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MINERALOGY, PETROLOGY AND ORIGIN OF THE ARCHAEAN BOESMANSKOP SYENITE, BARBERTON MOUNTAIN LAND, SOUTH AFRICA

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ABSTRACT

The Boesmanskop syenite consists of four intrusive bodies in the Archaean granite-greenstone terrane of the southwestern part of the Barberton Mountain Land, South Africa. The syenite occurrences, which have yielded an U-Pb mineral age of $\sim$ 3130 m.y. (Oosthuyzen, 1970) and a Rb-Sr whole rock age of $\sim$ 2850 m.y., are emplaced in a linear tectonic regime that has been subjected to faulting, shearing, dyke emplacement and thermal spring activity from Archaean times to the present.

The examination of a suite of rocks, ranging from syenite to granite *(sensu stricto)* indicates that the syenite magma evolved along an oversaturated trend extending from the critical undersaturation line (the alkali feldspar join) in petrogeny's residua system, away from the thermal maximum towards granite. This trend, although not uncommon, does not appear to have been documented in Archaean syenites.

Trace and rare-earth element modelling as well as Sr isotope data suggests that the parent magma of the Boesmanskop syenite suite was derived by extensive partial melting of an intermediate-to-felsic source. Portion of this melt intruded along a conduit to form a large dyke-like body known as the Weergevonden syeno-granite "tail" whereas the melt remaining in the magma chamber apparently underwent fractional crystallization to produce the syenites and quartz syenites of the Boesmanskop pluton and the syenites and granites *(sensu stricto)* of the Kees Zyn Doorns body.

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I. INTRODUCTION

Despite the vastness of the shield areas of the world there have been comparatively few reports of Archaean syenite occurrences. Those that are known appear to have received only limited attention with the possible exception of some small bodies in Zimbabwe-Rhodesia (Macgregor, 1930, 1932; Amm, 1940; Bliss, 1970) and Minnesota-Ontario (Goldich et al., 1972; Hanson and Goldich, 1972; Prince and Hanson, 1972; Sims and Mudrey, 1972). In South Africa two early Precambrian syenite occurrences are known, namely, the Schiel Alkaline Complex situated in the southern marginal zone of the Limpopo Mobile Belt (Du Toit and Van Reenen, 1977; Du Toit, 1979) and the Boesmanskop Syenite, which intrudes amphibolite xenoliths and trondhjemitic gneisses in the region southwest of the Barberton greenstone belt on the Kaapvaal craton (Fig. 1). Little is known of the Schiel syenites whereas the Boesmanskop occurrence has had various geological and geochemical aspects examined by Viljoen and Viljoen (1969a, b), Anhaeusser (1974, 1975), Glikson (1976, 1979) and Anhaeusser and Robb (1978).

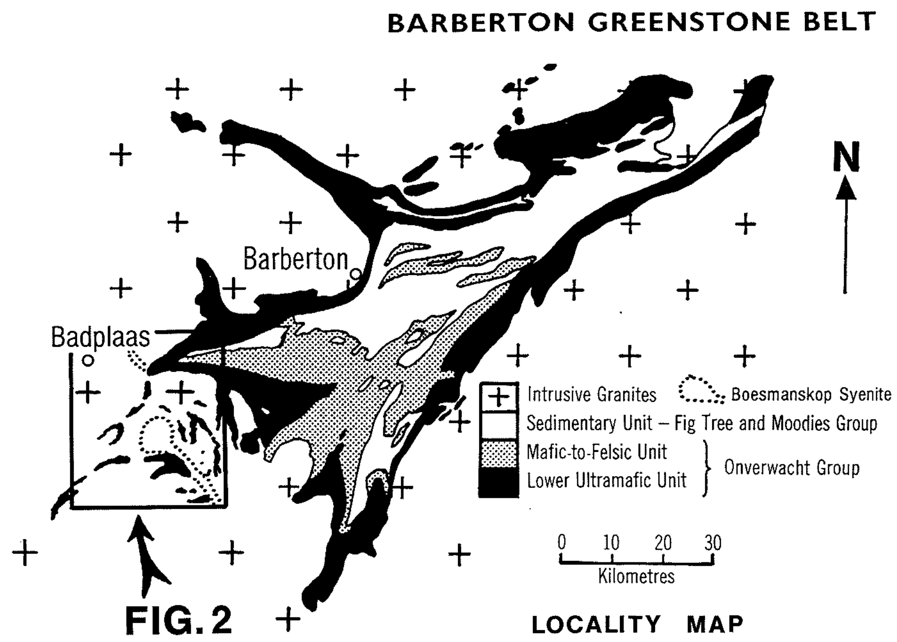

Figure 1 : Location of the Boesmanskop syenite intrusions in the southwestern part of the Barberton Mountain Land, South Africa.

The Boesmanskop syenite has yielded an U-Pb zircon age of 3130 m.y. (Oosthuyzen, 1970) and also a Rb-Sr whole rock age of $\sim$ 2850 m.y. (see later). Detailed studies of syenitic bodies with these ages are uncommon in the literature and this paper presents field and petrographic descriptions, major, trace and rare-earth element geochemistry as well as Rb-Sr and oxygen isotope data for this body. The Boesmanskop syenitic kindred provide an example of a magma which has evolved towards a silica oversaturated residuum; a marked contrast to syenites that either remain critically undersaturated or fractionate towards silica-undersaturated compositions. On the basis of the evidence presented in this paper the Boesmanskop syenite magma is considered to have been derived by partial melting of an intermediate-to-felsic source, a parent not dissimilar from that used by Condie and Hunter (1976) to derive post-kinematic granitic intrusives in different parts of the Barberton Mountain Land.

II. FIELD RELATIONS

The region southwest of the Barberton greenstone belt (Fig. 2) consists of a wide variety of granitic rock types, the oldest of which are the tonalitic or trondhjemitic gneisses that occur commonly in the form of discrete diapirs intrusive into the Barberton greenstone belt as well as numerous greenstone remnants rafted off from the latter. Available U-Pb age determinations undertaken by Oosthuyzen (1970) on zircons show a spread of ages ranging from ∿ 3170 - ∿ 3250 m.y. for some of the trondhjemitic gneiss plutons in the area. Follow-up Rb-Sr isotopic studies, which are currently in progress, have confirmed some of the earlier results and have demonstrated low initial $^{87}Sr/^{86}Sr$ ratios (J.M. Barton, unpublished data) that support the views expressed by Barker et al. (1976a) and Condie and Hunter (1976) that these early tonalitic gneisses were probably derived from the partial melting of basaltic rocks at mantle depths.

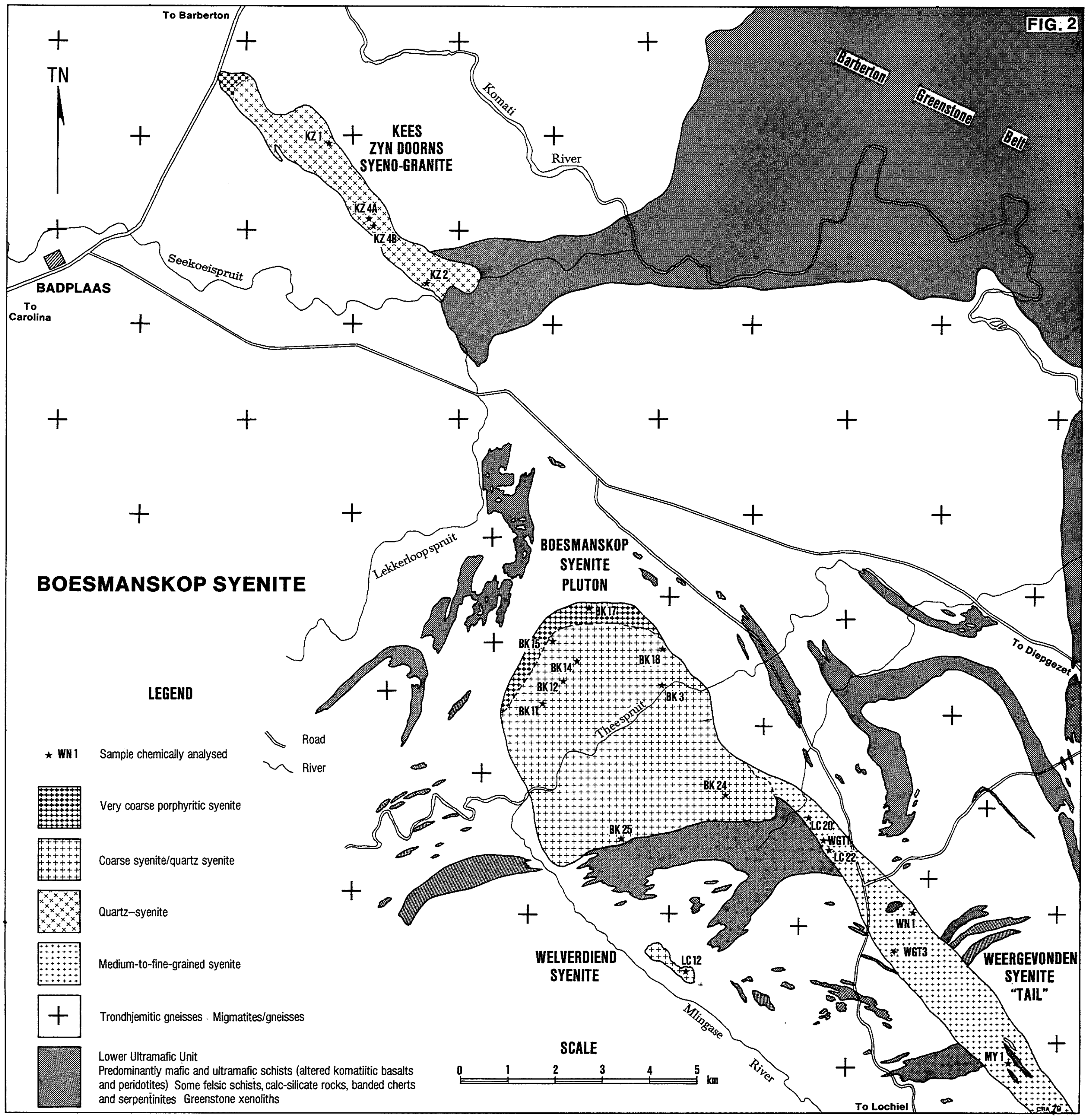

Figure 2 : *Simplified geological map of the granite greenstone terrane southwest of the Barberton greenstone belt showing the location of the various components associated with the Boesmanskop syenite intrusions as well as the locations of samples reported in this study.*

Intruded into this granite-greenstone terrane are a number of syenite and syeno-granitic bodies, the largest of which is the Boesmanskop syenite pluton which measures approximately 6 km NW-SE and 4 km SW-NE (Plate IA). From the southeastern extremity of the Boesmanskop pluton there extends a dyke-like syenite "tail" approximately 1 km wide and over 8 km long. This body, which has been named the Weergevonden syeno-granite, is overlain in the southeast by an extensive diabase sheet believed to be of Proterozoic age.

A third syenite occurrence, known as the Welverdiend syenite body, is located immediately south of the Boesmanskop pluton and is surrounded almost entirely by trondhjemitic gneisses (Fig. 2). The Welverdiend body is the smallest mappable syenitic occurrence in the study area. To the north-east of Badplaas lies a further intrusion known as the Kees Zyn Doorns syeno-granite. This body, which forms a low whale-back exposure 7 km long and approximately 1 km wide, is aligned parallel to the Boesmanskop pluton and its southeasterly trending Weergevonden syeno-granite "tail".

The preferred NW-SE orientation of the syenite occurrences coincides with a number of other geological features present in the area but which have been excluded from the accompanying geological map. These include a prominent dyke swarm, several major fracture or shear zones and the presence of hot springs, the largest of which is located at Badplaas. It is evident that the region occupied by the various syenitic bodies southwest of the Barberton greenstone belt has been involved in a long and complex history of crustal evolution - a process that is still active to this day, as manifest by the thermal spring activity in the region.

The term "Boesmanskop syenite" is used in this paper to embrace all the syenite occurrences named earlier and which appear in Figure 2. Being the largest and topographically most prominent of all the syenite bodies the Boesmanskop pluton has commanded the most attention in the past and only in recent years has there been an awareness of the existence of the Weergevonden and Welverdiend occurrences. The Kees Zyn Doorns body near Badplaas was first described by Visser et al. (1956) who recognized a suite of rocks ranging from pink hornblende granite to syenite or quartz syenite. Although there was uncertainty at the time as to the correlation of this body with any of the granitic rocks known in the region it is now considered to be linked with the remainder of the Boesmanskop syenitic rocks. Table 1 (after Oosthuyzen, 1970) shows that age determinations for the Kees Zyn Doorns syeno-granite and Boesmanskop syenite pluton are identical, thus supporting their cogenetic nature.

TABLE 1

AGE DETERMINATIONS FOR THE BOESMANSKOP AND KEES ZYN DOORNS SYENITE OCCURRENCES

	Mineral	Calculated Ages (m.y.) $^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	Concordia Intersection
Boesmanskop Syenite	Apatite	3 125	3 192	3 307	3 130 ± 30 m.y.
	Zircon	3 110	2 930	2 680	
Kees Zyn Doorns Syeno-Granite	Apatite	3 122	3 047	2 930	
	Zircon	3 115	3 080	3 030	

(after Oosthuyzen, 1970)

The Boesmanskop pluton is texturally the most varied of all the syenite bodies, The northern flank of the pluton consists of a very coarse porphyritic syenite with euhedral, zoned crystals of perthite and microperthite sometimes exceeding 3 cm in size (Plate IB). Most of the syenites to the south are coarsely crystalline (average grain size 5 mm), generally even-textured, homogeneous rocks, becoming medium-to-fine-grained in places, particularly along the southern contact zone where quartz syenites are mainly developed (samples BK 24 and BK 25).

Mafic inclusions, generally consisting of small amphibolite or biotite/chlorite xenoliths, most likely derived from the greenstones in the area, occur randomly distributed throughout the syenites and some of these show various stages of assimilation (Plate IC). Inclusions of medium-coarse-grained syenites were also noted in the very coarse porphyritic sector of the pluton (Plate ID). These, together with the frequent occurrence of thin, cross-cutting, syenitic and aplitic dykelets, suggests that the magma underwent a prolonged and complex cooling history.

In places within the syenite mass there are flow lines caused by a linear or parallel arrangement of the mineral constituents. These flow lines are emphasized in areas where ferro-magnesian components are prominent, but are also noticeable near the margins of the pluton where tabular feldspar crystals are aligned in subparallel planes. The aligned tabular feldspars and the foliation are probably related to magma tectonics, and dips are generally subvertical suggesting that the present level of exposure is well below the original roof of the intrusion where flatter dips might be expected. There is, however, no way of quantifying the present exposure level.

In total contrast to the pink, generally coarse-grained, Boesmanskop syenite, the Weergevonden syeno-granite is a light grey, medium-to-fine-grained, homogeneous rock outcropping relatively poorly except in a few river sections. Isolated granite-greenstone blocks also occur as xenoliths within the syenite tail.

The Welverdiend syenite body consists of coarse, porphyritic syenite, grading into finer grained quartz syenites and syeno-graintes. Exposure is variable and the syenites show signs of having been disturbed by shearing along the prominent fracture system responsible for the linear course of the Mlingase River. Sample LC 12 (Fig. 2) consists of pink, porphyritic, quartz syenite with feldspar phenocrysts and ferromagnesian components strongly aligned and possessing an augen texture. In places the feldspar phenocrysts measure upwards of 4 cm in length and the foliation is aligned in a northeasterly direction at right angles to the Mlingase shear direction. These rocks have clearly been tectonically deformed but poor exposure does not readily permit an assessment of the structural history of the Welverdiend body.

Near Badplaas, the Kees Zyn Doorns syeno-granite body is emplaced mainly into light grey leuco-trondhjemitic gneisses, but in the southeastern portion of the body the syenite intrudes rocks forming part of the base of the Onverwacht Group in the Barberton greenstone belt. In places the syenitic rocks are pink to brick-red in colour and are generally medium-grained. Porphyritic, coarse-grained syenites occur near the Badplaas-Barberton road and some very fine-grained, almost aplitic, phases occur in places, particularly in the north-central parts of the body. Strongly foliated pinkish gneissic syenites occur in the southeastern portion of the body in the vicinity of sample KZ 2. Aligned ferromagnesian minerals and small greenstone xenoliths are also evident in this region.

III. PETROGRAPHY

With the exception of the Weergevonden body all the other syenitic rocks in the areas east of Badplaas have a distinctive pink or reddish-pink colouration and also contain a significant ferromagnesian mineral content. The dominant minerals in the syenites are microcline, orthoclase, perthite and microperthite. Plagioclase feldspar is also prevalent in all the samples examined and consists mainly of oligoclase or albite.

In the porphyritic and coarse-grained syenites, particularly in the Boesmanskop pluton, euhedral, prominently zoned, perthitic feldspar crystals are common (Plate IE). These consist mainly of orthoclase microperthite, microcline microperthite, or microcline perthite and a wide variety of textures are evident, including stringlets, strings, rods, beads, interlocking, interpenetrating and replacement types (as defined by Alling, 1938).

Most of the syenites contain a sodium-rich plagioclase in addition to the potassium feldspars and perthites and must have crystallized at pressures such that the solvus intersected the solidus in the binary system $NaAlSi_3O_8$ - $KAlSi_3O_8$. Crystal zoning of the perthites (Plate IF) suggests that during crystallization the magma underwent fluctuations in temperature and pressure thereby resulting in oscillatory, or even possibly reversed, zoning.

In the Welverdiend syenite body the large porphyritic feldspars consist mainly of orthoclase and orthoclase microperthite. Microcline and lesser quantities of plagioclase occur as finer grained matrix components together with quartz and ferromagnesian minerals. The porphyritic syenite from the Kees Zyn Doorns body contains large insets of interpenetrating perthite set in a groundmass of orthoclase and antiperthite. Elsewhere in this body microcline and microperthite is prominent together with albite and orthoclase.

The dominant ferromagnesian mineral found in the syenites is a green or blue-green hornblende. This, in places, has cores of green augitic pyroxene which commonly displays prominent herringbone textures. The hornblende, in turn, has undergone alteration, either entirely, or along the crystal boundaries, to green chlorite. Some olive green biotite is also present in most specimens.

The amphiboles and other ferromagnesian components occur as aggregate clusters or as trains in the foliated syenites. Closely associated with these clusters are the accessory minerals apatite, magnetite, epidote, zircon and sphene.

Euhedral sphene and apatite crystals are particularly prominent in some rocks, the apatite, together with zircons, being used by Oosthuyzen (1970) to date both the Kees Zyn Doorns and Boesmanskop bodies. These minerals, together with magnetite, are often poikilitically enclosed in bladed hornblende.

Free quartz is not common in the main mass of the Boesmanskop pluton but does occur in the southern part of the body where the rocks are essentially quartz syenites. Quartz is commonly encountered in the Welverdiend and Kees Zyn Doorns bodies but is a subordinate component of the rocks. Myrmekitic intergrowths and some calcite were noted but are rare. Epidote and sericite occur erratically and in places epidote veins were found filling joints and hairline fractures in the syenite.

The Weergevonden syeno-granite, unlike the syenites described above, is a pale grey, leucocratic rock with a uniformly developed, medium-to-fine-grained texture. Ferromagnesian minerals are rare to absent in all the samples. The rocks are dominantly composed of microcline, microperthite, orthoclase and plagioclase (oligoclase-albite) with minor quartz. Epidote is a common component and the feldspars show varying degrees of sericitization. Muscovite flakes are in evidence and accessory quantities of apatite, sphene, chlorite and carbonate were observed.

IV. GEOCHEMISTRY

A. Major Elements

The major element compositions of twenty samples from the Boesmanskop syenite and quartz-syenite, the Weergevonden syeno-granite "tail", the Kees Zyn Doorns syeno-granite and the Welverdiend syenite are presented in Table 2. The variations in major element chemistry of the Boesmanskop syenitic kindred are illustrated in the form of mineral norms on the ternary diagram (Qtz-Ab-Or) of Figure 3.

TABLE 2

CHEMICAL ANALYSES OF THE BOESMANSKOP AND RELATED SYENITIC AND SYENO-GRANITIC BODIES

Sample	BK11	BK12	BK14	BK15	BK17	BK18+	BK3	BK24	BK25	LC12	LC20
Column	1	2	3	4	5	6	7	8	9	10	11
SiO_2	58,07	59,04	56,90	58,79	63,46	59,37	64,43	64,58	68,54	63,69	60,06
TiO_2	1,06	1,04	1,03	0,97	0,70	0,95	0,82	0,78	0,57	0,07	0,17
Al_2O_3	14,98	15,08	14,41	15,85	16,12	15,48	15,04	15,41	14,76	17,15	20,76
Fe_2O_3	3,77	3,16	3,55	2,93	2,26	2,68	2,64	2,51	1,95	1,93	1,61
FeO	3,73	3,67	3,94	3,46	1,94	3,74	2,09	2,02	1,09	1,65	0,43
MnO	0,19	0,17	0,17	0,17	0,11	0,14	0,13	0,12	0,08	0,09	0,06
MgO	2,24	2,15	2,22	1,78	0,97	2,08	1,25	1,19	0,56	1,55	0,47
CaO	4,19	3,79	4,41	4,03	2,26	3,94	2,79	2,82	1,71	2,12	4,83
Na_2O	4,26	4,15	4,04	4,99	4,90	4,67	4,29	4,36	4,34	4,84	4,72
K_2O	5,53	5,48	5,32	5,06	5,78	5,22	5,09	4,96	4,94	5,74	5,90
P_2O_5	0,80	0,73	0,85	0,70	0,41	0,68	0,51	0,52	0,30	0,26	0,07
H_2O^-	0,26	0,33	0,19	0,19	0,24	0,19	0,27	0,21	0,21	0,08	0,09
H_2O^+	0,41	0,21	0,36	0,30	0,15	0,31	0,21	0,26	0,46	0,36	0,67
CO_2	0,06	0,21	0,04	0,13	0,06	0,20	0,03	0,04	0,05	0,08	0,11
Totals	99,55	99,21	99,43	99,35	99,36	99,65	99,59	99,78	99,56	99,61	99,95
Rb	140	190	180	140	210	-	210	230	280	228	382
Sr	2000	1620	1800	1950	1320	-	1390	1530	1120	1294	372
Ba	2350	1750	2000	1950	1350	-	1650	1700	1250	1506	715
Qtz	3,5	6,1	6,7	2,0	8,3	4,5	15,5	15,7	21,5	8,4	0,6
Ab	51,3	49,6	49,3	58,1	50,9	53,6	46,8	47,6	44,3	50,1	53,0
Or	45,2	44,3	44,0	39,9	40,8	41,9	37,7	36,7	34,2	41,5	46,4

Sample	LC22	WN1*	MY1*	WGT1*	WGT3*	KZ1*	KZ2*	KZ4A*	KZ4B*		
Column	12	13	14	15	16	17	18	19	20	21	22
SiO_2	62,56	73,50	73,40	74,00	73,20	75,26	66,82	60,90	74,64	61,86	59,41
TiO_2	0,16	0,23	0,26	0,12	0,13	0,19	0,68	0,96	0,16	0,58	0,83
Al_2O_3	19,85	14,30	13,70	13,40	13,20	13,48	14,37	15,60	13,81	16,91	17,12
Fe_2O_3	0,75	1,38	1,66	1,51	1,58	1,15	4,18	5,80	1,40	2,32	2,19
FeO	0,79									2,63	2,83
MnO	0,05	0,01	0,05	0,03	0,01	0,04	0,04	0,08	0,01	0,11	0,08
MgO	0,87	0,40	0,50	0,30	0,59	0,36	1,83	2,00	0,51	0,96	2,02
CaO	2,10	1,22	1,33	0,50	0,59	0,90	2,07	3,12	0,89	2,54	4,06
Na_2O	4,53	4,40	4,30	4,70	4,20	3,34	3,29	4,40	4,07	5,46	3,92
K_2O	6,68	4,33	4,50	4,51	5,02	4,81	4,79	5,13	4,83	5,91	6,53
P_2O_5	0,07	0,06	0,10	0,03	0,04	0,08	0,27	0,55	0,07	0,19	0,38
H_2O^-	0,13										
H_2O^+	0,96	0,49	0,56	0,48	0,70	0,67	0,83	1,27	0,59	0,53	0,63
CO_2	0,07										
Totals	99,57	100,22	100,36	99,58	99,26	100,25	99,17	99,81	100,98	100,00	100,00
Rb	405	190	120	219	171	346	228	130	145	-	-
Sr	234	250	370	139	244	311	1169	1300	612	-	-
Ba	715	360	460	392	712	357	1050	1800	734	-	-
Qtz	5,9	30,9	30,6	30,3	30,9	38,2	28,6	10,5	32,1	2,1	2,7
Ab	46,3	40,9	40,1	42,2	38,5	30,8	35,4	49,3	37,1	55,7	44,9
Or	47,8	28,2	29,3	27,5	30,6	31,0	36,0	40,2	30,8	42,2	52,4

Columns 1- 6 : Boesmanskop Syenite; Columns 7- 9 : Boesmanskop Quartz-Syenite; Column 10 : Welverdiend Syenite
Columns 11-16 : Weergevonden Syenite; Columns 17-20 : Kees Zyn Doorns Syeno-granite; Column 21 : Average alkali syenite (Nockolds, 1954)
Column 22 : Average calc-alkali syenite (Nockolds, 1954)

(Analysts : National Institute of Metallurgy, Johannesburg; * Bergström and Bakker, Johannesburg; + F. Barker, USGS)

Clearly fractionation in this system has been from the thermal maximum along the Ab-Or tie-line, towards silica-oversaturated compositions. This trend, although not apparently uncommon, differs from that of certain syenites in the Gardar Province and, more specifically, the Borgtinderne syenite in Greenland (Brown et al., 1978) in that the latter have fractionated towards silica-undersaturated compositions on a quartz-nepheline-kalsilite diagram (see Figure 3, inset). The well-defined oversaturated fractionation trend also differs markedly from the Glen Desarry syenite in Invernesshire (Richardson, 1968) and the Kilonwa syenite in Tanzania (Kempe, 1968). In both of these examples the compositions tend to remain critically undersaturated on the thermal maximum in petrogeny's residua system. Morse (1969) has, in fact, stated that the majority of syenites have bulk compositions that remain critically undersaturated and his experimental work was directed towards determining the mechanisms behind this observation. The Boesmanskop syenitic kindred certainly represent one of the few syenites of great antiquity where there is record of pronounced fractionation towards oversaturated compositions.

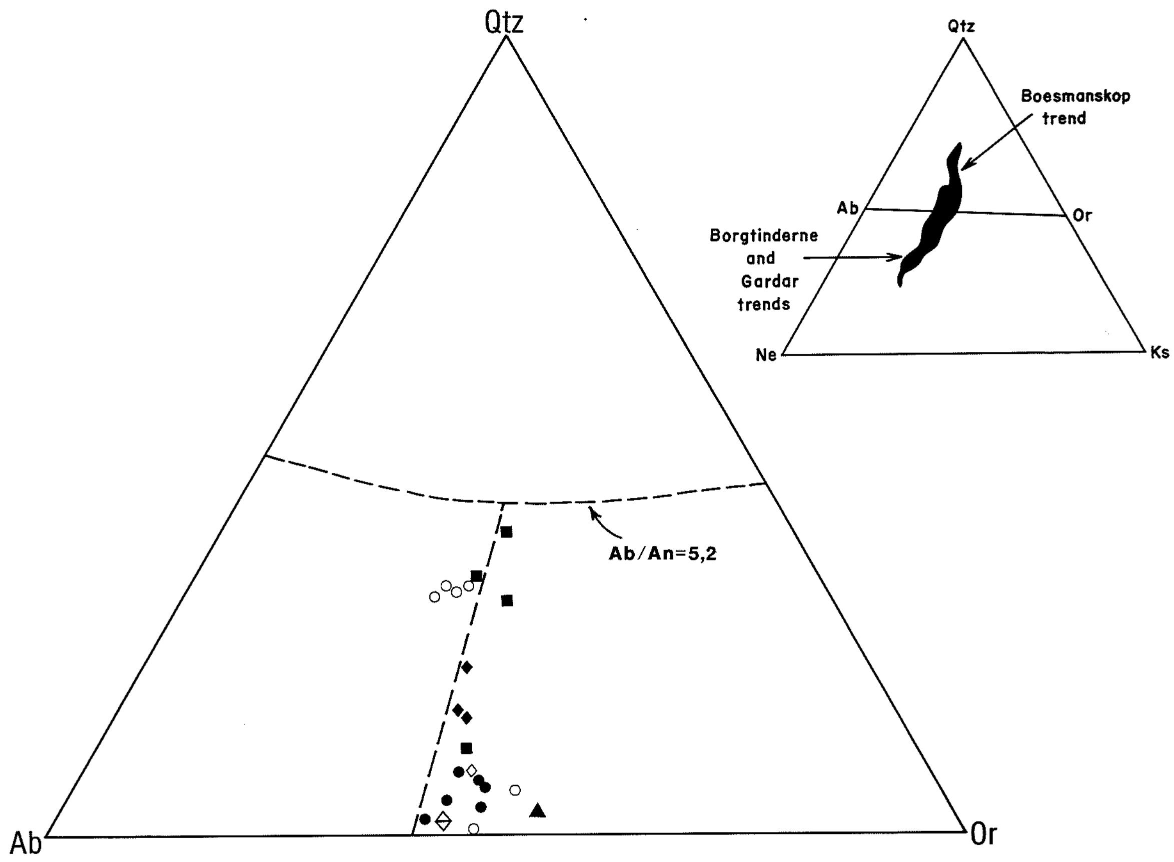

Figure 3 : Quartz-albite-orthoclase ternary diagram for data from the Boesmanskop syenite. The fractionation trend is from the thermal maximum on the Ab-Or tie-line towards the ternary minimum. Phase boundaries are for an Ab/An ratio of 5,2, a figure which approximately corresponds to that in the Boesmanskop syenite. Inset is a quartz-nepheline-kalsilite ternary diagram which illustrates the trend towards oversaturation in SiO_2 of the Boesmanskop syenite and the converse in the Borgtinderne syenite (Brown et al., 1978) and syenites of the Gardar Province (Watt, 1966). Solid circles : Boesmanskop pluton syenites and porphyritic syenites; Solid diamond : Boesmanskop pluton quartz syenites; Solid squares : Kees Zyn Doorns syeno-granites; Open circles : Weergevonden syenites and quartz syenites; Open diamond : Welverdiend quartz syenite; Solid triangle : Nockold's (1954) average calc-alkali syenite; Open diamond with bar : Nockold's average alkali syenite. Symbols used are the same for all succeeding data plots.

The Boesmanskop syenites may also be compared with the calc-alkaline ∿ 1040 m.y. old Pikes Peak batholith in North America, the latter consisting of a cogenetic suite of gabbro-anorthosite-syenite-granite *(sensu stricto)* (Barker et al., 1975). The presence of mafic rocks in the Pikes Peak batholith and the lack of such cogenetic phases in the Boesmanskop syenite is perhaps indicative that the former was fractionating *towards* petrogeny's residua system whereas the latter was fractionating *within* it. Although it is arguable that mafic phases of the Boesmanskop syenite may not be exposed, later considerations indicate that the parent material to this syenite is more likely to have been intermediate-to-felsic than mafic-to-ultramafic.

The fractionation within the Boesmanskop syenites is also illustrated in a series of Harker diagrams (Fig. 4). These plots of SiO_2 v TiO_2 (similar to P_2O_5), FeO + Fe_2O_3 (similar to MgO), Al_2O_3, Na_2O, CaO and K_2O all exhibit typical antipathetic relationships between SiO_2 and the other major element oxides. Particularly well displayed on the SiO_2 v TiO_2, total Fe, Al_2O_3 and K_2O plots (Fig. 4) is the fact that the samples from the Weergevonden and Welverdiend syeno-granites form a discrete trend compared to that of the remaining rocks in this suite. More specifically, rocks from the Weergevonden syenite are enriched in Al_2O_3 and K_2O and depleted in Fe and TiO_2 (as well as MgO and P_2O_5) relative to the remainder of the suite. Such divergent trends amongst a suite of rocks exhibiting reasonable field evidence for cogeneticity suggests two distinct possibilities; firstly, two distinct petrogenetic processes may have been operative within the same igneous system or, secondly, the rocks responsible for the two trends may not be cogenetic.

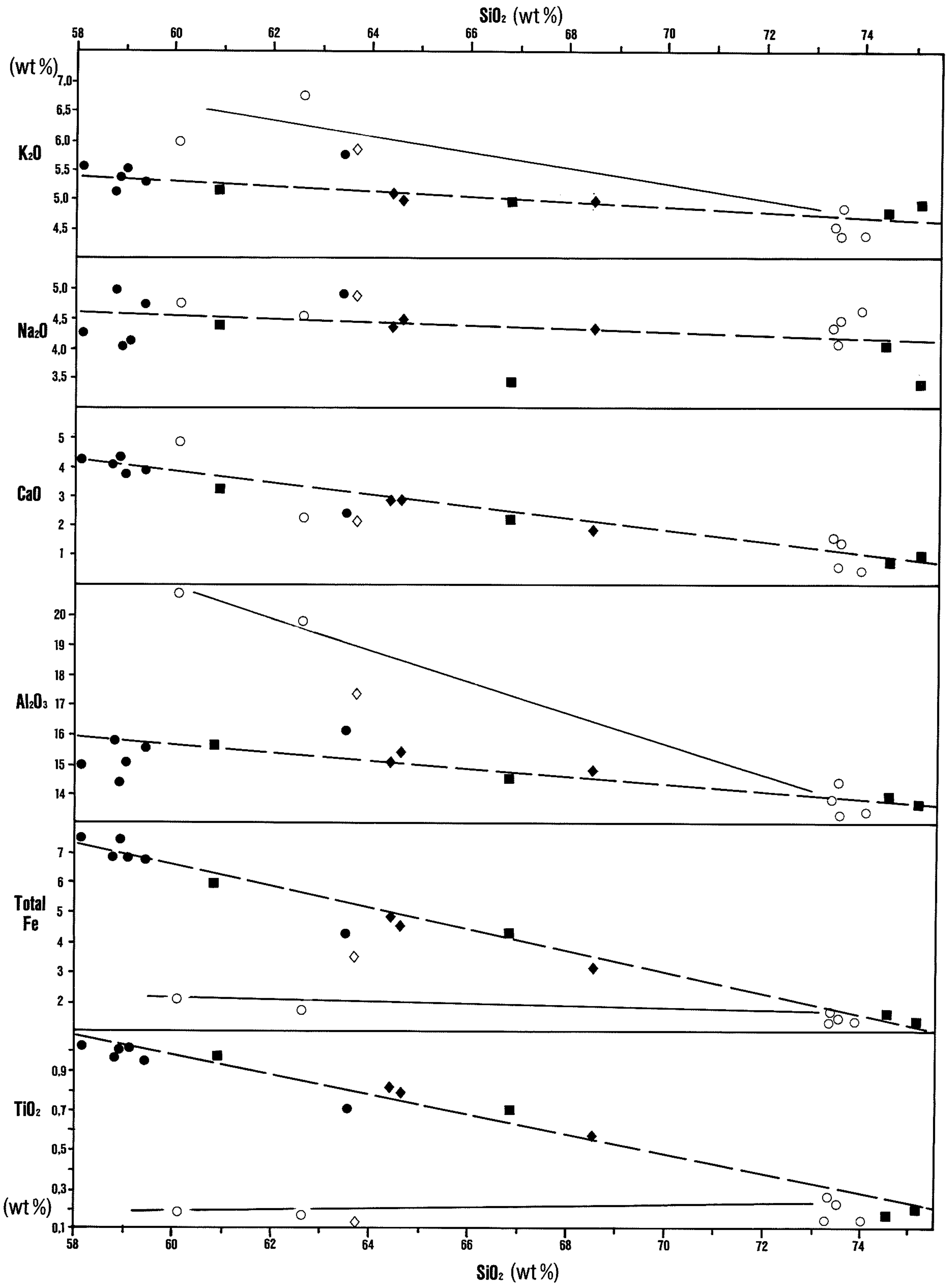

Figure 4 : *Harker diagram showing the variation of oxides with silica for the Boesmanskop syenitic samples listed in Table 2. Symbols used are identical to those shown in Figure 3. The dashed line represents the main Boesmanskop trend while the solid line represents the markedly different trend (in the case of TiO_2, Total Fe, Al_2O_3 and K_2O) of the Weergevonden syeno-granite.*

Workers on the calc-alkaline batholiths of the Lachlan Fold Belt in southeastern Australia recently described flat-trends in Harker-type diagrams (similar to those displayed in the SiO_2 v TiO_2 plot of the Weergevonden syeno-granites) and discussed their relationship to more typical, steeper trends (such as those exhibited by the remainder of the Boesmanskop suite). Interpretation of these phenomena lies in the view that a Harker-type trend is not necessarily indicative of fractionation but rather represents a partial (or "minimum") melt-restite mixing line (White and Chappell, 1977; Griffin et al., 1978). Steep trends would represent a minimum melt-restite mixture while a flat trend would represent a non-minimum melt (i.e. more enriched in mafic constituents, alumina and calcium)-restite mixture. Whereas the trace element models discussed later suggest a fractional crystallization origin for the main Boesmanskop syenite pluton, it is distinctly possible that the flat Weergevonden trend may be the result of a different petrogenetic process - namely that of partial melting. If this interpretation is correct then the Weergevonden syeno-granites would presumably have formed by melting a significant (to ensure a non-minimum melt) portion of an intermediate-to-felsic parent (with approximately 66-68% SiO_2, high alumina, and low TiO_2, MgO, P_2O_5 and Fe content) resulting in the production of a siliceous melt and leaving a syenitic residue, the latter not significantly enriched in mafic constituents. Whether this interpretation is feasible in terms of the available data is discussed later.

B. Trace Elements

The concentration and distribution of rubidium, strontium and barium in the Boesmanskop syenite is considered to be instructive in interpreting certain of the petrogenetic aspects relating to this suite. Plots of Rb v Sr and Rb v Ba (Figs. 5 and 6 respectively) illustrate two distinct trends; the first, which includes sample analyses of the Boesmanskop syenites and quartz syenites as well as the Kees Zyn Doorns syeno-granite, is characterized by a significant range in Ba and Sr (≅ 2 000 ppm) with a much smaller variation in Rb content (≅ 200 ppm). By contrast, the second trend, comprising samples from the Weergevonden syeno-granite "tail", has a much smaller range of Ba and Sr (≅ 300 ppm) over a correspondingly wider range of Rb contents (≅ 300 ppm). As such the two trends lie effectively at right angles to one another, a relationship which Hanson (1978) has described as being indicative of partial melting on the one hand and fractional crystallization on the other. This interpretation is necessarily restricted to binary plots of trace elements with high bulk partition coefficients (K_D) into a particular assemblage (on one axis) against trace elements with low bulk partition coefficients into the same assemblage (on the other axis). Thus, partial melting of a particular assemblage will enrich the incompatible element into the early melt phases whereas the high K_D element will be effectively retained in the residue exhibiting little variation in concentration in the melt. By contrast, during fractional crystallization, early cumulates will be enriched in the high K_D element whereas the incompatible element will be retained in the liquid, to be significantly enriched only after a high degree of fractionation.

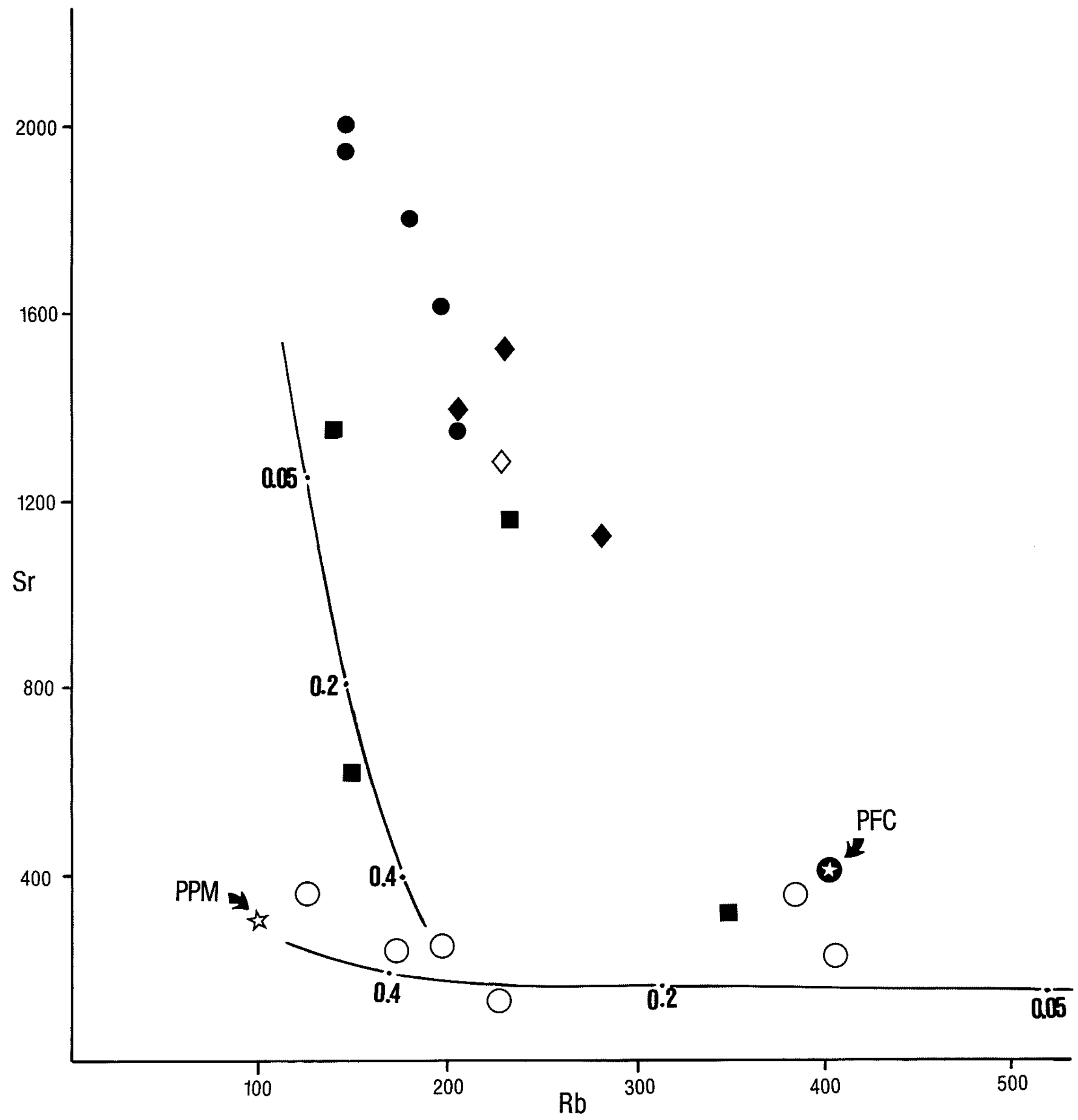

Figure 5 : A plot of Rb v Sr data points from the Boesmanskop syenite. Also shown in this diagram are model curves *for partial melting and fractional crystallization; the horizontal curve represents the partial melting of a parent rock at PPM over the range 5-40% melting. The vertical curve represents the trend of fractional crystallization from a liquid at PFC, also for the range 5-40% fractionation. The various parameters used to calculate these model curves are provided in the Appendix.*

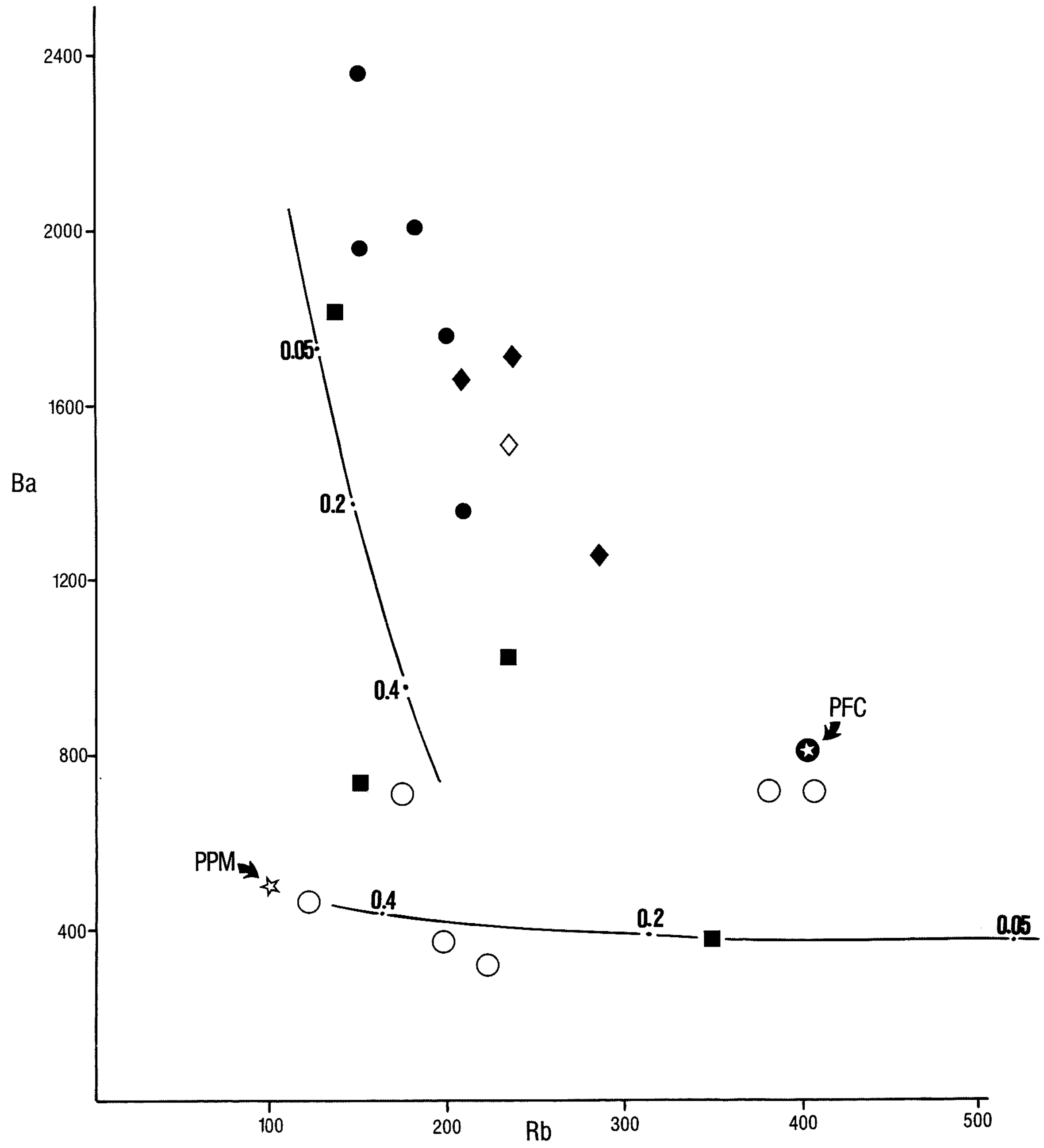

Figure 6 : *A plot of Rb v Ba data points from the Boesmanskop syenite. Details are the same as for Figure 5.*

In the granitic assemblages both Sr and Ba have high bulk partition coefficients (± 2-3, see Appendix) whereas Rb has a K_D of significantly less than unity. Thus in both the Rb v Sr and Rb v Ba plots the Weergevonden trend is reminiscent of partial melting processes whereas the main Boesmanskop syenite trend displays characteristics of fractional crystallization. In Figures 5 and 6 model curves that emulate these two processes are presented; in the case of the Weergevonden trend, modal melting equations (outlined by Arth, 1976) have been used to partially melt an intermediate-to-felsic parent with trace element composition at PPM. This is similar to the granodioritic composition which Condie and Hunter (1976) used as parental material to derive some of the post-kinematic granite intrusives in the Barberton region. In order to model the main Boesmanskop syenite trend, fractional crystallization (equations also outlined by Arth, 1976) of a typical syenitic assemblage was considered to take place from a parent of trace element composition at PFC. This parent coincides approximately with that of an early-formed liquid composition formed during the partial melting process. This implies that the main Boesmanskop syenite pluton fractionated from a liquid of composition possibly represented by the bulk composition of the Weergevonden syeno-granite tail. Both model trends approximate those of their empirical counterparts. Mineral modes, K_D's and parental compositions for the above two models are provided in the Appendix.

Thus, the inference gained from the trace element data described above is that the rocks of the Boesmanskop syenite suite appear to have characteristics of both melting and fractionation processes. The trace elements indicate that a significant melt fraction was originally formed by anatexis of an intermediate-to-felsic parent and that a portion of this melt subsequently underwent fractional crystallization to form the syenite-granite assemblage. The Weergevonden syenite "tail" appears to have been isolated from the effects of this fractional crystallization process by having been intruded along a conduit away from the main magma chamber, thereby crystallizing much more rapidly. This notion is supported by field evidence and the fine-grained texture of the latter. In terms of the major element chemistry of the Weergevonden syenite it has been suggested that the latter may represent a partial melt-restite mixture which, in part, confirms the suggestions of the trace-element evidence. However, significant discrepancies exist in this model and these will be discussed later.

C. Rare-Earth Elements (REE)

Four samples, one each from the Boesmanskop syenite and quartz syenite, the Kees Zyn Doorns syeno-granite and the Weergevonden syenite, were analysed for their REE content. These data are presented in Table 3 and in chondrite-normalized form in Figure 7. It is evident from this diagram that the two samples from the Boesmanskop syenite (BK 12 and BK 25) and one from the Kees Zyn Doorns syeno-granite (KZ 2) all have similar patterns, with enriched light REE contents and no significant Eu anomaly; features also noted by Glikson (1976) who analysed a single sample from the Boesmanskop pluton. A similar REE distribution pattern is displayed by the plot of a single sample from the Archaean Linden syenite pluton in Minnesota (Arth and Hanson, 1975) which has been included in Figure 8 for comparative purposes.

TABLE 3

RARE EARTH ELEMENT DATA FOR SELECTED SAMPLES FROM THE BOESMANSKOP AND RELATED SYENITIC AND SYENO-GRANITIC BODIES

	1	2	3	4	5
	BK 12	BK 25	LC 22	KZ 2	
La	153,5	123,5	62,1	97,9	-
Ce	282,8	205,2	92,5	213,5	406
Nd	108,9	72,8	26,9	63,9	183
Sm	26,4	15,8	8,3	13,6	28,1
Eu	6,1	3,2	0,9	3,9	6,6
Tb	2,2	1,4	1,2	1,5	-
Yb	3,5	2,6	3,6	3,1	1,5
Lu	0,3	0,2	0,4	0,2	0,2
Ce/Yb	80,6	77,1	25,5	67,8	265,3
Ce*/Yb*	20,8	19,9	4,4	8,0	-

(all values in ppm)

Columns 1 - 4 - REE data for the Boesmanskop syenite and related bodies.

Column 5 - Aegerine-augite syenite, Linden pluton, Minnesota. (after Arth and Hanson, 1975).

(REE analysed by epithermal neutron activation analysis. Details of the methods utilized are described by Fesq et al., 1973).

The Weergevonden syenite "tail" (represented by sample LC 22) has a REE pattern different from those of the remainder of the syenitic suite. It is characterized by lower light REE concentrations, a pronounced negative Eu anomaly and a lower Ce/Yb ratio (Table 3). These characteristics should reflect the petrogenetic processes described in the section dealing with trace element modelling, namely that the Weergevonden syenite trend has been formed by partial melting of an intermediate-to-felsic parent.

Any attempt to model the REE traces of the Boesmanskop syenites has to be approached with caution because of the effect that minor refractory minerals such as apatite and sphene have on petrogenetic processes in granitic rocks (McCarthy and Kable, 1978). A model of the fractionated sequence of the Boesmanskop syenite along the lines of the trace element model described above is

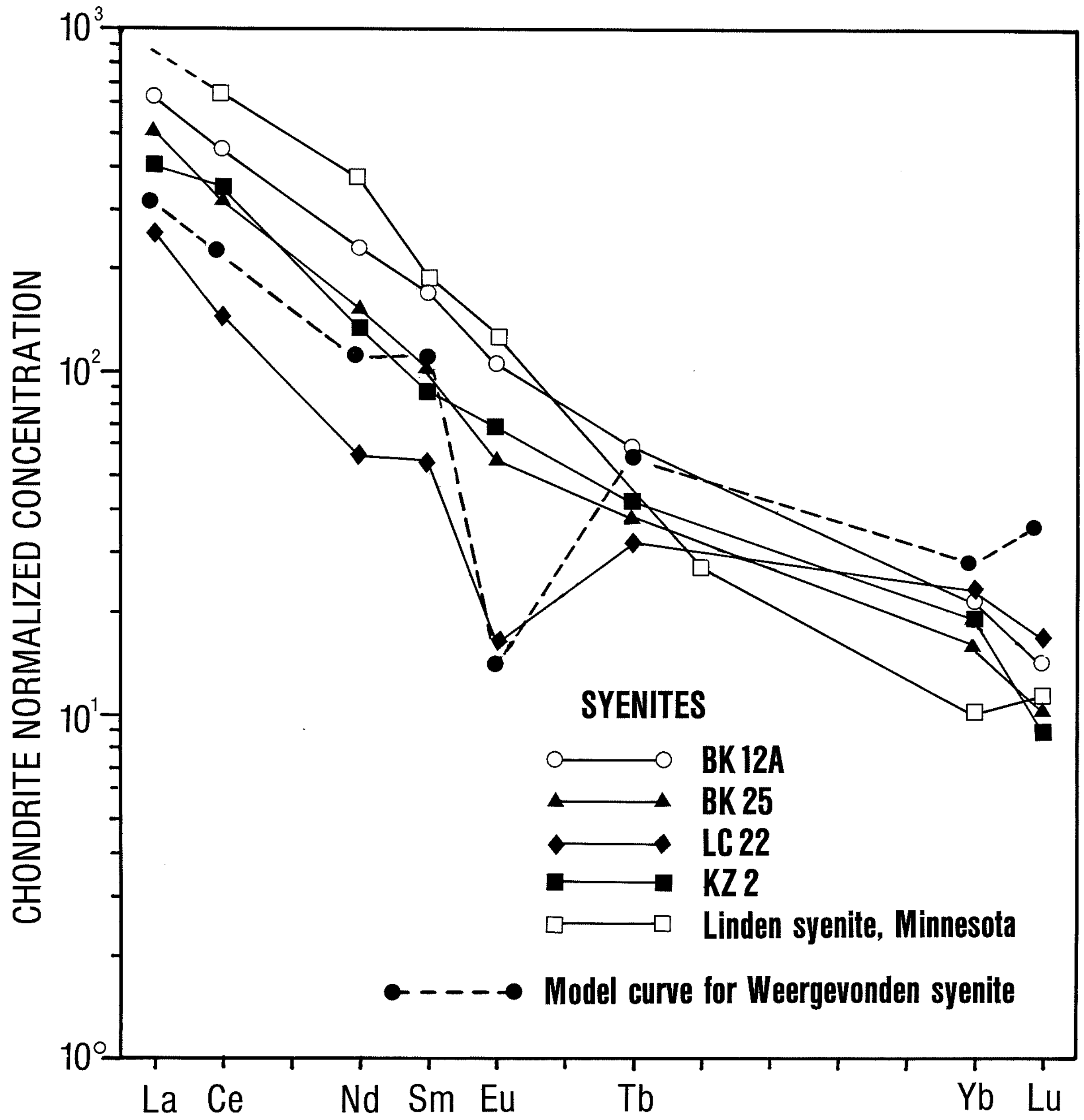

Figure 7 : *REE data for selected samples from the Boesmanskop syenitic bodies plotted on a chondrite normalized diagram. Data from the Linden syenite, Minnesota (after Arth and Hanson, 1975) is also included. A* model curve *simulating a sample of the Weergevonden syenite (LC 22) is plotted and represents a 5% partial melt of an intermediate-to-felsic parent similar in composition to the parent envisaged for the trace element models (see Figs. 5 and 6 and Appendix). The various parameters used in the calculation of this model are also provided in the Appendix.*

impossible. The dominant mineral phases considered in the trace element model (i.e. plagioclase + K-feldspar + quartz + hornblende + clinopyroxene + biotite; see Appendix) for fractional crystallization have K_D's for the light REE of less than unity, thereby making it impossible to enrich the latter in the rocks being formed. Clearly apatite and sphene, both of which form prominent minor mineral phases within the syenitic suite and for which the REE have extremely high partition coefficients, must have played a dominant role in concentrating the light rare-earth elements, in particular, into early fractionates.

However, in considering the partial melt model for the Weergevonden syeno-granite, the effects of refractory minor minerals are not likely to have been too pronounced. A feasible model for the REE distribution pattern in the Weergevonden syenite can be erected using modal melt equations and a melt phase compositionally identical to that employed in the trace element model (see Appendix). The parental REE composition, also provided in the Appendix, is considered to be typical of the parent envisaged for the trace element model. A model curve (representing a 5% partial melt of the suggested parent) is presented in Figure 7 and is seen to demonstrate the broad characteristics of the Weergevonden trend. The negative Eu anomaly in the model is created because of the retention of Eu in the parent (i.e. Eu having a high bulk partition coefficient into a granitic parent, see Appendix). Furthermore, during partial melting the concentration of a given element in the liquid relative to the parent is dependent only on the K_D of the restite.

The REE model therefore confirms the suggested partial melt origin of the Weergevonden syenite as having been derived from intermediate-to-felsic parental material.

V. ISOTOPE CHEMISTRY

A. Rubidium-Strontium Isotopes

Eleven whole rock samples from the Boesmanskop syenite were analyzed for their Rb and Sr isotopic compositions using the techniques described by Barton (1979). These results are summarized in Table 4. Regression of these results using the techniques of York (1969) yields an isochron of 2848 ± 31 m.y. (2σ) (Fig. 8) with an initial $^{87}Sr/^{86}Sr$ ratio of 0,7040 ± 0,0004 (2σ); (MSWD = SUMS/(n-2) = 1,21 < 2,5 (Brooks et al., 1972)).

TABLE 4

Rb-Sr WHOLE ROCK ISOTOPIC DATA, BOESMANSKOP PLUTON

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$**	$^{87}Sr/^{86}Sr$*
B-77-39A	238	1046	0,6590	0,7312
B-77-39B	229	693	0,9590	0,7442
B-77-39C	200	577	1,0044	0,7449
B-77-39D	205	994	0,5959	0,7287
B-77-39E	231	1108	0,6026	0,7349
B-77-39F	247	965	0,7419	0,7349
B-77-39G	222	995	0,6462	0,7304
B-77-39H	239	359	1,9380	0,7835
B-77-39I	183	1372	0,3859	0,7182
B-77-39J	164	370	1,9010	0,7822
B-77-39K	240	325	2,1530	0,7932

* Normalized to $^{88}Sr/^{86}Sr$ = 8,37521. Uncertainty in the ratio = ± 0,01%.

** Uncertainty in the ratio = ± 0,7%

This 2850 m.y. Rb-Sr whole rock isochron age is significantly different to the 3130 m.y. model U-Pb concordia intersect ages obtained by Oosthuyzen (1970) for a composite zircon fraction and a composite apatite fraction from a sample of the Boesmanskop syenite. In the case of the analytical results from the apatite fraction, the common Pb correction is critical and consequently the age is imprecise. However, in the case of the analytical results from the zircon fraction, the latter are relatively insensitive to the exact common Pb isotopic ratios utilized. In addition, the zircons themselves appear to be non-metamict and uniform (Oosthuyzen, 1970) and the data plot reasonably close to the concordia curve. Consequently, the U-Pb zircon age is reasonably precise.

These different ages are consistent with three possible interpretations. One is that the zircon age reflects the emplacement of the pluton and that the Rb-Sr age reflects a subsequent metamorphism of the pluton. The second interpretation is that the Rb-Sr age reflects the emplacement of the pluton whilst the zircon age reflects the age of the source rock of the pluton. The third interpretation is that neither age reflects the emplacement of the pluton. On the basis of the isotopic data alone, it is impossible to choose among these alternative interpretations. However, radiometric ages in the range 3200 ± 100 m.y. to 2900 ± 50 m.y. are common throughout the terrane surrounding the Boesmanskop syenite (Oosthuyzen, 1970; Barton, unpublished data) with the younger ages almost always associated with demonstrably younger plutonic bodies such as the Boesmanskop syenite. The older ages are associated with trondhjemitic orthogneisses which could conceivably represent the intermediate-to-felsic parent envisaged above for the Boesmanskop syenite. The combined radiometric data therefore suggests that the Boesmanskop syenite was emplaced approximately 2850 m.y. ago having been derived by partial melting (and subsequent fractionation) of an intermediate-to-felsic source rock that was at least 3130 m.y. old. In this light, Oosthuyzen's zircons may well represent xenocrysts in the syenite magma. The initial $^{87}Sr/^{86}Sr$ ratio (0,7040) also supports the idea of a felsic parentage as this value is not as low as those generally obtained for the trondhjemitic orthogneisses (Barton, unpublished

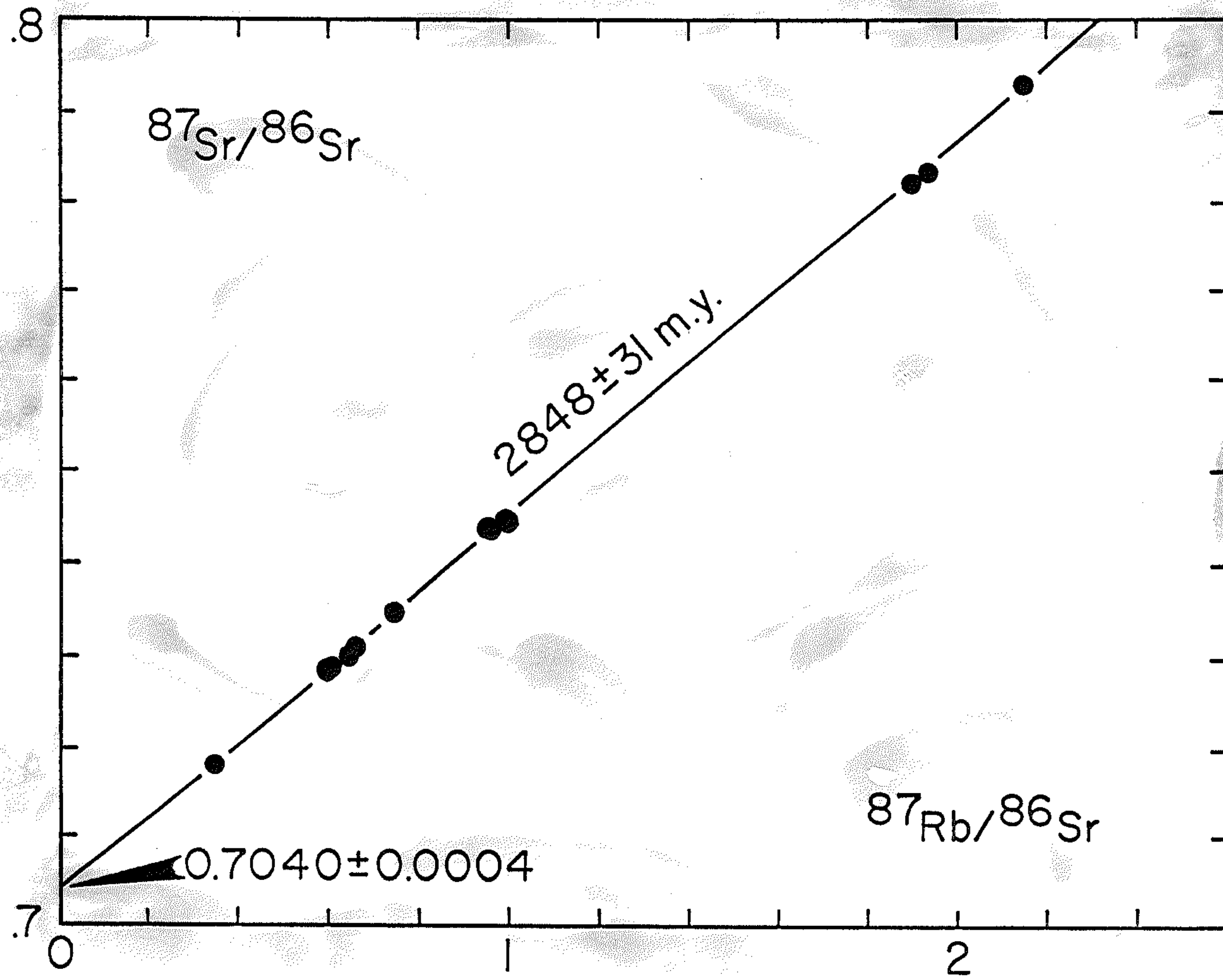

Figure 8 : Rb-Sr whole rock isochron plot of data from the Boesmanskop syenite pluton. The isotopic data used to construct the diagram is presented in Table 4. All the material analysed was collected in the vicinity of the quartz syenite sample locality BK 24 (Fig. 2).

data), the latter commonly believed to have formed by anatexis of primitive mantle-derived mafic material (Barker et al., 1976a; Condie and Hunter, 1976).

B. Oxygen Isotopes

Whole rock oxygen isotope analyses of samples from the Boesmanskop syenites and quartz syenites are given in Table 5. The syenites, which range between 56-64% SiO_2, have an average $\delta^{18}O$ of +6,2°/₀₀ whereas the quartz syenites, in the range of 64-69% SiO_2, average +7,4°/₀₀. The average $\delta^{18}O$ for all the Boesmanskop syenite samples analysed is +6,6°/₀₀ with a range of 4,3-7,9°/₀₀. These values are essentially indistinguishable from the $\delta^{18}O$ values of a wide variety of mafic and ultramafic rocks (including olivine-pyroxene rock types, basalts, gabbros, and andesites) as well as trachytes and syenites (Taylor, 1968). This range of O^{18} values contrasts with the higher range usually obtained for granitic rock types of between 7,8-10,2°/₀₀. Exceptions to the usual trend have also been found by Barker et al. (1976a) who showed that some trondhjemites, tonalites and acidic gneisses, including those of Archaean age southwest of the Barberton greenstone belt and in Swaziland, also possess low to intermediate $\delta^{18}O$ values (mean $\delta^{18}O$ of 6,4°/₀₀ and a range from 5,5-7,9°/₀₀).

The coincidence that basalts, andesites, trachytes and syenites, as well as certain Archaean trondhjemitic and tonalitic gneisses exhibit a restricted range of $\delta^{18}O$ values supports the view that the origin of these rocks may be related to a common process. There is increasing evidence, from geologic relations, Sr-isotopes, REE, and experimental studies, suggesting that these rock types were derived from parent basaltic magma by processes involving either differentiation or partial melting (Bowen, 1928; Bryan and Ewart, 1971; Ewart and Bryan, 1972; Green and Ringwood, 1968; Arth and Hanson, 1972, 1975; Barker et al., 1976a, b). However, oxygen isotopes cannot yet be used unequivocally in support of either differentiation or partial melting, nor can they be used to assess the composition of parental material in such processes.

TABLE 5

WHOLE ROCK OXYGEN ISOTOPE AND SiO_2 ANALYSES OF THE BOESMANSKOP SYENITES AND QUARTZ SYENITES

Sample No.	Rock Type	$\delta^{18}O$ (°/₀₀)	SiO_2
BK 14	Syenite	+ 7,9	56,90
BK 11	Syenite	+ 4,5	58,07
BK 15	Syenite	+ 7,2	58,79
BK 12	Syenite	+ 7,1	59,04
BK 18	Syenite	+ 4,3	59,37
BK 17	Porphyritic Syenite	+ 6,4	63,46
	Average Syenite	+ 6,2	59,27
BK 3	Quartz Syenite	+ 7,7	64,43
BK 24	Quartz Syenite	+ 7,1	64,58
BK 25	Quartz Syenite	+ 7,4	68,54
	Average Quartz Syenite	+ 7,4	65,85

($\delta^{18}O$ analyses by J.R. O'Neil, U.S. Geological Survey, Menlo Park, California)

VI. DISCUSSION

The evidence presented above has, for the major part, indicated a consistent petrogenetic model for the Boesmanskop syenite suite. In this light it is instructive to consider the origin of Archaean syenitic magmas with regard to the formation of early Precambrian sialic crust in general.

Both Glikson (1976), in the case of the Boesmanskop syenite, and Arth and Hanson (1975), in the case of the Linden syenite in Minnesota, have attributed the origin of these syenites to a process of partial melting of a primitive quartz-eclogite or mixed eclogite-peridotite source. Arth and Hanson (1975) refer to trace and rare-earth element modelling to support their contention and also cite a very low initial $^{87}Sr/^{86}Sr$ ratio ($\sim$ 0,7009) as evidence precluding granitic crust as a possible source. In the case of the Boesmanskop syenite suite, however, a much higher initial $^{87}Sr/^{86}Sr$ ratio applies ($\sim$ 0,7040) and as Glikson (1976) stated, " ..... neither process (i.e. partial melting or fractional crystallization of quartz eclogite) can be reconciled with the very high Sr abundance (1263 ppm), the very high Ba abundance (1500 ppm) and the lack of negative Eu anomaly .....". In this regard the origin of the Boesmanskop syenite, suggested in this paper, has added credence. In particular, the trace element model postulates that this suite originated by significant partial melting of an intermediate-to-felsic parent. Portion of this partial melt (i.e. the Weergevonden syeno-granite) appears to have been intruded along a linear conduit and crystallized rapidly to retain the chemical characteristics of the melt. The melt remaining in the magma chamber appears to have undergone fractional crystallization to produce a series of rock types ranging in composition from syenitic to granitic *(sensu stricto)*. REE traces apparently confirm the partial melt character of the Weergevonden syenite "tail" but, with regard to the remainder of the suite, fractionation appears to have been markedly influenced by apatite and sphene. Major element Harker trends for the Boesmanskop syenite and the Kees Zyn Doorns syeno-granite point to the fractionation that has taken place within this suite whereas the trend for the Weergevonden syeno-granite may be reminiscent of a non-minimum melt-restite mixture.

There are, however, two points, both related to the major element composition of the suite which, it is felt, are not entirely compatible with the envisaged model. The first concerns the composition of the liquid which is alleged to have formed by significant partial melting of an intermediate-to-felsic parent and the feasibility of fractionating the mineral phases required to produce the Boesmanskop syenite from it. The ternary Qtz-Ab-Or plot in Figure 3 indicates that this liquid (perhaps similar in composition to samples WNI and WGTI from the Weergevonden syenite) plots in the vicinity of the eutectic whereas early fractionates have a composition near the thermal maximum in the quartz-nepheline-kalsilite system. It does not seem altogether feasible to the authors that a relatively high temperature mineral assemblage can precipitate out of a liquid of apparently lower temperature. Volatiles may thus have played a subtle, yet important, role in the crystallization of the Boesmanskop syenite.

The second point derives from the major element composition of samples from the Weergevonden syenite "tail". In the trace element model for the Weergevonden syenite (Figs. 5 and 6) the early (minimum ?) melt fractions are most closely represented by samples LC 20 and LC 22, the latter constituting the syenitic portions of the "tail". However, in the alleged non-minimum melt-restite mixing curve of the Weergevonden syeno-granite (Fig. 4), these two samples clearly fall at the silica-depleted restite end of this curve. The only possible explanation for this is that these two samples contain a significant inherent restite component perhaps analogous to the anhedral calcic plagioclase cores described by White and Chappell (1977) from their restite-enriched rocks.

The two points discussed above raises the possibility that the Weergevonden syeno-granite may not be cogenetic with rocks of the neighbouring Boesmanskop syenites. However, the intimate spatial arrangement between the two (Fig. 2), the syenite-granite compositional affinities, and a feasible trace, REE and isotopic model, provides significant evidence for cogeneticity despite the possible discrepancies discussed above.

The evidence from this paper, together with that from other workers in the Barberton Mountain Land (Condie and Hunter, 1976; Robb, 1978) increasingly supports the suggestion that many of the post-kinematic granitic (*sensu lato*) intrusives in this region were derived from pre-existing felsic (ensialic) material rather than from a mafic (ensimatic) source. Condie and Hunter (1976) have pointed to possible mantle plumes as providing a heat source for remelting sialic source material; an alternative consideration might be subduction processes related to Archaean plate tectonism. A fuller understanding of possible mechanisms awaits the results of the investigations currently being undertaken in the region.

VII. CONCLUSIONS

The main conclusions pertaining to the Boesmanskop syenite can be summarized as follows :

1. The Archaean Boesmanskop syenite intrudes trondhjemitic gneisses and greenstone xenoliths of the crustal basement in the southwestern part of the Barberton Mountain Land. It has an U-Pb mineral age of ∿3130 m.y. and a Rb-Sr whole rock age of ∿2850 m.y.

2. The dominant minerals in the syenites are the feldspars which include microcline, orthoclase, perthite and plagioclase (albite-oligoclase). The porphyritic and coarse-grained syenites contain euhedral, prominently zoned, perthitic feldspars consisting of orthoclase microperthite, microcline microperthite, microcline perthite and antiperthite. The subsolvus feldspar assemblage is indicative of equilibration in a high P_{H_2O} environment and crystallization at deep crustal levels (Martin and Bonin, 1976).

3. The Boesmanskop syenites display a wide range of compositions extending from syenite to quartz syenite and granite (*sensu stricto*). There is no evidence of any cogenetic mafic phase associated with these rocks. Chemically, the syenite suite defines a prominently oversaturated trend - Archaean examples of which have seldom been documented.

4. Trace and rare-earth element modelling suggest that the parent magma of the Boesmanskop syenite suite was derived by extensive partial melting of an intermediate-to-felsic source somewhat similar in composition to the granodioritic parent that Condie and Hunter (1976) used to derive certain post-kinematic granite intrusives in the Barberton region. A portion of this melt was apparently intruded along a conduit, possibly at a higher crustal level, to form what is now the Weergevonden syeno-granite "tail".

5. The melt remaining in the magma chamber was probably influenced by a different set of pressure and temperature conditions and underwent fractional crystallization to produce the syenites and quartz syenites of the Boesmanskop pluton and the syenites and granites (*sensu stricto*) of the Kees Zyn Doorns body.

6. The U-Pb age (∿ 3130 m.y.) is considered to possibly represent the minimum age of the source material to the Boesmanskop syenite; the Rb-Sr age (∿ 2850 m.y.) is considered to be the age of emplacement of the syenite. The initial $^{87}Sr/^{86}Sr$ ratio (∿ 0,7040) is not compatible with a primitive basaltic source such as is envisaged for the Archaean Linden syenite in Minnesota; this ratio is indicative, rather of an intermediate-to-felsic source such as is suggested by the trace element data.

* *

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APPENDIX

A. Rb, Sr and Ba Model

(i) Partial melt model simulating the Weergevonden syeno-granite trend (Figs. 5 and 6) :

Mineral Phases in the melt	Bulk Partition Coefficients	Assumed Parent Composition
Plagioclase - 50%	Rb - 0,15	Rb - 100 ppm
Quartz - 30%	Sr - 2,18	Sr - 300 ppm
K-feldspar - 20%	Ba - 1,42	Ba - 500 ppm

(ii) Fractional crystallization model simulating the main Boesmanskop trend (Figs. 5 and 6) :

Fractionating Phases	Bulk Partition Coefficients	Assumed Parent Composition
Plagioclase - 44%	Rb - 0,3	Rb - 400 ppm
K-feldspar - 35%	Sr - 3,5	Sr - 400 ppm
Quartz - 6%	Ba - 2,3	Ba - 800 ppm
Clinopyroxene - 5%		
Hornblende - 5%		
Biotite - 5%		

B. REE Model for the Weergevonden Syeno-Granite (Fig. 7) :

Mineral Phases in the melt	Bulk Partition Coefficients	Assumed Parent Composition
Plagioclase - 50%	La - 0,3	La - 20 ppm
Quartz - 30%	Ce - 0,18	Ce - 40 ppm
K-feldspar - 20%	Nd - 0,12	Nd - 10 ppm
	Sm - 0,07	Sm - 2 ppm
	EU - 1,47	Eu - 1,0 ppm
	Tb - 0,025	Tb - 0,2 ppm
	Yb - 0,036	Yb - 0,4 ppm
	Ln - 0,03	Ln - 0,1 ppm

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PLATE I

A. View of the granite-greenstone terrane southwest of the Barberton Mountain Land showing the Boesmanskop syenite pluton (middle distance) surrounded by flat-flying trondhjemitic gneisses.

B. Porphyritic syenite in a fine-grained matrix of feldspar, hornblende and chlorite, northern contact zone of the Boesmanskop pluton.

C. Syenite from the Boesmanskop intrusion showing a partially assimilated amphibolite xenolith, the latter responsible for streaky hornblende-rich phases.

D. Coarse porphyritic syenite from the northern sector of the Boesmanskop pluton showing a large inclusion of syenite with a texture typical of that found in the central part of the body.

E. Photomicrograph of porphyritic syenite from the Boesmanskop pluton showing euhedral, oscillatory zoned, perthitic feldspars in a fine-grained matrix consisting of microcline, plagioclase, hornblende and biotite.

F. Photomicrographic enlargement of an euhedral, zoned, feldspar crystal showing flame-like perthitic intergrowth textures, Boesmanskop syenite body.

PLATE I