of the Drakensberg Group which are so extensive in the continental interior of Southern Africa. Although the radiometric age discussed above would, if accepted, support this correlation, the great difference in tectonic setting would amply justify considering the Suurberg rocks as an independent phenomenon. We would prefer to compare the latter with the Kaoko and Lebombo Groups, and to consider Suurberg volcanism as a response to continental separation and the development of the Agulhas Fracture Zone off the Southern African continental margin, even though the Suurberg volcanic rocks are not areally extensive, nor are they thick, when compared with the Kaoko and Lebombo occurrences.

South America started to move away from Africa very early in the Cretaceous.[15] The newly defined plates were separated by a rift, with minor transform offsets, off the west coast of Africa, while a major transform boundary was formed along the southeast edge of the continent (the Agulhas Fracture Zone).[16] The oldest magnetic anomaly recognized on the ocean floor west of Southern Africa is M12, approximately 128 million years old. This anomaly is located close to the continental edge and is therefore believed to be a good indicator of the timing of the initial rifting[17] and, therefore, also of the initial major displacement along the Agulhas fracture.

There are a number of east-west trending faults in the southern part of South Africa (Fig. 2), which are believed to have had an earlier history as high-angle reverse faults within the Cape Fold Belt.[2] The compressional regime of which they were a reflection probably continued to exist through the early and middle Jurassic, which would account for the observation that the Karoo dolerites and the Drakensberg Group basalts, to which they are believed to have been related, are not found south of a line which marks the approximate northern edge of the Cape Fold Belt (Fig. 2). By late in the Jurassic, the compressional regime gave way to one of extension, probably related to the imminent opening of the South Atlantic. This led to movements along the east-west faults which continued through a long period of time, and which can best be identified from fanglomerate sequences derived from the faults.

It will be noted from Fig. 2 that the direction of regional tension is oblique to the strike of the faults. This might be expected to lead to some combination of right-lateral strike-slip and normal dip-slip movement. The field evidence for a dip-slip

Table 1. Major[19] and trace element analyses of lavas and tuffs from the Suurberg Group.

	WZ-3	WZ-6	WM-1	WM-5	WM-9	WM-2	WM-7	WM-8
SiO_2	63.08	52.10	52.86	50.24	55.02	71.95	78.81	74.99
TiO_2	1.56	1.01	1.08	1.04	1.13	0.36	0.24	0.29
Al_2O_3	12.32	15.49	15.67	16.17	13.01	12.29	9.66	10.51
Fe_2O_3*	10.39	11.59	11.63	11.61	12.00	2.24	1.89	2.03
MnO	0.18	0.21	0.25	0.20	0.24	0.11	0.08	0.13
MgO	1.34	5.14	5.10	9.70	3.47	0.43	0.37	0.76
CaO	3.18	10.06	10.56	2.51	7.20	1.54	1.23	0.44
Na_2O	3.01	2.72	2.89	2.89	2.76	3.50	1.86	0.92
K_2O	3.09	0.68	0.58	0.69	0.98	4.25	3.21	5.87
P_2O_5	0.66	0.22	0.23	0.24	0.28	0.15	0.07	0.09
H_2O	0.89	0.95	0.31	1.31	1.36	0.90	0.35	1.22
LOI†	0.10	1.31	0.85	1.48	2.83	2.96	2.86	2.59
	99.80	101.48	102.01	100.34	100.28	99.69	100.63	99.84
Sr	112	195	203	212	931	618	765	103
Rb	98	24	19	18	15	140	98	174
Zr	354	99	107	110	117	275	205	177
Nb	20	4.8	5.1	5.9	5.4	13	11	12
Y	75	28	31	28	32	27	18	35
Zn	111	118	97	96	91	50	18	39
Cu	83	60	93	91	114	24	7	16
Ni	9	65	59	62	47	7	–	–
Co	16	52	42	40	35	5	3	8
Cr	5	243	269	132	96	20	13	10
V	72	258	251	284	260	10	9	6
La	32	14	17	11	10	39	26	62
Ce	70	22	23	25	30	71	46	88
Nd	44	17	16	18	21	30	21	49

Major and trace elements determined by X-ray fluorescence spectroscopy. *All Fe as Fe_2O_3. † Loss on ignition at 950°C. WM-3, Ferrolatite, Tygerkop; WZ-6, Basalt, Gorie Laaghte; WM-1, Basalt, Beyer's Vlei Outspan; WM-5, basalt, Beyer's Vlei Outspan; WM-9, differentiated basalt, Honeyvale; WM-2, tuff, Beyer's Vlei Outspan; SM-8, tuff, Tygerkop; WM-7, tuff, Beyer's Vlei Outspan.

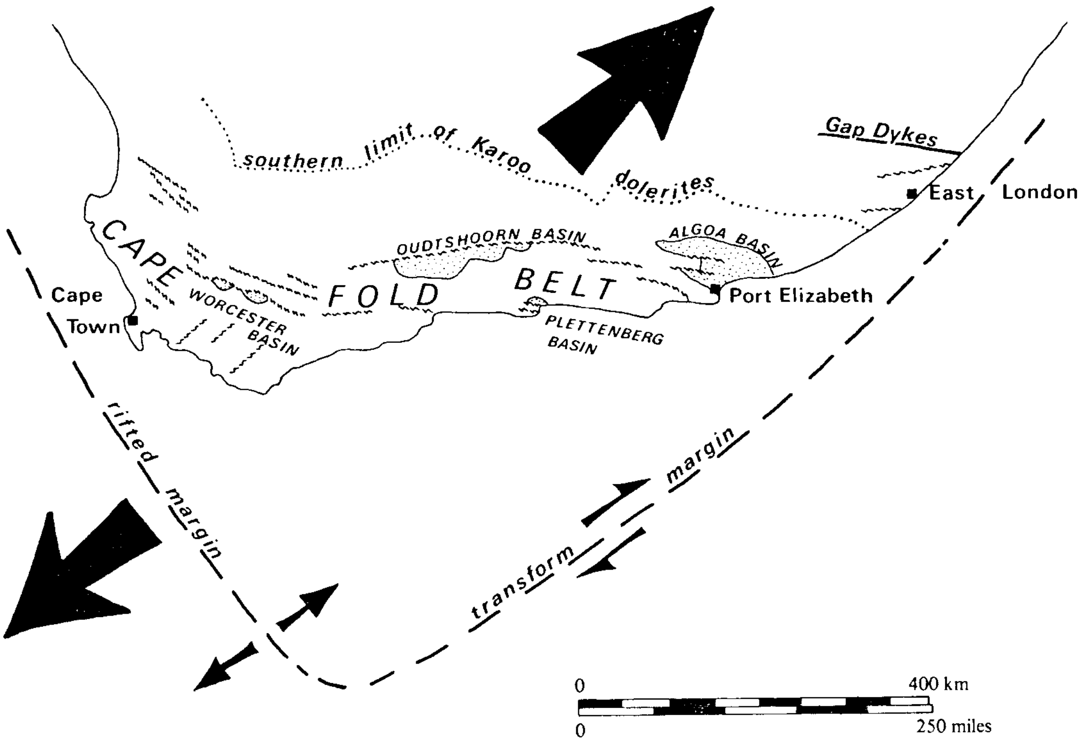

Fig. 2. The Cretaceous sedimentary basins which show evidence of associatted volcanism. Superimposed on the map is the direction of regional tension (oarge arrows) and the type of developing plate margins (heavy dashed line) in the early Cretaceous-late Jurassic.

component of movement is widespread, and includes the existence of the Cretaceous sedimentary basins.[1] Evidence for strike-slip is less clear, but it should be noted that first motion studies of the Tulbagh earthquake[18] indicate almost pure strike-slip displacement. Rotation of fault blocks led to the development of a series of half-graben, most of which are tilted towards the north, with numerous small antithetic faults. The northern Algoa Basin is one of the few exceptions in that the Kommando Kraal fault, which runs along part of its southern margin,[8] is the main controlling structure,[2] with downthrow to the north. The regional dip in the northern Algoa Basin is to the south.

There is no direct field evidence to link the Suurberg volcanic rocks with normal faulting, other than geographical proximity, but we believe that the magmatism and faulting are both reflections of the tensional regime which, by all evidence, was established in the southern Cape region in the late Jurassic or early Cretaceous in response to the break-up of western Gondwanaland.

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[1] Lock, B. E., Shone, R., Coates, A.T., and Hatton, C. J. (1975). Mesozoic Newark-type sedimentary basins within the Cape Fold Belt of Southern Africa. *IXth Int. Congr. Sedimentology, Nice, 1975, theme 4*, 217–226.

[2] Lock, B. E. (1978). The Cape Fold Belt of South Africa; tectonic control of sedimentation. *Proc. Geol. Ass.*, 89, 263–281.

[3] Rogers, A. W. (1905). The volcanic fissure under the Zuurberg. *Trans. phil. Soc. S. Afr.*, 16, 190–197.

[4] Hill, R. S. (1975). The geology of the northern Algoa Basin, Port Elizabeth. *Ann. Univ. Stell. Ser. A1 (Geol.)*, 1, 105–191.

[5] McLachlan, I. R. and McMillan, I. K. (1976). Review and stratigraphic significance of southern Cape Mesozoic Palaeontology. *Trans. geol. Soc. S. Afr.*, 79, 197–212.

[6] Lock, B. E. (1977). Precambrian ignimbrites and associated volcaniclastics from the Herbert District, northern Cape Province – discussion. *Trans. geol. Soc. S. Afr.*, 80, 47–48.

[7] Siedner, G. and Mitchell, J. G. (1976). Episodic Mesozoic volcanism in Namibia and Brazil: A K/Ar isochron study bearing on the opening of the South Atlantic. *Earth Planet. Sci. Lett.*, 30, 292–302.

[8] Cox, K. G. (1970). In *African Magmatism and Tectonics*, edit. T. N. Clifford and I. G. Gass, pp. 211–236. Oliver and Boyd, Edinburgh.

[9] Darracott, B. W. (1974). On the crustal structure and evolution of the south-eastern Africa and the adjacent Indian Ocean. *Earth Planet. Sci. Lett.*, 24, 282–290.

[10] Scrutton, R. A. (1973). The age relationships of igneous activity and continental break-up. *Geol. Mag.*, 110, 227–234.

[11] Dingle, R. V. and Scrutton, R. A. (1974). Continental break-up and the development of post-Palaeozoic sedimentary basins around southern Africa. *Geol. Soc. Am. Bull.*, 85, 1467–1474.

[12] For example on page 369 of S. H. Haughton's *Geological History of Southern Africa*. Geological Society of South Africa, Johannesburg (1969).

[13] McDougall, I. (1963). Potassium-argon age measurements on dolerites from Antarctica and South Africa. *J. geophys. Res.*, 68, 1533–1545.

[14] Fitch, F. J. and Miller, J. A. (1971). Potassium-argon radio ages of Karroo volcanic rocks from Lesotho. *Bull. Volc.*, 35, 64–84.

[15] Sclater, J. G. Hellinger, S. and Tapscott, C. (1977). The palaeobathymetry of the Atlantic Ocean from the Jurassic to present. *J. Geol.*, 85, 509–552.

[16] Scrutton, R. A. (1973). Structure and evolution of the sea floor south of South Africa. *Earth. Planet. Sci. Lett.*, 19, 250–256.

[17] Rabinowitz, P. D. (1976). Geophysical study of the continental margin of southern Africa. *Geol. Soc. Am. Bull.*, 87, 1643–1653.

[18] Guzman, J. A. (1974). Die Fokale meganisme van die hoofskok: 'n Oorsig. *S. Afr. Dept. Mines Geol. Surv. Seismology Series*, 4, 31–34.

[19] Norrish, K. and Hutton, J. T. (1969). An accurate X-ray spectrographic method for analysis of a wide range of geological samples. *Geochim. Cosmochim. Acta*, 33, 431–453.