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# Note: New constraints on the age of the Weener Intrusive Suite, the Gamsberg Granite and the crustal evolution of the Rehoboth Basement Inlier, Namibia

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The present study gives a new $^{207}Pb/^{206}Pb$ minimum age of 1723 Ma for zircons from a tonalite of the Weener Intrusive Suite as well as a discordia age of 1132 + 26 /-23 Ma for a granite of the Gamsberg pluton. $T_{DM}$ Sm-Nd model ages obtained for members of the Weener Intrusive Suite and the Gamsberg Granite Suite range between 1.6 and 2.4 Ga, thus confinning the fonnation of the Rehoboth crust during the early Proterozoic and its later reworking.

## Introduction

The Rehoboth Basement Inlier (RBI) is a major geological feature which forms the southern boundary of the Pan-African Damara Orogen in central Namibia. The entirely Precambrian RBI consists of various metavolcano-sedimentary sequences which have been intruded by several acid and basic magmas such as the Weener Intrusive Suite (WIS), the Piksteel Intrusive Suite (PIS), the Gamsberg Granite Suite (GGS), as well as acid and basic dykes (SACS, 1980; Stoessel & Ziegler, 1989). A geochemical characterisation of the granitoid intrusives of the RBI has been published elsewhere (Stoessel & Ziegler, 1989; Ziegler & Stoessel, 1990).

The isotopic dating of these intrusive suites by Burger & Coertze (1973, 1973-74, 1975-76a, b), Burger & Walraven (1977-78,1980), Seifert (1986), Reid*et al.* (1988) and Stoessel & Ziegler (1989) provided a framework for the understanding of the evolution of the RBI through the Precambrian and the Palaeozoic. Prior to this study, highly controversial Rb-Sr ages ranging between 1207 Ma and 1871 Ma (Seifert, 1986; Reid *et al.*, 1988) existed for the WIS while the age of the GGS was known to range between 926 Ma and 1229 Ma (Hugo & Schalk, 1972; Burger & Coertze, 1973-74; Seifert, 1986; Reid *et al.*, 1988). The aim of this study was to provide new constraints on the intrusive age of the WIS and the Gamsberg pluton of the GGS by means of U-Pb dating. In addition, the Sm-Nd technique was used to unravel the crustal evolution history of the WIS and the GGS in order to clarify their position in the regional evolution path of the RBI.

## Method

This study includes a total of seven whole-rock samples from the GGS and the WIS (see Fig. 1 for sample localities). For the analysis of the GGS, the sample G49 was collected on the farm Hohenheim, while the samples G53 and KAW2273 were taken from the farm Gamsberg. Samples from the WIS were collected on the farms Corona (W8, W10), Weener (KAW2291) and Morgenroth (W3). Petrographical and geochemical descriptions of the samples are given in Stoessel & Ziegler (1989; W3, W8, W10, G49, G53) and Seifert (1986; KAW2273 & KAW 2291).

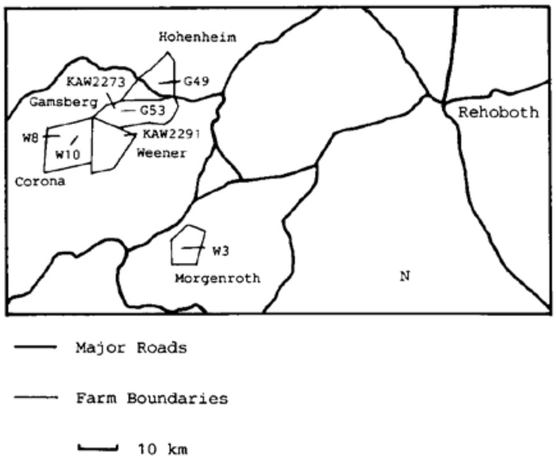


**Fig. 1:** Locality map of the analysed samples.

The U-Pb data were obtained by analysing different fractions of zircon separates. The zircons were separated from the samples KAW2273 and KAW2291 by the use of a Wilfley table, heavy liquids (bromoform and methylene iodide), and a Frantz magnetic separator. Different size fractions of zircons were obtained by the use of sieves. A selection of the purest crystals was then handpicked from the separates. The zircons were washed in nitric and hydrochloric acid before approximately 1-5 mg of the zircon concentrate was dissolved in PTFE-bombs which had previously been spiked with $^{205}Pb/^{235}U$ spike. Element separation followed the method of Krogh (1973). U and Pb were measured on a YG Sector thermal ionisation mass spectrometer. A common-Pb correction for the approximate age of the samples was carried out using the two-stage model of Stacey & Kramers (1975). The analytical total blank of Pb of modem composition was below 0.18 ng. All U-Pb age, concentration and error calculations were carried out using a computer program of G. Stoessel (Stoessel & Ziegler, 1989) and followed the methods described therein. The error limits of the Gamsberg discordia are the geometrical errors of the discordias in the Wetherill (1956) and Tera & Wasserburg (1972) diagrams, respectively.

The Rb-Sr concentrations and the Sr isotopic compositions were determined using the isotope dilution method described by Jäger (1979). The Sm-Nd concentrations and Nd isotopic compositions were determined using a two column element separation procedure (Stoessel & Ziegler, 1989). The Rb analyses were carried out on an Ion Instruments solid source mass spectrometer. Elemental Sr, Sm and Nd analyses were carried out on a YG Sector thermal ionisation mass spectrometer by single and triple filament modes, respectively. The $^{87}Sr/^{86}Sr$ ratios were normalised to $^{86}Sr/^{88}Sr = 0.1194$. The mean $^{87}Sr/^{86}Sr$ ratio for seven measurements of the NBS SRM-987 standard was 0.71022 ± 3 (1σ). The $^{143}Nd/^{144}Nd$ ratios were normalised to a $^{146}Nd/^{144}Nd$ ratio of 0.7219. The mean value for 14 analyses of the La Jolla isotopic standard was 0.51143 ± 15 (1σ). Total blanks were <1 ng for Sm, 0.01-0.1 ng for Nd and <10 ng for Sr.

## Results and discussion

The results of all the isotopic measurements are listed in Tables 1 and 2. The analysed zircon fraction (>200 mesh) of sample KAW2291 from the WIS was composed of clear, translucent, euhedral crystals without visible inherited cores. It yields an apparent $^{207}Pb/^{206}Pb$ minimum age of 1723 Ma and a highly radiogenic lead composition as indicated by a $^{206}Pb/^{204}Pb$ ratio of 1315. Since petrographic examination revealed no old inherited cores within the analysed Weener zircons, we believe that the obtained $^{207}Pb/^{206}Pb$ age represents a meaningful minimum age for the intrusion of members of the WIS on the farm Weener. This age is considerably older than the lower of the two ages calculated by Seifert (1986) on different combinations of Weener data points (which both include KAW2291 and which yield Rb-Sr ages of 1560± 100 Ma and 1871 ± 143 Ma) but falls within the age range of Seiferts" older reference line. The Rb-Sr age of 1207 ± 170 Ma which was determined by Reid *et al.* (1988) for a different pluton assigned to the WIS is also considerably younger than our $^{207}Pb/^{206}Pb$ age. As the intrusion of Gamsberg magmas caused a strong disturbance of the Rb-Sr systems of the intruded older crust (Stoessel & Ziegler, 1989), we believe that the $^{207}Pb/^{206}Pb$ age of 1723 Ma confirms the "final possibility" of Reid *et al.* (1988) and Seifert (1986) considering an intrusion age of 1700 Ma to 1900 Ma for the WIS. Only further U-Pb investigations could show if the Gamsberg age of Reid *et al.*'s Weener samples and Seiferts' 1560 ± 100 Ma age are really due to partial resetting of the Rb-Sr systems of older rocks by the intrusion of magmas of the GGS as has already been demonstrated for several plutons of the PIS by the authors (Stoessel & Ziegler, 1989).

The various size fractions of euhedral, clear zircons lacking visible inherited cores of the Gamsberg sample KAW2273 yielded apparent $^{207}Pb/^{206}Pb$ minimum ages between 1040 and 1105 Ma. The large age difference between the individual grain size fractions is caused by the large correction for common Pb which had to be applied to every fraction. The calculation of discordia ages according to the method of Wetherill (1956) and Tera & Wasserburg (1972) gives ages of 1124 + 28 /-22 Ma (Fig. 2a) and 1132 + 26 /-23 Ma (Fig. 2b), respectively. These discordia ages, which are identical within their error limits, are somewhat lower than the Rb-Sr isochron ages for the Gamsberg pluton of 1229 ± 29 Ma and 1190 ± 23 Ma proposed by Seifert (1986). The Rb-Sr age of 1079 Ma ± 25 Ma obtained by Reid *et al.* (1988) for a data set composed of samples from the Gamsberg and Nauchas plutons overlaps within its error limits with the Gamsberg discordia age obtained during this study. Although a correction for common Pb assuming initial common Pb compositions different from the model Pb compositions of Stacey & Kramers (1975) could shift the obtained age considerably, we think that the present U-Pb age helps constrain the age of the Gamsberg pluton to approximately 1.1 - 1.2 Ga.

The Sm-Nd whole-rock data obtained on the Weener samples yield $T_{Depleted\ Mantle}$ model ages (calculated according to the method described by De Paolo, 1988) between 1.77 Ga and 2.31 Ga, whereas $T_{DM}$ model ages of 1.68 and 2.00 Ga were obtained for the GGS. The model age of the Weener sample W3 from the farm Morgenroth is considerably younger than the model ages of W8 and W10 which were collected on the farm Corona. This implies that the individual plutons of the WIS have different crustal evolution (assimilation and

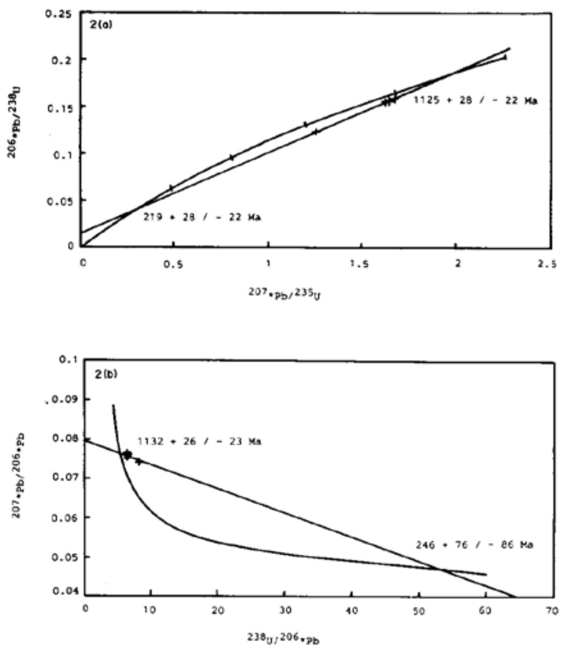


**Fig. 2:** (a) Wetherill (1956) diagram for the U-Pb results of the Gamsberg sample KAW2273. (b) Diagram of Tera & Wasserburg (1972) for the U-Pb results of the Gamsberg sample KAW2273.

**TABLE 1:** Tabulation of the U-Pb data obtained for analysed samples from the WIS (KAW2291) and GGS (KAW2273).

| Sample | Fraction microns | U ppm | $Pb_{rad}$ ppm | $Pb_{nonrad}$ ppm | $^{206}Pb/^{204}Pb$ meas. | Atomic ratios | | | | Apparent Ages | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $^{206}Pb/^{238}U$ | $^{207}Pb/^{235}U$ | $^{207}Pb/^{206}Pb$ | $^{208}Pb/^{206}Pb$ | $^{206}Pb/^{238}U$ | $^{207}Pb/^{235}U$ | $^{207}Pb/^{206}Pb$ |
| KAW2291 | >200 | 254 | 73.8 | 3.00 | 1315 | 0.2639 | 3.839 | 0.1055 | 0.1764 | 1510 | 1601 | 1723 |
| KAW2273 | 112-155 | 273 | 51.9 | 83.5 | 47.85 | 0.1586 | 1.670 | 0.07636 | 0.3157 | 949 | 997 | 1105 |
| KAW2273 | 40-75 | 542 | 87.1 | 254 | 32.46 | 0.1231 | 1.255 | 0.07395 | 0.4419 | 748 | 825 | 1040 |
| .KAW2273 | 75-112 unmag | 268 | 50.4 | 84.7 | 46.60 | 0.1573 | 1.628 | 0.07500 | 0.3132 | 942 | 981 | 1070 |
| KAW2273 | Fission track separate | 252 | 45.7 | 9.16 | 275.0 | 0.1563 | 1.643 | 0.07625 | 0.2735 | 936 | 987 | 1102 |

**TABLE 2:** Tabulation of the Rb-Sr and Sm-Nd results obtained for analysed samples from the WIS (W samples) and GGS (G samples).

| Sample | Rb ppm | Sr ppm | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ | +/- (2σ) | $\varepsilon Sr_{(0)}$ | $\varepsilon Sr_{(t)}$ | Sm ppm | Nd ppm | $^{147}Sm/^{144}Nd$ | $^{143}Nd/^{144}Nd$ | +/- (2σ) | $\varepsilon Nd_{(t)}$ | $T_{DM}$ (Ma) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W3 | 102.4 | 631.4 | 0.4695 | 0.71067 | 1 | 87.6 | -48.3 | 5.870 | 37.00 | 0.0959 | 0.511784 | 8 | 5.49 | 1777 |
| W8 | 63.06 | 308.0 | 0.5928 | 0.71510 | 1 | 150.5 | -28.6 | 8.432 | 39.00 | 0.1307 | 0.511902 | 11 | 0.09 | 2302 |
| W10 | 88.18 | 280.9 | 0.9096 | 0.72370 | 1 | 272.6 | -17.7 | 6.236 | 30.31 | 0.1244 | 0.511829 | 7 | 0.06 | 2264 |
| G49 | 303.3 | 13.30 | 72.55 | 1.72148 | 2 | 14.4 | -1463.9 | 8.133 | 33.67 | 0.1460 | 0.512272 | 20 | -0.25 | 1995 |
| G53 | 84.34 | 227.7 | 1.074 | 0.72808 | 1 | 334.7 | 103.2 | 8.381 | 44.80 | 0.1131 | 0.521052 | 22 | 0.77 | 1676 |

*$\varepsilon Sr_{(0)} = \varepsilon Sr_{(today)}$

**$\varepsilon Sr_{(t)}$ and $\varepsilon Nd_{(t)}$ are calculated for $t$ = 1080 Ma (Gamsberg samples) and $t$ = 1720 Ma (Weener samples)* fractional crystallisation) histories. Nonetheless, it can be stated that the analysed members of the WIS represent crustal material which formed during the early Proterozoic.

The model ages of the Gamsberg samples are much older than the intrusion ages of the respective plutons. This implies that the calc-alkaline Gamsberg magmas represent a mixture of pre-existing early Proterozoic crustal material and younger mantle-derived material.

Earlier work by Stoessel & Ziegler (1989) has shown early Proterozoic $T_{DM}$ model ages for the PIS, the Neuhof Formation and the Elim Formation of the RBI. McDermott (1986) analysed granitic rocks of the Pan-African Damara Orogen and found model ages ranging between 1.0 and 3.0 Ga. This led to a theory of a continuous reworking of crustal material in the central part of Namibia from the early Proterozoic to the early Phanerozoic (Stoessel & Ziegler, 1989). The present $T_{DM}$ model ages obtained for the WIS and the GGS fit very well into this model and thus support the theory of a continuous reworking of the Rehoboth crust.

Due to their very low $^{87}Sr/^{86}Sr_{(t)}$ ratios, the Weener values (calculated for a minimum formation age t of 1720 Ma) plot below the bulk earth Sr evolution trend of O'Nions *et al.* (1979). This indicates that the Rb-Sr systems of the analysed Weener samples either derive from a strongly Rb-depleted mantle region or that they have been affected by post-crystallisation alteration processes. The Gamsberg sample from the farm Hohenheim (G49) must have been affected by post-emplacement alteration processes as indicated by its primordial $^{87}Sr/^{86}Sr_{(t=1080\ Ma)}$ ratio, while the sample from the farm Gamsberg (G53) probably reflects an undisturbed Sr isotopic composition.

## Conclusions

The present data are in good agreement with earlier results from Stoessel & Ziegler (1989) on the metavolcano-sedimentary units and the PIS of the RBI which suggested that the major part of the Rehoboth crust must have formed during the early Proterozoic. Due to the new data on the WIS and the GGS, it is now possible to reconstruct the following history of crustal evolution in the RBI.

After an early phase of crustal reworking, represented by the lower units of the metavolcano-sedimentary sequences of the RBI, the Rehoboth area was (between 1.7 and 1.9 Ga) intruded by the calc-alkaline members of the WIS and the PIS. The Alberta Mafic Complex was then emplaced in the northern part of the RBI at about 1.4 Ga (Reid *et al.*, 1988). This was followed by the intrusion of the calc-alkaline GGS between 1.25 and 0.9 Ga, causing a major disturbance of the Rb-Sr systems of the intruded rock units. The $T_{DM}$ model ages of the GGS exceeding 1.6 Ga again indicate reworking of older continental crust. Crustal reworking continued into the early Phanerozoic as shown by McDermott (1986) who determined model ages between 1.0 and 3.0 Ga for granitic rocks of the Pan-African Damara Orogen to the north of the RBI.

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