Chapter 4
Results and Discussion

In this chapter I discuss the results of my study on the effects of mass spectrometric procedures on accurate determination of μ^{142}Nd and results obtained from our efforts in search of μ^{142}Nd anomalies in Indian rocks.

4.1 Effect of mass spectrometric procedures on accuracy of ^{142}Nd/^{144}Nd

The mass spectrometric procedures involve data acquisition and reduction methods. To understand the effect of these on the accuracy of ^{142}Nd results obtained, the 1.48 Ga alkaline rocks from Khariar were analysed as a case study. The report of negative μ^{142}Nd anomaly (-13ppm) in these rocks by Upadhyay et al. (2009) needed an independent verification since these were the only non-Archean rocks reported to have preserved signatures of early silicate Earth differentiation. Considering the highly dynamic nature of the Earth's earliest mantle and the time elapsed since its formation, it is extremely difficult to encounter μ^{142}Nd anomalies in rocks younger than Archean. All other accepted discoveries of μ^{142}Nd anomalies come from the Hadean and Archean rocks (Bennett et al. 2007; Boyet and Carlson, 2006; Boyet et al. 2003; Caro et al. 2003, 2006; O'Neil et al. 2008; Rizo et al. 2011, 2012; Roth et al. 2013, 2014a).This particular finding being from very young rocks, has the potential to change our understanding of the preservation and longevity of the evidence for the earliest crust-mantle differentiation. Since these rocks are believed to have originated from a lithospheric mantle, the authors had argued for preservation of ^{142}Nd anomaly in a non-convective mantle domain in cratonic roots for at least for 2.7 billion years since its formation (Upadhyay et al. 2006, 2009). However, if these anomalies turn out to be analytical artefacts then the hypothesis of continental lithospheres being sites of preservation of ^{142}Nd anomalies would be invalidated, restricting the anomalous signals only to the rocks of Hadean and Archean. Therefore, it is imperative that the robustness of these results is verified through independent investigations by different laboratories.

In an attempt to verify these negative ^{142}Nd anomalies, Roth et al. (2014b) measured ^{142}Nd/^{144}Nd in the same aliquots of the samples of Upadhyay et al. (2009), but could not reproduce the results. In their data acquisition protocol on TIMS, Roth et al. (2014b) had employed a 2-sequence multi-dynamic mode in contrast to a 3-sequence mode utilized by Upadhyay et al. (2009). To minimize the time delay between the measurements of ^{144}Nd/^{146}Nd and ^{142}Nd/^{144}Nd, Roth et al. (2014b) acquired these ratios in sequences 1 and 2, instead of sequences 1 and 3 as followed by Upadhyay et al. (2009). This was done to remove the analytical bias in the (mass) fractionation corrected ^{142}Nd/^{144}Nd in the 3-sequence mode, caused by higher relative rate of fractionation ($r_f > 1$). Where r_f = average fractionation rate (r_a) /threshold fractionation rate (r_t), and r_t = external reproducibility /time gap between the sequences (1 and 2 in 2-sequence mode or 1 and 3 in 3-sequence mode). Average fractionation rate was calculated for each analysis by finding the slope of the regressed line when uncorrected $^{146}Nd/^{144}Nd$ from sequence-1 is plotted against the time.

Roth et al. (2014b) also proposed a correction procedure to reduce the 3-sequence data of Upadhyay et al. (2009), where r_t was lower than that in a 2-sequence mode, and showed that in all except one sample the anomalies vanished. According to the authors, this correction procedure was not advocated for general use, but rather is an approximation to re-assess published data. The number of sequences was not the only analytical parameter that was different in the two studies. Another important parameter which was not given a due importance was the law of fractionation correction (e.g., exponential vs. power law). The protocol followed by Roth et al. (2014b) was grossly different from that of Upadhyay et al. (2009). The details are given in Tables 3.1 - 3.3 (Chapter 3).

It is therefore, important that we also understand the role of the fractionation correction on the accuracy of $^{142}Nd/^{144}Nd$ isotopic data and its contribution (if any) to the generation of the analytical artefacts. To study these aspects and to further investigate the accuracy of the negative $\mu^{142}Nd$ anomalies reported in the alkaline silicate rocks of the Khariar complex, India (Upadhyay et al. 2009), we analysed samples re-collected from the same geological outcrops for their Nd isotopic compositions applying different fractionation correction procedures. We followed identical experimental procedure as in the original study of Upadhyay et al. (2009) and that proposed later by Roth et al. (2014b). Experimental details are provided in Tables 3.2 and 3.3. Both the techniques were evaluated in light of over correction of $^{142}Nd/^{144}Nd$ resulting from excessive fractionation correction. We have used Ames Nd standard for normalization of $^{142}Nd/^{144}Nd$ of samples, because it was routinely analysed along with the samples in our laboratory. We have also analysed JNdi-1 standard and rock standard BHVO-2 for accuracy check.

4.1.1 Data acquisition: 2- versus 3- sequence multi dynamic mode

In this study, the effect of number of sequences used in the multi-dynamic mode of data acquisition, on the accuracy of isotopic results was studied. All standards and samples of alkaline rocks from Khariar were analysed using multi-dynamic scheme of data acquisition employing both 3- and 2-sequence modes. Fifteen and eighteen loads of Ames Nd were analysed for the 3- sequence and 2- sequence modes, respectively. In the 3-sequence mode, isotopic ratios were corrected for mass fractionation using the *power (law)-normalised exponential law* as in Upadhyay et al. (2009) and our experiment yielded an average value of 1.1418375 for $^{142}Nd/^{144}Nd$ of Ames Nd with an external reproducibility of 7.1 ppm (Table 4.1 – a). In the 2-sequence mode, the simple *exponential fractionation law* (as in Roth et al. 2014b) was used and an average value of 1.1418390 for $^{142}Nd/^{144}Nd$ was obtained with an external reproducibility of 8.9 ppm (Table 4.1 – b). Our external precision (2 SD) is lower than that reported by most studies on such experiments (i.e., ~5 ppm), in spite of the fact that the within-run precisions are < 5ppm (2 SE). The reason for the lower external precision could be because of the aging (> 12 years old) of the Faraday Cups. Because I have used two different schemes of data acquisition for the Khariar samples and BHVO-2, the above two values of $^{142}Nd/^{144}Nd$ for Ames Nd have been used for determination of $\mu^{142}Nd$ (Figure 4.1). $\mu^{142}Nd$ values of Khariar samples obtained through a 3-sequence method appear to be slightly negative, albeit unresolvable within 2SD, compared to those obtained through a 2-sequence method.

If the external precision for $^{142}Nd/^{144}Nd$ measurements were considered to be 5 ppm, then the respective r_t values would have been 0.22 ppm/s and 0.44 ppm/s for corresponding time durations of 22.8 s and 11.4 s, respectively. Our isotopic data from the analyses of standards and Khariar samples, by both modes, show r_a < 0.22 ppm/s (Tables 4.1- 4.3), suggesting r_f < 1.This is unlike what Roth et al. (2014b) observed for the 3-sequence data of Upadhyay et al. (2009), where r_f >1. Consequently, there was no need for the time correction (an empirical solution for the data of Upadhyay et al. 2009) of the data acquired in 3-sequence mode to deal with any excess fractionation, as was suggested by Roth et al. (2014b).

A few analyses carried out using 3-sequence data acquisition mode prior to this experiment show r_a between 0.20 ppm/s and 0.40 ppm/s, in which case r_f > 1. However, if I consider the actual external precision for the present study, which is 8.9 ppm, then value of r_t for three sequence mode becomes 0.39 ppm/s instead of 0.22 ppm/s and in this case, for all the data, r_f < 1. In addition, there is absence of any significant correlation between the fractionation corrected $^{142}Nd/^{144}Nd$ isotopic ratios and average fraction rates (r_a), as can be seen in Figure 4.2. Therefore, it is inferred that the time-gaps between successive sequences in a multi-dynamic mode do not affect the quality of the data acquired when r_a < r_t. The number of sequences in a multi-dynamic dynamic mode of data acquisition has no effect on the average fractionation rates (r_a).

4.1.2 Corrections for Isobaric Interferences

Isobaric interferences on Nd isotopes from Sm and Ce were monitored by measuring ^{147}Sm and ^{140}Ce, respectively. The ^{140}Ce/^{142}Nd for the all analysed samples is given in the tables provided at the end of this chapter. The maximum and minimum values of ^{140}Ce/^{142}Nd were 3.77×10^{-4} and 9.18×10^{-7}, respectively. On an average ^{140}Ce/^{142}Nd was in the order of 10^{-5}. ^{147}Sm/^{144}Nd values never exceeded order of 10^{-7} and hence deemed insignificant for any correction. Nonetheless, interference corrections for Ce and Sm were applied to the standard and samples. We do not see any significant correlation between ^{140}Ce/^{142}Nd and the corresponding fractionation corrected ^{142}Nd/^{144}Nd (Figure 4.3).

4.1.3 Correction for Mass Dependent Fractionation

A comparison of the pattern of mass fractionation observed in our data with the theoretical patterns expected from various empirical fractionation laws (Habfast, 1998), with the help of ^{142}Nd/^{144}Nd versus ^{150}Nd/^{144}Nd, reveals that the *exponential law* best explains the observed pattern in each individual sequences (Figure 4.4), which are equivalent to static mode of data acquisitions.

A fractionation line corresponding to the power-normalised exponential law for multi dynamic data acquisition cannot be drawn. We therefore compare the two commonly used empirical laws, *exponential* and *power (law)-normalised exponential laws*, for the residual correlations in the fractionation corrected data. The details of the two laws are already provided in the Table 3.3. The raw/uncorrected data for 67 Ames Nd aliquots (Table 4.3) analysed during and prior to this experiment over a period of 3 years, were corrected for mass fractionation using the (1) *power-normalised exponential law*, and (2) *exponential law*. Data acquired using 2-sequence mode were not included in this exercise, because barring ^{142}Nd/^{144}Nd all other Nd isotopic ratios cannot be corrected for fractionation using the first law (i.e. 1; Tables 3.1 and 3.3). The figures 4.5 and 4.6 show results of this exercise.

We observed that: (1) isotopic ratios corrected using the *power-normalised exponential law* do not show any significant inter correlation (Figures 4.5a-d and 4.6a-d), whereas the *exponential law* correction method leaves behind substantial residual correlations, especially for ^{150}Nd/^{144}Nd and ^{148}Nd/^{144}Nd (Figs. 4.5e-h and 4.6e-h); (2) *power-normalised exponential law* noticeably improves precisions (2SD) for ^{143}Nd/^{144}Nd (5.1 ppm), ^{145}Nd/^{144}Nd (4.6 ppm) and ^{148}Nd/^{144}Nd (11.7 ppm) ratios, compared to those obtained through *exponential correction* (Table 4.3; Figures 4.3 and 4.4), which are 17.4 ppm, 11.7 ppm and 26.5 ppm, respectively. However, the 2SD values for ^{150}Nd/^{144}Nd are similar in both the methods because it is obtained from only one sequence (i.e., sequence-1), like that in a static mode but with different β values (Tables 3.1 and 3.2). Residual correlations as described above, in (1), are undesirable and indicate insufficiency of the method/law used for mass fractionation (Andreasen and Sharma, 2009). We, therefore, infer that application of the *power-normalised exponential law* for correction of mass dependent fractionation in a multi-dynamic method is the most appropriate data reduction approach.

Using the *power-normalised exponential law* we corrected data for Khariar samples acquired through both the 3- and 2-sequence modes (Figure 4.7), but could not reproduce the anomalies of Upadhyay et al. (2009). We, however, observed that the mean μ^{142}Nd values of some of the sample-replicates plotted outside, on the negative side, the 7.1 ppm range defined for the standard – which is also corrected using the *power-normalised exponential law*. In contrast, sample data from both 3- and 2-sequence modes corrected using the *exponential law* plotted well within the 8.9 ppm range for the standard, corrected using the *exponential law* (Figure 4.7). In addition to μ^{142}Nd, inter comparison was also done for stable Nd isotopic compositions acquired through 3-sequence mode and corrected using both the laws (Figures 4.8 and 4.9). As can be seen data corrected using the *exponential law* show larger spread compared to those corrected using the *power-normalised exponential law* (Figures 4.8 and 4.9). It is therefore evident that it is the method of fractionation correction and not the mode of acquisition that controls the quality of data.

4.1.4 Choice of Terrestrial Standard Used: Ames Nd versus JNdi-1

Because the ^{142}Nd/^{144}Nd isotopic ratio of the terrestrial standard is key to the definition of μ^{142}Nd it is essential that the standard has uniform and reproducible isotopic ratio and truly represents the modern accessible mantle. Several terrestrial standards have been used over the years in ^{142}Nd studies – such as LaJolla Nd, JNdi-1, Ames Nd and many in-house standards. Although it is expected that all the stable Nd isotopic ratios and ^{142}Nd/^{144}Nd of these standards are identical, observations suggest otherwise (e.g., Brandon et al. 2009; O'Neil et al. 2008; Saji et al. 2016; Wakaki and Tanaka, 2012). This may lead to appearance or disappearance of anomalies depending on choice of the standard (Gautam et al., 2017; Gautam and Ray, 2017).

I analysed two commonly used Nd terrestrial standards viz. Ames Nd and JNdi-1 during the course of this study. Eleven aliquots of JNdi-1 were analysed along with six of Ames Nd (Table 4.4(a); Figure 4.10). As can be seen in Figure 4.10 all Nd isotopic ratios of JNdi-1, although overlap at 2SD with those of the Ames standard, show minor differences in the mean values. The average value of $^{142}Nd/^{144}Nd$ for JNdi-1 is lower by 6 ppm than the long term average of $^{142}Nd/^{144}Nd$ for Ames Nd (Figure 4.10). Since the two commonly used Nd standards do not have identical $^{142}Nd/^{144}Nd$, the comparison in μ^i values can be confusing. To avoid this, $^{142}Nd/^{144}Nd$ isotopic ratios of the two standards analysed over the course of this study are directly compared in Figure 4.11. This helps in comparing the actual values instead of relative change with respect to only one standard.

When $^{142}Nd/^{144}Nd$ of Khariar samples were normalized with respect to Ames Nd and JNdi-1, the slight negative $\mu^{142}Nd$ obtained using Ames Nd became normal with respect to JNdi-1 (Figure 4.12). The mean values of $\mu^{142}Nd$ of BHVO-2 measured by us are different with respect to each standard; however, they overlap within the external reproducibility of each standard (Figure 4.12). It should be noted that Upadhyay et al. (2009) used La Jolla as reference whereas Roth et al. (2014b) used JNdi-1. La Jolla has higher $^{142}Nd/^{144}Nd$ with respect to JNdi-1 (Wakaki and Tanaka, 2012), similar to what we observe in the case of Ames Nd (Figure 4.12; Table 4.4a). We speculate that the conflicting results obtained from the same aliquots of the Khariar samples by Upadhyay et al. (2009) and Roth et al. (2014b) are a combined effect of the choice of fractionation correction law and terrestrial standard used for calculation of μ.

Because different batches of Ames are known to have different Nd isotopic compositions, JNdi-1 is a more homogenoues standard than Ames Nd. Therefore, we strongly recommend that JNdi-1 should be used as the terrestrial reference standard for ^{142}Nd isotopic measurements. We provide a cross-calibration for JNdi-1 and Ames Nd analysed by us (Figure 4.13). We followed the method as desribed in Tanaka et al. (2000). A total of five JNdi-1 and six Ames Nd (single batch) analyses were included in this exercise. We got a linear relationship of $(^{142}Nd/^{144}Nd)_{JNdi\text{-}1} = 0.809695\times(^{142}Nd/^{144}Nd)_{Ames\ Nd} + 0.2172901$ with a R^2 value of 0.89 (Figure 4.13). Using this relation, a value of 1.1418302 for JNdi-1 was obtained corresponding to our long term average of 1.1418375 for Ames Nd. We use this as the reference to compare the ^{142}Nd isotope composition of the samples analysed by us in various batches during the course of this study. External reproducibilty obtained for for JNdi-1 was 0.0000082 (2SD; Table 4.4a).

4.2 In search of $\mu^{142}Nd$ anomalies in Indian rocks

Considering the effects of analytical parameters which affect the accuracy of $^{142}Nd/^{144}Nd$ ratio and value of $\mu^{142}Nd$, we decided to:

- correct data for mass fractionation using the *power-normalised exponential law,*
- use JNdi-1 as the reference material to compare that data for any anomalous composition, and
- report the ^{142}Nd isotope composition in terms of $^{142}Nd/^{144}Nd$ values instead of μ notation.

Rock standard BHVO-2 was analysed multiple times during the course of the study. Other rock standards, BCR-2, JB-1(a) and JB-3 were also analysed. Figure 4.14 shows the $^{142}Nd/^{144}Nd$ in reference to JNdi-1 for these rock standards. Nd isotopic data is in Table 4.5. In all the plots shown hereafter, the reference value for JNdi-1 is 1.1418302 with an external precision of 0.0000082 (2SD) presented as an orange shaded area. The long term average value obtained for Ames Nd along with its external reproducibility (2SD) in the present study is also shown.

4.2.1 $^{142}Nd/^{144}Nd$ isotopic composition of continental alkaline rocks of India

Alkaline rocks from various locations and of different ages were analysed: Carbonatites from Amba Dongar, Sung Valley and Newania were analysed in two fractional aliquots for each sample as carbonates and silicates. No resolvable anomalous ^{142}Nd isotopic composition on the repeat analyses of these is observed with respect to JNdi-1 (Figures 4.15 – 4.17). The associated silicate rocks from Amba Dongar and Sung Valley also do not show any resolvable anomalous ^{142}Nd isotopic composition. Kimberlites from Eastern Dharwar Craton, alkali basalts from Phenai Mata Complex and nepheline syenites from Kishengarh lack any resolvable anomalous $^{142}Nd/^{144}Nd$ composition (Figure 4.18). The data are presented in Tables 4.6 to 4.10.

The analysed rocks are believed to have been derived from the non-convective mantle domain – SCLM, and cover a vast span of time in terms of their ages of emplacement, from 1.5 Ga to 65 Ma. The absence of anomalous ^{142}Nd isotope composition in these suggests that the SCLM region involved in the generation of these magmas, did not inherit any signature of the early silicate differentiation events. Also, if at all any such signatures were acquired, they have been lost to dilution because of contamination in the source or within the crust.

Mantle xenoliths from Kutch could not be analysed as the Nd+ signal for 142 mass was not sufficient to run the sample. This is due to the low concentration of Nd (less than 0.01ppm) in these peridotites.

4.2.2 ^{142}Nd/^{144}Nd of Archean rocks

TTGs (3.5 Ga) from Singhbhum Craton and biotite gneisses (3.3 Ga) from BGC-1, Aravalli Craton, were analysed for their ^{142}Nd isotopic composition. With respect to Ames Nd, TTGs from Singhbhum do not show any resolvable anomalous ^{142}Nd composition (Figure 4.19), however, with respect to JNdi-1, these rocks show resolvable higher ^{142}Nd/^{144}Nd ratios. In terms of μ^{142}Nd calculated with respect to JNdi-1, TTGs of Singhbhum show a +13 ppm anomaly. The biotite gneisses from BGC-1 do not show any resolvable anomalous ^{142}Nd composition with respect to both, Ames Nd and JNdi-1. The values are given in Table 4.11. Whereas, it is clear that the Archean rocks of BGC-1 do not carry any evidence of early silicate differentiation, a possibility of the preservation of such evidence is hinted at in the Singhbhum TTGs. Therefore, it is essential to replicate the results for Singhbhum rocks.

Studying the 3.45 Ga Archean rocks of India we find a hint of preservation of an EDR signature in the mantle source of the TTGs of Singhbhum. If true, this would be the first evidence from Indian Shield for an early silicate differentiation process. On a global perspective, this is interesting as the 3.8 Ga Archean TTGs from Greenland (+15 ppm) and 3.73 Ga Yilgran (+5 ppm) carry positive anomalies (Bennett et al. 2007; Caro et al. 2006), whereas those from 4.28 Ga Canada rocks show negative (- 16 ppm) anomalies (O'Neil et al. 2008). Our finding suggests that high positive anomalies persisted at least 350 million years beyond the formation of the TTGs of Greenland.

4.2.3 ^{142}Nd evolution of Indian mantle domains

Our attempts to extract information about earliest silicate differentiation from the mantle domains that formed Indian Shield have yielded some interesting information. We found that Archean mantle responsible for the generation of the Singhbhum TTGs appears to possess signature of the EDR, whereas the mantle sources of the 200 million years younger BGC-1 granitoids have no trace of such evidence (Figure 4.20). The latter could be explained by the loss of μ^{142}Nd excess to mixing with magmas derived from EER type of mantle domains (Figure 4.20). Alternately, their generation involved neither EDR nor EER but, was a mantle domain that had remained unaffected by the earliest silicate differentiation. The non-convective mantle studied by us, as represented in carbonatites, kimberlites and alkaline rocks, shows no evidence of any of the early formed reservoirs.

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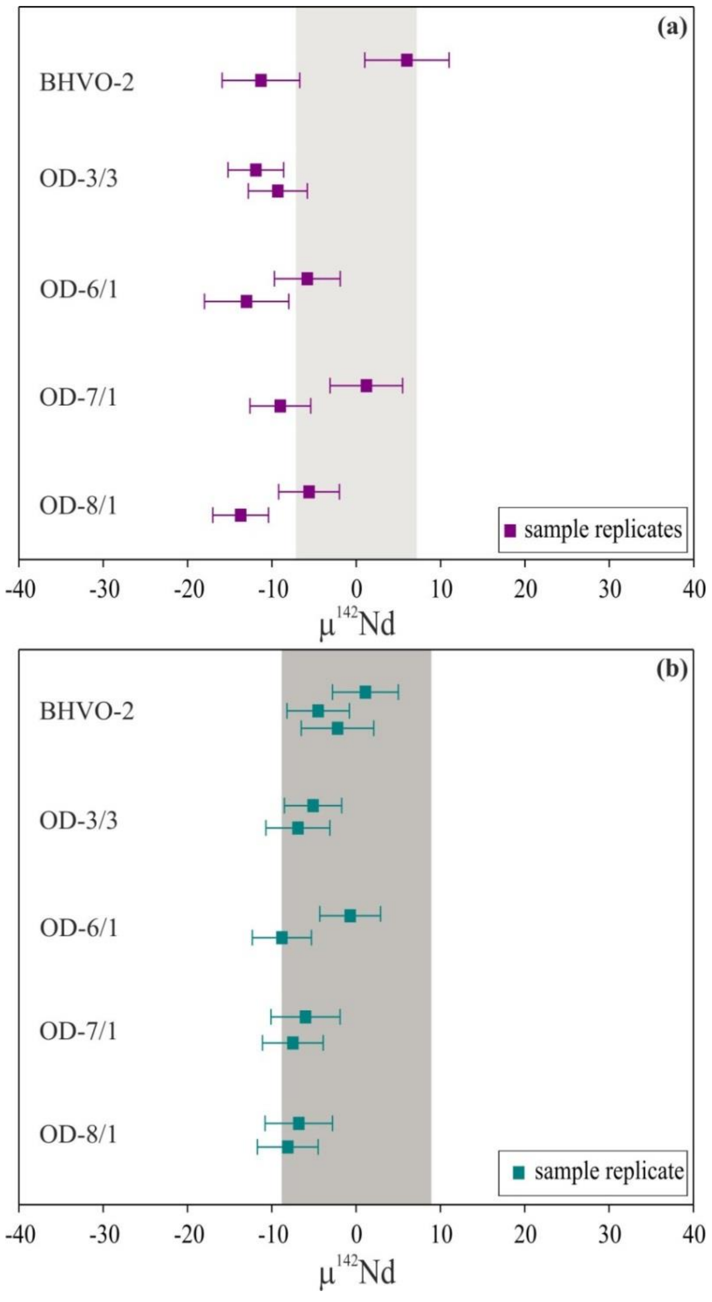

Figure 4.1 *μ^{142}Nd values of 1.48 Ga alkaline rocks from Khariar analysed in this study: (a) data acquired using a 3-sequence multi dynamic mode and corrected for mass fractionation using the power-normalised exponential law; (b) data acquired using a 2- sequence multi dynamic mode and corrected for mass fractionation using the exponential law. The average values of Ames Nd used for calculating μ^{142}Nd in (a) and (b) are 1.1418375 ±7.1*

ppm (2RSD, n = 15) and 1.1418390 ±8.9 ppm (2RSD, n = 18), respectively. The grey bands encompass ± 2RSD, external reproducibility, for Ames Nd standard.

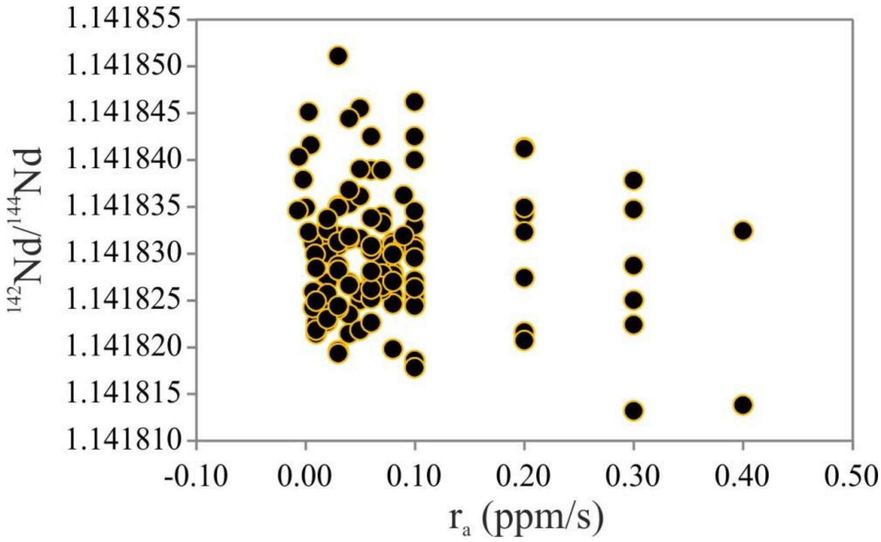

Figure 4.2 *Plot shows fractionation corrected $^{142}Nd/^{144}Nd$ versus average fractionation rate (r_a) for Khariar and other sample analysed during the course of this study.*

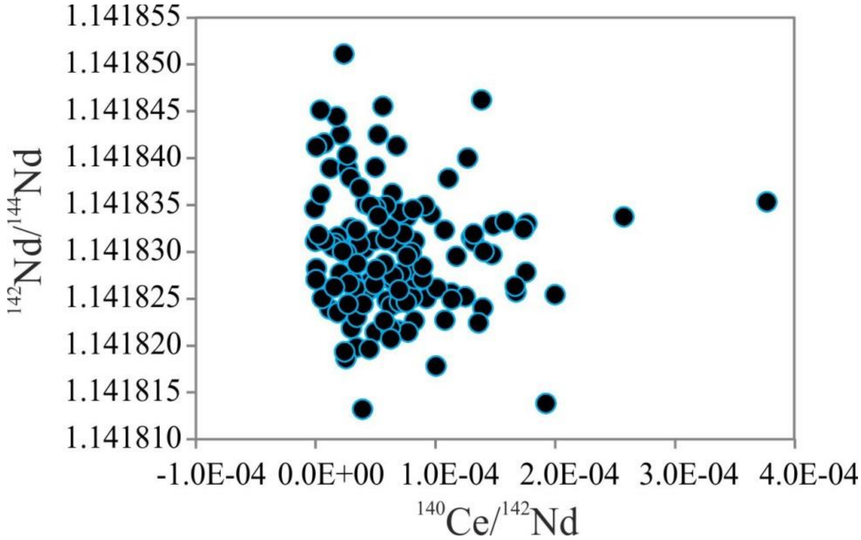

Figure 4.3 *Interference monitor $^{140}Ce/^{142}Nd$ versus corrected $^{142}Nd/^{144}Nd$ for Khariar and other samples analysed during the course of this study. Data are corrected using power-normalised exponential law. This lack of correlation suggests that the interference corrections applied for Ce did not bias the final $^{142}Nd/^{144}Nd$ data and therefore, were robust.*

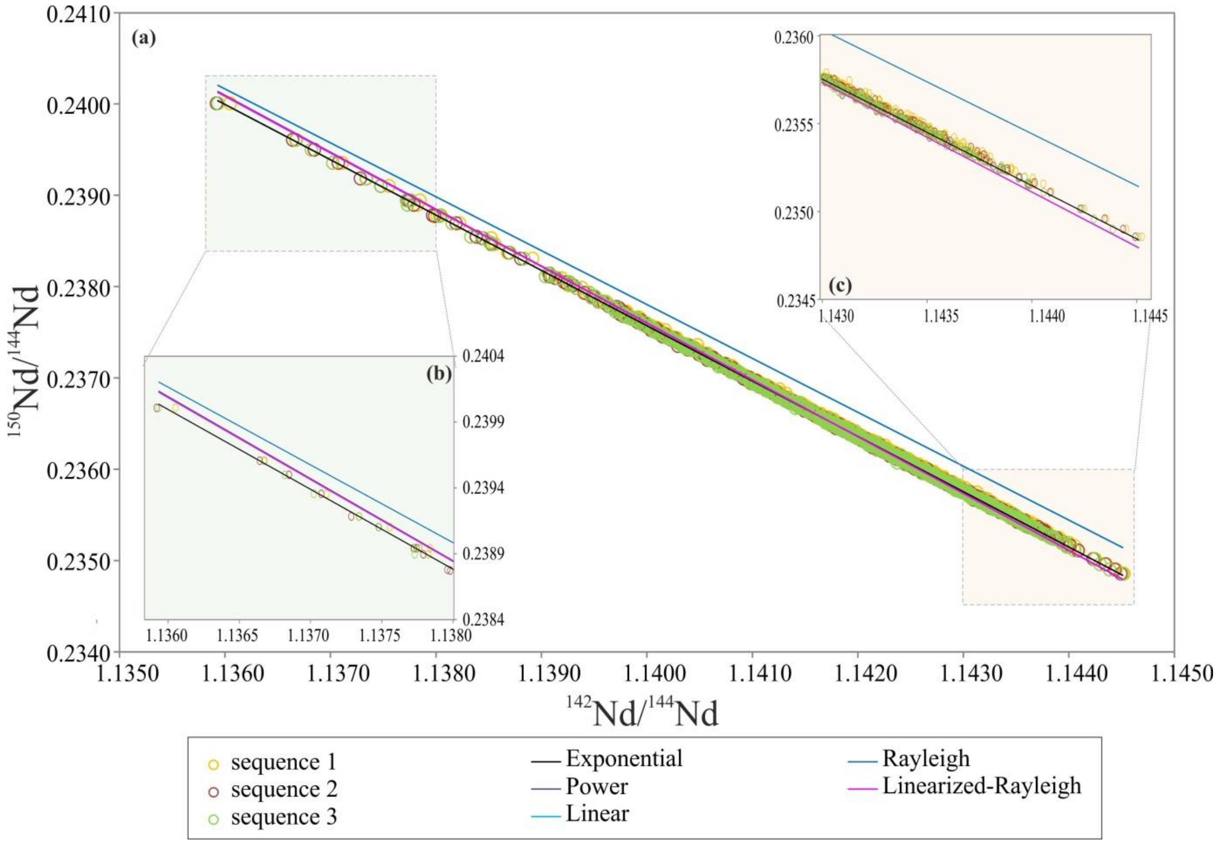

Figure 4.4 *(a) Plot of uncorrected $^{150}Nd/^{144}Nd$ versus $^{142}Nd/^{144}Nd$ isotopic ratios for Ames Nd standard acquired using a 3-sequence multi-dynamic mode. $^{142}Nd/^{144}Nd$ values are from all the three sequences and $^{150}Nd/^{144}Nd$ from the first sequence only. Each point is an average of 10 cycles (one block) and the plot contains data from 752 blocks for 14 analyses. Lines corresponding to different fractionation laws are also shown; (b) and (c) represent enlarged versions of the marked segments of the plot.*

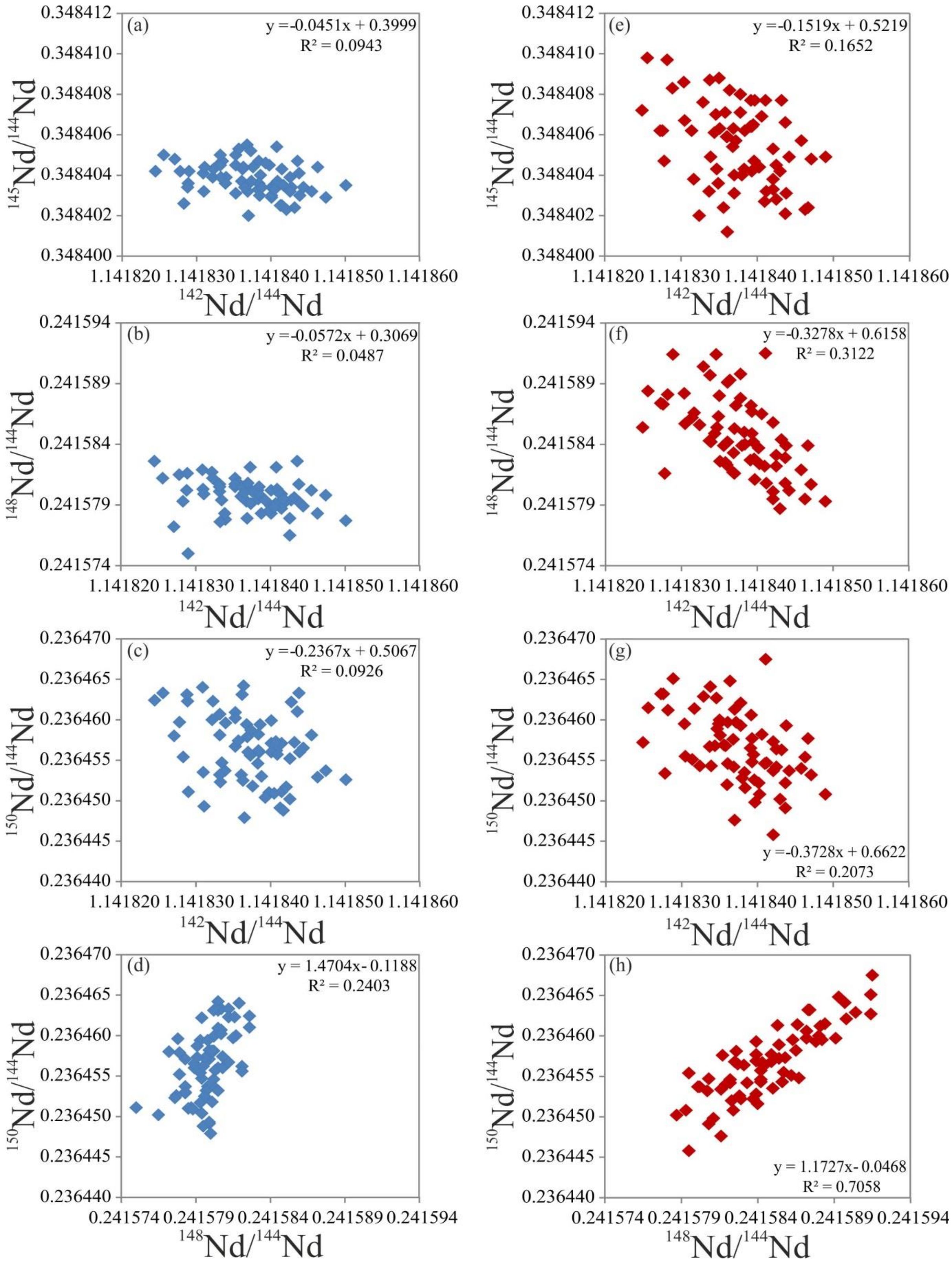

Figure 4.5 *Plots of Nd isotopic ratios (except for $^{143}Nd/^{144}Nd$) for Ames Nd standard (n = 67) obtained during 3-sequence data acquisition method (data are in Table 4.3). Each datum (raw, corrected only for interference corrections) is corrected offline using the power-normalised exponential law (a-d) as well as the exponential law (e-h).*

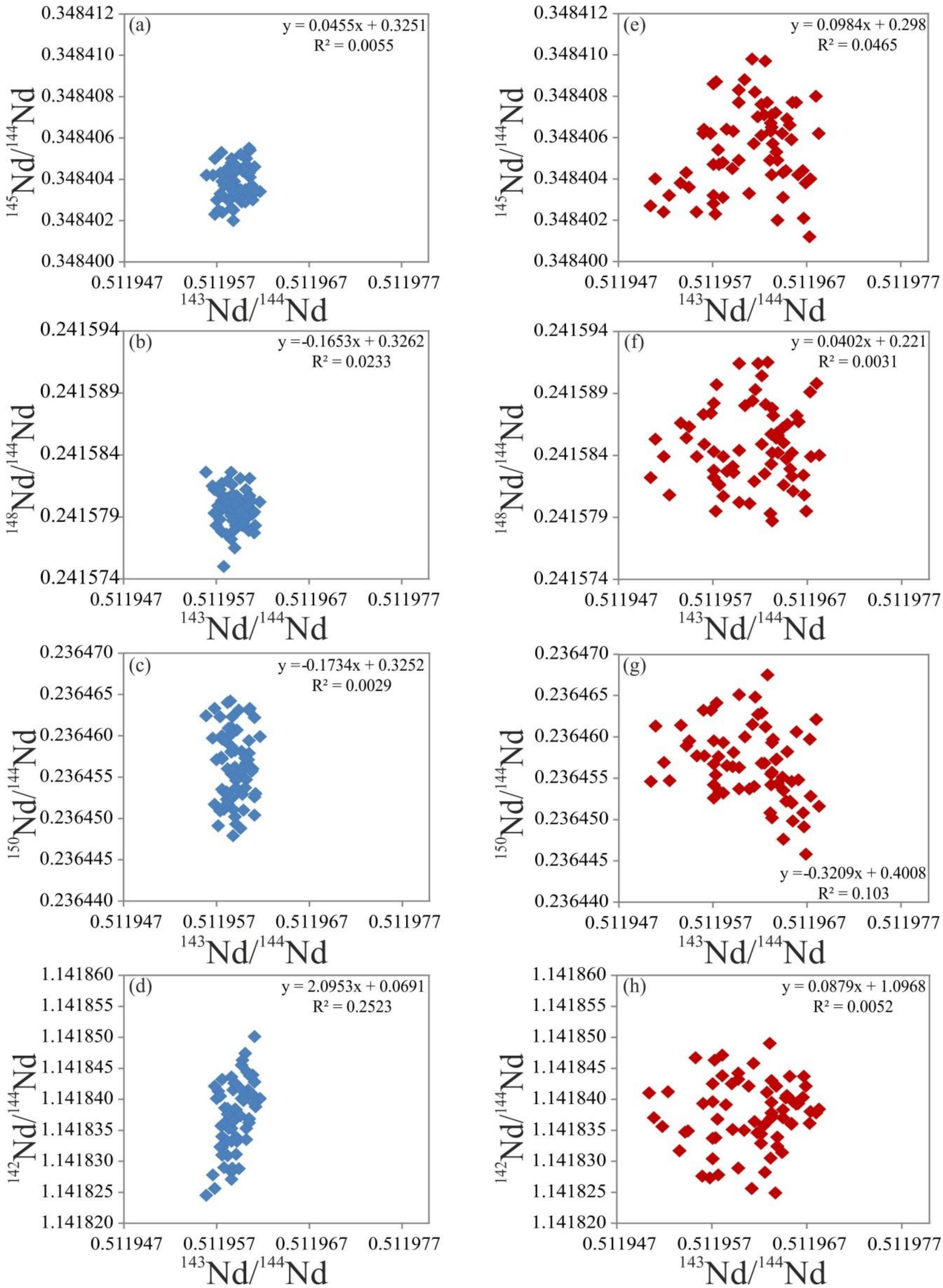

Figure 4.6 *^{143}Nd/^{144}Nd isotopic ratio of Ames Nd is compared with the other Nd isotopic ratios (n=67). The data was acquired during 3-sequence method (Table 4.3) and corrected offline for mass fractionation using both the laws, i.e. power-normalised exponential law (a-h) and exponential law (e-h).*

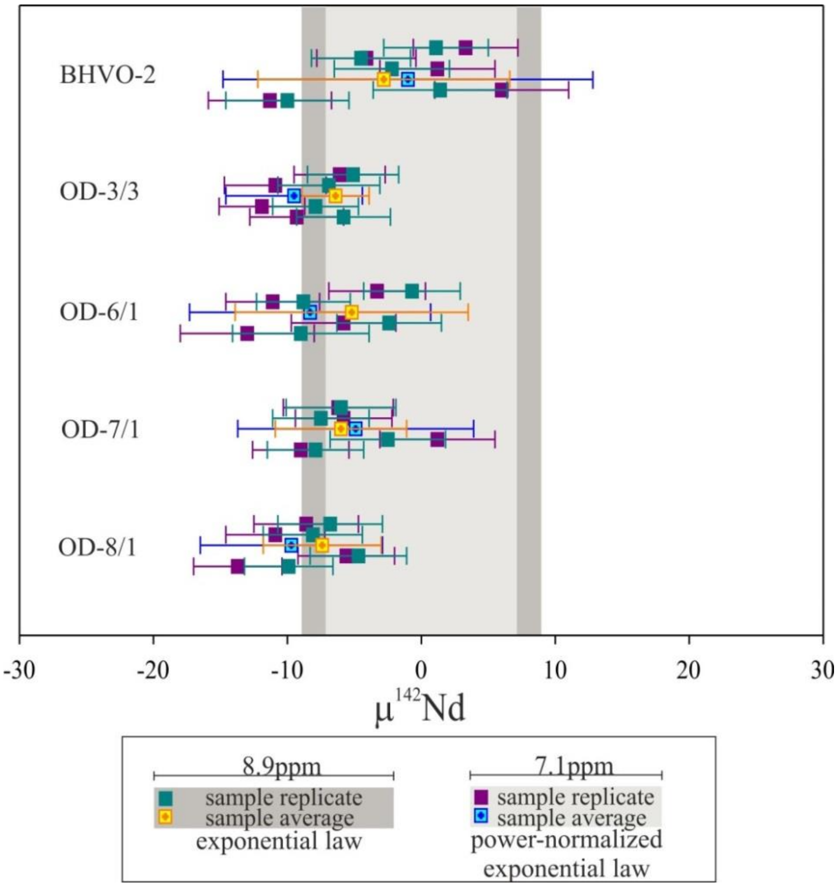

Figure 4.7 *μ^{142}Nd of Khariar rocks and BHVO-2 analysed in this study, with respect to the Ames Nd. The data acquired in both 3- and 2-sequences are corrected offline for mass fractionation using both the power-normalised exponential law and the exponential law. The average values of four replicates for each sample are also plotted with errors; 2SE for individual analyses and 2SD for the average values (Table 4.2). The external reproducibility (2RSD) for the Ames Nd standard is 7.1 ppm for power-normalised exponential law (inner light grey band) and 8.9 ppm for exponential law (outer dark grey band).*

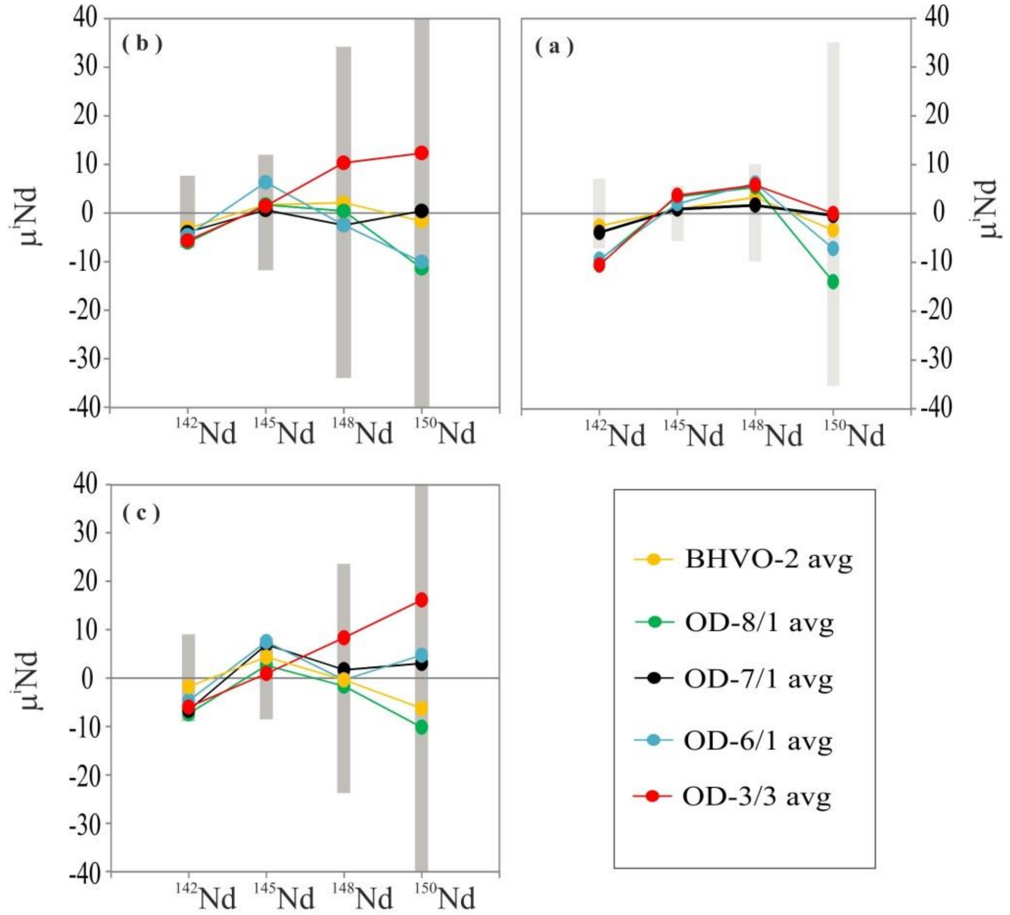

Figure 4.8 *Plot showing average μ^iNd (i= 142, 145, 148 and150) calculated from two replicates of the four samples and BHVO-2. The raw data are taken from 3-sequence mode and corrected using (a) the power-normalised exponential law and (b) the exponential law. The data acquired during 2-sequence mode, corrected using the exponential law is shown in (c). 2RSD for respective μ^iNd is represented by the light brown bar (power -normalised exponential law) and dark brown bar (exponential law). The external reproducibilities for ^{150}Nd in figures (b) and (c) extend beyond the scale in the figure.*

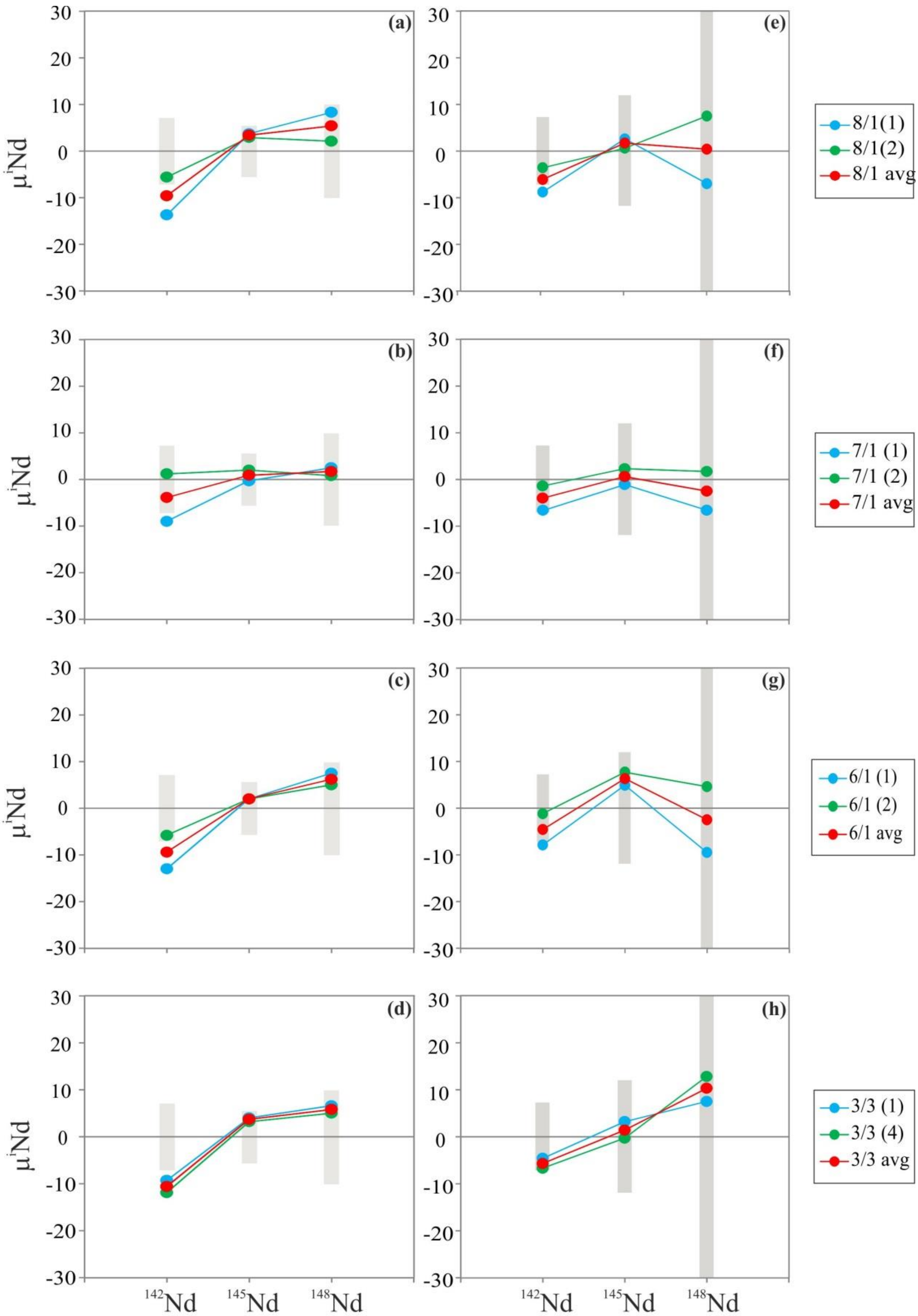

Figure 4.9 *Plot of $\mu^{i}Nd$ (i = 142, 145 and 148) for the data acquired during the 3-sequence mode. The plot is similar to Figure 4.8 except that the individual measurements are also shown along with the average value for each sample. Left panel (a – d) shows the data corrected using the power- normalised exponential law and right panel (e – h) shows the data corrected using the exponential law. The coloured bars refer to the external reproducibilities (2RSD).*

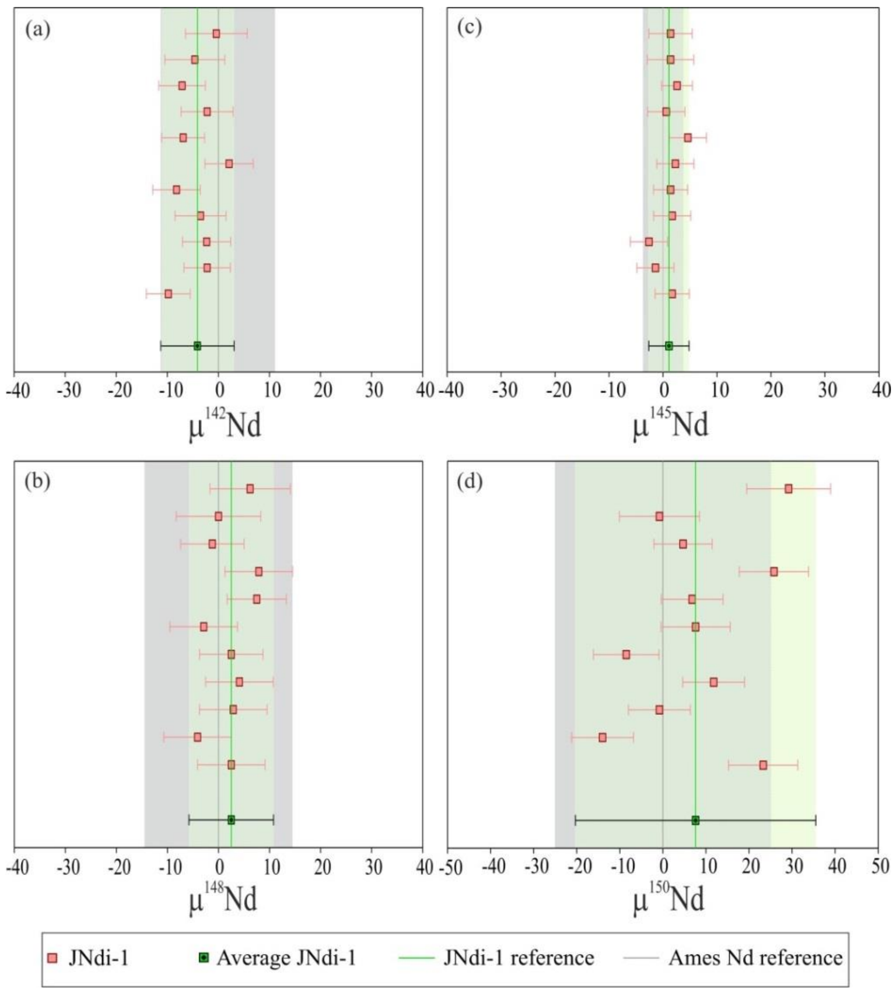

Figure 4.10 *Comparison of various Nd isotopic compositions of JNdi-1 (n=11) and Ames Nd (n=6) in μ notation.* $\mu^{i} = ((^{i}Nd/^{144}Nd)_{JNdi\text{-}1}/(^{i}Nd/^{144}Nd)_{Ames})-1)\times10^{6}$ *, where i = 142, 145, 148 and 150. Data are given in Table 4.4. Pink squares represent individual measurements of the JNdi-1and green square (cross - haired) represents average value for JNdi-1. The green shaded area shows external reproducibility (2RSD) for JNdi-1 whereas grey shaded area represents the same for Ames Nd.*

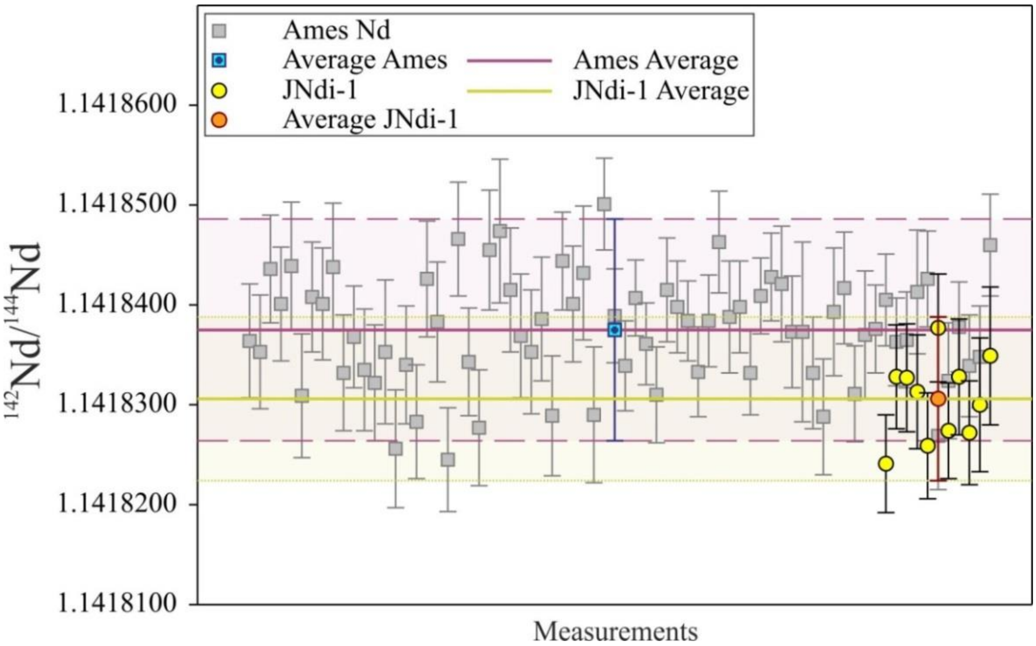

Figure 4.11 *$^{142}Nd/^{144}Nd$ isotopic ratio of individual measurements of Ames Nd analysed between April 2014 – November 2016 (n = 73) and JNdi-1 analysed during October-November 2016 (n = 11). The long term averages for both the standards with external reproducibility (2σ) are also shown. For Ames Nd, it is 1.1418372±111 and for JNdi-1 it is 1.1418306±82.*

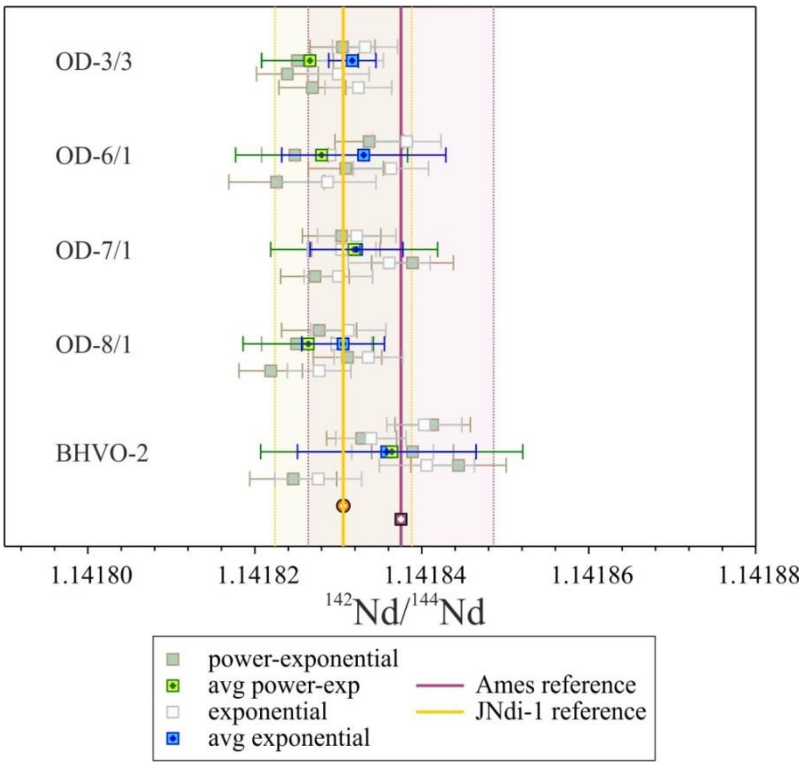

Figure 4.12 *This plot shows$^{142}Nd/^{144}Nd$ of the Khariar alkaline rocks and terrestrial standard BHVO-2*

analysed by us. The reference value for Ames Nd is 1.1418375, whereas for JNdi-1 it is 1.1418306. Pink shaded area shows external reproducibility for Ames Nd (2RSD) and yellow shaded area shows external reproducibility (2RSD) of JNdi-1. Errors of individual points are 2SE and that for average values is 2SD.

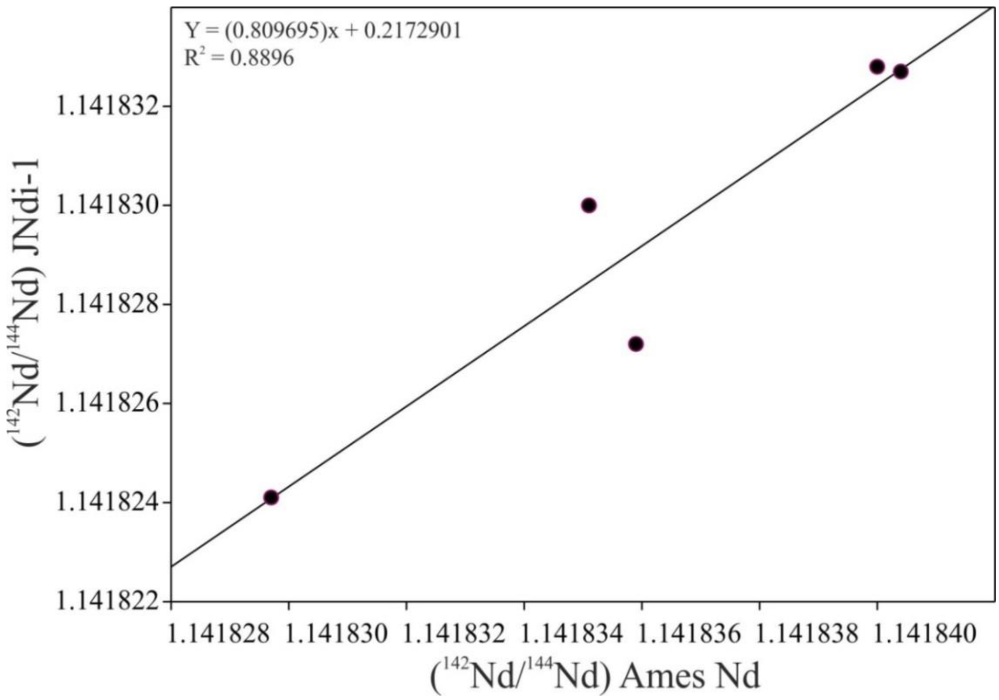

Figure 4.13 *Cross calibration of $^{142}Nd/^{144}Nd$ value of JNdi-1 against that of Ames Nd. Data for each aliquot of JNdi-1 is plotted against averaged Ames Nd data measured before and after the JNdi-1. The data are given in Table 4.4(b).*

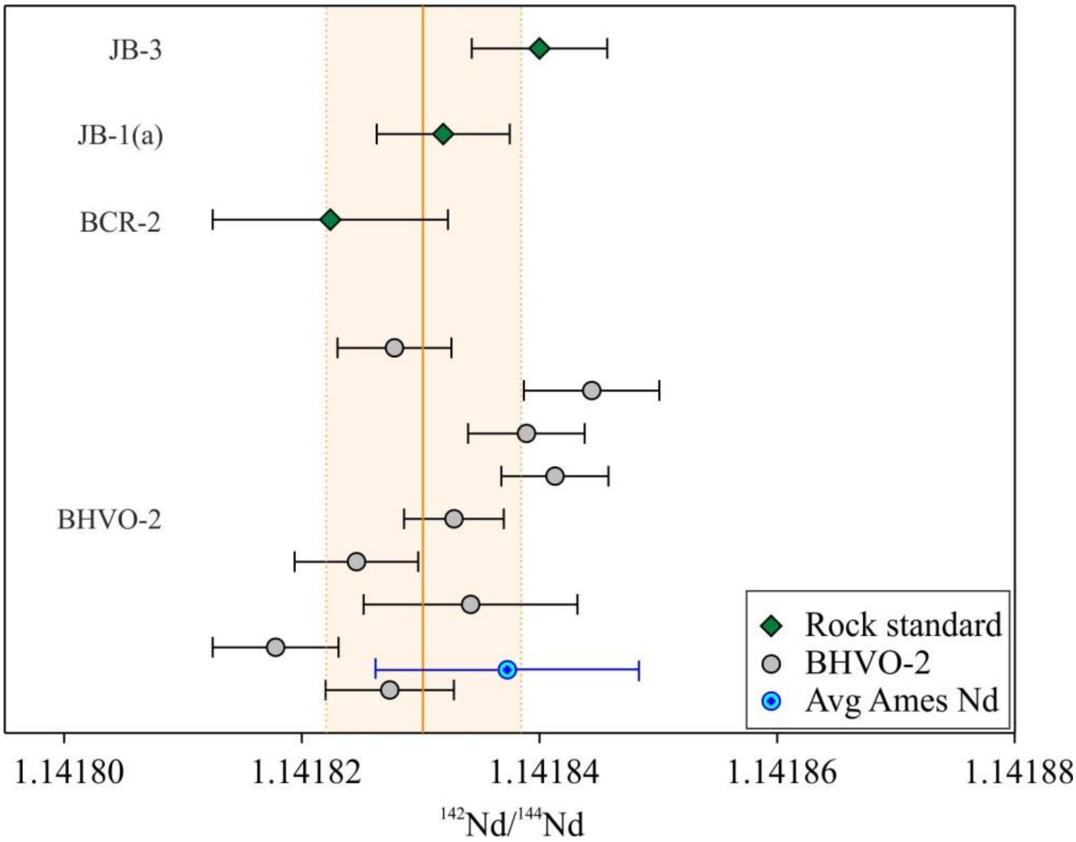

Figure 4.14 *$^{142}Nd/^{144}Nd$ of BHVO-2 and other rock standards analysed in this study. The average $^{142}Nd/^{144}Nd$ of JNdi-1 is shown in yellow line with its 2SD as a shaded envelope. Errors on individual data points are 2SE whereas the long term average value of Ames Nd (shown in blue data point) shows 2SD.*

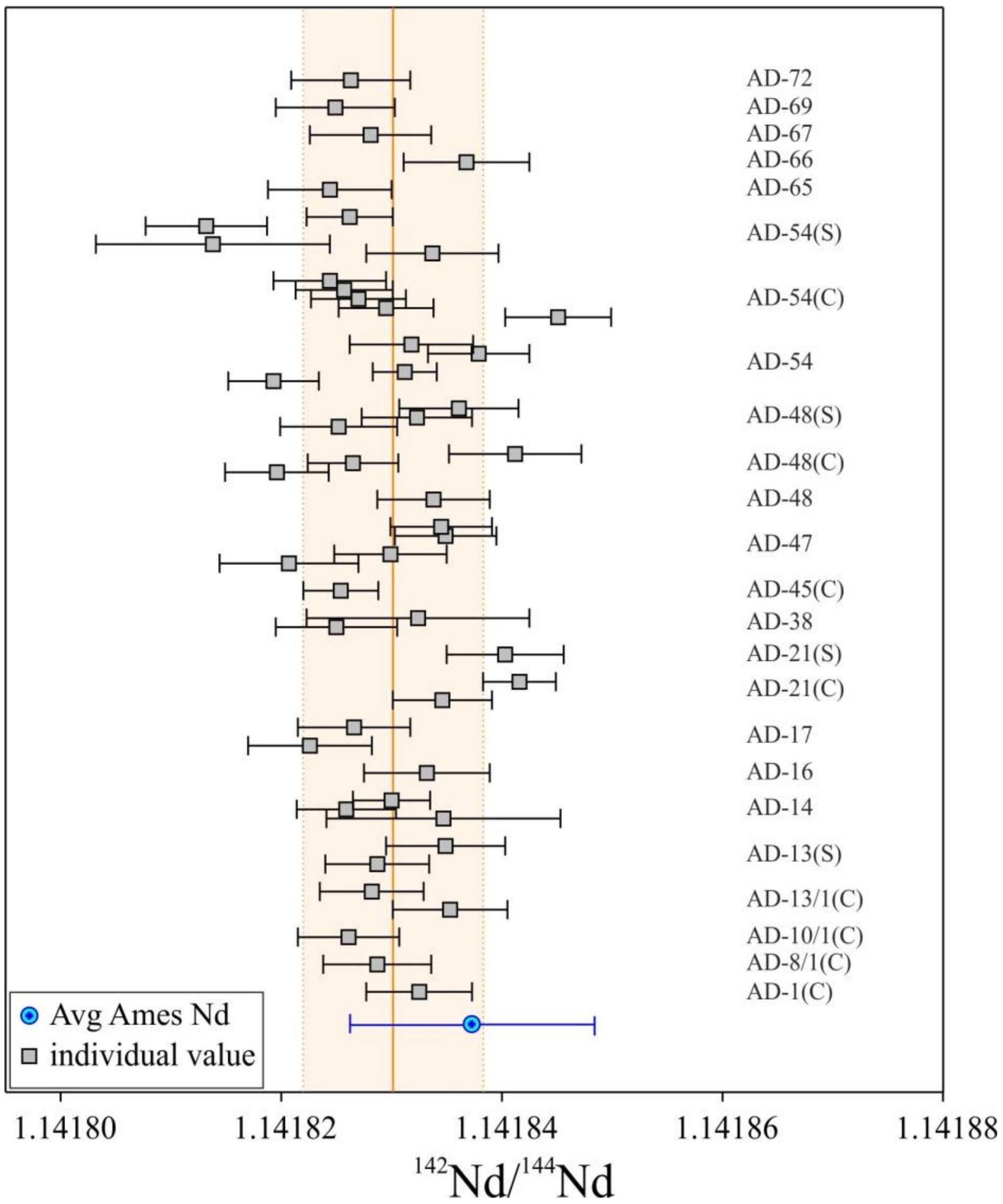

Figure 4.15 *Plot of $^{142}Nd/^{144}Nd$ of carbonatites and associated silicate rocks from Amba Dongar. C and S represent carbonate and silicate fractions, respectively, of carbonatite samples. Errors as shown in Figure 4.14.*

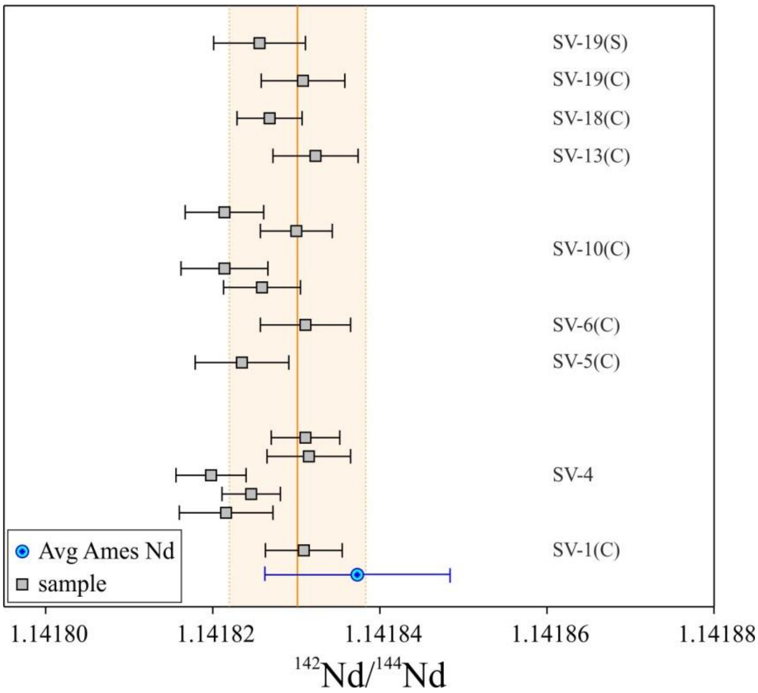

Figure 4.16 *Plot of $^{142}Nd/^{144}Nd$ of carbonatites and associated silicate alkaline rocks from Sung Valley. C and S represent carbonate and silicate fractions, respectively, of carbonatite samples. Errors as shown in Figure 4.14.*

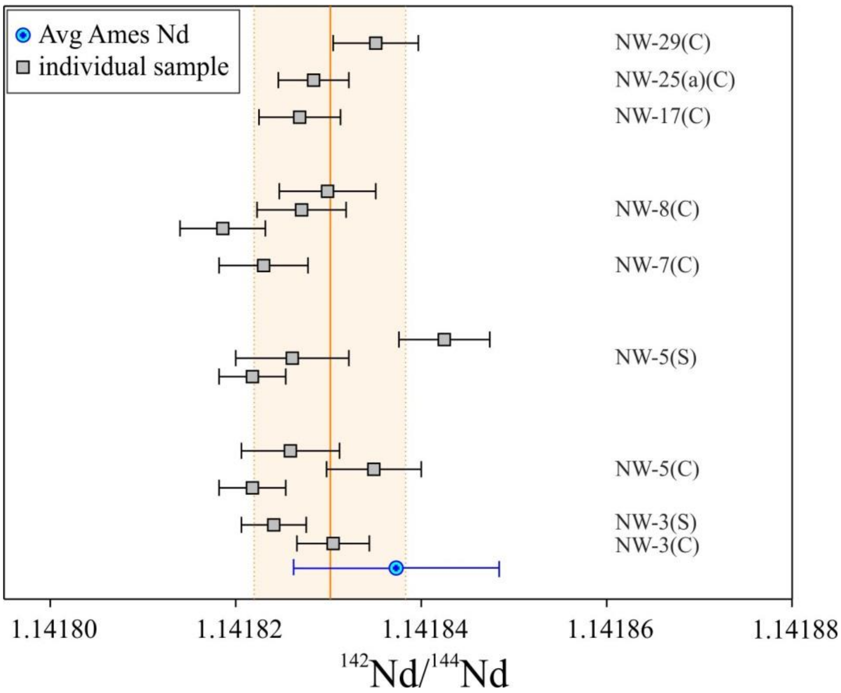

Figure 4.17 *Plot of $^{142}Nd/^{144}Nd$ of carbonatites from Newania. . C and S represent carbonate and silicate fractions, respectively, of carbonatite samples. Errors as shown in Figure 4.14.*

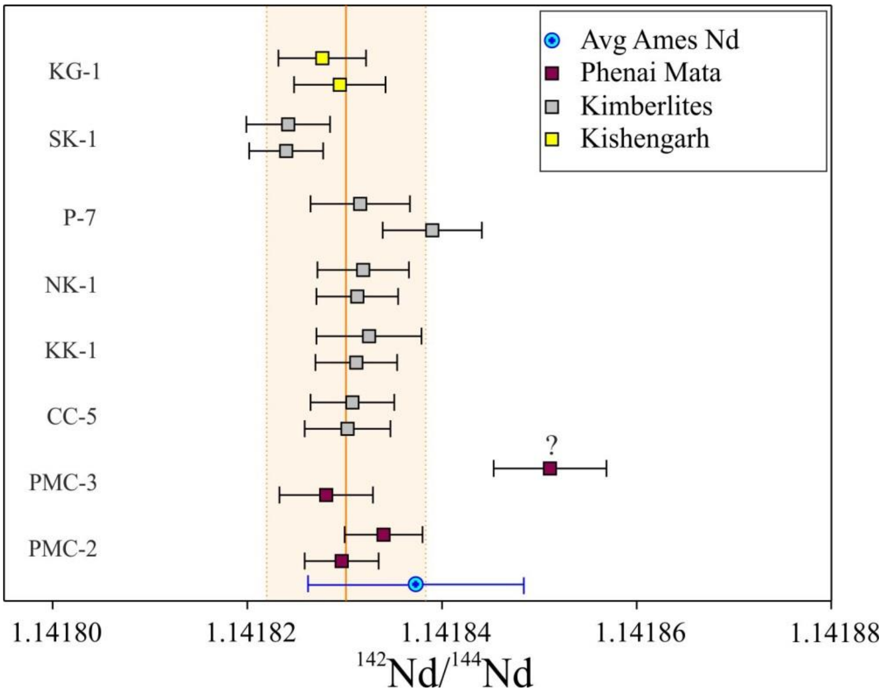

Figure 4.18 *Plot of $^{142}Nd/^{144}Nd$ of alkali basalts from Phenai Mata Complex, Kimberlites from Eastern Dharwar Craton and nepheline syenite from Kishengarh. Errors as shown in Figure 4.14.*

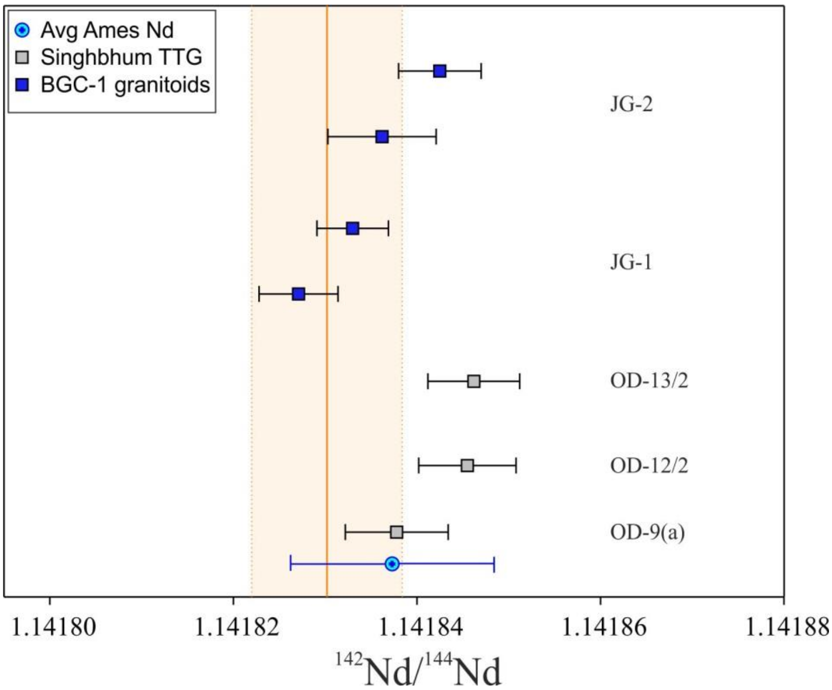

Figure 4.19 *Plot of $^{142}Nd/^{144}Nd$ of TTGs from Singhbhum Craton and granitoids of BGC-1 from Aravalli Craton. Errors as in Figure 4.14.*

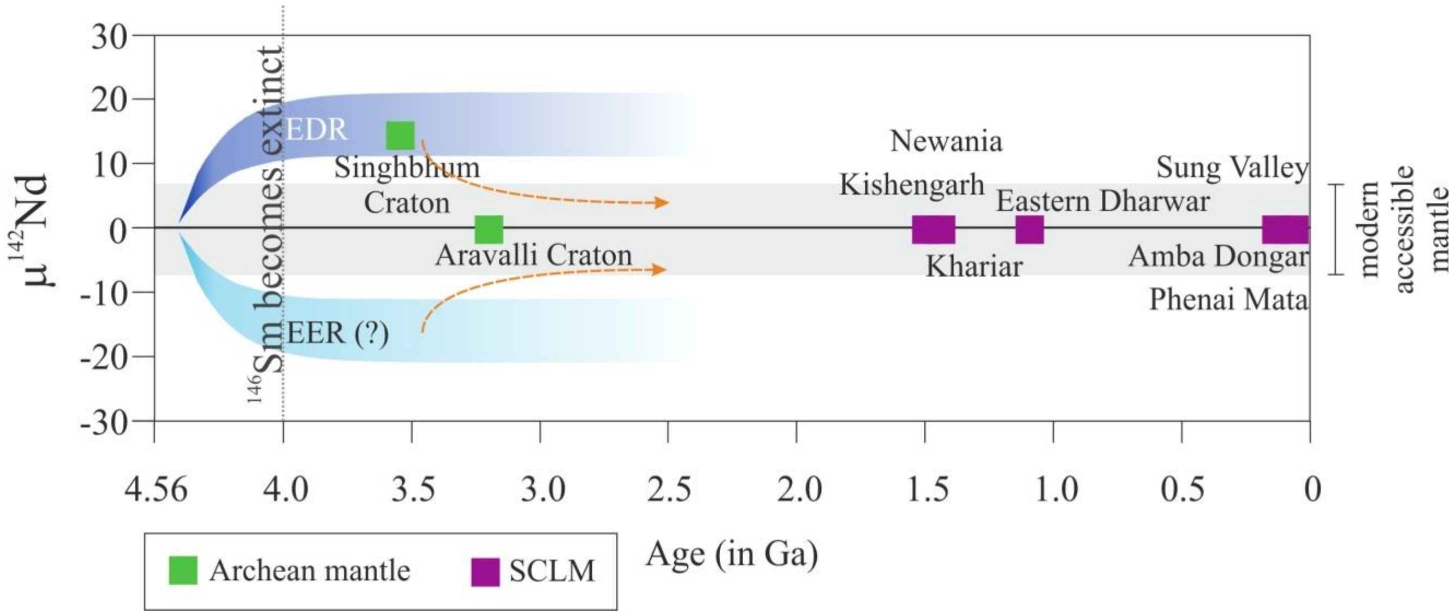

Figure 4.20 *Schematic illustration of the results obtained for ^{142}Nd study of Indian rocks. Grey shaded area shows the external reproducibility (7.2 ppm) for JNdi-1 analysed by us, representing the modern accessible mantle devoid of any early differentiation signatures. Orange arrows show mixing of EDR and EER. Evolution of EDR and EER are from Rizo et al. (2012).*

Tables

Table 4.1

Nd isotopic ratios of AMES standard analysed during the course of our experiment.

(a) Data for three sequence method – corrected for fractionation using power law normalised exponential law

Sr. No.	^{142}Nd/^{144}Nd	μ^{142} Nd	^{143}Nd/^{144}Nd	^{145}Nd/^{144}Nd	μ^{145}Nd	^{148}Nd/^{144}Nd	μ^{148}Nd	^{150}Nd/^{144}Nd	μ^{150}Nd	Av.Fr.Rate (ppm/s)
1	1.1418373 (56)	-0.2	0.5119596 (18)	0.3484052 (12)	4.3	0.2415821 (16)	9.9	0.2364556 (18)	12.7	0.05
2	1.1418373 (90)	-0.1	0.5119586 (30)	0.3484037 (20)	0.0	0.2415791 (26)	-2.5	0.2364587 (30)	25.8	0.10
3	1.1418332 (56)	-3.8	0.5119581 (18)	0.3484045 (12)	2.3	0.2415805 (16)	3.3	0.2364532 (18)	2.5	0.06
4	1.1418288 (58)	-7.6	0.5119594 (20)	0.3484034 (12)	-0.9	0.2415802 (16)	2.1	0.2364631 (18)	44.4	0.10
5	1.1418426 (48)	4.5	0.5119590 (16)	0.3484032 (10)	-1.4	0.2415765 (14)	-13.2	0.2364502 (16)	-10.2	0.08
6	1.1418393 (64)	1.6	0.5119611 (20)	0.3484046 (14)	2.6	0.2415794 (18)	-1.2	0.2364504 (20)	- 9.3	0.04
7	1.1418417 (56)	3.7	0.5119596 (18)	0.3484035 (12)	-0.6	0.2415795 (16)	-0.8	0.2364488 (18)	-16.1	0.04
8	1.1418311 (48)	-5.6	0.5119591 (16)	0.3484044 (10)	2.0	0.2415799 (14)	0.8	0.2364493 (16)	-14.0	0.03
9	1.1418370 (64)	-0.4	0.5119588 (22)	0.3484020 (14)	-4.9	0.2415808 (20)	4.6	0.2364560 (20)	14.4	0.09
10	1.1418376 (44)	0.1	0.5119582 (14)	0.3484044 (10)	2.0	0.2415801 (14)	1.7	0.2364518 (14)	- 3.4	0.06
11	1.1418405 (46)	2.6	0.5119574 (16)	0.3484033 (10)	-1.1	0.2415788 (16)	-3.7	0.2364509 (16)	- 7.2	0.05
12	1.1418363 (44)	-1.1	0.5119587 (14)	0.3484044 (10)	2.0	0.2415796 (14)	-0.4	0.2364525 (14)	- 0.4	0.05
13	1.1418365 (48)	-0.9	0.5119588 (16)	0.3484034 (10)	-0.9	0.2415800 (12)	1.2	0.2364479 (16)	-19.9	0.10
14	1.1418413 (62)	3.3	0.5119572 (18)	0.3484025 (14)	-3.4	0.2415799 (18)	0.8	0.2364491 (20)	-14.8	0.05
15	1.1418421 (58)	4.0	0.5119568 (18)	0.3484023 (12)	-4.0	0.2415793 (16)	-1.7	0.2364517 (18)	- 3.8	0.04
Average	1.1418375		0.5119587	0.3484037		0.2415797		0.2364526		
2RSD (ppm)	0.0000071		0.0000042	0.0000053		0.0000099		0.0000352		

(b) Data for two sequence method – corrected for fractionation using simple exponential law

Sr. No.	$^{142}Nd/^{144}Nd$	$\mu^{142}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$\mu^{145}Nd$	$^{148}Nd/^{144}Nd$	$\mu^{148}Nd$	$^{150}Nd/^{144}Nd$	$\mu^{150}Nd$	Av.Fr.Rate (ppm/s)
1	1.1418353 (60)	-3.2	0.5119636 (28)	0.3484037 (16)	0.9	0.2415894 (20)	20.3	0.2364629 (27)	44.0	0.01
2	1.1418414 (76)	2.1	0.5119614 (36)	0.3484022 (22)	-3.4	0.2415820 (26)	-10.3	0.2364479 (34)	-19.5	0.02
3	1.1418355 (61)	-3.1	0.5119622 (28)	0.3484031 (19)	-0.9	0.2415821 (21)	-9.9	0.2364494 (27)	-13.1	0.04
4	1.1418374 (54)	-1.4	0.5119639 (26)	0.3484017 (16)	-4.9	0.2415905 (19)	24.8	0.2364600 (25)	31.7	0.004
5	1.1418371 (54)	-1.7	0.5119645 (25)	0.3484051 (16)	4.9	0.2415840 (19)	-2.1	0.2364506 (26)	-8.0	0.03
6	1.1418355 (57)	-3.1	0.5119636 (27)	0.3484038 (17)	1.1	0.2415841 (20)	- 1.7	0.2364507 (26)	-7.6	0.02
7	1.1418330 (69)	-5.3	0.5119669 (32)	0.3484023 (20)	-3.2	0.2415852 (23)	2.9	0.2364515 (32)	-4.2	0.05
8	1.1418388 (57)	-0.2	0.5119662 (28)	0.3484060 (17)	7.5	0.2415833 (19)	- 5.0	0.2364489 (28)	-15.2	0.06
9	1.1418436 (136)	4.0	0.5119671 (64)	0.3484030 (41)	-1.1	0.2415812 (48)	-13.7	0.2364492 (66)	-14.0	0.10
10	1.1418393 (50)	0.3	0.5119649 (24)	0.3484023 (15)	-3.2	0.2415840 (18)	- 2.1	0.2364531 (23)	2.5	0.03
11	1.1418376 (53)	-1.2	0.5119647 (27)	0.3484024 (16)	-2.9	0.2415819 (18)	-10.8	0.2364493 (24)	-13.5	0.06
12	1.1418426 (56)	3.2	0.5119643 (26)	0.3484042 (16)	2.3	0.2415815 (19)	-12.4	0.2364494 (24)	-13.1	0.09
13	1.1418364 (50)	-2.3	0.5119634 (26)	0.3484050 (14)	4.6	0.2415889 (18)	18.2	0.2364620 (23)	40.2	0.05
14	1.1418334 (52)	-4.9	0.5119649 (23)	0.3484025 (15)	-2.6	0.2415882 (17)	15.3	0.2364598 (24)	30.9	0.06
15	1.1418460 (54)	6.1	0.5119666 (26)	0.3484036 (16)	0.6	0.2415842 (19)	-1.2	0.2364492 (25)	-14.0	0.10
16	1.1418486 (58)	8.4	0.5119664 (27)	0.3484064 (17)	8.6	0.2415833(20)	-5.0	0.2364496 (27)	-12.3	0.03
17	1.1418320 (46)	-6.1	0.5119624 (20)	0.3484011 (13)	-6.6	0.2415842 (15)	-1.2	0.2364496 (20)	-12.3	0.10
18	1.1418482 (52)	8.1	0.5119675 (25)	0.3484026 (16)	-2.3	0.2415833 (18)	-5.0	0.2364520 (23)	-2.1	0.10
Average	1.1418390		0.5119647	0.3484034		0.2415845		0.2364525		
2RSD (ppm)	0.0000089		0.0000070	0.0000085		0.0000235		0.0000420		

Table 4.2

Nd isotopic ratio data for Khariar samples analysed in this work.

Sample ID	Method	$^{142}Nd/^{144}Nd$	$\mu^{142}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate (ppm/s)
OD-8/1									
(1)	3- sequence	1.1418219 (38)	-13.7	0.5116305 (12)	0.3484050 (09)	0.2415817 (11)	0.2364475 (13)	1.08E-04	0.02
(2)	3- sequence	1.1418311 (41)	- 5.6	0.5116324 (146)	0.3484047 (08)	0.2415802 (11)	0.2364510 (13)	8.31E-05	0.08
Average		1.1418265 (130)	- 9.6	0.5116315 (27)	0.3484049 (04)	0.2415810 (21)	0.2364493 (49)		
(3)	2- sequence	1.1418298 (42)	- 8.1	0.5116386 (19)	0.3484049 (12)	0.2415835 (14)	0.2364485 (19)	9.25E-05	0.05
(4)	2- sequence	1.1418312 (45)	- 6.8	0.5116380 (21)	0.3484037 (13)	0.2415847 (15)	0.2364516 (20)	2.07E-05	0.06
Average		1.1418305 (20)	- 7.4	0.5116383 (8)	0.3484043 (17)	0.2415841 (17)	0.2364501 (44)		
OD-7/1									
(1)	3- sequence	1.1418272 (41)	- 9.0	0.5116740 (12)	0.3484036 (09)	0.2415803 (12)	0.2364503 (13)	5.47E-05	0.08
(2)	3- sequence	1.1418389 (49)	1.2	0.5116776 (15)	0.3484044 (10)	0.2415799 (15)	0.2364546 (17)	1.25E-05	0.06
Average		1.1418331 (165)	- 3.9	0.5116758 (51)	0.3484040 (11)	0.2415801 (06)	0.2364525 (61)		
(3)	2- sequence	1.1418304 (41)	- 7.5	0.5116803 (19)	0.3484049 (11)	0.2415828 (14)	0.2364504 (19)	3.56E-05	0.10
(4)	2- sequence	1.1418322 (47)	- 6.0	0.5116812 (21)	0.3484066 (14)	0.2415869 (16)	0.2364559 (23)	3.29E-05	0.07
Average		1.1418313 (25)	- 6.7	0.5116808 (13)	0.3484058 (24)	0.2415849 (58)	0.2364532 (78)		
OD-6/1									
(1)	3- sequence	1.1418226 (57)	-13.0	0.5116595 (18)	0.3484044 (12)	0.2415815 (16)	0.2364463 (19)	8.28E-05	0.01
(2)	3- sequence	1.1418309 (45)	- 5.8	0.5116573 (14)	0.3484044 (10)	0.2415809 (12)	0.2364554 (14)	6.76E-05	0.02
Average		1.1418268 (117)	- 9.4	0.5116584 (31)	0.3484044 (0)	0.2415812 (08)	0.2364509 (129)		
(3)	2- sequence	1.1418290 (40)	- 8.8	0.5116601 (20)	0.3484056 (11)	0.2415811 (13)	0.2364488 (18)	5.98E-05	0.10
(4)	2- sequence	1.1418382 (41)	- 0.7	0.5116611 (17)	0.3484064 (11)	0.2415876 (14)	0.2364583 (18)	7.68E-05	0.02

Average		1.1418336 (130)	- 4.7	0.5116606 (14)	0.3484060 (11)	0.2415844 (92)	0.2364536 (134)		
OD-3/3									
(1)	3- sequence	1.1418269 (40)	- 9.3	0.5115282 (11)	0.3484051 (08)	0.2415813 (11)	0.2364546 (13)	6.48E-05	0.02
(4)	3- sequence	1.1418239 (37)	-11.9	0.5115335 (11)	0.3484048 (07)	0.2415809 (11)	0.2364506 (12)	1.20E-05	0.02
Average		1.1418254 (42)	-10.6	0.5115309 (75)	0.3484050 (04)	0.2415811 (06)	0.2364526 (57)		
(2)	2- sequence	1.1418311 (43)	- 6.9	0.5115413 (19)	0.3484050 (12)	0.2415877 (15)	0.2364580 (20)	8.09E-05	0.01
(3)	2- sequence	1.1418332 (39)	- 5.1	0.5115408 (19)	0.3484023 (12)	0.2415853 (15)	0.2364546 (18)	2.13E-05	0.08
Average		1.1418322 (30)	- 6.0	0.5115411 (07)	0.3484037 (38)	0.2415865 (34)	0.2364563 (48)		
BHVO-2									
(A)	3-sequence	1.1418246 (52)	-11.3	0.5129695 (16)	0.3484046 (12)	0.2415814 (15)	0.2364523 (17)	7.60E-05	0.08
(C)	3-sequence	1.1418444 (57)	6.0	0.5129723(19)	0.3484034(13)	0.2415797(17)	0.2364513(18)	1.79E-05	0.04
Average		1.1418345(279)	- 2.6	0.5129709(39)	0.3484040(18)	0.2415805(24)	0.2364518(14)		
(B)	2- sequence	1.1418365(49)	- 2.2	0.5129762(21)	0.3484053(13)	0.2415834(16)	0.2364470(22)	1.49E-04	0.07
(B)-2	2- sequence	1.1418339(42)	- 4.5	0.5129732(19)	0.3484057(13)	0.2415858(14)	0.2364533(19)	2.70E-05	0.08
(C)-2	2- sequence	1.1418403(45)	1.1	0.5129763(20)	0.3484036(12)	0.2415841(15)	0.2364526(20)	6.80E-05	0.20
Average		1.1418369(64)	- 1.8	0.5129753(35)	0.3484049(22)	0.2415844(24)	0.2364510(69)		

Note: 3-sequence and 2-sequence μ^{142}Nd values were determined using AMES Nd standard ^{142}Nd/^{144}Nd of 1.1418375 and 1.4148390, respectively. It should be noted that the 3-sequence data have been corrected for mass fractionation using a power- normalized exponential law, whereas that of 2-seqeuence using exponential law. The internal precision (2SE) is given in parentheses. For average values, 2 standard-deviations (2SD) are given in the parentheses. Av. Fr. Rate = Average Fractionate Rate = slope of the linear regression in a plot of ^{146}Nd/^{144}Nd from the first sequence versus time.

Table 4.3 Nd isotope ratios of Ames Nd analysed using 3-sequence method.

(a)

Sr. No.	**$^{142}Nd/^{144}Nd$**	**$^{143}Nd/^{144}Nd$**	**$^{145}Nd/^{144}Nd$**	**$^{148}Nd/^{144}Nd$**	**$^{150}Nd/^{144}Nd$**	**Avg fr. Rate (ppm/sec)**
1.	1.1418364 (57)	0.5119585 (19)	0.3484036 (14)	0.2415805 (17)	0.2364642 (21)	0.04
2.	1.1418353 (57)	0.5119602 (18)	0.3484050 (14)	0.2415812 (18)	0.2364567 (20)	0.06
3.	1.1418436 (54)	0.5119586 (19)	0.3484047 (13)	0.2415826 (17)	0.2364610 (20)	0.01
4.	1.1418401 (57)	0.5119617 (20)	0.3484034 (13)	0.2415802 (18)	0.2364599 (20)	0.01
5.	1.1418439 (64)	0.5119609 (24)	0.3484030 (15)	0.2415792 (20)	0.2364560 (21)	0.01
6.	1.1418309 (62)	0.5119582 (21)	0.3484041 (14)	0.2415819 (17)	0.2364640 (22)	0.02
7.	1.1418408 (55)	0.5119606 (20)	0.3484054 (13)	0.2415821 (18)	0.2364562 (20)	0.02
8.	1.1418401 (56)	0.5119597 (20)	0.3484029 (14)	0.2415789 (18)	0.2364560 (23)	0.07
9.	1.1418438 (64)	0.5119606 (22)	0.3484041 (14)	0.2415807 (18)	0.2364633 (21)	0.01
10.	1.1418332 (58)	0.5119592 (25)	0.3484046 (13)	0.2415807 (17)	0.2364607 (20)	0.04
11.	1.1418353 (72)	0.5119583 (25)	0.3484045 (15)	0.2415805 (21)	0.2364609 (25)	0.01
12.	1.1418322 (58)	0.5119576 (20)	0.3484039 (14)	0.2415817 (17)	0.2364600 (23)	0.02
13.	1.1418335 (61)	0.5119602 (18)	0.3484047 (13)	0.2415794 (17)	0.2364547 (21)	0.09
14.	1.1418368 (51)	0.5119605 (16)	0.3484055 (11)	0.2415793 (15)	0.2364594 (17)	0.04
15.	1.1418256 (59)	0.5119568 (18)	0.3484050 (13)	0.2415812 (19)	0.2364633 (19)	0.07
16.	1.1418340 (59)	0.5119576 (21)	0.3484039 (13)	0.2415778 (17)	0.2364596 (20)	0.04
17.	1.1418283 (57)	0.5119586 (20)	0.3484026 (13)	0.2415793 (19)	0.2364554 (21)	0.10
18.	1.1418426 (58)	0.5119589 (20)	0.3484039 (13)	0.2415779 (17)	0.2364552 (19)	0.04
19.	1.1418383 (60)	0.5119591 (19)	0.3484033 (14)	0.2415802 (17)	0.2364546 (21)	0.04
20.	1.1418245 (52)	0.5119559 (18)	0.3484042 (14)	0.2415826 (17)	0.2364624 (19)	0.03
21.	1.1418357 (57)	0.5119575 (16)	0.3484053 (12)	0.2415808 (16)	0.2364574 (18)	0.03
22.	1.1418323 (54)	0.5119574 (18)	0.3484043 (11)	0.2415812 (17)	0.2364623 (19)	0.05

23.	1.1418278 (58)	0.5119566 (17)	0.3484042 (12)	0.2415815 (17)	0.2364597 (19)	0.03
24.	1.1418455 (60)	0.5119597 (21)	0.3484032 (13)	0.2415802 (19)	0.2364581 (22)	0.02
25.	1.1418474 (73)	0.5119601 (25)	0.3484029 (16)	0.2415798 (21)	0.2364537 (24)	0.05
26.	1.1418415 (62)	0.5119604 (20)	0.3484043 (13)	0.2415799 (19)	0.2364571 (22)	0.04
27.	1.1418369 (62)	0.5119605 (20)	0.3484032 (14)	0.2415779 (18)	0.2364579 (21)	0.07
28.	1.1418353 (62)	0.5119586 (21)	0.3484031 (14)	0.2415807 (19)	0.2364602 (21)	0.05
29.	1.1418386 (62)	0.5119579 (19)	0.3484040 (14)	0.2415798 (18)	0.2364594 (21)	0.02
30.	1.1418289 (60)	0.5119587 (21)	0.3484036 (14)	0.2415816 (18)	0.2364623 (24)	0.02
31.	1.1418444 (49)	0.5119603 (17)	0.3484034 (10)	0.2415789 (14)	0.2364565 (16)	0.05
32.	1.1418401 (58)	0.5119570 (19)	0.3484030 (13)	0.2415783 (17)	0.2364571 (20)	0.03
33.	1.1418432 (67)	0.5119576 (21)	0.3484024 (13)	0.2415796 (19)	0.2364572 (22)	0.01
34.	1.1418290 (67)	0.5119578 (17)	0.3484042 (10)	0.2415750 (17)	0.2364511 (22)	0.20
35.	1.1418385 (46)	0.5119582 (14)	0.3484030 (10)	0.2415805 (13)	0.2364560 (14)	0.05
36.	1.1418501 (47)	0.5119611 (15)	0.3484035 (09)	0.2415777 (13)	0.2364526 (15)	0.08
37.	1.1418362 (49)	0.5119605 (17)	0.3484043 (11)	0.2415805 (15)	0.2364631 (18)	0.02
38.	1.1418339 (45)	0.5119591 (15)	0.3484036 (10)	0.2415783 (13)	0.2364537 (14)	0.07
39.	1.1418407 (38)	0.5119601 (12)	0.3484035 (08)	0.2415791 (12)	0.2364573 (13)	0.05
40.	1.1418361 (41)	0.5119578 (13)	0.3484037 (09)	0.2415797 (12)	0.2364532 (14)	0.07
41.	1.1418415 (52)	0.5119588 (16)	0.3484025 (11)	0.2415787 (15)	0.2364511 (18)	0.10
42.	1.1418310 (48)	0.5119576 (14)	0.3484032 (10)	0.2415803 (13)	0.2364535 (15)	0.06
43.	1.1418271 (34)	0.5119586 (13)	0.3484048 (08)	0.2415772 (11)	0.2364580 (13)	0.20
44.	1.1418384 (40)	0.5119590 (13)	0.3484036 (09)	0.2415795 (12)	0.2364562 (13)	0.07
45.	1.1418333 (45)	0.5119581 (14)	0.3484039 (10)	0.2415776 (14)	0.2364523 (16)	0.10
46.	1.1418384 (46)	0.5119590 (14)	0.3484047 (09)	0.2415799 (13)	0.2364582 (15)	0.03
47.	1.1418463 (51)	0.5119598 (15)	0.3484044 (09)	0.2415783 (14)	0.2364529 (16)	0.08
48.	1.1418388 (56)	0.5119612 (16)	0.3484034 (11)	0.2415783 (14)	0.2364530 (16)	0.05

49.	1.1418398 (46)	0.5119599 (15)	0.3484045 (11)	0.2415785 (13)	0.2364510 (15)	0.09
50.	1.1418332 (43)	0.5119586 (14)	0.3484050 (10)	0.2415801 (14)	0.2364581 (15)	0.06
51.	1.1418409 (39)	0.5119608 (12)	0.3484037 (08)	0.2415803 (12)	0.2364557 (13)	0.04
52.	1.1418428 (45)	0.5119611 (14)	0.3484034 (09)	0.2415794 (13)	0.2364622 (15)	0.02
53.	1.1418374 (90)	0.5119586 (30)	0.3484037 (20)	0.2415791 (26)	0.2364587 (30)	0.10
54.	1.1418288 (57)	0.5119594 (19)	0.3484034 (12)	0.2415802 (16)	0.2364631 (18)	0.10
55.	1.1418426 (47)	0.5119590 (15)	0.3484032 (11)	0.2415765 (14)	0.2364502 (15)	0.08
56.	1.1418393 (64)	0.5119611 (19)	0.3484046 (14)	0.2415794 (18)	0.2364504 (20)	0.04
57.	1.1418373 (57)	0.5119596 (18)	0.3484052 (13)	0.2415821 (17)	0.2364556 (18)	0.05
58.	1.1418332 (55)	0.5119581 (17)	0.3484045 (12)	0.2415805 (16)	0.2364532 (17)	0.06
59.	1.1418370 (65)	0.5119588 (22)	0.3484020 (14)	0.2415808 (19)	0.2364560 (21)	0.09
60.	1.1418376 (45)	0.5119582 (13)	0.3484044 (09)	0.2415801 (13)	0.2364518 (15)	0.06
61.	1.1418363 (44)	0.5119587 (15)	0.3484044 (10)	0.2415796 (14)	0.2364525 (14)	0.05
62.	1.1418413 (62)	0.5119572 (18)	0.3484025 (14)	0.2415799 (17)	0.2364491 (20)	0.05
63.	1.1418405 (47)	0.5119574 (16)	0.3484033 (11)	0.2415788 (15)	0.2364509 (16)	0.05
64.	1.1418421 (58)	0.5119568 (18)	0.3484023 (12)	0.2415793 (16)	0.2364517 (19)	0.04
65.	1.1418365 (48)	0.5119588 (15)	0.3484034 (10)	0.2415800 (12)	0.2364479 (15)	0.10
66.	1.1418311 (48)	0.5119591 (15)	0.3484044 (11)	0.2415799 (15)	0.2364493 (17)	0.03
67.	1.1418417 (55)	0.5119596 (17)	0.3484035 (11)	0.2415795 (15)	0.2364488 (18)	0.04
Average	1.1418372	0.5119590	0.3484038	0.2415797	0.2364564	
2SD	0.0000109	0.0000026	0.0000016	0.0000028	0.0000085	
2RSD (ppm)	0.0000096	0.0000051	0.0000046	0.0000117	0.0000360	

Data is corrected for mass fractionation using (a) a power-normalised exponential law. 2SE associated with each measurement is given in the parentheses. Average fractionation rate (calculated as explained in the main text) is given.

(b)

Sr. No.	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$
1.	1.1418370 (57)	0.5119509 (28)	0.3484040 (18)	0.2415853 (20)	0.2364613 (27)
2.	1.1418356 (57)	0.5119518 (29)	0.3484024 (19)	0.2415839 (21)	0.2364569 (29)
3.	1.1418467 (54)	0.5119553 (26)	0.3484024 (17)	0.2415839 (20)	0.2364577 (27)
4.	1.1418410 (58)	0.5119504 (28)	0.3484027 (19)	0.2415822 (21)	0.2364546 (27)
5.	1.1418463 (64)	0.5119573 (29)	0.3484023 (20)	0.2415795 (24)	0.2364554 (28)
6.	1.1418317 (62)	0.5119536 (27)	0.3484038 (17)	0.2415866 (20)	0.2364614 (25)
7.	1.1418425 (56)	0.5119571 (27)	0.3484028 (17)	0.2415822 (20)	0.2364542 (26)
8.	1.1418412 (56)	0.5119524 (26)	0.3484032 (20)	0.2415808 (21)	0.2364547 (26)
9.	1.1418438 (63)	0.5119581 (28)	0.3484031 (18)	0.2415839 (21)	0.2364593 (28)
10.	1.1418347 (58)	0.5119542 (24)	0.3484043 (16)	0.2415854 (19)	0.2364589 (26)
11.	1.1418368 (72)	0.5119576 (36)	0.3484054 (21)	0.2415817 (24)	0.2364576 (32)
12.	1.1418349 (58)	0.5119545 (28)	0.3484036 (17)	0.2415863 (19)	0.2364595 (28)
13.	1.1418337 (62)	0.5119571 (26)	0.3484032 (18)	0.2415843 (20)	0.2364567 (29)
14.	1.1418391 (51)	0.5119585 (24)	0.3484064 (15)	0.2415827 (18)	0.2364565 (24)
15.	1.1418276 (59)	0.5119560 (28)	0.3484062 (18)	0.2415873 (21)	0.2364632 (27)
16.	1.1418351 (60)	0.5119592 (27)	0.3484063 (17)	0.2415826 (20)	0.2364581 (27)
17.	1.1418278 (57)	0.5119577 (27)	0.3484047 (19)	0.2415816 (20)	0.2364534 (26)
18.	1.1418442 (58)	0.5119598 (26)	0.3484049 (18)	0.2415802 (19)	0.2364537 (25)
19.	1.1418396 (60)	0.5119571 (28)	0.3484047 (18)	0.2415828 (19)	0.2364526 (27)
20.	1.1418273 (52)	0.5119568 (25)	0.3484062 (17)	0.2415874 (18)	0.2364632 (24)
21.	1.1418393 (57)	0.5119561 (26)	0.3484064 (16)	0.2415849 (20)	0.2364577 (25)

22.	1.1418338 (55)	0.5119574 (22)	0.3484087 (15)	0.2415897 (17)	0.2364641 (24)
23.	1.1418304 (58)	0.5119571 (26)	0.3484086 (16)	0.2415882 (20)	0.2364595 (27)
24.	1.1418458 (60)	0.5119614 (26)	0.3484057 (19)	0.2415819 (21)	0.2364540 (28)
25.	1.1418471 (74)	0.5119581 (36)	0.3484048 (20)	0.2415807 (26)	0.2364532 (34)
26.	1.1418425 (62)	0.5119591 (29)	0.3484045 (19)	0.2415831 (22)	0.2364564 (31)
27.	1.1418358 (62)	0.5119625 (29)	0.3484071 (18)	0.2415825 (21)	0.2364568 (28)
28.	1.1418350 (62)	0.5119604 (27)	0.3484088 (19)	0.2415880 (23)	0.2364600 (28)
29.	1.1418392 (63)	0.5119659 (28)	0.3484077 (17)	0.2415872 (21)	0.2364606 (29)
30.	1.1418282 (60)	0.5119626 (28)	0.3484097 (17)	0.2415881 (21)	0.2364612 (27)
31.	1.1418432 (49)	0.5119598 (23)	0.3484077 (14)	0.2415844 (16)	0.2364563 (21)
32.	1.1418395 (58)	0.5119633 (27)	0.3484065 (18)	0.2415842 (20)	0.2364557 (28)
33.	1.1418421 (67)	0.5119609 (31)	0.3484033 (19)	0.2415801 (21)	0.2364537 (28)
34.	1.1418249 (68)	0.5119637 (20)	0.3484072 (12)	0.2415854 (14)	0.2364572 (20)
35.	1.1418369 (46)	0.5119632 (19)	0.3484063 (13)	0.2415833 (15)	0.2364542 (19)
36.	1.1418490 (47)	0.5119631 (21)	0.3484049 (12)	0.2415793 (16)	0.2364508 (20)
37.	1.1418364 (50)	0.5119615 (23)	0.3484082 (15)	0.2415893 (17)	0.2364648 (22)
38.	1.1418406 (38)	0.5119649 (18)	0.3484069 (11)	0.2415865 (13)	0.2364582 (18)
39.	1.1418360 (41)	0.5119654 (20)	0.3484059 (12)	0.2415823 (14)	0.2364520 (20)
40.	1.1418397 (52)	0.5119655 (24)	0.3484077 (14)	0.2415811 (16)	0.2364498 (22)
41.	1.1418314 (49)	0.5119644 (22)	0.3484062 (13)	0.2415862 (16)	0.2364551 (21)
42.	1.1418256 (34)	0.5119612 (16)	0.3484098 (09)	0.2415884 (11)	0.2364615 (15)
43.	1.1418378 (40)	0.5119633 (19)	0.3484071 (12)	0.2415878 (13)	0.2364593 (18)
44.	1.1418305 (45)	0.5119632 (22)	0.3484067 (14)	0.2415857 (17)	0.2364555 (22)
45.	1.1418372 (46)	0.5119634 (22)	0.3484057 (13)	0.2415872 (14)	0.2364597 (20)

46.	1.1418437 (51)	0.5119652 (21)	0.3484066 (13)	0.2415829 (16)	0.2364522 (21)
47.	1.1418361 (56)	0.5119654 (23)	0.3484059 (14)	0.2415842 (16)	0.2364546 (21)
48.	1.1418384 (46)	0.5119683 (22)	0.3484062 (13)	0.2415840 (16)	0.2364516 (21)
49.	1.1418329 (43)	0.5119622 (21)	0.3484076 (14)	0.2415904 (17)	0.2364629 (22)
50.	1.1418421 (39)	0.5119638 (18)	0.3484053 (12)	0.2415858 (14)	0.2364573 (19)
51.	1.1418411 (45)	0.5119628 (21)	0.3484077 (12)	0.2415915 (14)	0.2364675 (20)
52.	1.1418346 (90)	0.5119618 (40)	0.3484070 (28)	0.2415914 (30)	0.2364627 (40)
53.	1.1418289 (57)	0.5119598 (26)	0.3484083 (17)	0.2415914 (18)	0.2364651 (26)
54.	1.1418430 (47)	0.5119633 (21)	0.3484042 (14)	0.2415787 (16)	0.2364502 (22)
55.	1.1418393 (64)	0.5119661 (28)	0.3484042 (19)	0.2415867 (21)	0.2364548 (28)
56.	1.1418378 (57)	0.5119680 (25)	0.3484080 (17)	0.2415898 (19)	0.2364621 (26)
57.	1.1418339 (55)	0.5119639 (25)	0.3484049 (17)	0.2415842 (18)	0.2364543 (25)
58.	1.1418361 (65)	0.5119673 (31)	0.3484012 (19)	0.2415891 (23)	0.2364597 (29)
59.	1.1418383 (45)	0.5119645 (20)	0.3484043 (13)	0.2415850 (14)	0.2364535 (20)
60.	1.1418380 (44)	0.5119674 (22)	0.3484040 (13)	0.2415839 (16)	0.2364528 (20)
61.	1.1418421 (63)	0.5119669 (29)	0.3484038 (18)	0.2415795 (20)	0.2364458 (26)
62.	1.1418403 (47)	0.5119666 (24)	0.3484044 (15)	0.2415824 (18)	0.2364508 (23)
63.	1.1418402 (58)	0.5119648 (27)	0.3484044 (17)	0.2415837 (19)	0.2364522 (26)
64.	1.1418370 (49)	0.5119645 (21)	0.3484031 (14)	0.2415816 (16)	0.2364476 (22)
65.	1.1418324 (48)	0.5119639 (22)	0.3484020 (15)	0.2415856 (17)	0.2364543 (23)
66.	1.1418437 (55)	0.5119667 (25)	0.3484021 (16)	0.2415808 (18)	0.2364491 (25)
Average	1.1418374	0.5119610	0.3484055	0.2415847	0.2364566
2SD	0.0000109	0.0000089	0.0000041	0.0000064	0.0000089
2RSD (ppm)	0.0000095	0.0000174	0.0000117	0.0000265	0.0000377

Data is corrected for mass fractionation using (b) an exponential law. 2SE associated with each measurement is given in the parentheses.

Table 4.4

Neodymium isotopic ratios of JNdi-1 and Ames analysed with JNdi-1.

(a)

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$
JNdi-1					
091116	1.1418241 (49)	0.5120979 (17)	0.3484048 (11)	0.2415805 (16)	0.2364540 (19)
111116	1.1418328 (52)	0.5120989 (15)	0.3484037 (12)	0.2415789 (16)	0.2364452 (17)
131116	1.1418327 (54)	0.5121015 (16)	0.3484033 (12)	0.2415806 (16)	0.2364483 (17)
181116	1.1418313 (57)	0.5120997 (18)	0.3484048 (12)	0.2415809 (16)	0.2364513 (17)
191116	1.1418259 (53)	0.5120983 (17)	0.3484047 (11)	0.2415805 (15)	0.2364465 (18)
211116	1.1418377 (54)	0.5121003 (17)	0.3484050 (12)	0.2415792 (16)	0.2364503 (19)
181116	1.1418274 (48)	0.5120976 (15)	0.3484058 (12)	0.2415817 (14)	0.2364501 (17)
211116	1.1418328 (58)	0.5121000 (19)	0.3484044 (12)	0.2415818 (16)	0.2364546 (19)
101116	1.1418272 (52)	0.5120997 (17)	0.3484051 (10)	0.2415796 (15)	0.2364496 (16)
091116	1.1418300 (67)	0.5121006 (23)	0.3484047 (15)	0.2415799 (20)	0.2364483 (22)
221116	1.1418349 (69)	0.5121019 (21)	0.3484047 (14)	0.2415814 (19)	0.2364554 (23)
Average	1.1418306	0.5120997	0.3484046	0.2415805	0.2364503
2SD	0.0000082	0.0000028	0.0000013	0.0000020	0.0000066
Ames Nd					
081116	1.1418269 (54)	0.5119586 (17)	0.3484044 (14)	0.2415819 (17)	0.2364496 (17)
081116	1.1418324 (58)	0.5119571 (18)	0.3484036 (12)	0.2415801 (16)	0.2364490 (18)
101116	1.1418378 (45)	0.5119625 (14)	0.3484052 (11)	0.2415800 (14)	0.2364475 (16)

111116	1.1418339 (51)	0.5119573 (15)	0.3484045 (10)	0.2415816 (14)	0.2364491 (16)
141116	1.1418348 (51)	0.5119585 (17)	0.3484034 (11)	0.2415775 (16)	0.2364435 (17)
141116	1.1418460 (51)	0.5119606 (17)	0.3484039 (11)	0.2415784 (17)	0.2364524 (18)
Average	1.1418353	0.5119591	0.3484042	0.2415799	0.2364485
2SD	0.0000127	0.0000042	0.0000013	0.0000035	0.0000059

The data is acquired using three sequence multi dynamic mode and corrected for the fractionation using power-normalised exponential law (normalised to $^{146}Nd/^{144}Nd$ = 0.7219). Internal precision is given in brackets (2SE). For average values, 2standard deviation (2SD) is given.

(b) Data used for cross-calibration of $^{142}Nd/^{144}Nd$ of JNdi-1 and Ames Nd.

Sr. No.	**($^{142}Nd/^{144}Nd$) JNdi-1**	**($^{142}Nd/^{144}Nd$) AMES**
1.	1.1418241	1.1418297
2.	1.1418300	1.1418351
3.	1.1418272	1.1418359
4.	1.1418328	1.1418400
5.	1.1418327	1.1418404

The values of Ames Nd are the average value calculated before and after the measurements of JNdi-1, from single batch.

Table 4.5 Nd isotopic ratios rock standards analysed during the course of this study.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
BHVO-2	1.1418274 (54)	0.5126199 (17)	0.3484062 (12)	0.2415784 (15)	0.2364511 (19)	6.48E-05	0.20
BHVO-2(a)	1.1418178 (53)	0.5129692 (17)	0.3484059 (10)	0.2415775 (14)	0.2364520 (17)	1.01E-04	0.10
BHVO-2(b)	1.1418342 (90)	0.5129701 (26)	0.3484031 (17)	0.2415778 (25)	0.2364501 (31)	7.08E-05	0.20
BHVO-2(A)	1.1418246 (52)	0.5129695 (16)	0.3484046 (12)	0.2415814 (15)	0.2364523 (17)	7.60E-05	0.08
BHVO-2(B)	1.1418328 (42)	0.5129732 (19)	0.3484057 (13)	0.2415858 (14)	0.2364533 (19)	1.49E-04	0.02
BHVO-2(C)	1.1418413 (45)	0.5129763 (20)	0.3484036 (12)	0.2415841 (15)	0.2364526 (20)	6.80E-05	0.20
BHVO-2(B) (2SQ)	1.1418389 (49)	0.5129762 (21)	0.3484053 (13)	0.2415834 (16)	0.2364470 (22)	2.70E-05	0.07
BHVO-2(C)	1.1418444 (57)	0.5129723 (19)	0.3484034 (13)	0.2415797 (17)	0.2364513 (18)	1.79E-05	0.04
BHVO-2(E)	1.1418278 (48)	0.5129699 (15)	0.3484050 (10)	0.2415796 (14)	0.2364488 (15)	1.76E-04	0.07
Average	1.1418321	0.5129330	0.3484048	0.2415809	0.2364509		
2SD	0.0000172	0.0002349	0.0000023	0.0000060	0.0000040		
BCR-2	1.1418224 (99)	0.5129715 (30)	0.3484038 (19)	0.2415887 (30)	0.2364593 (33)	1.36E-04	0.30
JB-1(a)	1.1418319 (56)	0.5127699 (18)	0.3484047 (12)	0.2415807 (17)	0.2364595 (20)	1.32E-04	0.09
JB-3	1.1418400 (57)	0.5130424 (19)	0.3484014 (13)	0.2415774 (17)	0.2364537 (20)	1.27E-04	0.10

Table 4.6 Nd isotopic ratios of rocks (carbonatites and associated alkaline silicate rocks) analysed from Amba Dongar, Gujarat.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
AD-1-(C)	1.1418325 (48)	0.5123949 (15)	0.3484057 (11)	0.2415817 (14)	0.2364542 (16)	6.22E-05	0.02
AD-8-1(C)	1.1418287 (49)	0.5124947 (15)	0.3484060 (12)	0.2415818 (16)	0.2364524 (18)	3.48E-05	0.03
AD-10/1(C)	1.1418261 (46)	0.5125085 (15)	0.3484067 (10)	0.2415812 (14)	0.2364567 (16)	3.35E-05	0.07
AD-13/1 (C)	1.1418353 (52)	0.5124610 (16)	0.3484056 (11)	0.2415787 (15)	0.2364473 (16)	3.77E-04	0.04
AD-13/1(T)(C)	1.1418282 (47)	0.5124573 (16)	0.3484033 (11)	0.2415805 (14)	0.2364614 (17)	9.18E-07	0.03
Average	1.1418318	0.5124592	0.3484045	0.2415796	0.2364544		
2SD	0.0000100	0.0000052	0.0000033	0.0000025	0.0000199		
AD-13/1(S)	1.1418287 (47)	0.5124590 (14)	0.3484059 (10)	0.2415771 (13)	0.2364458 (15)	5.78E-05	0.30
AD-13/1(T)(S)	1.1418349 (54)	0.5124593 (17)	0.3484036 (10)	0.2415801 (14)	0.2364589 (17)	5.89E-05	0.03
Average	1.1418318	0.5124592	0.3484048	0.2415786	0.2364524		
2SD	0.0000088	0.0000004	0.0000033	0.0000042	0.0000185		
AD-14	1.1418347 (106)	0.5124342 (34)	0.3484015 (21)	0.2415754 (33)	0.2364575 (35)	5.04E-05	0.30
AD-14(3)	1.1418259 (45)	0.5124363 (21)	0.3484030 (13)	0.2415860 (16)	0.2364554 (20)	7.00E-05	0.05
AD-14(4)	1.1418300 (35)	0.5124341 (11)	0.3484042 (07)	0.2415795 (10)	0.2364512 (11)	2.26E-05	0.08
Average	1.1418302	0.5124349	0.3484029	0.2415803	0.2364547		
2SD	0.0000088	0.0000025	0.0000027	0.0000107	0.0000064		

AD-16	1.1418332 (57)	0.5124132 (19)	0.3484057 (12)	0.2415791 (17)	0.2364538 (18)	1.58E-04	0.07
AD-17	1.1418226 (56)	0.5123637 (19)	0.3484060 (11)	0.2415813 (17)	0.2364604 (18)	5.74E-05	0.06
AD-17	1.1418266 (51)	0.5124361 (14)	0.3484042 (10)	0.2415796 (14)	0.2364526 (16)	2.81E-05	0.04
Average	1.1418246	0.5123999	0.3484051	0.2415805	0.2364565		
2SD	0.0000057	0.0001024	0.0000025	0.0000024	0.0000110		
AD- 21(T)(C)	1.1418346 (45)	0.5124957 (14)	0.3484041 (10)	0.2415800 (12)	0.2364604 (14)	-5.03E-07	-0.007
AD-21(C)	1.1418416 (33)	0.5124965 (10)	0.3484046 (07)	0.2415810 (10)	0.2364587 (11)	7.56E-06	0.005
Average	1.1418381	0.5124961	0.3484044	0.2415805	0.2364596		
2SD	0.0000099	0.0000011	0.0000007	0.0000014	0.0000024		
AD-21(T)(S)	1.1418403 (53)	0.5124971 (15)	0.3484044 (10)	0.2415800 (15)	0.2364593 (16)	2.67E-05	-0.006
AD-38(C)	1.1418250 (55)	0.5125573 (19)	0.3484051 (13)	0.2415736 (16)	0.2364413 (20)	5.75E-06	0.30
AD-38(S)	1.1418324 (101)	0.5125473 (27)	0.3484060 (18)	0.2415742 (25)	0.2364458 (30)	1.74E-04	0.40
AD-45(C)	1.1418254 (34)	0.5124029 (10)	0.3484052 (07)	0.2415785 (10)	0.2364501 (10)	2.00E-04	0.10
AD-47	1.1418207 (63)	0.5114563 (20)	0.3484045 (12)	0.2415786 (18)	0.2364644 (19)	6.30E-05	0.20
AD-47	1.1418299 (51)	0.5114579 (17)	0.3484049 (12)	0.2415790 (16)	0.2364553 (18)	8.02E-05	0.08

AD-47(3)	1.1418349 (46)	0.5114614 (21)	0.3484054 (12)	0.2415869 (15)	0.2364559 (20)	4.59E-05	0.20
AD-47(4)	1.1418345 (46)	0.5114537 (14)	0.3484035 (09)	0.2415784 (13)	0.2364536 (15)	8.17E-05	0.10
Average	1.1418300	0.5114573	0.3484046	0.2415807	0.2364573		
2SD	0.0000132	0.0000064	0.0000016	0.0000082	0.0000097		
AD-48	1.1418338 (51)	0.5122114 (15)	0.3484044 (10)	0.2415793 (15)	0.2364600 (16)	5.26E-05	0.06
AD-48(T)-(C)	1.1418196 (47)	0.5122088 (16)	0.3484051 (11)	0.2415790 (13)	0.2364615 (18)	4.52E-05	0.03
AD-48-C(3)	1.1418265 (41)	0.5122872 (21)	0.3484034 (12)	0.2415840 (14)	0.2364526 (20)	4.92E-05	0.07
AD-48-C(4)	1.1418412 (60)	0.5122854 (18)	0.3484023 (12)	0.2415778 (18)	0.2364475 (19)	9.22E-07	0.20
Average	1.1418291	0.5122605	0.3484036	0.2415803	0.2364539		
2SD	0.0000221	0.0000895	0.0000028	0.0000066	0.0000142		
AD-48(T)-(S)	1.1418252 (53)	0.5122049 (17)	0.3484045 (11)	0.2415796 (17)	0.2364644 (17)	1.25E-04	0.06
AD-48(4)	1.1418323 (50)	0.5122960 (23)	0.3484040 (14)	0.2415812 (18)	0.2364458 (23)	3.45E-05	0.20
AD-48(4)	1.1418361 (54)	0.5122927 (19)	0.3484028 (12)	0.2415779 (16)	0.2364472 (18)	4.57E-06	0.05
Average	1.1418312	0.5122645	0.3484038	0.2415796	0.2364525		
2SD	0.0000111	0.0001033	0.0000017	0.0000033	0.0000207		
AD-54	1.1418193 (41)	0.5124838 (14)	0.3484054 (09)	0.2415810 (13)	0.2364534 (15)	2.45E-05	0.03
AD-54-N	1.1418312 (29)	0.5124856 (09)	0.3484050 (06)	0.2415806 (08)	0.2364532 (09)	7.89E-06	0.03
AD-54(N)-(4)	1.1418379 (46)	0.5124952 (22)	0.3484046 (14)	0.2415865 (16)	0.2364570 (20)	2.91E-05	-0.002
AD-54(N)-(4)	1.1418318 (56)	0.5124869 (16)	0.3484024 (11)	0.2415773 (15)	0.2364456 (17)	2.73E-06	0.04
Average	1.1418301	0.5124879	0.3484044	0.2415814	0.2364523		

2SD	0.0000156	0.0000101	0.0000027	0.0000076	0.0000096		
54-S	1.1418451 (48)	0.5124889 (14)	0.3484044 (09)	0.2415802 (14)	0.2364547 (16)	4.25E-06	0.003
AD-54(a)(N)(C)	1.1418295 (43)	0.5124885 (14)	0.3484078 (09)	0.2415757 (13)	0.2364389 (14)	7.65E-05	0.10
AD-54(N)(T)(C)	1.1418270 (43)	0.5124860 (13)	0.3484047 (09)	0.2415796 (12)	0.2364650 (14)	7.94E-07	0.08
AD-54(N)-C(3)	1.1418257 (44)	0.5124912 (21)	0.3484057 (12)	0.2415839 (15)	0.2364486 (19)	1.68E-04	0.02
AD-54(N)-C(4)	1.1418244 (51)	0.5124820 (17)	0.3484057 (11)	0.2415793 (15)	0.2364462 (17)	4.00E-05	0.03
Average	1.1418303	0.5124873	0.3484057	0.2415797	0.2364507		
2SD	0.0000169	0.0000070	0.0000027	0.0000058	0.0000196		
54-R	1.1418337 (60)	0.5124887 (21)	0.3484034 (18)	0.2415847 (22)	0.2364563 (23)	2.58E-04	0.02
AD-54(a)(S)	1.1418138 (106)	0.5124850 (31)	0.3484059 (21)	0.2416062 (29)	0.2364613 (35)	1.92E-04	0.40
AD-54(a) (N) (S)	1.1418132 (55)	0.5124833 (16)	0.3484053 (11)	0.2415794 (16)	0.2364425 (17)	3.93E-05	0.30
AD-54(N)(T)(S)	1.1418262 (39)	0.5124866 (11)	0.3484049 (09)	0.2415810 (12)	0.2364521 (14)	1.59E-05	0.06
Average	1.1418217	0.5124859	0.3484049	0.2415878	0.2364531		
2SD	0.0000200	0.0000046	0.0000021	0.0000249	0.0000160		
AD-65	1.1418244 (56)	0.5124756 (17)	0.3484043 (12)	0.2415786 (16)	0.2364570 (18)	2.73E-05	0.10
AD-66	1.1418368 (57)	0.5124252 (18)	0.3484033 (12)	0.2415790 (15)	0.2364562 (17)	3.71E-05	0.04
AD-67	1.1418281 (55)	0.5123712 (18)	0.3484044 (13)	0.2415778 (17)	0.2364494 (19)	5.09E-05	0.06
AD-69	1.1418249 (54)	0.5126833 (16)	0.3484048 (11)	0.2415811 (17)	0.2364553 (18)	1.14E-04	0.01

AD-72	1.1418263 (54)	0.5123275 (18)	0.3484042 (13)	0.2415791 (16)	0.2364638 (20)	1.67E-04	0.10

Table 4.7 Nd isotopic ratios of rocks (carbonatites) analysed from Newania, Rajasthan.

Sample ID	^{142}Nd/^{144}Nd	^{143}Nd/^{144}Nd	^{145}Nd/^{144}Nd	^{148}Nd/^{144}Nd	^{150}Nd/^{144}Nd	^{140}Ce/^{142}Nd	Av. Fr. Rate ppm/s
NW-3(C)	1.1418305 (39)	0.5115192 (12)	0.3484071 (08)	0.2415765 (11)	0.2364512 (13)	1.49E-05	0.10
NW-3(S)	1.1418241 (35)	0.5110260 (12)	0.3484049 (08)	0.2415801 (11)	0.2364500 (12)	3.29E-05	0.03
NW-5(T) (C)	1.1418218 (36)	0.5115806 (10)	0.3484055 (08)	0.2415795 (11)	0.2364622 (12)	6.28E-05	0.01
NW-5C-(2)	1.1418349 (51)	0.5115843 (24)	0.3484005 (14)	0.2415855 (18)	0.2364512 (25)	9.16E-05	0.00
NW-5C-(2)	1.1418259 (53)	0.5115794 (17)	0.3484050 (11)	0.2415807 (15)	0.2364525 (16)	4.39E-05	0.01
Average	1.1418275	0.5115814	0.3484037	0.2415819	0.2364553		
2SD	0.0000134	0.0000051	0.0000055	0.0000063	0.0000120		
NW-5(T)(S)	1.1418218 (36)	0.5113425 (12)	0.3484057 (07)	0.2415803 (11)	0.2364528 (12)	3.02E-05	0.05
NW-5(2)	1.1418261 (61)	0.5112577 (28)	0.3484036 (19)	0.2415815 (23)	0.2364480 (29)	1.02E-04	0.06
NW-5(2)	1.1418425 (49)	0.5112562 (15)	0.3484034 (11)	0.2415803 (14)	0.2364527 (17)	2.09E-05	0.06
Avg	1.1418301	0.5112855	0.3484042	0.2415807	0.2364512		
2SD	0.0000218	0.0000988	0.0000025	0.0000014	0.0000055		

NW-7(C)	1.1418230 (48)	0.5114537 (16)	0.3484048 (11)	0.2415826 (14)	0.2364520 (16)	3.46E-05	0.02
NW-8(C)	1.1418186 (46)	0.5114059 (14)	0.3484056 (09)	0.2415776 (13)	0.2364534 (14)	2.57E-05	0.10
NW-8C-(2)	1.1418271 (48)	0.5114112 (21)	0.3484033 (12)	0.2415857 (15)	0.2364542 (21)	8.95E-05	0.10
NW-8C-(2)	1.1418299 (52)	0.5115785 (16)	0.3484047 (11)	0.2415788 (15)	0.2364512 (17)	2.58E-05	0.01
Avg	1.1418252	0.5114652	0.3484045	0.2415807	0.2364529		
2SD	0.0000118	0.0001963	0.0000023	0.0000087	0.0000031		
NW-17(C)	1.1418269 (44)	0.5116009 (14)	0.3484051 (09)	0.2415793 (13)	0.2364504 (15)	3.20E-05	0.04
NW-25(a)(C)	1.1418284 (38)	0.5115738 (13)	0.3484055 (08)	0.2415798 (11)	0.2364484 (12)	9.00E-05	0.01
NW-29(C)	1.1418351 (46)	0.5115306 (14)	0.3484045 (10)	0.2415821 (13)	0.2364580 (15)	4.20E-05	0.03

Table 4.8 Nd isotopic ratios of rocks (carbonatites and associated alkaline silicate rocks) analysed from Sung-Valley, Meghalaya.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
SV-1(C)	1.1418309 (46)	0.5126411 (15)	0.3484048 (10)	0.2415789 (13)	0.2364553 (14)	1.66E-05	0.08
SV-4	1.1418216 (56)	0.5126304 (18)	0.3484034 (12)	0.2415791 (17)	0.2364535 (19)	6.89E-05	0.20
SV-4(3)	1.1418246 (35)	0.5126348 (16)	0.3484064 (10)	0.2415873 (12)	0.2364563 (16)	7.01E-05	0.10
SV-4(4)	1.1418198 (42)	0.5126294 (13)	0.3484041 (09)	0.2415787 (12)	0.2364523 (14)	3.44E-05	0.08
SV-4(5)	1.1418315 (50)	0.5126323 (16)	0.3484040 (10)	0.2415796 (14)	0.2364494 (15)	1.30E-04	0.04

SV-4(6)	1.1418311 (41)	0.5126309 (12)	0.3484041 (08)	0.2415783 (11)	0.2364472 (14)	1.32E-04	0.09
Average	1.1418257	0.5126316	0.3484044	0.2415806	0.2364517		
2SD	0.0000108	0.0000042	0.0000023	0.0000076	0.0000071		
SV-5(C)	1.1418235 (56)	0.5126322 (18)	0.3484046 (11)	0.2415802 (16)	0.2364536 (18)	1.89E-05	0.04
SV-6(C)	1.1418311 (54)	0.5126358 (17)	0.3484038 (12)	0.2415801 (17)	0.2364567 (19)	2.09E-07	0.007
SV-10(C)	1.1418259 (46)	0.5126388 (14)	0.3484073 (10)	0.2415821 (13)	0.2364550 (15)	4.49E-05	0.01
SV-10(C)	1.1418214 (52)	0.5126394 (17)	0.3484067 (11)	0.2415801 (15)	0.2364555 (16)	7.75E-05	0.01
SV-10(3)	1.1418300 (43)	0.5126435 (20)	0.3484034 (11)	0.2415878 (14)	0.2364587 (22)	1.41E-04	0.02
SV-10(4)	1.1418214 (47)	0.5126367 (14)	0.3484036 (10)	0.2415824 (12)	0.2364514 (15)	4.98E-05	0.04
Average	1.1418247	0.5126396	0.3484053	0.2415831	0.2364552		
2SD	0.0000083	0.0000057	0.0000041	0.0000066	0.0000060		
SV-13(C)	1.1418323 (51)	0.5126387 (16)	0.3484046 (11)	0.2415810 (17)	0.2364561 (17)	1.08E-04	0.003
SV-18(C)	1.1418268 (39)	0.5126393 (12)	0.3484056 (08)	0.2415809 (11)	0.2364521 (13)	4.54E-05	0.04
SV-19(C)	1.1418308 (50)	0.5126396 (19)	0.3484051 (12)	0.2415800 (15)	0.2364618 (19)	3.69E-05	0.06
SV-19(S)	1.1418256 (55)	0.5126586 (21)	0.3484047 (13)	0.2415837 (16)	0.2364522 (22)	1.13E-04	0.08

Table 4.9 Nd isotopic ratios of alkaline rocks analysed from Phenai Mata Complex (alkali basalts), Gujarat and Kishengarh (nepheline syenites), Rajasthan.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
PMC-2(1)	1.1418297 (38)	0.5127007 (18)	0.3484037 (11)	0.2415825 (12)	0.2364498 (17)	1.48E-04	0.07
PMC-2(2)	1.1418340 (40)	0.5126953 (12)	0.3484040 (08)	0.2415784 (12)	0.2364517 (13)	9.66E-05	0.07
Average	1.1418319	0.5126980	0.3484039	0.2415805	0.2364508		
2SD	0.0000061	0.0000076	0.0000004	0.0000058	0.0000027		
PMC-3(1)	1.1418281 (48)	0.5120854 (20)	0.3484026 (13)	0.2415816 (16)	0.2364441 (21)	7.78E-05	0.08
PMC-3(2)	1.1418511 (58)	0.5120809 (17)	0.3484030 (12)	0.2415760 (16)	0.2364498 (19)	2.39E-05	0.03
Average	1.1418396	0.5120832	0.3484028	0.2415788	0.2364470		
2SD	0.0000325	0.0000064	0.0000006	0.0000079	0.0000081		
KG-1(1)	1.1418295 (47)	0.5117437 (23)	0.3484031 (13)	0.2415844 (15)	0.2364510 (22)	1.18E-04	0.10
KG-1(2)	1.1418277 (45)	0.5117244 (15)	0.3484047 (01)	0.2415787 (13)	0.2364451 (15)	7.15E-05	0.08
Average	1.1418286	0.5117341	0.3484039	0.2415816	0.2364481		
2SD	0.0000025	0.0000273	0.0000023	0.0000081	0.0000083		

Table 4.10 Nd isotopic ratios of kimberlites analysed from Eastern Dharwar Craton, Karnataka.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
CC-5	1.1418303 (44)	0.5119822 (20)	0.3484022 (13)	0.2415878 (16)	0.2364582 (20)	4.08E-05	0.06
CC-5(3SEQ)	1.1418308 (43)	0.5119785 (15)	0.3484039 (10)	0.2415805 (13)	0.2364562 (15)	2.05E-05	0.03
Average	1.1418306	0.5119804	0.3484031	0.2415842	0.2364572		
2SD	0.0000007	0.0000052	0.0000024	0.0000103	0.0000028		
KK-1	1.1418312 (42)	0.5119987 (20)	0.3484038 (12)	0.2415849 (14)	0.2364524 (20)	4.93E-05	0.08
KK-1(3SEQ)	1.1418325 (54)	0.5119909 (16)	0.3484042 (11)	0.2415813 (15)	0.2364520 (17)	2.96E-05	0.02
Average	1.1418319	0.5119948	0.3484040	0.2415831	0.2364522		
2SD	0.0000018	0.0000110	0.0000006	0.0000051	0.0000006		
NK-1	1.1418313 (42)	0.5119638 (20)	0.3483996 (13)	0.2415839 (15)	0.2364496 (20)	5.90E-05	0.09
NK-1(3SEQ)	1.1418319 (47)	0.5119582 (16)	0.3484046 (10)	0.2415791 (14)	0.2364499 (16)	7.38E-05	0.03
Average	1.1418316	0.5119610	0.3484021	0.2415815	0.2364498		
2SD	0.0000008	0.0000079	0.0000071	0.0000068	0.0000004		
P-7	1.1418390 (51)	0.5116737 (24)	0.3484024 (15)	0.2415832 (18)	0.2364497 (23)	5.03E-05	0.05
P-7(3SEQ)	1.1418316 (51)	0.5116671 (16)	0.3484044 (11)	0.2415805 (14)	0.2364510 (17)	1.89E-05	0.05
Average	1.1418353	0.5116704	0.3484034	0.2415819	0.2364504		
2SD	0.0000105	0.0000093	0.0000028	0.0000038	0.0000018		
SK-1	1.1418240 (38)	0.5119946 (18)	0.3484066 (10)	0.2415899 (13)	0.2364629 (17)	1.40E-04	0.02

SK-1(3SEQ)	1.1418242 (43)	0.5119889 (15)	0.3484036 (10)	0.2415810 (13)	0.2364595 (15)	6.31E-05	0.007
Average	1.1418241	0.5119918	0.3484051	0.2415855	0.2364612		
2SD	0.0000003	0.0000081	0.0000042	0.0000126	0.0000048		

Table 4.11 Nd isotopic ratios of Archean rocks analysed from BGC-1 (granitoids) from Rajasthan and TTGs from Singhbhum craton, Odisha.

Sample ID	$^{142}Nd/^{144}Nd$	$^{143}Nd/^{144}Nd$	$^{145}Nd/^{144}Nd$	$^{148}Nd/^{144}Nd$	$^{150}Nd/^{144}Nd$	$^{140}Ce/^{142}Nd$	Av. Fr. Rate ppm/s
JG-1(1)	1.1418271 (43)	0.5124740 (13)	0.3484041 (09)	0.2415784 (12)	0.2364517 (14)	8.31E-05	0.10
JG-1(2)	1.1418330 (39)	0.5124831 (19)	0.3484014 (11)	0.2415867 (13)	0.2364547 (18)	1.77E-04	0.10
Average	1.1418301	0.5124786	0.3484028	0.2415826	0.2364532		
2SD	0.0000083	0.0000129	0.0000038	0.0000117	0.0000042		
JG-2(1)	1.1418362 (59)	0.5106304 (19)	0.3484031 (11)	0.2415773 (17)	0.2364521 (20)	6.44E-05	0.09
JG-2(2)	1.1418425 (45)	0.5106311 (21)	0.3484038 (12)	0.2415841 (15)	0.2364504 (20)	5.24E-05	0.10
Average	1.1418394	0.5106308	0.3484035	0.2415807	0.2364513		
2SD	0.0000089	0.0000010	0.0000010	0.0000096	0.0000024		
OD-9(a)	1.1418378 (56)	0.5106004 (26)	0.3484031 (15)	0.2415848 (19)	0.2364527 (24)	1.11E-04	0.30
OD-12/2	1.1418455 (53)	0.5106809 (25)	0.3484045 (14)	0.2415823 (17)	0.2364489 (22)	5.65E-05	0.05
OD-13/2	1.1418462 (50)	0.5105013 (24)	0.3484035 (15)	0.2415845 (17)	0.2364486 (23)	1.39E-04	0.10