Sm-Nd ISOTOPIC SYSTEMATICS OF THE ANCIENT GNEISS COMPLEX, SOUTHERN AFRICA. R. W. Carlson[1], D. R. Hunter[2], and F. Barker[3]; [1]Department of Terrestrial Magnetism, 5241 Broad Branch Rd., Washington, D.C., 20015, U.S.A.; [2]University of Natal, Pietermaritzburg, 3200, Natal, South Africa; [3]U. S. Geological Survey, 4200 University Dr.,Anchorage, Al., 99508

The igneous core of southwestern Africa's Kaapvaal craton consists of the Onverwacht Group of mafic to ultramafic volcanics of the Barberton greenstone belt and a complex gray gneiss terrain called the Ancient Gneiss Complex(AGC) (e.g. 1,2). Until recently, precise geochronologic information for these two units has been difficult to obtain due to the effects of post-formation metamorphism. Even the assignment of relative ages between the AGC and the Onverwacht is complicated by the lack of direct contact between these two units in the field(1).

Recently, by applying the Sm-Nd radiometric system, Hamilton et. al.(3) determined a whole-rock age of 3,530±50 Ma for the lower ultramafic unit of the Onverwacht Group. Compared to this age, Rb-Sr dates for gneisses of the oldest unit of the AGC, the Bimodal Suite (BMS), tend to be slightly younger(3,200-3,300 Ma; 4). However, these Rb-Sr ages most likely reflect later metamorphic episodes rather than the emplacement ages of the interlayered metabasalts and tonalite-trondhjemite gneisses that make up the BMS. Based on a correlation between initial $^{87}Sr/^{86}Sr$ and age of individual gneiss units within the AGC, Davies and Allsopp (4) suggested an emplacement age of about 3,400 Ma for the AGC parental materials, some 100 Ma younger than the Onverwacht volcanics. In contrast, Barton et al.(5) reported a Rb-Sr whole rock age of 3,555±111 Ma for the BMS placing its formation at about the same time as the Onverwacht Group.

In order to shed some new light on the question of the absolute and relative ages of the AGC and Onverwacht Group, a Sm-Nd whole-rock and mineral isochron study of the AGC was begun. At this point, the whole-rock study of samples from the BMS selected from those studied for their geochemical characteristics by Hunter et al.(6) has been completed. We discuss here these results and their implications for the chronologic evolution of the Kaapvaal craton and the sources of these ancient rocks.

Sm-Nd data for samples of the BMS (Table 1) precisely define a line on the isochron diagram shown in the figure. The line corresponds to an age of 3,417±34 Ma with an initial $^{143}Nd/^{144}Nd$ = 0.508149±31 or initial ε_{Nd} = +1.1±0.6 (using the "bulk-earth" Sm-Nd parameters of Jacobsen and Wasserburg(7)). All data points lie within analytical uncertainty of the best fit line with the exception of the data for sample SWZ-6 which lies below the isochron by only 5 parts in 10^5. The excellent colinearity of these data is surprising given the wide variation in chemical composition of the samples from siliceous gneiss (SWZ-5; SiO_2 = 76%) to tonalite(SWZ-6; SiO_2 = 66%), diorite(SWZ-3; SiO_2 = 57%), and metabasalt(SWZ-10 and 12; SiO_2 = 49%). Even the data for the stratigraphically younger quartz-monzonite gneiss, SWZ-4, lie on the same line defined by the remainder of the data. If the data for SWZ-4 are left out of the line regression, the isochron shifts to only a slightly older age of 3.45±0.04 Ga with the initial ε_{Nd} increasing by only 0.1 unit.

Because of the excellent colinearity of the Sm-Nd data, the age indicated is interpreted as the time of extraction of the parental materials of the BMS from a common, isotopically homogeneous, source. The positive initial ε_{Nd} for the AGC indicates that its source was in the mantle and not in a much older, LREE enriched, crustal section. This is not to say that all the varied chemical species that make up the AGC were derived directly from the mantle in a single igneous event. Rather, the Sm-Nd data allow for a variety of petrogenetic mechanisms, from direct partial melting of the mantle for the basaltic components to anatectic melting of slightly older crustal materials for the more silicic rocks as long as these events occurred within the time interval specified by the isochron.

The age determined for the BMS is distinct and some 100 Ma younger than that of the Onverwacht volcanics(3) in accord with the suggestion of Davies and Allsopp (4). Though the similar initial isotopic compositions of the AGC and Onverwacht allow for some of the more silicic members of the AGC to have been derived by remelting of a basaltic crust of Onverwacht age, the presence of basaltic members in the BMS also indicates a significant contribution to the AGC from the mantle. Thus the Kaapvaal craton appears to have originated by at least two episodes of mantle derived mafic volcanism occurring over a period of about 100 Ma.

The positive initial ε_{Nd} of the BMS,and its agreement with that determined for the Onverwacht Group(3), shows the presence of a relatively homogeneous mantle source for the oldest units of the Kaapvaal craton. This source appears to have been relatively depleted in the LREE for a considerable time prior to the formation of the AGC and the Onverwacht volcanics. The increasing occurrence of positive initial ε_{Nd} values for the oldest crustal rocks (e.g. 8-11) implies either that differentiation events within the earth occurred well before (i.e. several hundred million years before) the time of preservation of the oldest observed crustal sections, or that a "chondritic" model for the evolution of the Sm-Nd system of the bulk-earth is not appropriate. The answer to this question carries with it important consequences for models of the bulk composition and early evolution of the earth. However, because of the possible homogenizing effects of convective mixing within the mantle over earth history, further constraints on the early geochemical evolution of the earth clearly must be sought in more complete and precise isotopic data for the ancient rocks of the continental crust.

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Table 1: Sm-Nd Results for samples of the Bimodal Suite

Sample	Sm[a]	Nd[a]	$^{147}Sm/^{144}Nd$[b]	$^{143}Nd/^{144}Nd$[c]
SWZ-4	2.39	16.1	0.08982	0.510293±18
SWZ-6	3.20	20.0	0.09661	0.510403±25
SWZ-5	9.66	45.5	0.1282	0.511146±20
SWZ-3	2.07	7.89	0.1584	0.511822±24
SWZ-10	1.68	5.21	0.1953	0.512668±29
SWZ-12	0.772	2.25	0.2078	0.512946±29

a) Concentrations expressed in ppm. Sm and Nd blanks of 20 pg. and 80 pg. respectively, are negligible for the sample sizes analysed.

b) Determined with tracers calibrated with AMES Sm and Nd metal standard solutions and cross-checked against the CIT n(Sm/Nd) β standard. Uncertainty ∿0.1%.

c) Measured as NdO^+, fractionation corrected to $^{146}NdO/^{144}NdO$ = 0.722251 ($^{146}Nd/^{144}Nd$ = 0.7219). Data reported relative to a value of $^{143}Nd/^{144}Nd$ = 0.511860 for the La Jolla Nd standard.

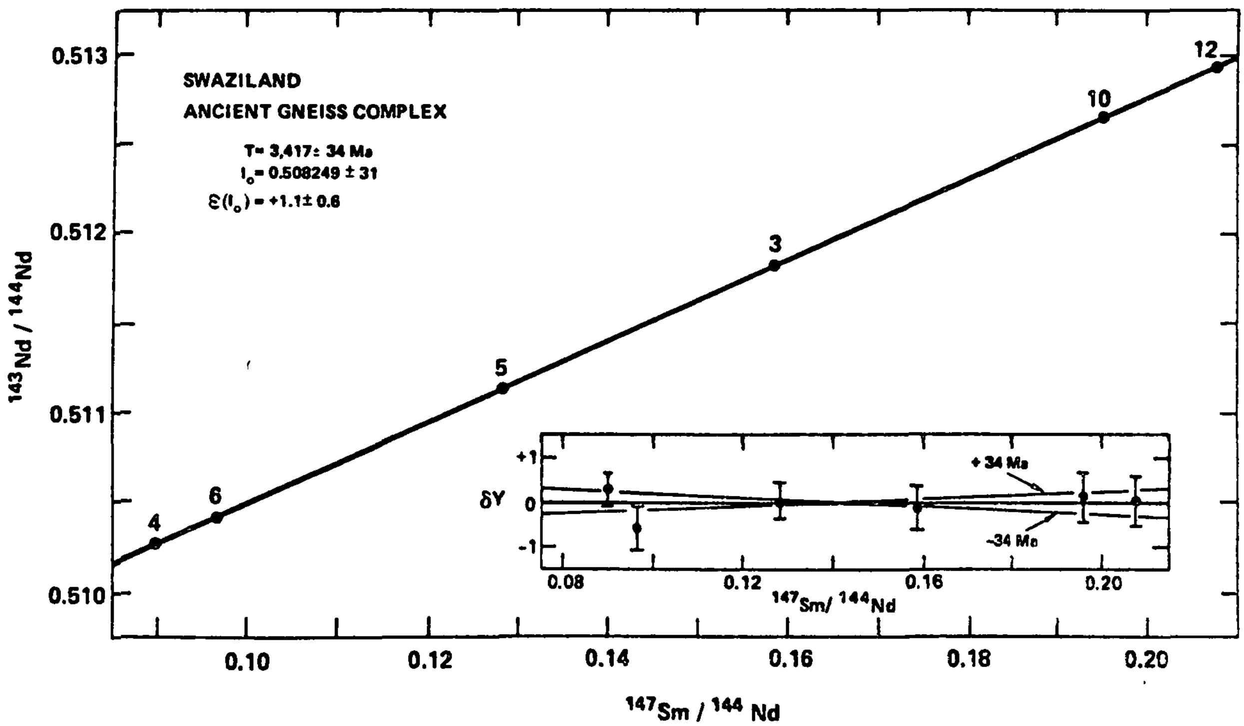

Figure 1: Sm-Nd isochron diagram for samples of the Bimodal Suite. Inset shows deviations (δY) in parts in 10,000 of the data from the best fit line.