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Visiting Graduate Fellow - 3 May 1982 - 6 August 1982

(NASA-CR-170311) USE OF BASALTIC MAGMAS TO CHARACTERIZE PROCESSES IN PLANETARY INTERIORS: A TEST CASE IN THE SOUTHWESTERN UNITED STATES Monthly Progress Report, May 1982 (Lunar and Planetary Inst.) 12 p

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Use of basaltic magmas to characterize processes in planetary interiors: a test case in the southwestern United States

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## INTRODUCTION

Whether or not basaltic rocks can be used as mantle "probes" depends upon the degree to which their compositions reflect their source regions rather than their subsequent histories. The purpose of this study was to investigate mantle heterogeneities in the central Arizona Transition Zone and examine the degree to which interaction with the crust has modified the lavas masking these original variations. Basalts from a thick sequence of basaltic flows in the Hickey Formation and two younger flows were sampled in order to provide a time-transgressive suite of rocks. These rocks have been dated and an extensive set of analytical data is now available for them.

Everson (1979) delineated mantle heterogeneities on the scale of 1000s of kilometers in the southwestern U.S. based upon the Pb-isotopic composition of young basaltic rocks. He described two major subprovinces: the Colorado Plateau (CP) and the Basin and Range (BR) which are separated by the Transition Zone. He argued that the lavas he examined were derived uncontaminated by crustal material from the underlying mantle. His BR province was marked by relatively radiogenic Pb and his CP province by unradiogenic Pb. Lavas from the edges of the CP (Transition Zone and similar regions) defined linear arrays upon Pb-Pb diagrams which Everson interpreted as secondary isochrons indicating ages of 1.4 to 1.7 billion years. He noted that these were the ages of basement in the region but did not consider these lines to be the result of mixing mantle derived material with continental crust which would produce similar results. Data from this study suggest that the effect of crustal contamination is significant when dealing with some samples and is often masked by major element effects.

## ANALYTICAL DATA

Nine samples were analysed at Johnson Space Center for Sr- and Nd-isotopic initial ratios and an additional nine were analysed only for Sr initial ratios. These data are presented in Table 1, with the sample type and age. Ten samples were analysed by INAA for rare earth element (REE), Ni, Cr, Hf, Sc, and Ta compositions. These data are presented in Table 2.

## DISCUSSION AND INTERPRETATION OF RESULTS

### ISOTOPIC DATA

The Nd-isotopic data are noteworthy for their relative uniformity over a wide range of major element compositions (see figure 1). For example the alkali olivine basalts plot in the same general field as the tholeiitic lavas, showing only a slight degree of depletion relative to them. Epsilon Nd values for the lavas range from -0.88 to +2.81 generally. As noted below the slightly lower Nd ratios for the the tholeiites may be the result of crustal contamination. Only two samples (VC-1 and MD-5) show any major deviation from essentially a chondritic Nd ratio. VC-1 has an epsilon value of 4.86 and MD-5 of -6.66. (JSC reports a value of 0.511798 for chondrites.) These two samples have more extreme major element chemistry than the others: MD-5 is very alkalic and enriched in K2O and VC-1 is a very basic sample collected from a vent fissure.

Sr-isotopic data in contrast are variable and show a gross correlation with rock type and Sr abundance. Most samples have ratios in the range of 0.7048 to 0.7053. The K-rich trachybasalts generally have the highest ratios (0.7052 to 0.7055) as well as the highest Sr abundances (greater than 2500 ppm). Alkali olivine basalts are intermediate in Sr ratio (0.7054 to 0.7049) and abundance (about 1400 ppm). Tholeiites have the lowest abundances (less than 600 ppm) and ratios (about 0.7047). Sample M-7's anomalous behavior is as yet unexplained.

Figure 2 demonstrates the rough abundance vs. ratio correlation. The trend observed is the opposite of that which one would expect to see from interaction with the continental crust (high ratios, low abundances). This coupled with the high Sr abundances suggests that the Sr-isotopic pattern is not the result of crustal contamination. One important ascept of the Sr data is the fact that the ratios observed are not supported by sufficently high Rb/Sr ratios, suggesting a Rb depletion event occured prior to magma production. The younger basalts examined have significantly lower Sr-ratios than any on the Hickey lavas.

### REE DATA

The REE data for all samples suggest that the source regions of the Hickey basalts were light REE-enriched. It is possible to produce the patterns observed by small degrees of melting (<2%) of a source with chondritic abundances and an overall enriched nature, but the degrees of melting seem unreasonably small. The La/Yb ratios are variable depending upon magma type, reflecting the degree of melting; lower ratios result from dilution of an initially very light REE-enriched melt. Tholeiites have La/Yb values of about 9, alkali olivine basalts about 30, and trachybasalts and basanites about 75.

The alkali olivine basalts show a surprizing clustering given their wide chemical variation (figure 3). Fractionation of olivine and/or clinopyroxene should have only a small effect upon REE abundances, but in this case, accounting for this fractionation results in less tightly clustered patterns. It is suggested therefore that the sources of these magmas had sightly different REE abundances with similar patterns.

One of the most primitive lavas, PRS-34, has heavy REE abundances very similar to the alkali olivine basalts (figure 4), but is significantly enriched in light REE. This suggests a lower degree of melting for the basanite, with similar amounts of garnet retained in the source. Similarly, MD-5 has a high degree of light REE-enrichment, which may be in part due to fractional crystallization (figure 5).

The tholeiitic lavas have markedly different REE patterns reflecting the higher degrees of melting which produced them (figure 6). Specifically, the relatively "flat" patterns suggest that little garnet is retained in the source. Overall REE abundances for these samples are lower as the result of dilution and prehaps a previous depletion by a light REE-enriched melt. Most notable about these lavas are the positive Eu anomalies, a characteristic shared by PRS-228, another high SiO2 rock (about 50%) and surprisingly by the very basic lava VC-1.

It seems likely that the Eu anomalies are the result of assimilation of lower crustal material, specifically plagioclase. Plagioclase formed during the creation of continental crust about 1.7 by ago should have a low Sr ratio and the samples with Eu anomalies do have low Sr ratios compared with the other Hickey lavas. PRS-228 for example has a markedly lower ratio than MD-5 a sample from an interbedded flow.

## CONCLUSIONS

The analysis of thre data presented here is still progressing but some preliminary conclusions can be made based upon these and other data.

(1) The source of the lavas was heterogeneous. K/Rb ratios fall in to clusters, about 400, and about 600. These clumps probably reflect mineralogical differences in the K-bearing phases in the mantle. Micas have generally much lower K/Rb values than amphiboles and the presence of phlogopite-bearing vs. amphibole-bearing peridote is postulated.

(2) Sr initial ratios indicate a variability in Rb/Sr existed in the source at one time. Present Rb/Sr values are too low to produce the Sr-isotopic values observed, and a Rb-depletion event is suggested prior to generation of the Hickey lavas.

(3) The source is light REE-enriched. The REE data coupled with the Nd-isotopic data suggest a metasomatic event produced the REE composition of the source. A close correlation of REE with P2O5 is consistant with apatite control of the REE abundances, but there is no strong evidence for variable REE patterns in the source.

(4) Crustal contamination has played a role in determining the isotopic and REE compostions of the more silicic Hickey lavas. Plagioclase plays an important role in this effect. The Pb-isotopic data of Everson (1979) thus are interpreted as mixing lines between continental material and mantle-derived melt.

The presently favored model favors a heterogeneous source with regions dominated by phlogopite vs. amphibole. Sr-isotopic ratios are also variable in these regions. Into this source have been introduced P2O5- and REE-richmetasomatic veins (dominated by apatite). Variations in the trace element compositions reflect different proportions of these components.

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TABLE 1

| Sample | Rock Type | Sr | Rb | $^{87}Sr/^{86}Sr$ | $^{143}Nd/^{144}Nd$ | Age |
|---|---|---|---|---|---|---|
| FV-1 | trachybasalt | 3290 | 27.0 | 0.70519±4 | - | 13.19 my |
| MM-4W | trachybasalt | 3135 | 42.5 | 0.70551 4 | - | 14.96 |
| MD-5 | trachybasalt | 2[illegible]* | 35* | 0.70523 4 | 0.511471±23 | 14.01 |
| PRS-220 | hawaiite | 1478* | 13* | 0.70496 2 | 0.511753 25 | 13.89 |
| M-50 | hawaiite | 1435 | 17.1 | 0.70526 6 | - | - |
| PRS-34 | basanite | 1700 | 26.0 | 0.7048[illegible] 5 | - | 11.90 |
| M-1 | alk. ol. basalt | 1247* | 10* | 0.70541 5 | 0.511846 24 | - |
| M-2 | alk. ol. basalt | 1305 | 16.4 | 0.7050[illegible] 4 | - | - |
| M-5 | alk. ol. basalt | 1139* | 9* | 0.70491 4 | 0.511919 34 | - |
| M-7 | alk. ol. basalt | 2532* | 22* | 0.70646 7 | 0.511942 28 | - |
| M-13 | tholeiite | 521 | 7.5 | 0.70467 4 | - | - |
| MM-1W | tholeiite | 492* | 5* | 0.70477 3 | 0.511860 25 | 13.66 |
| MM-2W | tholeiite | 579* | 7* | 0.70472 4 | 0.511795 30 | 11.88 |
| VC-1 | ankaramite | 717* | 1[illegible]* | 0.70405 4 | 0.512047 31 | 3.92 |
| PRS-25 | ol. tholeiite | 423* | 16* | 0.70440 4 | 0.511768 14 | - |

TABLE 2

| Sample | Ni | Cr | La | Ce | Sm | Eu | Tb | Yb | Hf | Sc | Ta |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MD-5 | 130 | 95 | [illegible].5 | 100 | 10.5 | 2.25 | 0.72 | 1.39 | 5.5 | 17 | 1.1 |
| PRS-220 | 170 | 230 | 46.6 | 98.6 | 5.95 | 2.35 | 0.75 | 1.74 | 4.5 | 19 | 1.4 |
| PRS-34 | 410 | 440 | 91.6 | 185 | 11.8 | 2.30 | 0.90 | 1.93 | 4.5 | 24 | 3.1 |
| M-1 | 240 | 600 | 62.1 | 140 | 9.[illegible] | 2.90 | 1.19 | 2.00 | 4.4 | 28 | 2.4 |
| M-2 | 330 | 3[illegible] | 62.2 | 135 | 10.5 | 2.75 | 0.92 | 1.96 | 4.4 | 25 | 3.0 |
| M-5 | 250 | 770 | 51.4 | 117 | 8.0 | 2.80 | 1.07 | 1.90 | 4.3 | 27 | 2.1 |
| M-7 | 110 | 165 | 60.5 | 130 | 9.4 | 2.52 | 0.91 | 1.94 | 4.4 | 26 | 2.3 |
| MM-1W | 150 | 210 | 12.6 | 2[illegible].0 | 4.00 | 1.57 | - | 1.56 | 2.9 | 21 | 0.7 |
| MM-2W | 125 | 4[illegible] | 13.[illegible] | 24.0 | 3.43 | 1.41 | 0.64 | 1.52 | 2.3 | 17 | 0.6 |
| VC-1 | 265 | 920 | 49.4 | 105 | 7.40 | 2.51 | 0.78 | 1.76 | 3.4 | 31 | 2.5 |

Note: Sr and Rb analyses marked * were done by XRF, all others by isotope dilution.

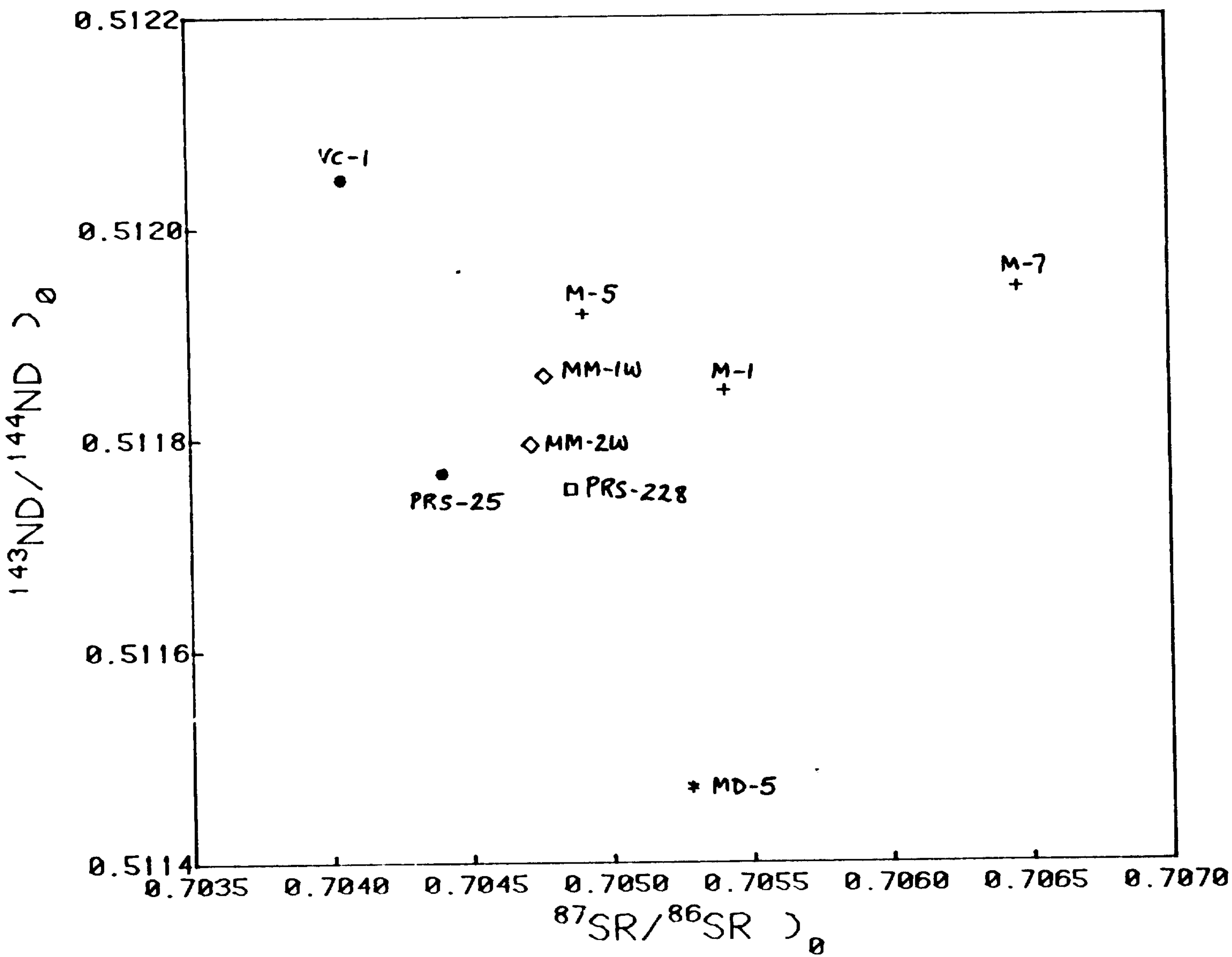


fig 1. Nd-ratios vs. Sr-ratios

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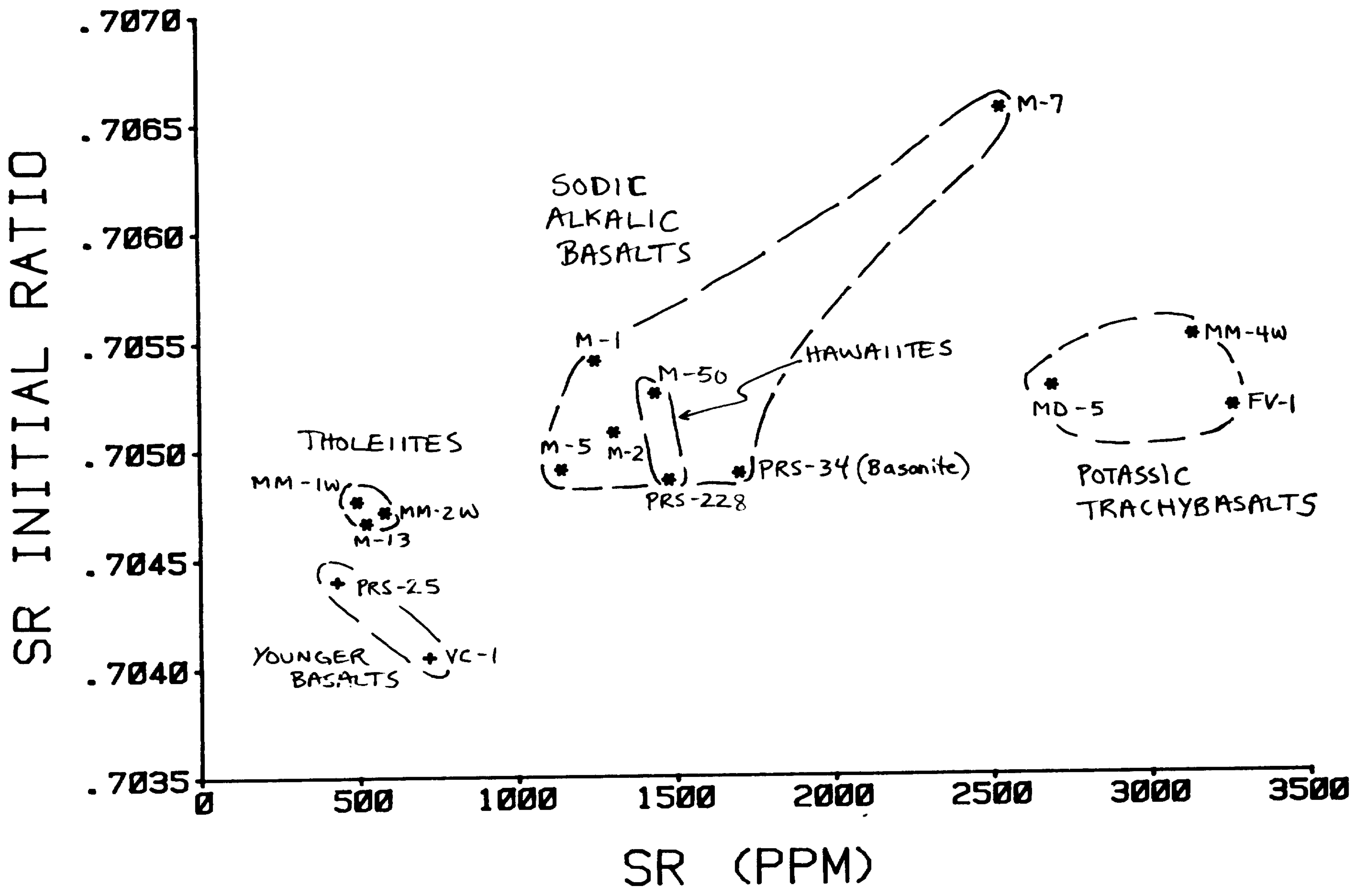

fig. 3:

ALKALI OLIVINE BASALTS

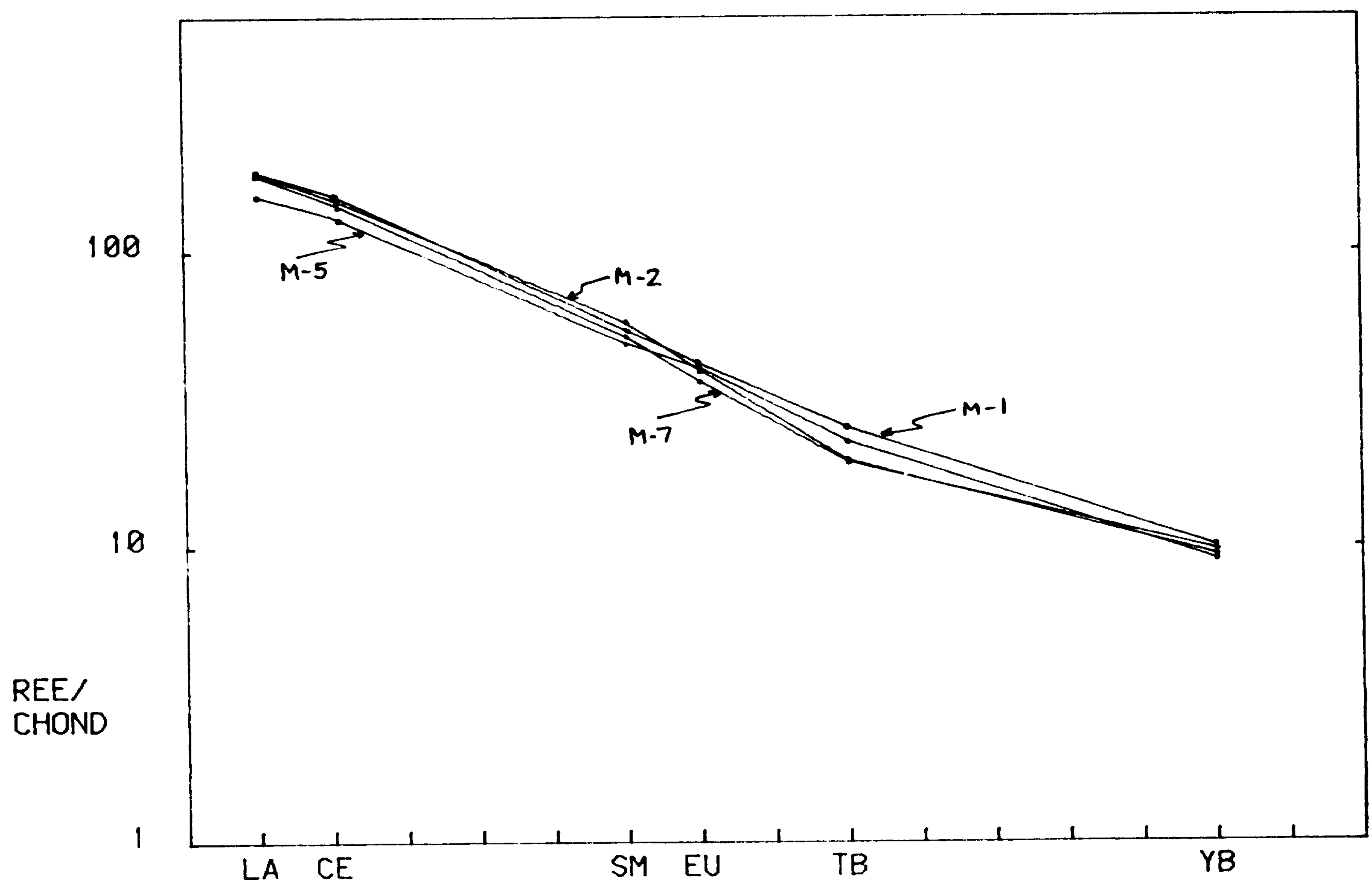

fig.4 :
BASANITE & ANKARAMITE

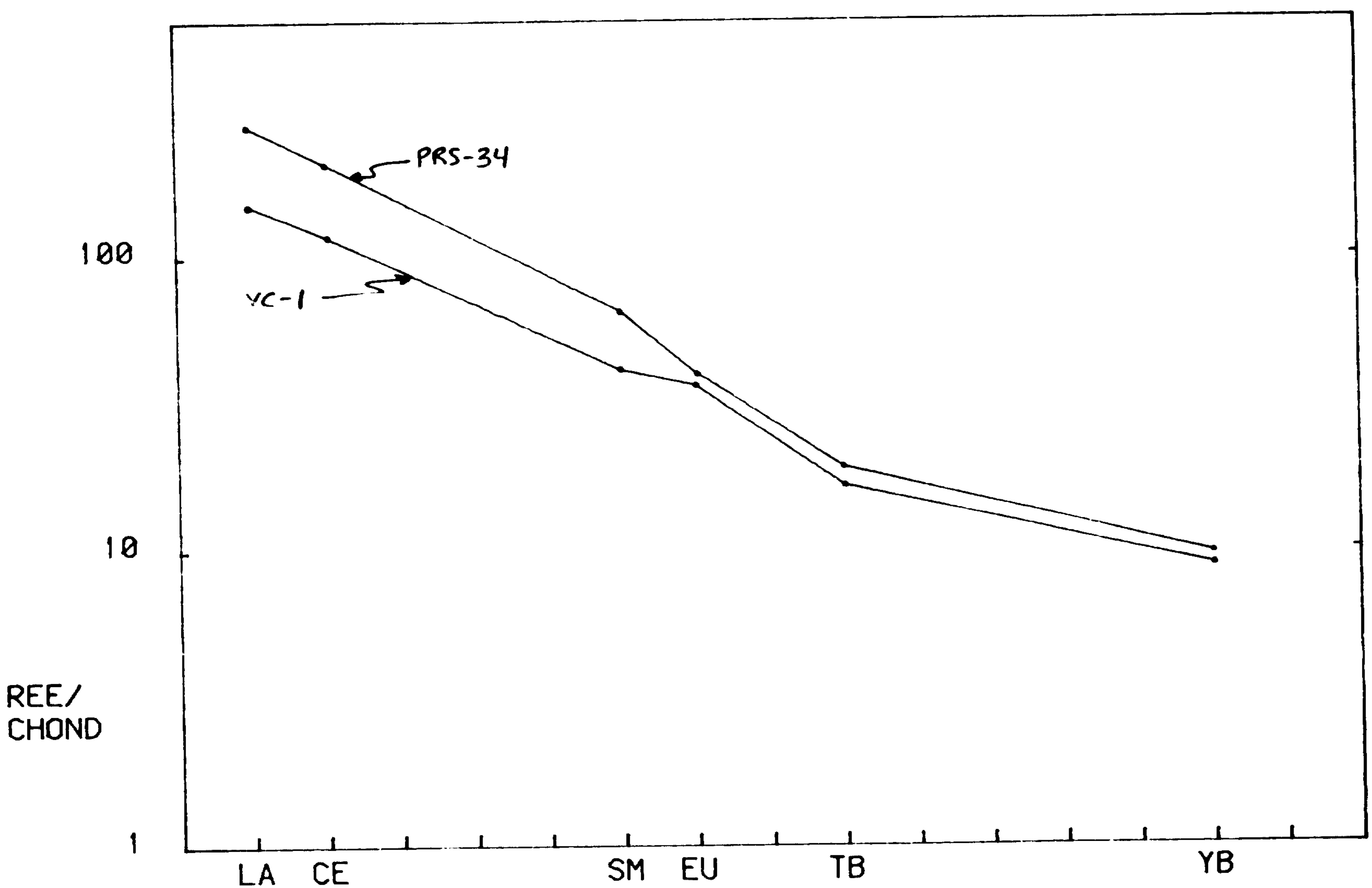

fig. 5:
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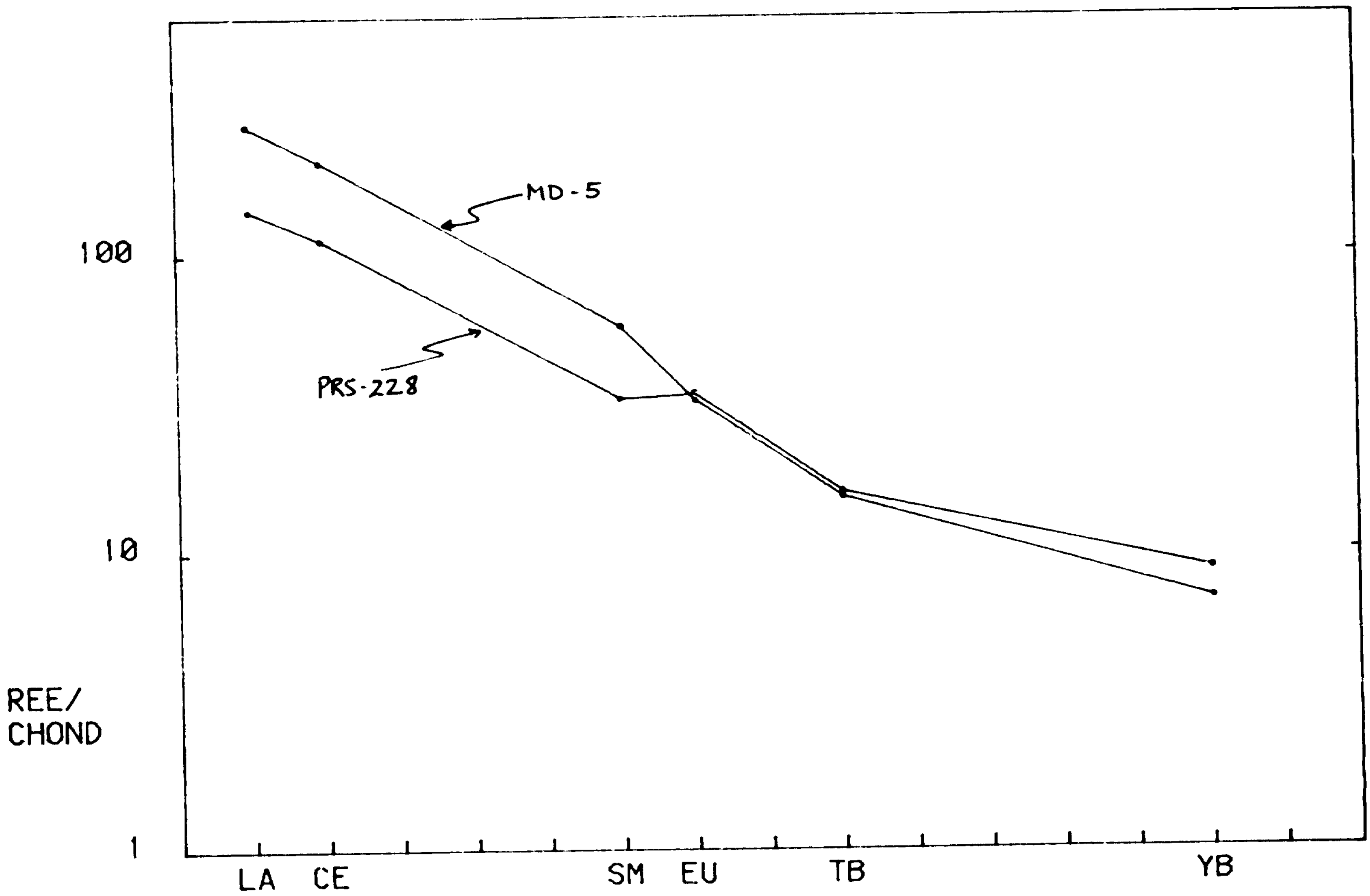
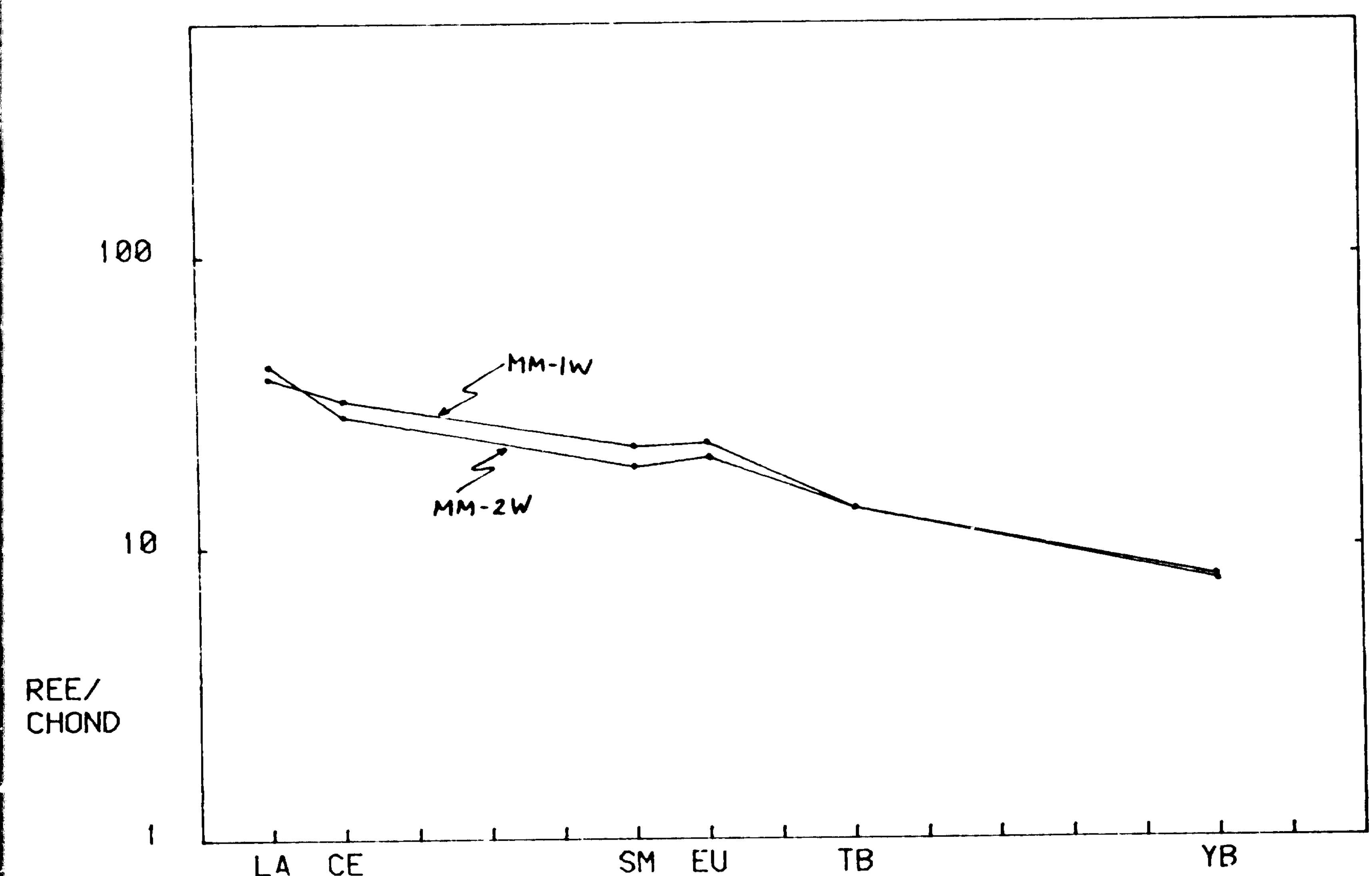


fig. 6:
THOLEIITES



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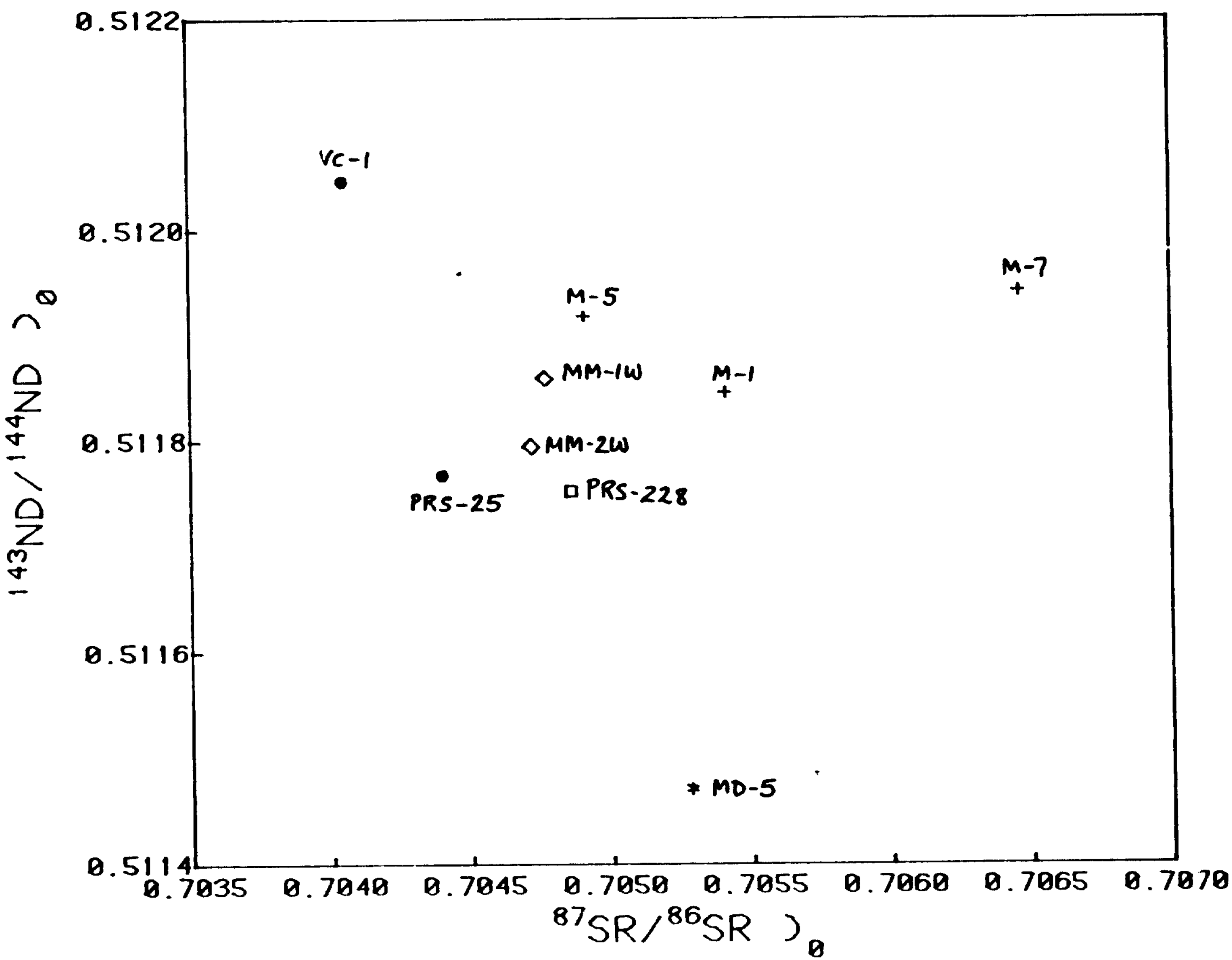


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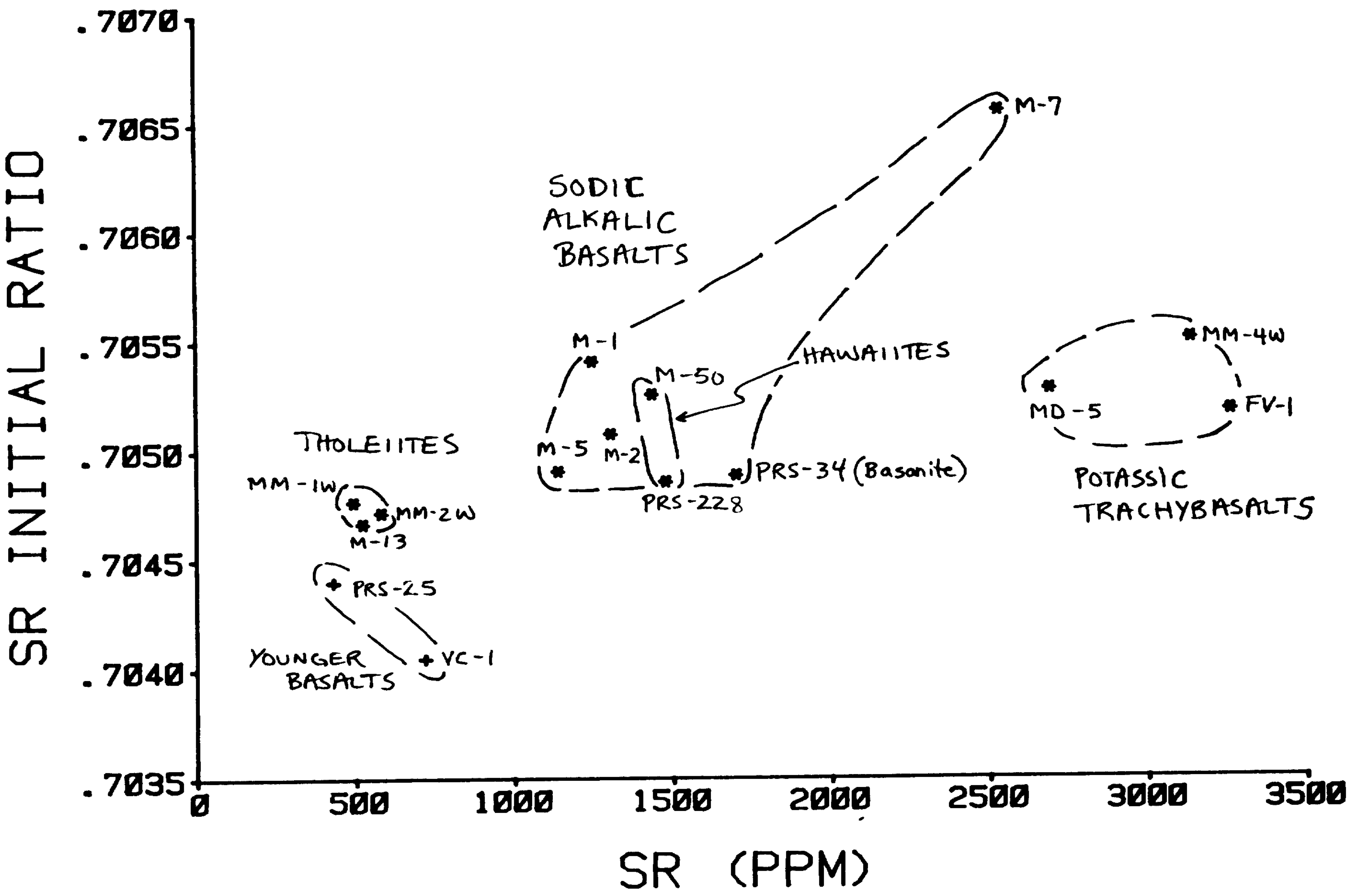
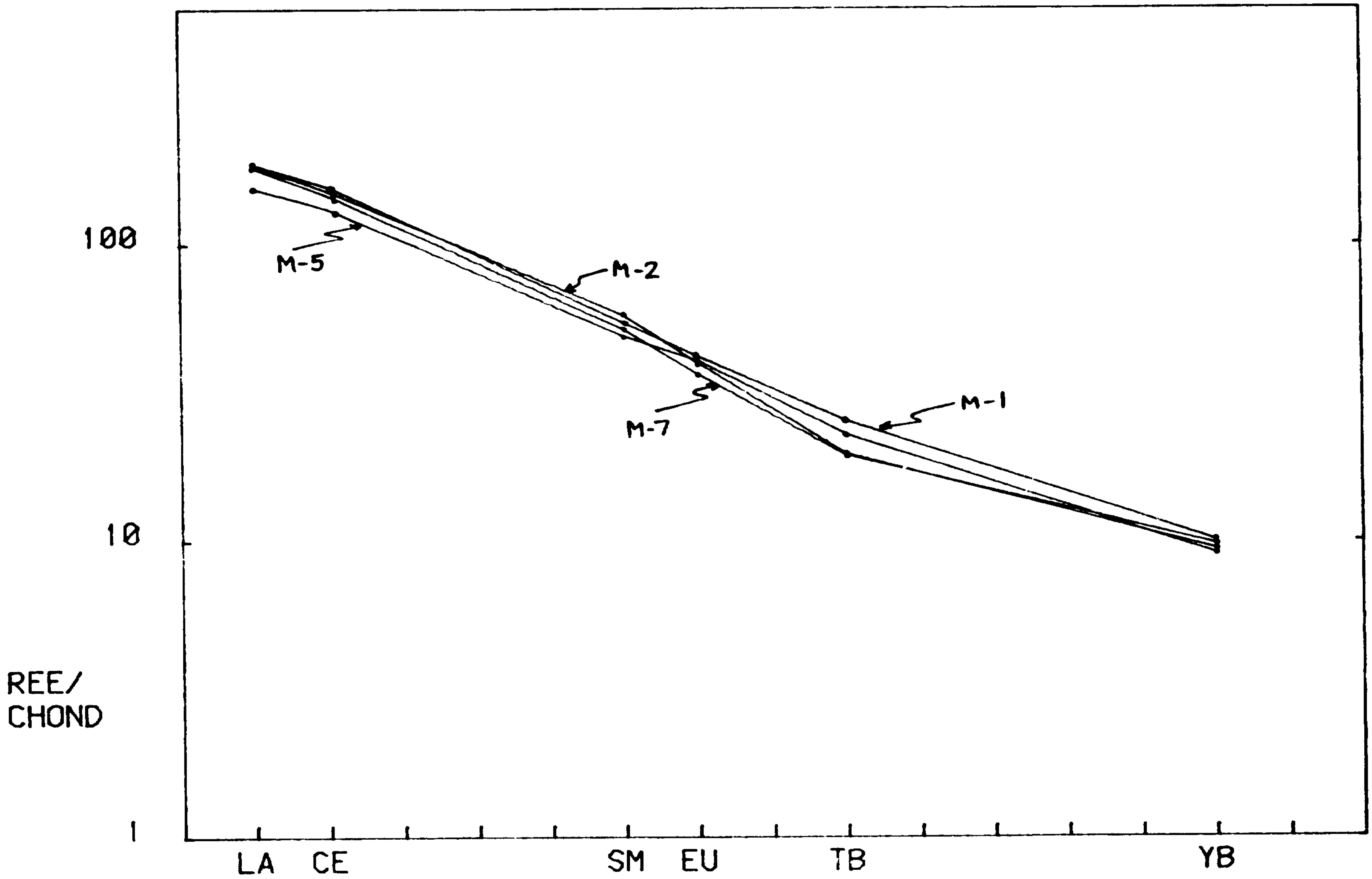


fig. 3:

ALKALI OLIVINE BASALTS



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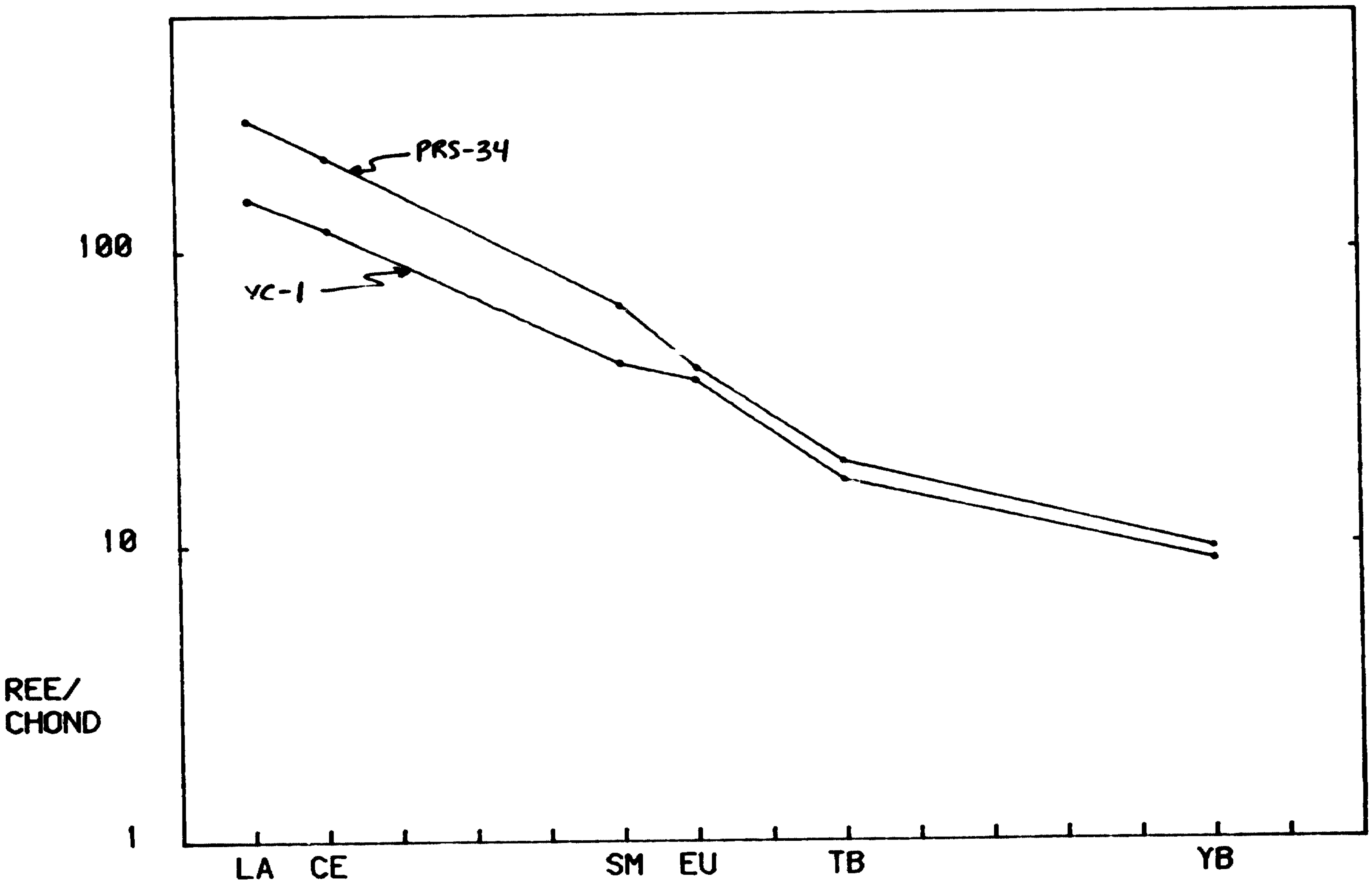
BASANITE & ANKARAMITE



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HAWAIITE & TRACHYBASALT

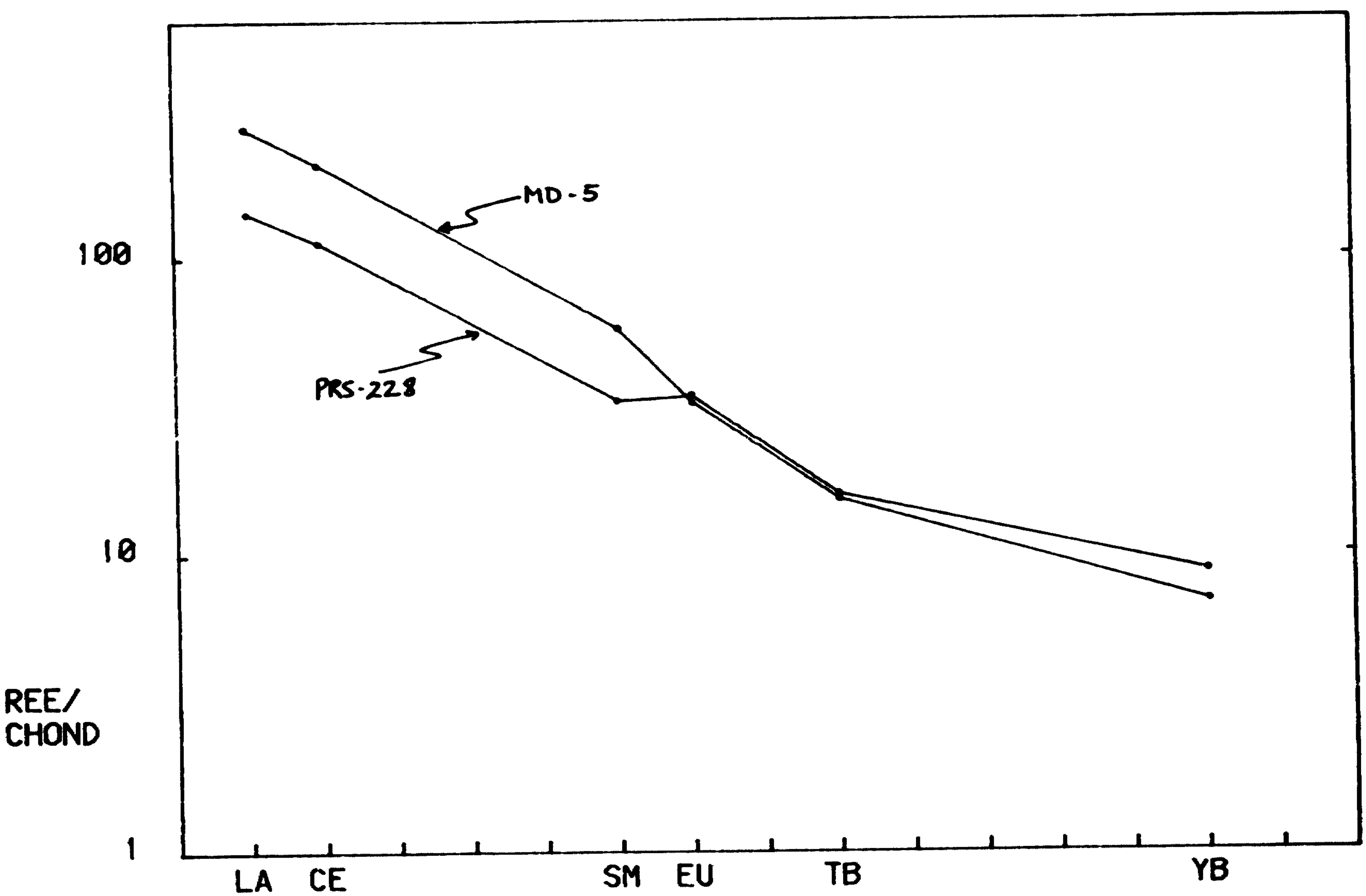

fig. 6:

THOLEIITES