Chapter 6 –

Sr-Nd ISOTOPIC DATA

6.1 Introduction

Sr-Nd isotopic data were obtained for 6 samples of Serre calcalkaline dykes (two basaltic andesites, two andesites and two dacite-rhyodacites) and for 4 samples of alkaline and tholeiitic Sicilian dykes (two alkali basalts and two tholeiitic basalts).
Considering that almost all samples suffered an extensive hydrothermal alteration, the least altered sample have been chosen. Nevertheless, the possibility that the Rb-Sr values, especially, may have suffered post-magmatic modifications must be taken in consideration.

Although reliable geochronological information is so far lacking for the calcalkaline dykes intruding Hercynian metapelites and late-Hercynian undeformed granitoid rocks in the Serre Massif, Sr-Nd isotopic data have been age-corrected to 290 Ma.
Isotopic data for alkaline and tholeiitic dykes, intruding the Ladinic and Middle Triassic - Early Carnian terrains of the Lercara Fm., respectively, have been age-corrected for 230 Ma.
However, errors in the ages of tens of Ma would make insignificant differences in the values calculated, especially for the εNd values, for both Calabria and Sicilian dykes.
Sample list and obtained data are reported in the following table 6.1.
Analytical methods are reported in Appendix 3.

Table 6.1: Sr-Nd isotopic data for analyzed samples.

Sample	*Rb (ppm)*	*Sr (ppm)*	$^{87}Sr/^{86}Sr$	$(^{87}Sr/^{86}Sr)i$	*Sm (ppm)*	*Nd (ppm)*	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Nd_i	*ε Nd*
Calcalkaline rocks										
LMA 3	39.44	439.53	0.711621 ± 38	0.7116	11.65	66.31	0.1062 ± 6	0.512333 ± 10	0.512145	-5.96
PDL 12	34.69	317.98	0.709787 ± 26	0.7098	13.44	101.05	0.0804 ± 4	0.512203 ± 10	0.512061	-8.49
A1A	119.67	367.95	0.712727 ± 32	0.7127	5.40	27.75	0.1176 ± 8	0.512428 ± 36	0.512220	-4.10
A3C	123.06	175.71	0.716074 ± 32	0.7161	3.89	20.64	0.1140 ± 6	0.512377 ± 20	0.512176	-5.09
ST39	125.88	193.72	0.712668 ± 32	0.7127	5.57	27.14	0.1242 ± 8	0.512371 ± 22	0.512152	-5.21
ST40	121.11	82.00	0.725422 ± 72	0.7254	10.74	49.90	0.1301 ± 8	0.512263 ± 32	0.512033	-7.32
Alkaline rocks										
VG 1	22.75	600.46	0.706040 ± 34	0.7060	6.10	24.97	0.1476 ± 8	0.512827 ± 16	0.511974	3.69
VG11	7.32	519.27	0.706654 ± 52	0.7067	5.11	21.87	0.1412 ± 8	0.512814 ± 10	0.512601	3.43
Tholeiitic rocks										
BM 2	0.42	350.71	0.707426 ± 36	0.7074	5.59	21.78	0.1550 ± 10	0.512528 ± 18	0.512295	-2.15
MA 3	8.34	249.99	0.707920 ± 30	0.7079	6.67	25.54	0.1578 ± 10	0.512553 ± 10	0.512315	-1.66

Uncertainties are given as 2 S.D. to the last significant digits.

Sr_i and Nd_i (*i* = initial) vakues are calculated for t = 290 Ma (for calcalkaline lithotypes) and for t = 230 Ma (alkaline and tholeiitic lithotypes).

$\varepsilon Nd = \{[^{143}Nd/^{144}Nd] / [^{143}Nd/^{144}Nd_{CHUR}] - 1\} * 10^4$, where CHUR: Chondrite Uniform Reservoir.

6.2 Calabrian dykes

Calabrian dykes, as described in the previous chapter, show typical features of orogenic magmas, such as a calcalkaline composition, LILE enrichment coupled with low abundances of HFSE and generally high LILE/HFSE ratios.

These geochemical features have been commonly assumed to suggest mantle sources modification by addiction of crustal components, mostly during subduction processes (e.g., *Turner et al., 1999; Innocenti et al., 2005; Peccerillo and Martinotti, 2006*).

Sr–Nd isotope composition of Serre dykes appears also very similar to that of typical orogenic magmas [$^{87}Sr/^{86}Sr$ generally higher than Bulk Silicate Earth (BSE) estimates (>0.70445), and $^{143}Nd/^{144}Nd$ lower than the Chondritic Uniform Reservoir (ChUR) estimates (<0.51264)] (*Lustrino et al., 2007*).

$^{87}Sr/^{86}Sr_i$ and $^{143}Nd/^{144}Nd_i$ ratios are characterized by large variation ranges of 0.7098 – 0.7254 and 0.51220 – 0.51237, respectively. In the εNdi vs. $^{87}Sr/^{86}Sr$ diagram (Fig. 6.1), studied rocks plot in the enriched portion of the graph suggesting an enriched mantle source at least for basaltic andesites, andesites and silica-poor dacite-rhyodacites groups. Variable interaction with crustal material are also possible.

The silica-rich dacite-rhyodacites group shows instead an isotopic composition very similar to that of the metasedimentary rocks from the Calabria lower crust (*Caggianelli et al., 1991*), likely suggesting a direct crustal origin.

The difference in the sources invoked to explain the composition of studied calcalkaline Serre dykes is compatible with the variable sources and mechanisms generally indicated to explain the production of calcalkaline magmas in a post-collisional context, as that envisaged for the emplacement of studied dykes.

In fact, for the most basic rocks, decompression melting of an asthenospheric mantle source, previously metasomatized by subduction-related fluids/melts (*Johnson et al., 1978; Cameron et al., 2003*) or of a continental lithospheric mantle previously modified by subduction (*Hawkesworth et al., 1995; Wilson et al., 1997*), is commonly suggested.

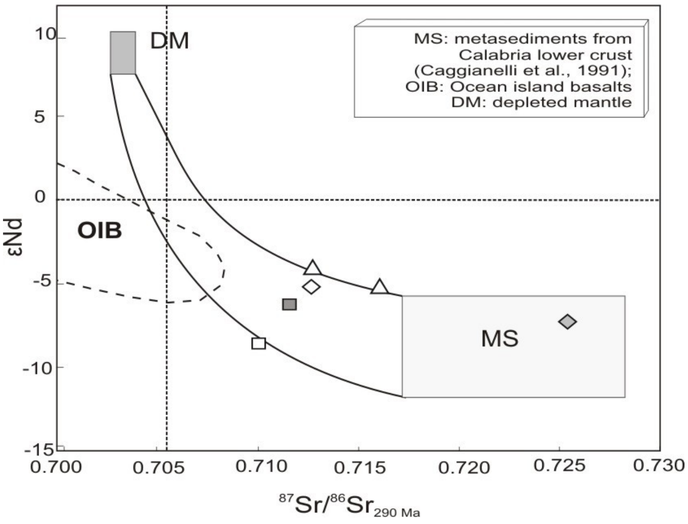

Fig. 6.1: εNd vs. $^{87}Sr/^{86}Sr_{290\ Ma}$ diagram for Serre calcalkaline rocks. DM: depleted mantle: MS: metasediments from Calabria lower crust (*Caggianelli et al., 1991*). Dashed curves are two possible mixing lines between DM and MS (*Rottura et al., 1991*). Empty square: PDL12 sample; filled square: LMA3 sample; empty triangles: A samples; empty rhomb: ST39 sample (Silica-poor group); filled rhomb: ST40 sample (silica-rich group).

Moreover, the same calcalkaline compositions could also represent the effects of the interaction between mantle-derived melts with the continental crust, through concurrent wall-rock assimilation and fractional crystallization (*Stille and Buletti, 1987; Innocent et al., 1994; Rottura et al., 1998; Cannic et al., 2002*).

For the most acidic rocks, a direct origin from crustal anatexis, possibly triggered by underplating of mantle-derived melts at the base of the crust, is instead considered very likely.

In such a context, basaltic andesites, andesites and silica-poor dacite-rhyodacites Serre dykes could be considered as the result of partial melting of an enriched mantle source, metasomatized by subduction-related components, and later variable interaction of produced magmas via AFC or mixing processes, with silicic crustal rocks, as supported by the positive correlation between $^{87}Sr/^{86}Sr$ and SiO_2 contents (Fig. 6.2). Indeed, simple FC processes produce typically a near-horizontal trend at constant $^{87}Sr/^{86}Sr$ values, whereas interaction with crustal components, shifts the trend towards the isotopic compositions of the crustal component. The silica-rich dacite-rhyodacite, characterized by higher Sr isotopic values deviating from the observed trend (Fig. 6.2), is instead compatible with a direct crustal origin.

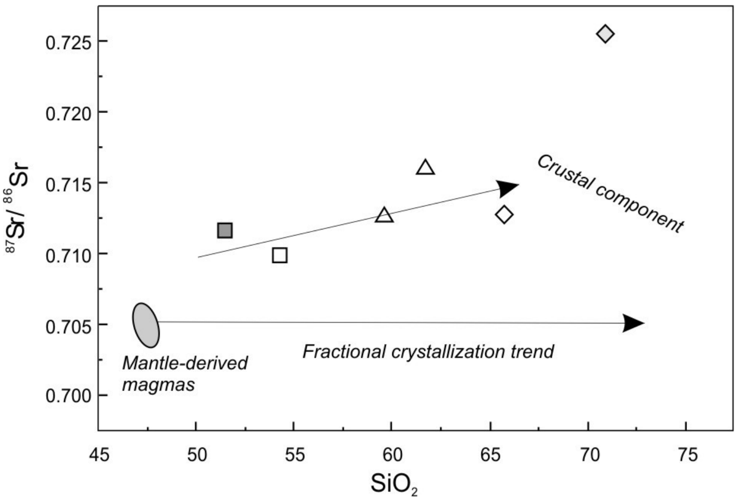

Fig. 6.2: $^{87}Sr/^{86}Sr_i$ vs. SiO_2 diagram for Serre calcalkaline rocks. Symbol as in Fig. 6.1.

6.3 Sicilian dykes

Most anorogenic magmatic products (sodic-alkaline to tholeiitic) are typically characterized by major and trace element (high HFSE and high HFSE/LILE ratios) and isotopic composition ($^{87}Sr/^{86}Sr$ generally lower than BSE, and $^{143}Nd/^{144}Nd$ higher than CHUR) indicating a derivation from enriched mantle sources not modified by subduction-related processes (*Lustrino et al., 2007*).

In studied rocks, these conditions are partly verified. In fact, although in both alkaline and tholeiitic rocks, major and trace elements composition typical of anorogenic magmas have been recognized (Chapter 5), the isotopic compositions show some inconsistencies.

Indeed, VG alkaline basalts show Nd isotopic ratios ($^{143}Nd/^{144}Nd_i$ = 0.51283 - 0.51281) always higher than CHUR, whereas $^{87}Sr/^{86}Sr_i$ (0.7060 - 0.7067) values are higher than BSE, indicating a magma source more enriched than a typical primitive reservoir (*BSE-type*) but less enriched than a typical enriched one (*EMI-type*).

In the εNd vs. $^{87}Sr/^{86}Sr$ diagram (Fig. 6.3), points representative of samples overlap the wide compositional field of OIB-type source, reflecting the influence of a moderately depleted source, and fall near the Permian Pyrenees alkaline rocks compositions (*Lago et al., 2004*).

The depleted character of the envisaged source, however, strongly contrasts with trace elements patterns signatures suggesting a derivation from an enriched mantle source. Nevertheless, this apparent contrast could be referred to a possible metasomatic event by LILE-rich fluids, and thus a re-enrichment of an originally depleted source (*Obst et al., 2004*).

A similar mechanism has been indeed hypothesized to explain the composition of the Permian Pyrenees alkaline rocks, for which authors suggested a derivation from an isotopic depleted mantle source that had experienced a recent metasomatic enrichment (*Lago et al., 2004*).

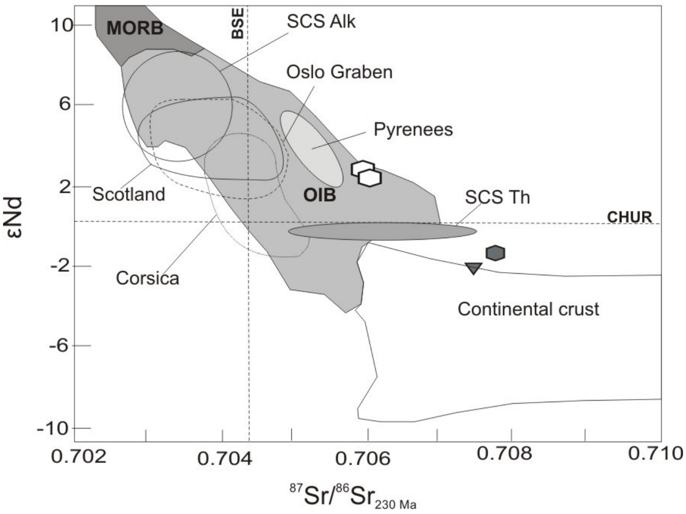

Fig. 6.3: εNd vs. $^{87}Sr/^{86}Sr_{230\ Ma}$ diagram for Sicilian dykes. MORB and OIB fields after *Zindler and Hart* (1986). Compositional fields of Pyrenees, Oslo Graben, Spanish Central System (SCS Alk: alkaline lamprophyres, SCS Th: tholeiitic dykes), Scotland and Corsica are from *Lago et al.* (2004), *Neumann et al.* (2004), *Orejana et al.* (2008); *Upton et al.* (2004) and *Bonin* (2004), respectively.

Tholeiitic rocks are characterized by $^{87}Sr/^{86}Sr_i$ ratios of 0.70743 - 0.70792 and $^{143}Nd/^{144}Nd_i$ ratios of 0.51253 - 0.51255.

They fall in the enriched portion of the εNd vs. $^{87}Sr/^{86}Sr_i$ diagram (Fig. 6.3), characterized by higher radiogenic Sr values and negative $εNd_i$ (from -1.66 to -2.15), indicating partial melting of an enriched mantle source and variable interaction with crustal rocks or, alternatively, the direct involvement of a reservoir broadly similar to the *EM-II type* (Fig. 6.4), whose enriched character is related to the incorporation of recycled crustal material into the mantle source, through subduction process (*Zindler and Hart, 1986*).

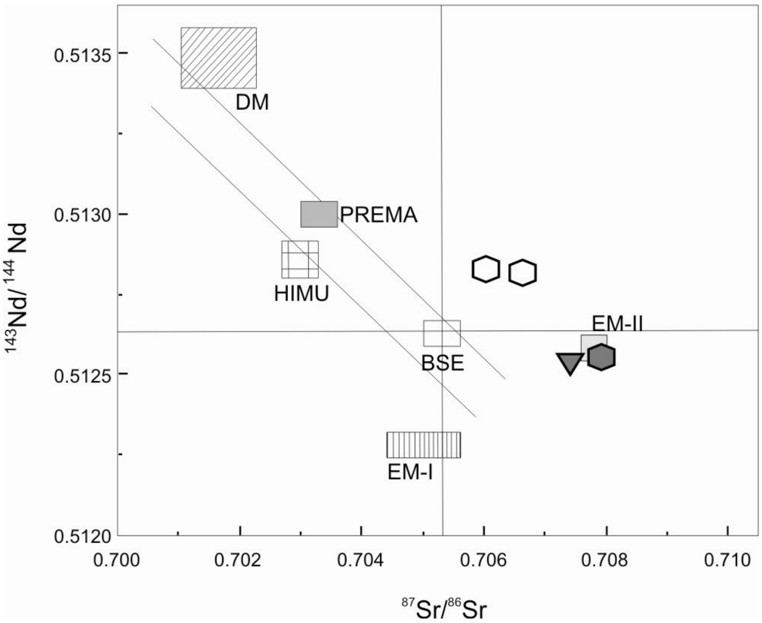

Fig. 6.4: $^{143}Nd/^{144}Nd_i$ vs. $^{87}Sr/^{86}Sr$ diagram for Sicilian dykes. DM: depleted mantle; enriched mantle: EM-I (metasomatised lithosphere), EM-II (subducted continental material), HIMU (oceanic lithosphere). BSE: Bulk Silicate Earth; PREMA: Prevalent Mantle (*Zindler and Hart, 1986*).