Data Repository Item 2003108:

"Comment to 'Neogene volcanism at the front of the central Mexican volcanic belt: Basaltic andesites to dacites, with contemporaneous shoshonites and high-TiO_2 lava' by D.L. Blatter, I.S.E. Carmichael, A.L. Deino, and P.R. Renne",

by Ignacio S. Torres-Alvarado and Surendra P. Verma

[insert here the file DR1.gif]

Figure DR1. Location map for the Mexican volcanic belt (MVB) and the Central American volcanic arc (CAVA; modified after Verma, 2002a). MAT = Middle America trench; EPR = East Pacific Rise; TeR = Tehuantepec ridge; MPF = Motagua-Polochic fault system; G = Guatemala; B = Belize; S = El Salvador; H = Honduras; N = Nicaragua; C = Costa Rica; and P = Panama. The approximate age (Ma) of the Cocos plate is shown schematically by contours marked 5, 10, 15, 20, and 25. Depth contours (km) of the subducting Cocos plate (as inferred from earthquakes by Pardo and Suárez, 1995) are included for reference. Approximate locations of Deep Sea Drilling Project legs 66 (L66), 67 (L67), and 84 (L84) are also indicated. Our geochemical database for the MVB (411 individual samples) concerns a wider area to the East and to the West than the region studied by Blatter et al. (2001). The data sources are: (1) the Michoacán-Guanajuato volcanic areas (Hasenaka and Carmichael, 1987; Hasenaka, 1992; McBirney et al., 1987); (2) the Zitácuaro-Valle de Bravo region (Blatter et al., 2001, including their complete data repository; Blatter and Carmichael, 2001); (3) the Chichinautzin volcanic field (Swinamer, 1989; Wallace and Carmichael, 1999; Verma, 1999, 2000a; Velasco-Tapia and Verma, 2001); (4) the Acoculco caldera (Verma, 2001a); (5) the Amealco caldera (Verma et al., 1991); (6) the Meseta Río San Juan (Verma, 2001b); (7) the Tizayuca and Apan region (Verma, 2002b; García-Palomo et al., 2002); (8) the Huichapan caldera (Verma, 2001c); and (9) Popocatépetl and Iztaccíhuatl volcanoes (Boudal, 1985; Siebe et al., 1999; Nixon, 1988). Only geochemical data from volcanic regions corresponding to the Cocos plate were selected. The western part of the MVB was not considered here, because it is above a different tectonic plate, namely the Rivera plate, with important tectonic as well as geochemical differences (some of them already described by Blatter et al., 2001). We prefer to compare these data from the central and west-central part of MVB with the geochemical compilation by Carr and co-workers for the Central America volcanic arc (CAVA; Carr et al., 1990, and data presented in Carr's web page: http://www-rci.rutgers.edu/carr/index.html), because both areas (MVB and CAVA) would correspond to a single subducting slab (Cocos plate). For our present purposes, we use the distinction between front and back arcs as defined by Carr et al. (1990) for CAVA, and arbitrarily designate the front arc for the MVB all those samples that are closer to the Middle America Trench. The locations of the samples discussed in this work are represented with circles for the MVB and with triangles for CAVA. Filled symbols in both regions represent the front arc samples; open circles represent the back arc samples. Note that MVB is not parallel to the Middle America trench but makes an angle of ~20^{o} to it (Molnar and Sykes, 1969), whereas CAVA follows the expected subparallel trend to MAT. Note also that the Wadati-Benioff zone beneath southern Mexico is seismically very poorly defined, and is completely absent beneath the central MVB (Singh and Pardo, 1993; Pardo and Suárez, 1995).

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Figure DR2. Ba-Zr diagram for basic (SiO_2 < 52 wt%) and intermediate (52 < SiO_2 < 63 wt%) volcanic rocks from MVB and CAVA. Ba is a highly nonconservative element, and Zr a conservative one (Pearce and Peate, 1995). Such a plot could differentiate volcanic rocks with and without a detectable contribution of the subducting slab. The symbols used are shown as inset. Note that MVB rocks define a different field than CAVA rocks. How can this difference be possible considering that both groups of rocks are supposed to be generated from the same subducting slab, namely the Cocos plate? Note in addition that numerous back arc basic rocks from CAVA plot within the field of MVB lavas.

[insert here the file DR3.gif]

Figure DR3. Selected geochemical parameters for basic (SiO_2 < 52 wt%) and intermediate (52 < SiO_2 < 63 wt%) volcanic rocks from MVB and CAVA. See legend of Figure DR3B for the symbols used in all four diagrams. Note that due to large number of samples, only basic rocks are plotted for clarity in Figure DR3D. $(TiO_2)_{adj}$ means TiO_2-content (wt. %) adjusted to a 100%, volatile-free basis (using the computer program SINCLAS, Verma et al., 2002, and following the suggestions of the IUGS Subcommission for Classification of Volcanic Rocks, Le Bas et al., 1986; Le Bas, 1989, 2000). A: Nb/Yb-Zr/Yb diagram (Nb and Zr being HFSE and, therefore, highly incompatible, they are thought to be least effectively transferred from slab to the melting column; Pearce and Peate, 1995). Note that MVB lavas show higher Nb/Yb as well as higher Zr/Yb values than the rocks from CAVA suggesting different sources for melt generation in both regions. B: Ba/La-La/Yb plot (Ba, being LILE, is relatively fluid mobile, compared with the relatively fluid immobile elements La and Yb). Note that MVB rocks show lower Ba/La and higher La/Yb ratios than CAVA rocks. C: Sr/Ce-Ba/Zr diagram. Note that MVB lavas show low values for both Sr/Ce and Ba/Zr. D: Ba/$(TiO_2)_{adj}$-(Rb/Zr)*100 plot. The subduction component as evidenced in CAVA rocks, seems to have high values of both parameters plotted. Most MVB rocks fall in the field of low values of both variables, except five samples (H-428T, H-520, H-542, Jor-46, and Jor-46D) that belong to the Michoacán-Guanajuato volcanic field, and one sample (WC-115) located in the Chichinautzin volcanic field. Because of the proximity of the Michoacán-Guanajuato volcanic field to the Rivera plate, these high Ba/TiO_2 values might be related to the influence of this plate, and certainly to the influence of the chemically heterogeneous continental crust, specially for the only sample from the Chichinautzin volcanic field (WC-115). Unfortunately, the continental crust in Mexico has been only partially characterized for its chemical as well as isotopic compositions (see, for example, Patchett and Ruiz, 1987, for Sr and Nd isotopic composition and related trace elements from Precambrian rocks; Ruiz et al., 1988, for Nd isotopic studies of Precambrian rocks; Roberts and Ruiz, 1989, for major and several trace elements in granulites and granulitic xenoliths; Schaaf et al., 1994, for major and trace elements, as well as Sr an Nd (but not Pb) isotopic analyses of lower crust xenoliths from San Luis Potosí). The Earth's continental crust has been extensively analyzed by Rudnick and Taylor (1987), Rudnick (1992), and Rudnick et al. (1998), demonstrating its very heterogeneous compositions. All four diagrams presented in Figure DR3 show that no chemical distinction is observed between front and back arc lavas for MVB, whereas most back arc lavas from CAVA overlap with the combined fields of front and back arc lavas from MVB. Where should we consider the volcanic front of MVB if all rocks are similar to back arc rocks? Is it really an arc? The geochemical data show that it is not an arc.

[insert here the file DR4.gif]

Figure DR4. Subducted slab-indicating ratios (A: Ba/La, B: Ba/Nb) against $^{87}Sr/^{86}Sr$ for MVB rocks and their comparison with CAVA samples. The symbols used for both diagrams are shown in inset of Figure DR4A. Note that most MVB samples, including the intermediate, and therefore more evolved ones, show low Ba/La and Ba/Nb ratios, as compared with CAVA (both basic and intermediate) lavas. Note also that most back arc basic lavas from CAVA plot toward very low Ba/La and Ba/Nb ratios, and also low $^{87}Sr/^{86}Sr$ values. If MVB is a continental arc, why are the MVB rocks so chemically different from CAVA lavas, if both are generated by the involvement of the same oceanic plate?

[insert here the file DR5.gif]

Figure DR5. $^{87}Sr/^{86}Sr$ - $^{143}Nd/^{144}Nd$ plot for volcanic rocks from selected areas belonging to MVB and CAVA as reported in the literature (initial in-situ-growth-corrected values are used). Trace of the "Mantle-array" (heavy dot lines) is shown for reference. The trend of the MVB samples (decreasing $^{143}Nd/^{144}Nd$ with increasing $^{87}Sr/^{86}Sr$) is consistent with mantle derived magmas and their evolution through assimilation of continental crust, as has been inferred in numerous studies (e.g., McBirney et al., 1987; Verma et al., 1991; Hochstaedter et al., 1996; Ruiz et al., 1998; Verma, 1999, 2000b, 2001a, b, c, 2002b; Luhr, 2000; Righter, 2000; Sheth et al., 2000; Chesley et al., 2000). The thick solid curve represents the mixing line of two-component mixing of Cocos plate MORB with sediments from the subducting Cocos plate (sampled at Sites 487 and 488, leg L66 in Fig. DR1, Verma, 2000a). The numbers (2 to 20%) indicate the % of the sediment component in this mixture. The isotopic compositions of sediments sampled in DSDP legs L67 and L84 (Fig. 1) are very similar to those analyzed from L66. Consequently, the two-component mixing model Cocos plate MORB-sediments can be considered valid for the Middle America trench, also south of the Tehuantepec ridge. The solid arrows represent schematically a possible three component mixtures of a mantle (less-depleted than MORB mantle), altered MORB, and sediments from the subducting Cocos plate. Interestingly, numerous volcanic rocks from the CAVA show the predicted trend for three component mixtures. If MVB rocks were generated with fluids, melt, or mass influx from the subducting slab, they should plot in the general area of subduction-related magmas, just where the CAVA rocks plot. How can this be explained by the involvement of the subducted Cocos plate in the genesis of MVB magmas?

References

Blatter, D.L., and Carmichael, I.S.E., 2001, Hydrous phase equilibria of a Mexican high-silica andesite: a candidate for a mantle origin?: Geochimica et Cosmochimica Acta, v. 65, p. 4043-4065.

Blatter, D.L., Carmichael, I.S.E., Deino, A.L., and Renne, P.R., 2001, Neogene volcanism at the front of the central Mexican volcanic belt: basaltic andesites to dacites, with contemporaneous shoshonites and high-TiO_2 lava: Geological Society of America Bulletin, v. 113, p. 1324-1342.

Boudal, C., 1985, Pétrologie d'un grand volcan andésitique mexicain: le Popocatepetl [Thèse de Doctorat]: Univ. Clermont-Ferrand II, 140 p.

Carr, M.J., Feigenson, M.D., and Bennett, E.A., 1990, Incompatible element and isotopic evidence for tectonic control of source mixing and melt extraction along the Central American arc: Contributions to Mineralogy and Petrology, v. 105, p. 369-380.

Chesley, J.T., Ruiz, J., and Righter, K., 2000, Source versus crustal contamination in arc magmatism: Evidence for lower crustal assimilation in the trans-Mexican volcanic belt: EOS, Transactions of the American Geophysical Union, Fall Meeting, San Francisco, USA, p. F1269.

García-Palomo, A., Macías, J.L., Tolson, G., Valdez, G., and Mora, J.C., 2002, Volcanic stratigraphy and geological evolution of the Apan region, east-central sector of the Trans-Mexican volcanic belt: Geofísica Internacional, v. 41, p. 133-150.

Hasenaka, T., 1992, Appendix 3. Chemical compositions of selected samples, *in* Aoki, K., ed., Subduction volcanism and tectonics of western Mexican Volcanic Belt. International Scientific Research Program (No. 03041014) Japan-Mexico Co-operative Research: Sendai, Japan, The Faculty of Science, Tohoku University, p. 238-247.

Hasenaka, T., and Carmichael, I.S.E., 1987, The cinder cones of Michoacán-Guanajuato, Central Mexico: petrology and chemistry: Journal of Petrology, v. 28, p. 241-269.

Hochstaedter, A.G., Ryan, J.G., Luhr, J.F., Hasenaka, T., 1996, On B/Be ratios in the Mexican volcanic belt: Geochemica Cosmochemica Acta, v. 60, p. 613-628.

Le Bas, M.J., 1989, Nephelinitic and basanitic rocks: Journal of Petrology, v. 30, p. 1299-1312.

Le Bas, M.J., 2000, IUGS reclassification of the high-Mg and picritic volcanic rocks: Journal of Petrology, v. 41, p. 1467-1470.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks on the total alkali4silica diagram: Journal of Petrology, v. 27, p. 745-750.

Luhr, J.F., 2000, The geology of Volcán San Juan Nayarit, México and the compositionally zoned Tepic Pumice: Journal of Volcanology and Geothermal Research, v. 95, p. 109-156.

McBirney, A.R., Taylor, H.P., and Armstrong, R.L., 1987, Paricutin re-examined: a classical example of crustal assimilation in calc-alkaline magma: Contributions to Mineralogy and Petrology, v. 95, p. 4-20.

Molnar, P., and Sykes, L.R., 1969, Tectonics of the Caribbean and Middle America regions from focal mechanisms and seismicity: Geological Society of America Bulletin, v. 80, p. 1639-1684.

Nixon, T.G., 1988, Petrology of the younger andesites and dacites of Iztaccíhuatl volcano, Mexico: II. Chemical stratigraphy, magma mixing, and the composition of basaltic magma influx: Journal of Petrology, v. 29, p. 265-303.

Pardo, M., and Suárez, G., 1995, Shape of the subducted Rivera and Cocos plates in southern Mexico: Seismic and tectonic implications: Journal of Geophysical Research, v. 100, p. 12373-12373.

Patchett, P.J., and Ruiz, J., 1987, Nd isotopic ages of crust formation and metamorphism in the Precambrian of eastern and southern Mexico: Contributions to Mineralogy and Petrology, v. 96, p. 523-528.

Pearce, J.A., and Peate, D.W., 1995, Tectonic implications of the composition of volcanic arc magmas: Annual Review of Earth and Planetary Sciences, v. 23, p. 251-285.

Righter, K., 2000, A comparison of basaltic volcanism in the Cascades and western Mexico: compositional diversity in continental arcs: Tectonophysics, v. 318, p. 99-117.

Roberts, S.J., and Ruiz, J., 1989, Geochemistry of exposed granulite facies terrains and lower crustal xenoliths in Mexico: Journal of Geophysical Research, v. 94, p. 7961-7974.

Rudnick, R.L., 1992, Xenoliths — samples of the lower continental crust, *in* Fountain, D.M., Arculus, R., and Kay, R.W., eds., Continental lower crust: Development of Geotectonics: Amsterdam, Elsevier, p. 269-316.

Rudnick, R.L., and Taylor, S.R., 1987, The composition and petrogenesis of the lower crust: a xenolith study: Journal of Geophysical Research, v. 92, p. 13981-14005.

Rudnick, R.L., McDonough, W.F., and O´Connell, R.J., 1998, Thermal structure, thickness and composition of continental lithosphere: Chemical Geology, v. 145, p. 395-411.

Ruiz, J., Patchett, P.J., and Ortega-Gutierrez, F., 1988, Proterozoic and Phanerozoic basement terranes of Mexico from Nd isotopic studies: Geological Society of America Bulletin, v. 100, p. 274-281.

Ruiz, J., Chelsey, J.T., and Righter, K., 1998, Os isotopic composition of basaltic andesites and hawaiites of western Mexico (abstract): Miner. Mag., v. 62A, p. 103

Schaaf, P., Heinrich, W., Besch, T., 1994, Composition and Sm-Nd isotopic data of the lower crust beneath San Luis Potosí, central Mexico: evidence from a granulite-facies xenolith suite: Chemical Geology, v. 118, p. 63-84.

Sheth, H.C., Torres-Alvarado, I.S., and Verma, S.P., 2000, Beyond subduction and plumes: a unified tectonic-petrogenetic model for the Mexican volcanic belt: International Geology Review, v. 42, p. 1116-1132.

Siebe, C., Schaaf, P., and Urrutia-Fucugauchi, J., 1999, Mammoth bones embedded in a late Plesitocene lahar from Popocatépetl volcano, near Tocuila, central Mexico: Geological Society of America Bulletin, v. 111, p. 1550-1562.

Singh, S.K., and Pardo, M., 1993, Geometry of the Benioff zone and state of stress in the overriding plate in central Mexico: Geophysical Research Letters, v. 20, p. 1483-1486.

Swinamer, R.T., 1989, The geomorphology, petrography, geochemistry and petrogenesis of the volcanic rocks in the Sierra del Chichinautzin, Mexico [M. Sc. Thesis]: Queen's University, 212 p.

Velasco-Tapia, F., and Verma, S.P., 2001, First partial melting inversion model for a rift-related origin of the Sierra de Chichinautzin volcanic field, central Mexican volcanic belt: International Geology Review, v. 43, p. 788-817.

Verma, S.P., 1999, Geochemistry of evolved magmas and their relationship to subduction-unrelated mafic volcanism at the volcanic front of the central Mexican volcanic belt: Journal of Volcanology and Geothermal Research, v. 93, p. 151-171.

Verma, S.P., 2000a, Geochemistry of the subducting Cocos plate and the origin of subduction-unrelated mafic volcanism at the volcanic front of the central Mexican volcanic belt: Geological Society of America Special Paper 334, p. 195-221.

Verma, S.P., 2000b, Geochemical evidence for a lithospheric source for magmas from Los Humeros caldera, Puebla, Mexico: Chemical Geology, v. 164, p. 35-60.

Verma, S.P., 2001a, Geochemical evidence for a lithospheric source for magmas from Acoculco caldera, eastern Mexican volcanic belt: International Geology Review, v. 43, p. 31-51.

Verma, S.P., 2001b, Geochemical evidence for a rift-related origin of bimodal volcanism at Meseta Rio San Juan, north-central Mexican volcanic belt: International Geology Review, v. 43, p. 475-493.

Verma, S.P., 2001c, Geochemical and Sr-Nd-Pb isotopic evidence for the petrogenesis of volcanic rocks from Huichapan caldera, Hidalgo, Mexico: Lithos, v. 56, p. 141-164.

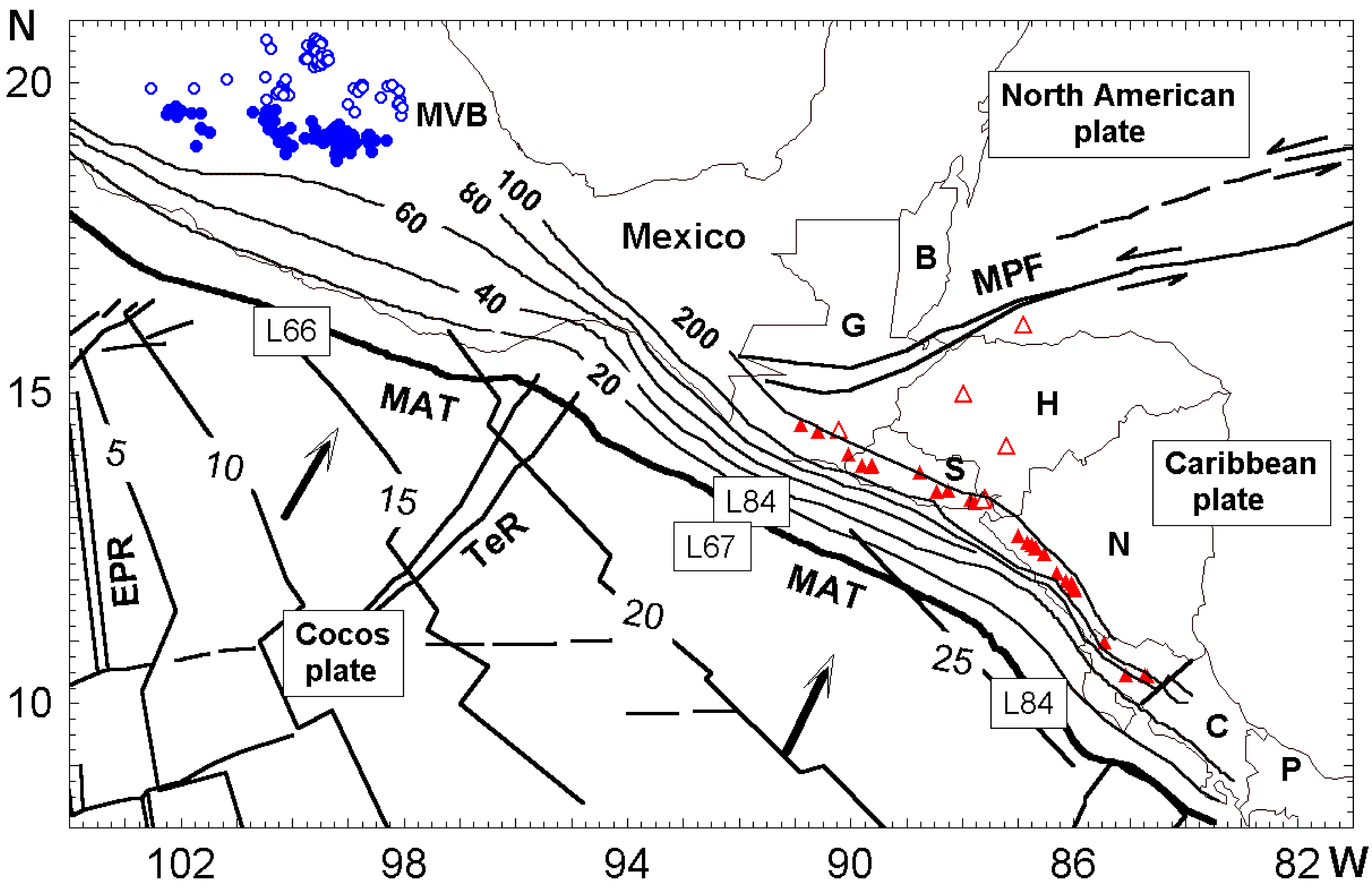
Verma, S.P., 2002a, Absence of Cocos plate subduction-related basic volcanism in southern Mexico: a unique case on Earth?: Geology, v. 30, p. 1095-1098.

Verma, S.P., 2002b, Geochemical and Sr-Nd isotopic evidence for a rift-related origin of magmas in Tizayuca volcanic field, central Mexican volcanic belt: Journal of Geological Society of India, in press.

Verma, S.P., Carrasco-Núñez, G., and Milán, M., 1991, Geology and geochemistry of Amealco caldera, Qro., Mexico: Journal of Volcanology and Geothermal Research, v. 47, p. 105-127.

Verma, S.P., Torres-Alvarado, I.S., and Sotelo-Rodríguez, Z.T., 2002, SINCLAS: standard igneous norm and volcanic rock classification system: Computers & Geosciences, v. 28, p. 711-715.

Wallace, P. J., and Carmichael, I. S. E., 1999, Quaternary volcanism near the Valley of Mexico: implications for subduction zone magmatism and the effects of crustal thickness variations on primitive magma compositions: Contributions to Mineralogy and Petrology, v. 135, p. 291-314.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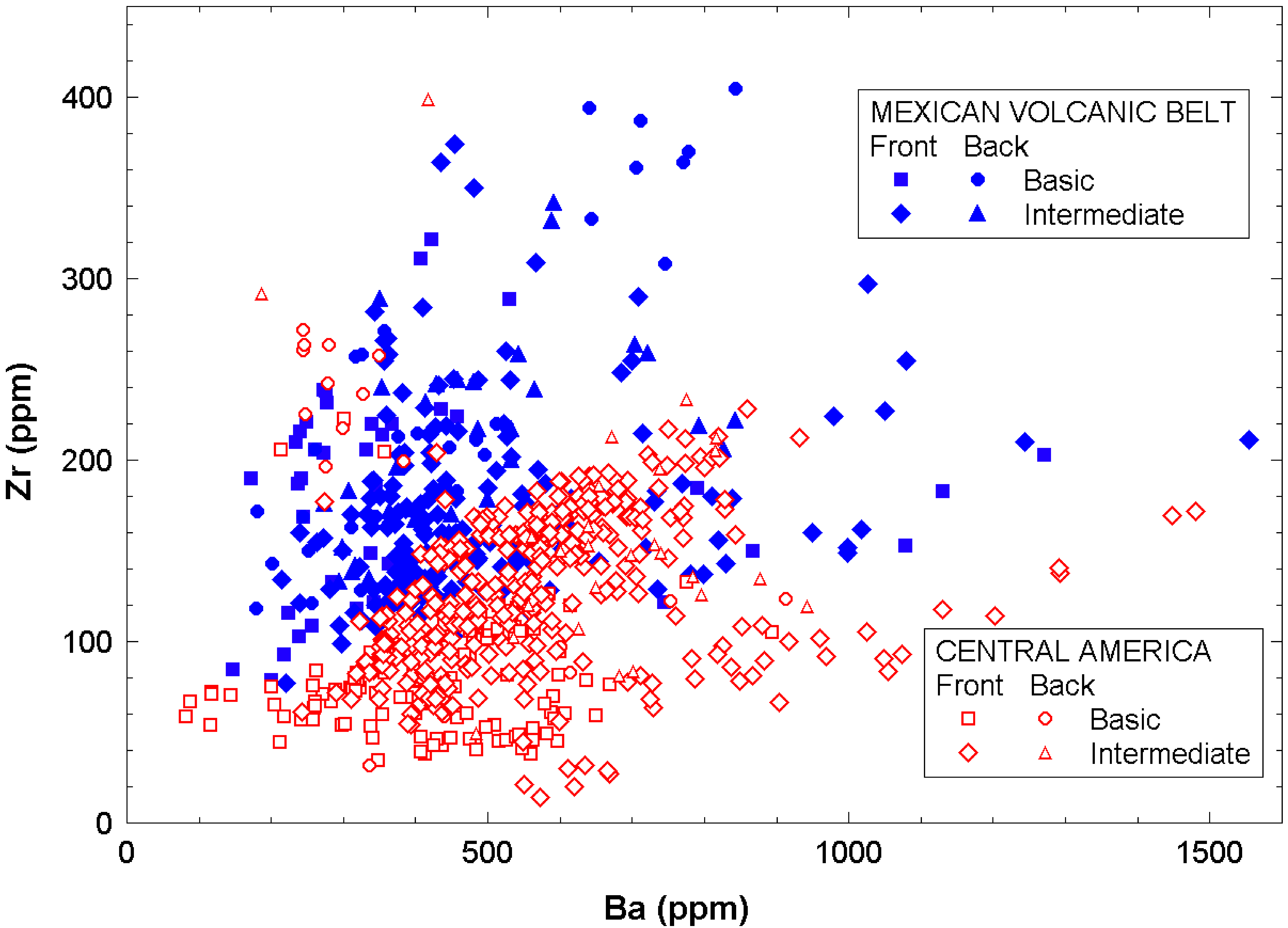

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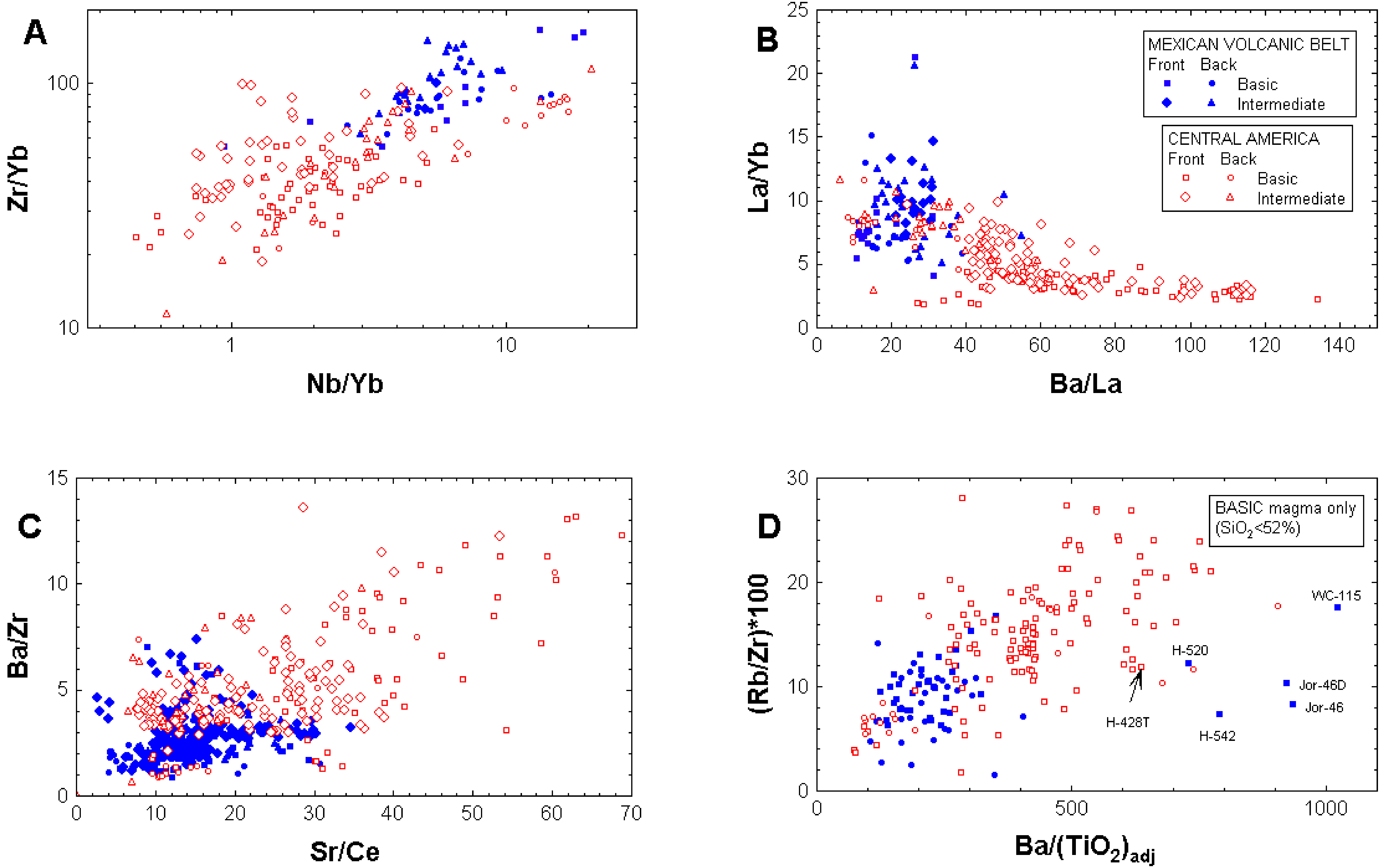
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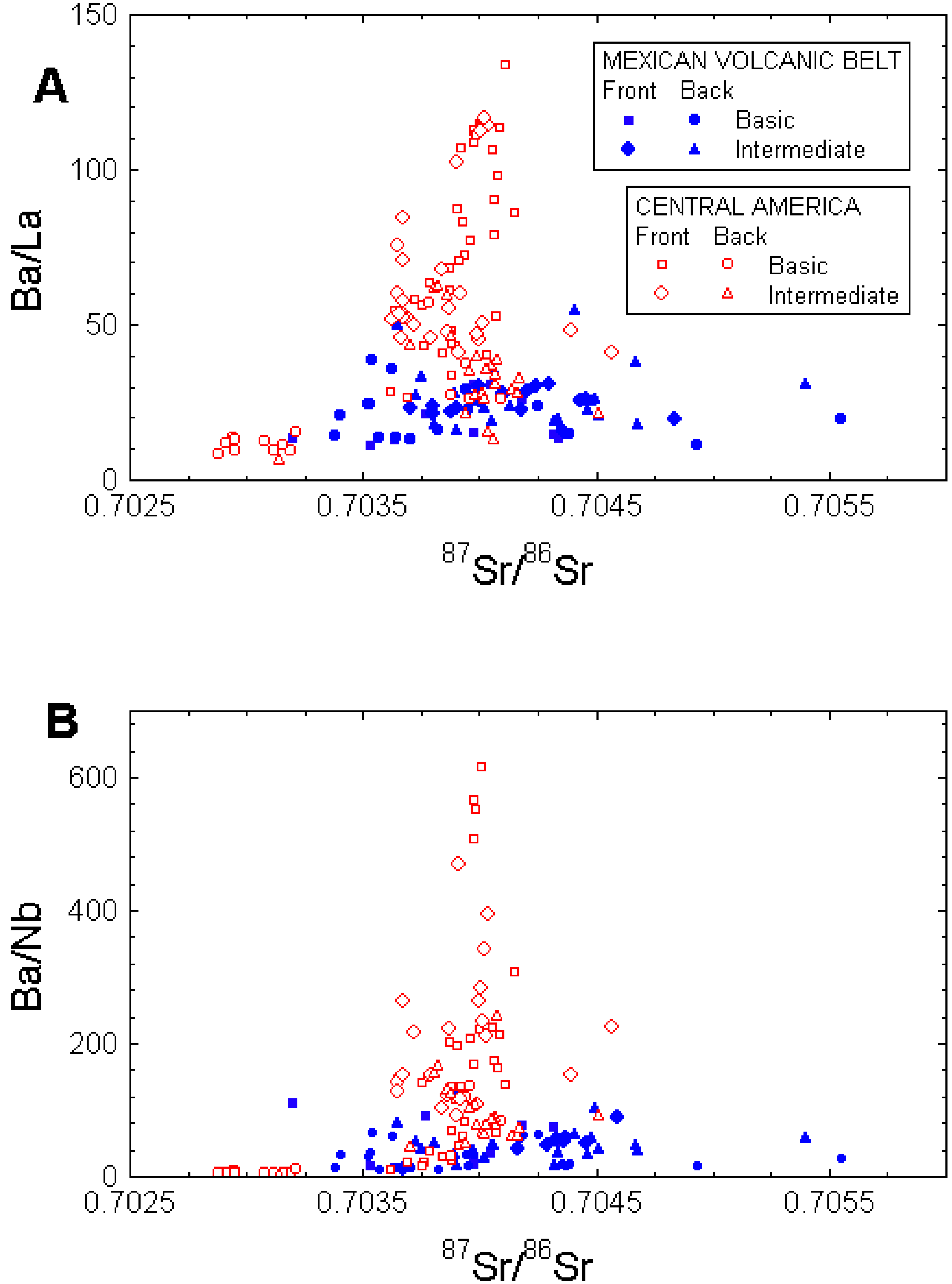
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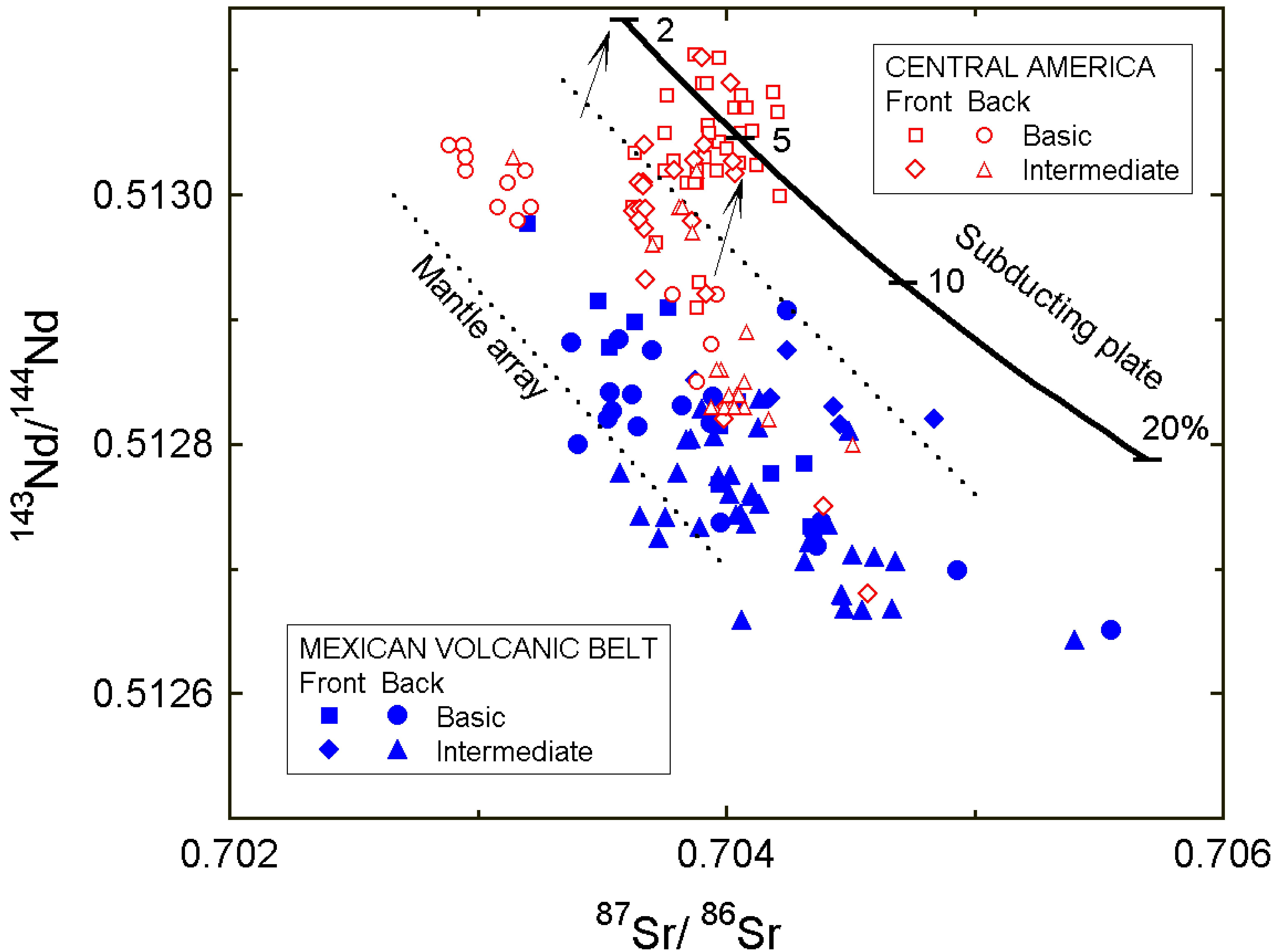

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