U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

A geochemical and isotopic (Nd-Pb) comparison of volcanic rocks erupted during the last 3,550 yrs. B.P. of interplinian activity of Somma-Vesuvius volcano, Southern Italy

R. Somma[1-2], R.A. Ayuso [1], B.De Vivo [2]

[1] U.S. Geological Survey, National Center, Mail Stop 954 Reston, VA 20192, USA

[2] Dipartimento di Geofisica e Vulcanologia , Via Mezzocannone 8, Napoli, 80134, Italy.

Open File Report 99-365

Abstract

Detailed stratigraphic sampling of formations from Somma-Vesuvius (Southern Italy) volcano complex erupted during the last 3550 years of inteplinian activity provide a framework for comprehensive chemical analyses and isotopic studies. The evolution of major- and trace-element abundances of these rocks suggest that fractional crystallization together with crustal assimilation are only a partial explanation of the complex processes occurring in the magma chamber. Our Nd and Pb isotopic data point to complex processes involving contributions from heterogeneus lithosphere, assimilation of continental crust, and magma mixing.

Introduction

This study is focused on establishing the geochemical and radiogenic isotope (Sr, Nd, Pb) signatures of magma sources of lavas and tephra erupted during Protohistoric (3550 yrs. BP.-79 A.D), Ancient Historic (A.D.79-472) and Medieval (472-1139 A.D.) interplinian activity of Somma-Vesuvius volcano (Fig.1). These data contribute to understanding the chemical evolution of the magmas during the interplinian activity at Mount Somma-Vesuvius and the relation between magma chemistry and its possible contribution to the mechanisms triggering explosive and effusive eruptions. We present here a progress report of the isotopic work done in the radiogenic lab of the U.S. Geological Survey, Reston VA.

The interplinian eruptions vary systematically in composition from tephri-phonolite to phono-tephrite (Fig.2). Radiogenic isotope compositions ($^{143}Nd/^{144}Nd$: 0.512504-0.512233; $^{206}Pb/^{204}Pb$: 18.984-19.051; $^{207}Pb/^{204}Pb$: 15.625-15.708; $^{208}Pb/^{204}Pb$: 39.132-39.229) are similar to the overall Mount Somma-Vesuvius record for recent magmatic activity (Cortini and van Calstern, 1985; Ferrara et al., 1986; Civetta et al.1987; Cortini and Don Hermes, 1981;Civetta et al., 1991; Santacroce et al., 1993; Cioni et al., 1995; Caprarelli et al., 1993; D'Antonio et al. 1995; Ayuso et al., 1998) and the Roman Comagmatic Province in general (Vollmer, 1976; Vollemer and Hawkesworth, 1980;

Vollmer et al., 1981; Civetta et al., 1981; Rogers et al., 1985) and suggest the presence of enriched mantle sources. Chemical data obtained for the interplinian activity are compared to data for the plinian eruptions from the literature; the new geochemical database will be used to improve predictive models needed for evaluating the volcanic hazards associated with Mount Somma-Vesuvius.

Volcanological aspects of the interplinian activity at Mount Somma-Vesuvius.

Mitigation of volcanic hazards in densely inhabited areas is vital to ensure the welfare of people in the region-- about 800,000 people live on and around the flanks of Mount Somma-Vesuvius and there is a high potential for loss of lives and significant impact on the infrastructure of the region (Fig. 1). More than 15 cities are located on the flanks of Somma-Vesuvius - all are susceptible to destruction in the event of renewed explosive activity.

The Somma-Vesuvius volcanic complex is at the southern end of the Roman Comagmatic Province and is characterized by rocks belonging to the high potassium (HK) series. The volcanic material ranges from effusive lava to explosive tephra deposits. Recently, Ayuso et al. (1998) focused on three main cycles of activity, which reflect cycles identified by Arno' et al. (1987), and further defined by tephrostratigraphic and tephrocronologic studies by Rolandi et al. (1998). The first cycle of activity (>25-14 Ky B.P.) is characterized by several huge explosive eruptions (Codola, Sarno, Novelle, Seggiari, Lagno Amendolare) separated by small-scale effusive activity. The second cycle (8 Ky B.P.- 79 A.D.) is dominated by two plinian eruptions (Ottaviano and Avellino) and moderate strombolian-vulcanian activity. The third cycle of activity (79 A.D.-1944) is characterized by plinian ("Pompei") and subplinian eruptions ("Pollena", 1631) and "interplinian" strombolian-vulcanian activity.

Previous studies (Vollmer, 1976; Hawkesworth and Vollmer, 1979; Vollmer and Hawkesworth, 1980; Cortini and Don Hermes, 1981; Cortini and van Calstern, 1985; Santacroce et al., 1993; D'Antonio et al., 1995; Cioni et al., 1995, Aysuo et al., 1998) focused on the geochemical and radiogenic composition of the magmas erupted during the plinian activity--only limited data are now available for the interplinian activity.

Knowledge about the interplinian activity at Mount Somma-Vesuvius before the 1631 A. D. interplinian eruption is incomplete due to the relatively small amount of magma erupted, relatively few scattered outcrops, and the difficulty of reconstructing valid stratigraphic sections for these deposits. Interplinian activity during the 25,000-14,500 yr B.P., predating the main Sarno plinian eruption, is found along the N and NE flanks of the volcano and mainly consists of lava flows and scoria fall layers emitted during strombolian-vulcanian activity. Successively different tephra outcrops belonging to the interplinian activity have also been recognized along the Mount Somma flanks. They mainly consist of scoria fall layers, lava flows and black nuee' ardent scoria deposits.

After the Avellino eruption (3,800 yr B.P.), well-defined interplinan activity has been identified on the N-NE to S-SE flanks of the volcano (Rolandi et al., 1998). Evidence for three main eruptions has been found intercalated with paleosoils rich in charcoal. The deposits consist of pumice layers of different grain-sizes and of conspicuous enrichment of lithic fragments and crystals in the finer fractions. The volume of magma erupted varies from 0.07 km^3 dense rock equivalent (DRE) for the 1^{st} protohistroric eruption to 0.19 km^3 DRE for the 3^{rd} protohistoric eruption.

The four strombolian-phreatomagmatic Medieval deposits were emplaced between the eruptive deposits of 472 A.D. and 1631 A.D. The volume of magma erupted for each event ranges between 0.05-0.10 km^3 DRE. Isopleth maps of selected interplinian layers show dispersion axes oriented toward the southeast except for tephra erupted during the 1^{st} Medieval event which shows a dispersion axis toward the northeast. The data confirm that the eruptive columns which emplaced the interplinian layers had low energy and reached altitudes no higher than 10 km.

The activity at Somma-Vesuvius after the 1631 eruption is characterized by more than 300 years of nearly constant effusive eruptions with minor pyroclastic events usually occuring at the end of the eruptive cycles. This interplinian activity consists of a series of intermediate eruptions and of strombolian activity preceding the final eruption; Arno' et al. (1987) recognized 18 cycles of activity based on historic records.

Geochemical and isotopic (Nd-Pb) features of Protohistoric, Ancient Historic and Medieval interplinian activity at Mount Somma-Vesuvius

The geochemical analyses show that the products of the Medieval eruption vary from tephri-phonolite to phono-tephrite (Na_2O+K_2O: 8.1-11.4 wt %; SiO_2 49.9-46.8 wt %) (Fig.1). The radiogenic isotopic compositions (Table 1) for scoria ($^{143}Nd/^{144}Nd$: 0.512422-0.512504; $^{206}Pb/^{204}Pb$: 18.984-19.051; $^{207}Pb/^{204}Pb$: 15.625-15.708; $^{208}Pb/^{204}Pb$: 39.132-39.229) show values similar to the recent Mount Somma-Vesuvius magmatic activity (Ayuso et al., 1998; Caprarelli et al., 1993). Fig.3a-b shows the lead isotopic compositions for Protohistoric, Ancient Historic and Medieval interplinian activities. The $^{206}Pb/^{204}Pb$ isotopic compositions have distinct trends, from less radiogenic (Protohistoric) to more radiogenic (Ancient Historic), and than back to less radiogenic for the Medieval activity and ultimately to compositions that nearly match those of the Protohistoric rocks, suggesting the presence of heterogeneity in the sources involved during the interplinian activity.

Lavas and tephra erupted during the Recent 1631-1944 A.D. activity (Arno' et al., 1987; Belkin et al., 1993 a, b; Trigila et De Benedetti, 1993) have a relatively narrow range for SiO_2, TiO_2, FeO (total), MnO and P_2O_5 wt %; systematic variations exist between MgO, K_2O, Na_2O, Al_2O_3 and CaO wt % that point to a relative depletion or accumulation of clinopyroxene from the magma. Isotopic compositions of Nd and Sr for the Recent activity (Hawkesworth and Vollmer, 1979; Cortini and Hermes, 1981; Civetta et al., 1991) show a slightly smaller range than values reported by Caprarelli et al. (1993) for the same units ($^{143}Nd/^{144}Nd$: 0.512379-0.512605; $^{87}Sr/^{86}Sr$: 0.70716-0.70790). The $^{143}Nd/^{144}Nd$ isotopic ratios for the interplinian Protohistoric, Ancient Historic and Medieval tephra analyzed in this study plot within the range determined for the Recent interplinan activity (Caprarelli et al., 1993; Ayuso et al., 1998).

We also note that the Nd isotopic compositions change systematically according to the stratighraphic position of the sample. From the Protohistoric ($^{143}Nd/^{144}Nd$: 0.512404-0.512470) to the Ancient Historic ($^{143}Nd/^{144}Nd$: 0.512449-0.512507), the values generally increase. The opposite trend exists for the Medieval ($^{143}Nd/^{144}Nd$: 0.512504-0.512406) interplinian activity (Fig.4). Our preliminary conclusion is that the isotopic variations of Pb and Nd could be explained by the progressive emptying of a zoned magma chamber containing isotopically heterogeneous magmas. The isotopically heterogeneous magmas could reflect the interaction of magmas derived from enriched-type mantle and the continental crust or continental mantle lithosphere (Stoltz et al., 1996; Ayuso et al., 1998). Heterogeneous sources may also result from melting of underplated subcontinental lithosphere in this area during crustal extension involved during the opening of the Tyrrhenian Sea (Lavecchia and Stoppa, 1996; Ayuso et al., 1998).

References

Arno' V., Principe C., Rosi M., Santacroce R., Sbrana A. & Sheridan M.F., 1987, Eruptive history: Santacroce ed., *CNR* Quad. Ric. Sci. 114, p. 197-220

Ayuso R., De Vivo B., Rolandi G., Seal II R.R. and Paone A., 1998, Geochemical and isotopic (Nd-Pb-Sr-O) variations bearing on the genesis of volcanic rocks from Vesuvius, Italy: Journal of Volcanological and Geothermal Research, v. 82, p. 53-78.0

Belkin H.E., Kilburn C.R.J., and De Vivo B., 1993a, Chemistry of the lavas and tephra from the recent (A.D. 1631-1944) Vesuvius (Italy) volcanic activity: U.S. Geological Survey Open file report 93-399, p. 44

Belkin H.E., Kilburn C.R.J., and De Vivo B.,1993b, Sampling and major element chemistry of the recent (A.D. 1631-1944) Vesuvius activity; Journal of Volcanological and Geothermal Research, v. 58, p. 273-290

Caprarelli G., Togashi S. and De Vivo B., 1993, Preliminary Sr and Nd isotopic data for recent laves from Vesuvius volcano: Journal of Volcanological and Geothermal Research, v. 58, p 377-381.

Cioni R., Civetta L., Marianelli P., Metrich N., Santacroce R. and Sbrana A.,1995, Compositional layering and syn-eruptive mixing of a periodically rifilled shallow magma chamber: the A.D. 79 plinian eruption of Vesuvius: J. of Petrology, v. 36, p. 739-776.

Civetta L., Galati R. and Santacroce R., 1991, Magma mixing and convective compositional layering within the Vesuvius magma chamber. Bull. Volcanol., v. 53, p. 287-300.

Civetta L., D'Antonio M., Paone E., Santacroce R., 1987, Isotopic studies of the products of the 472 A.D. Pollena eruption (Somma-Vesuvius): Bollettino GNV, 1987, p. 263-271.

Civetta L., Innocenti F., Manetti P., Peccerillo A. and Poli G., 1981,. Geochemical characteristics of potassic volcanics form Mts. Ernici (Southern Latium, Italy): Contr. Mineral. Petrol., v. 78, p. 37-47.

Cortini M. and Don Hermes O. ,1981, Sr isotopic evidence for a multi-source origin of the potassic magmas in the Neapolitan Area (S. Italy): Contrib Mineral. Petrol., v. 77, p. 47-55.

Cortini M. and van Calstern W.C.,1985, Lead isotope differences between whole-rock and phenocrysts in recent lavas from southern Italy: Nature, v. 314, p. 343-345.

D'Antonio M., Tilton G.R. and Civetta L., 1995, Petrogenesis of Italian alkaline laves deduced from Pb-Sr-Nd isotope relationships: American Geophysical Union Monogr. Dedicated to M. Tatsumoto and G. R. Tilton, p. 253-267.

De Vivo B., Torok K., Ayuso R.A., Lima A. and Lirer L., 1995, Fluid inclusion evidence for magmatic silicate/saline /CO_2 immiscibility and geochemistry of alkaline xenoliths from Ventotene Island, Italy: Geochim. Cosm. Chim. Acta, v. 59, p. 2941-2953.

Ferrara G., Preite-Martinez M., Taylor H.P. Jr, Tonarini S. and Turi B., 1986, Evidence for crustal assimilation, mixing of magmas, and a ^{87}Sr-rich upper mantle: Contr. Mineral. Petrol., v. 92, p. 269-280.

Hawkesworth C.J. and Vollmer R., 1979, Crustal contamination versus enriched mantle: ^{143}Nd/^{144}Nd and ^{87}Sr/^{86}Sr evidence from the Italian volcanics: Contr. Mineral. Petrol., v. 69, p. 151-165.

Lavecchia G. and Stoppa F., 1996, The tectonic significance of Italian magmatism: an alternative view to popular interpretations: Terra Nova, v. 8, p. 435-446.

Rogers N.W., Hawkesworth C.J., Parker R.J. and Marsh J.S., 1985, The geochemistry of potassic lavas form Vulsini, central Italy and implications form mantle enrichment processes beneath the Roman region: Contrib. Mineral. Petrol., v. 90, p. 244-257.

Rolandi G., Petrosino P. and Mc Geehin J., 1998, The interplinian activity at Somma-Vesuvius in the last 3500 years: Journal of Volcanological and Geothermal Research., v. 82, p. 19-52.

Santacroce R., Bertagnini A., Civetta L., Landi P. and Sbrana A., 1993, Eruptive dynamics and petrogenetic processes in a very shallow magma resevoir: the 1906 Eruption of Vesuvius: J. of Petrology, v. 34, p. 383-425.

Stoltz A.J., Jochum K.P., Spettel B., Hoffman A.W., 1996, Fluid- and melt-related enrichment in the subarc mantle: evidence from Nb/Ta variations in island arc basalts: Geology, v. 24, p. 587-590

Trigila R. and De Benedetti A. A., 1993, Petrogenesis of Vesuvius historical lavas constrained by Pearce element ratios analysis and experimental phase equilibria: Journal of Volcanological and Geothermal Research., v. 58, p. 315-343.

Vollmer R., 1976, Rb-Sr and U-Th-Pb systematics of alkaline rock: the alkaline rocks from Italy: Geoch. Cosm. Acta, v. 40, p. 283-295.

Vollmer R. and Hawkesworth C.J., 1980, Lead isotopic composition of potassic rocks from Roccamonfina (South Italy): Earth Planet Sci. Lett., v. 47, p. 91-101.

Vollmer R., Johnston K., Ghiara M.R., Lirer L. and Munno R., 1981, Sr isotope geochemistry of megacrysts form continental rift and converging plate margin alkaline volcanism in Southern Italy: Journal of Volcanological and Geothermal Research, v. 11, p. 317-327.

CAPTIONS

Tab.1. Lead and neodymium isotopic compositions for whole rocks form Protohistoric, Ancient Historic and Medieval interplinian activity.

Fig.1. Generalized geologic map of Somma-Vesuvius volcano and location of samples used in the comprehensive studies of this region (Ayuso et al., 1998). Samples used in this study shown in bold and underlined.

Fig.2. Silica/total alkali plot for Protohistoric, Ancient Historic and Medieval eruption glasses (Rolandi et al., 1998), and Recent (1631-1944 A. D.) interplinian activity (Belkin et al., 1993 a-b). Also shown for reference are the three compositional groups identified by Ayuso et al. (1998) and reported as insert the trend of Plinian Somma-Vesuvius activity in a silica/total alkali simplified plot.

Fig. 3. Pb isotope diagrams for interplinian Protohistoric, Ancient Historic and Medieval whole rocks: (a) $^{208}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$, (b) $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$. Ventotene xenoliths from De Vivo et al. (1995); Somma-Vesuvius cumulate from Cortini and van Calstern (1985); Recent (1631-1944 A. D.) interplinian activity from Caprarelli et al. (1993) and Ayuso et al. (1998). Arrows show possible mixing lines for Protohistoric, Ancient Historic and Medieval interplinian activity.

Fig.4. $^{143}Nd/^{144}Nd$ vs. Stratigraphic position for interplinian Protohistric, Ancient Historic and Medieval whole rocks. Also reported are results of the Recent interplinian activity (Caprarelli et al.,1993 and Ayuso et al.,1998).

Table 1

ID	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{143}Nd/^{144}Nd$
	Medieval (472-1631 A.D.)			
R-1(1) Res	19.0337	15.6788	39.1414	0.512504
R-1(1) L1	19.0532	15.7090	39.2254	
R-1(1)L2	19.0236	15.6719	39.1107	
R-2(1) Res	18.9827	15.6429	39.0161	0.512472
R-2(1) L1	19.0390	15.7108	39.2413	
R-2(1) L2	18.9726	15.6282	38.9584	
R-3(1)A Res	18.9772	15.6466	39.0054	0.512453
R-3(1)A L1	18.9733	15.6413	38.9945	
R-3(1)A L2	18.9645	15.6304	38.9595	
R-3(1)B Res	19.0142	15.6704	39.1065	0.512440
R-3(1)B L1	18.9765	15.6319	38.9868	
R-3(1)B L2	18.9998	15.6561	39.0703	
R-3(1)C Res	19.0009	15.6425	39.0321	0.512454
R-3(1)C L1	18.9932	15.6332	38.9991	
R-3(1)C L2	19.0313	15.6805	39.1587	
R-3(1)D Res	19.0409	15.6875	39.1812	0.512436
R-3(1)D L1	19.0324	15.6752	39.1421	
R-3(1)D L2	19.0199	15.6622	39.1022	
R-3(1)E Res	19.0005	15.6353	39.0121	0.512471
R-3(1)E L1	18.9897	15.6209	38.9645	
R-3(1)E L2	19.0307	15.6717	39.1351	
R-3(1)F Res	19.0334	15.6664	38.7599	0.512463
R-3(1)F L1	18.9952	15.6252	38.9772	
R-3(1)F L2	18.9923	15.6316	39.0175	
R-4(1)A Res	18.9926	15.6700	39.0854	0.512234
R-4(1)A L1	19.0239	15.6952	39.1893	
R-4(1)A L2	18.9687	15.6342	38.9716	
R-4(1)B Res	19.0053	15.6626	39.0703	0.512406
R-4(1)B L1	18.9809	15.6467	39.0131	
R-4(1)B L2	19.0434	15.6398	39.0167	
	Ancient Historic (A.D. 79-472)			
S20(1) Res	19.0488	15.6554	39.0894	0.512449
S20(1) L1	19.0333	15.6341	39.0186	
S20(1) L2	19.0433	15.6492	39.0657	
S20(2) Res	19.0642	15.6630	39.1092	0.512481
S20(2) L1	19.0530	15.6456	39.0581	
S20(2) L2	19.0587	15.6535	39.0836	
S20(3) Res	19.0615	15.6601	39.1029	0.512462
S20(3) L1	19.0503	15.6456	39.0581	
S20(3) L2	19.0440	15.6401	39.0381	
S20(4) Res	19.0407	15.6473	39.0504	0.512477
S20(4) L1	19.0444	15.6427	39.0442	
S20(4) L2	19.0623	15.6678	39.1238	
S20(5) Res	19.0438	15.6462	39.0432	0.512024
S20(5) L1	19.0884	15.6948	39.2193	
S20(5) L2	19.0601	15.6662	39.1201	
S20(6) Res	19.0188	15.6438	39.0188	0.512467
S20(6) L1	19.0319	15.6383	39.0191	
S20(6) L2	19.0445	15.6560	39.0740	

L1= 1st leach (1.5N HBR+2N HCl) 2.5hrs on low hot plate

L2= 2nd leach (9N HBr) 9 hrs on low hot plate

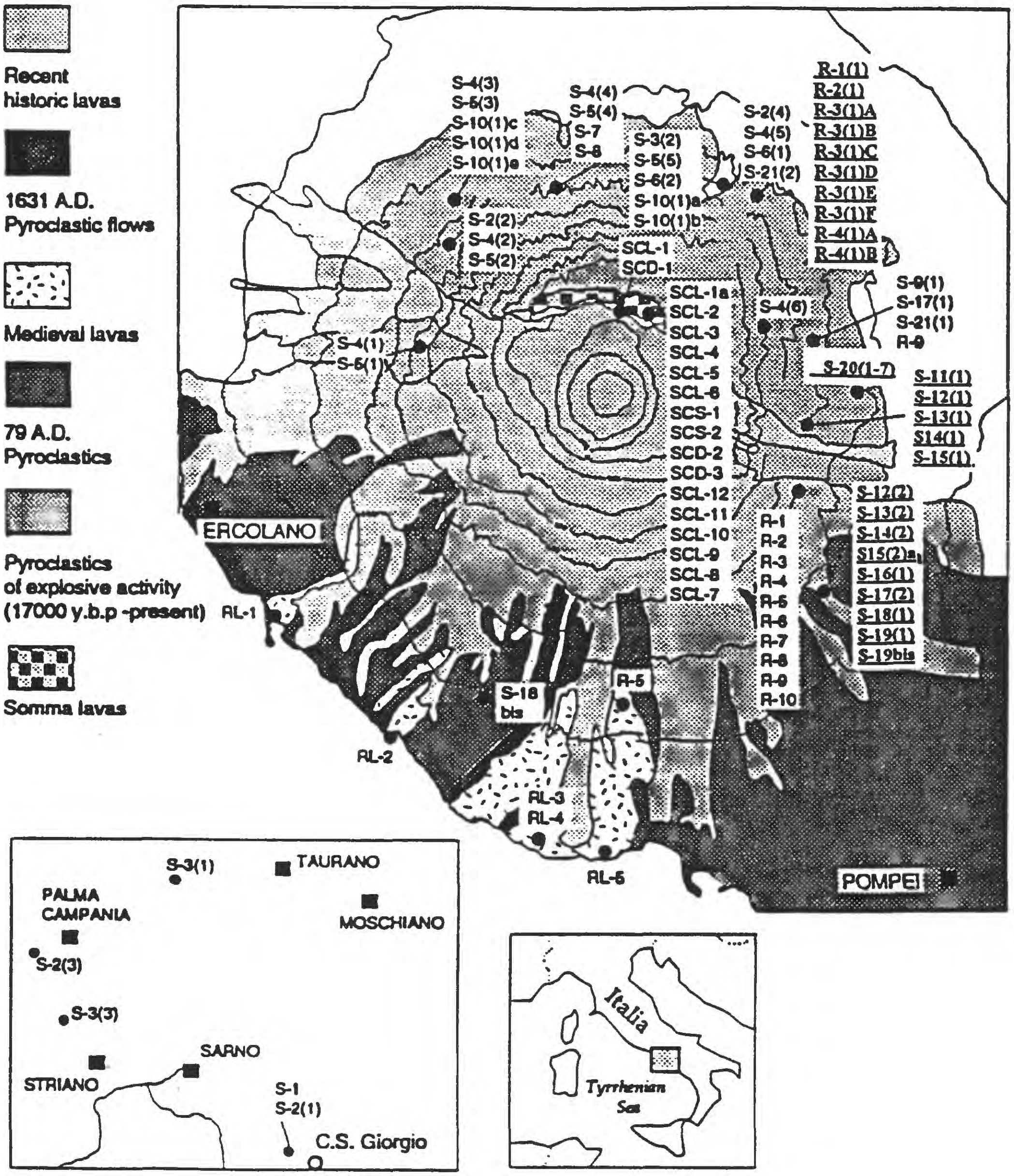
Res.= Residue

Table 1

ID	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{143}Nd/^{144}Nd$
S20(7) Res	19.0811	15.7047	39.2364	0.512507
S20(7) L1	19.0406	15.6490	39.0541	
S20(7) L2	19.0451	15.6563	39.0754	
	Protohistoric (3550 yrs. B.P.- A.D. 79)			
S11(1) Res	18.9779	15.6732	39.1036	0.512405
S11(1) L1	18.9424	15.6218	38.9283	
S11(1) L2	18.9668	15.6516	39.0286	
S12(1) Res	18.9714	15.6524	39.0297	0.512443
S12(1) L1	18.9657	15.6449	39.0049	
S12(1) L2	18.9614	15.6413	38.9925	
S12(2) Res				0.512434
S13(2)a Res				0.512461
S13(2)b Res				0.512404
S13(1)b Res	18.9501	15.6385	38.9876	0.512453
S13(1)b L1	18.9369	15.6305	38.9540	
S13(1)b L2	18.9434	15.6371	38.9777	
S14(1) Res	18.9417	15.6339	38.9699	0.51247
S14(1) L1	18.9572	15.6533	39.0301	
S14(1) L2 wr	18.9488	15.6326	38.9601	
S14(2) Res				0.51243
S15(1)b Res	18.9497	15.6419	38.9951	
S15(1)b L1	18.9481	15.6367	38.9749	
S15(1)b L2	18.9331	15.6191	38.9167	
S15(2)a Res	18.9636	15.6543	39.0362	0.512445
S15(2)a L1	18.9560	15.6412	38.9900	
S15(2)a L2	18.9440	15.6393	38.9906	
S16(1) Res	18.9633	15.6617	39.0584	0.512456
S16(1) L1	18.9978	15.6920	39.1571	
S16(1) L2	18.9767	15.6716	39.0887	
S17(1)a Res	18.9466	15.6325	38.9615	0.512462
S17(1)a L1	18.9558	15.6441	38.9970	
S17(1)a L2	18.9425	15.6305	38.9538	
S17(1)b Res				0.512447
S17(2)a Res				0.512246
S17(2)b Res				0.512460
S18(1)a Res	18.9549	15.6387	38.9805	0.512469
S18(1)a L1	18.9533	15.6378	38.9718	
S18(1)a L2	18.9542	15.6404	38.9807	
S18 bis Res	18.9786	15.6496	39.0551	
S18 bis L1	18.9292	15.6414	38.9628	
S18 bis L2	18.9682	15.6311	38.9800	

L1= 1st leach (1.5N HBR+2N HCl) 2.5hrs on low hot plate
L2= 2nd leach (9N HBr) 9 hrs on low hot plate
Res.= Residue

Fig.1



Recent historic lavas
1631 A.D. Pyroclastic flows
Medieval lavas
79 A.D. Pyroclastics
Pyroclastics of explosive activity (17000 y.b.p -present)
Somma lavas
ERCOLANO
POMPEI
RL-1
RL-2
RL-3
RL-4
RL-5
S-18 bis
R-5
TAURANO
MOSCHIANO
PALMA CAMPANIA
STRIANO
SARNO
C.S. Giorgio
S-3(1)
S-2(3)
S-3(3)
S-1
S-2(1)
Italia
Tyrrhenian Sea

Fig. 2

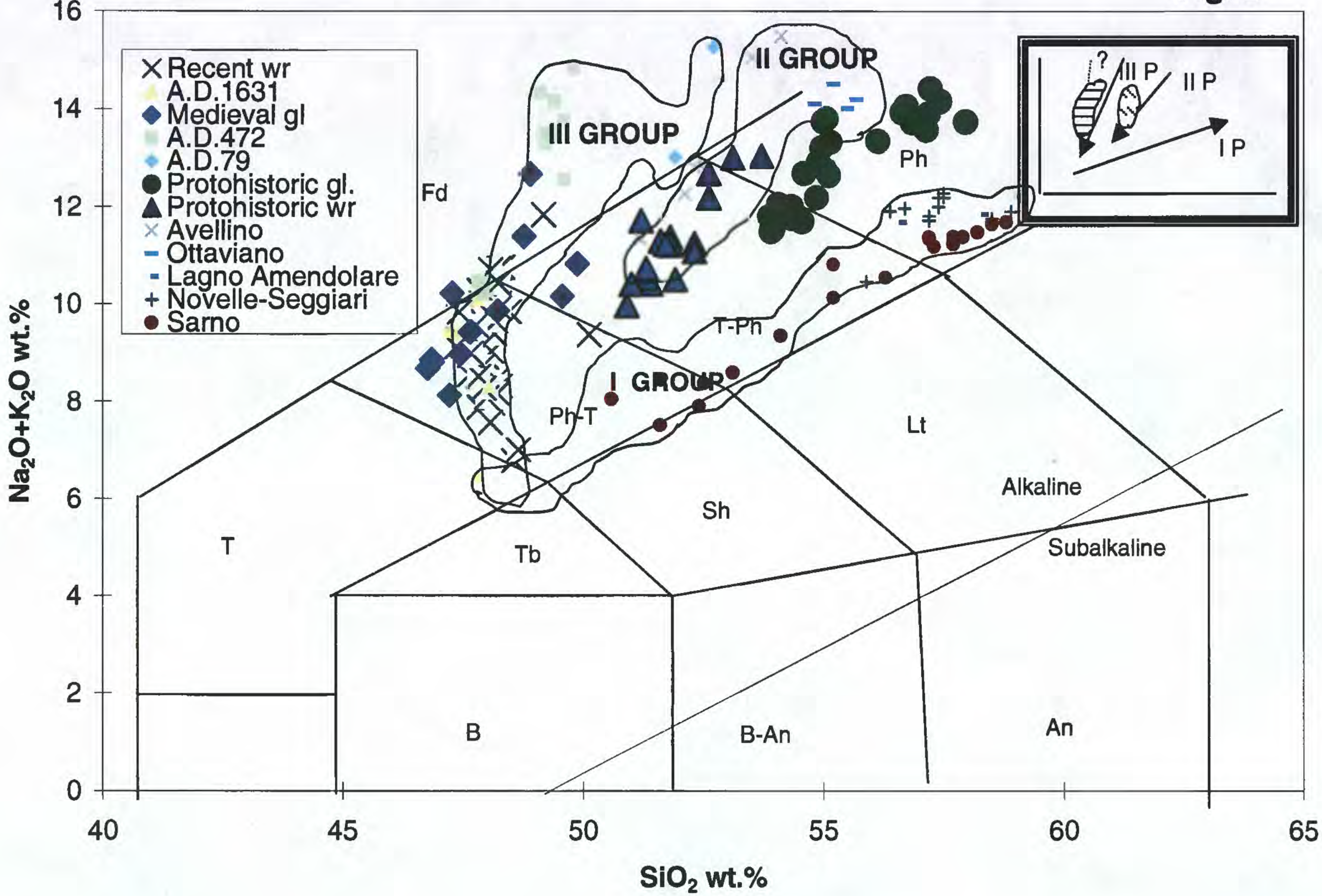

Recent wr
A.D.1631
Medieval gl
A.D.472
A.D.79
Protohistoric gl.
Protohistoric wr
Avellino
Ottaviano
Lagno Amendolare
Novelle-Seggiari
Sarno
III GROUP
II GROUP
I GROUP
Fd
Ph
T-Ph
Ph-T
Lt
Sh
Tb
T
B
B-An
An
Alkaline
Subalkaline
? III P
II P
I P
Na_2O+K_2O wt.%
SiO_2 wt.%
0
2
4
6
8
10
12
14
16
40
45
50
55
60
65

Fig. 3a

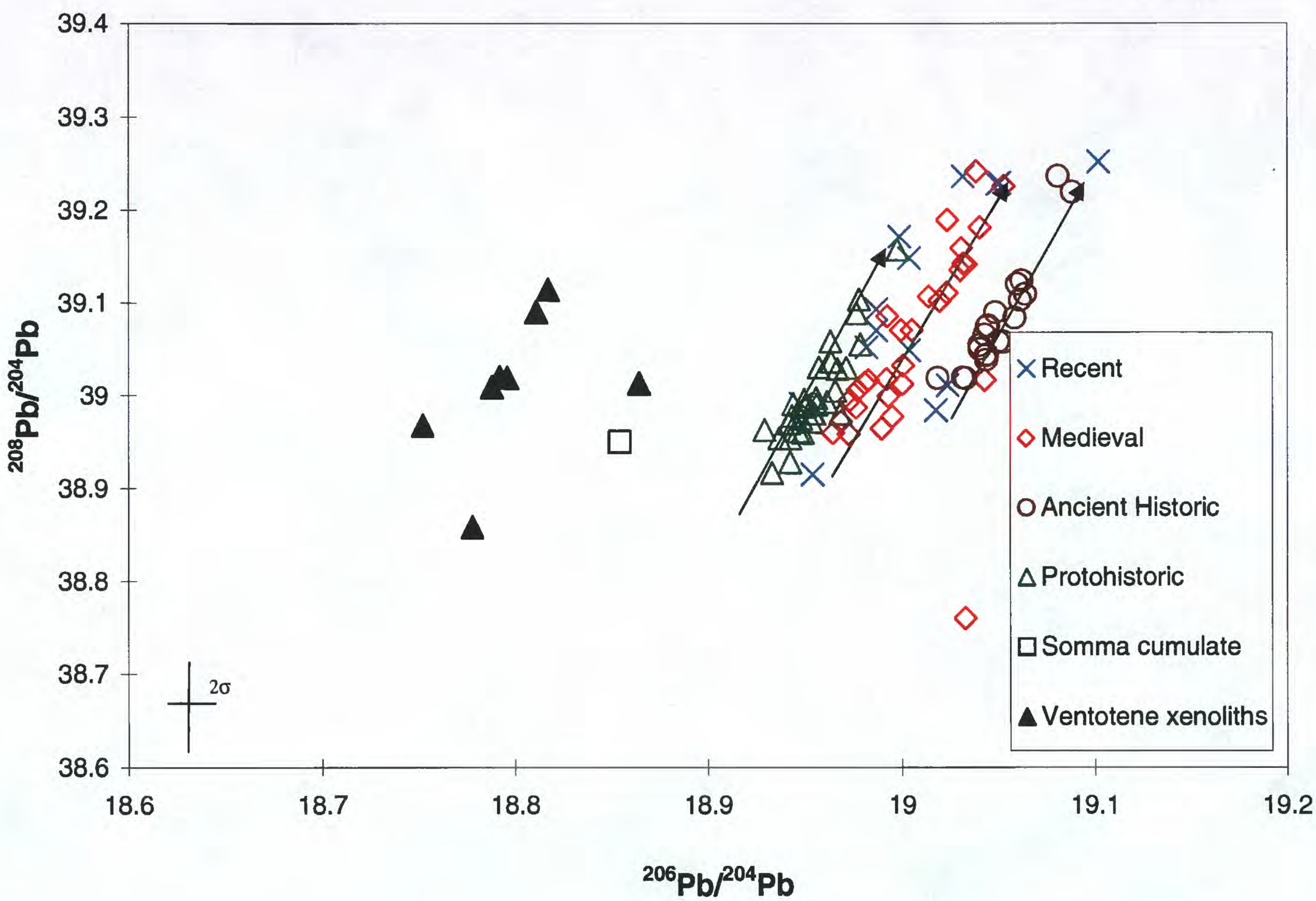
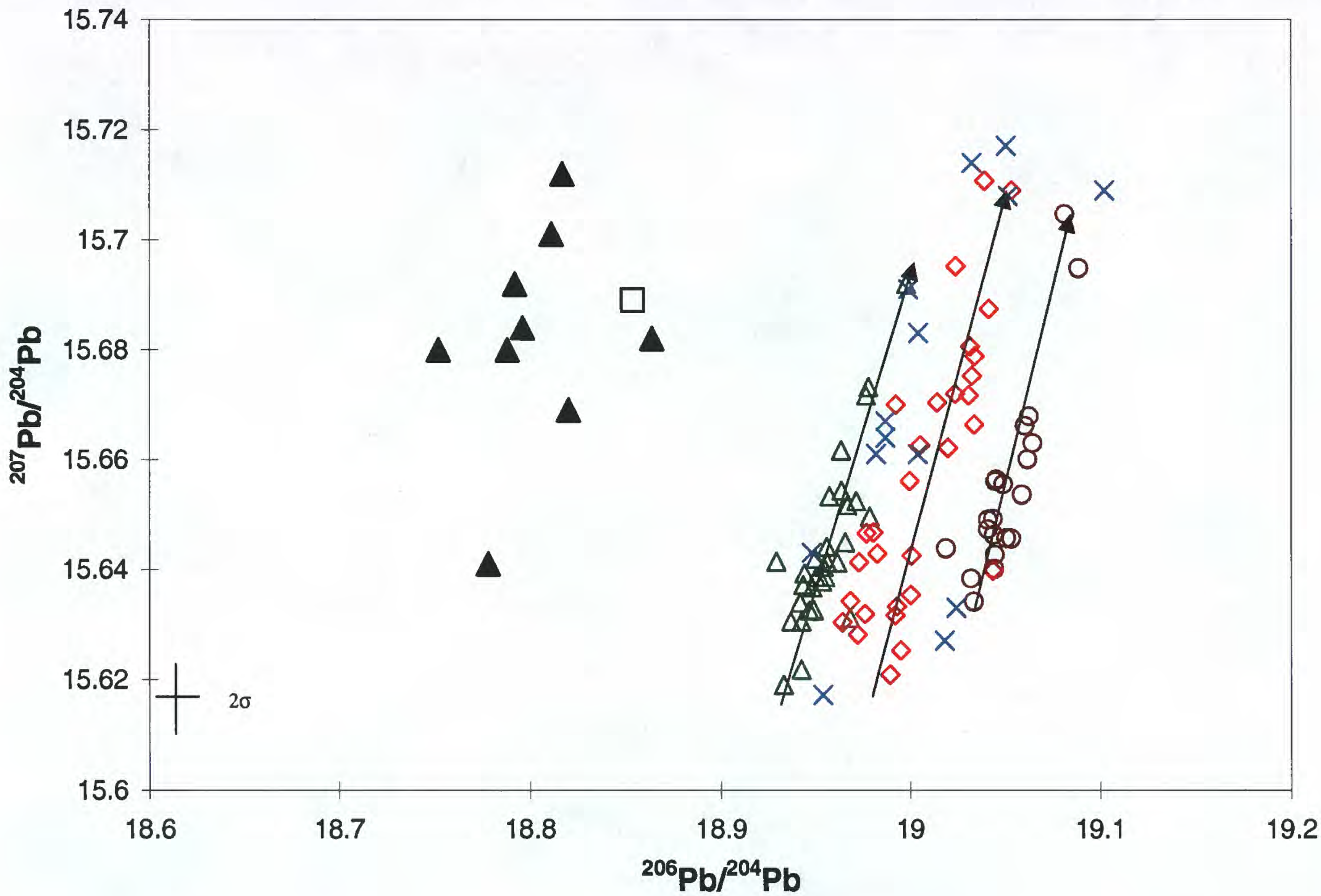
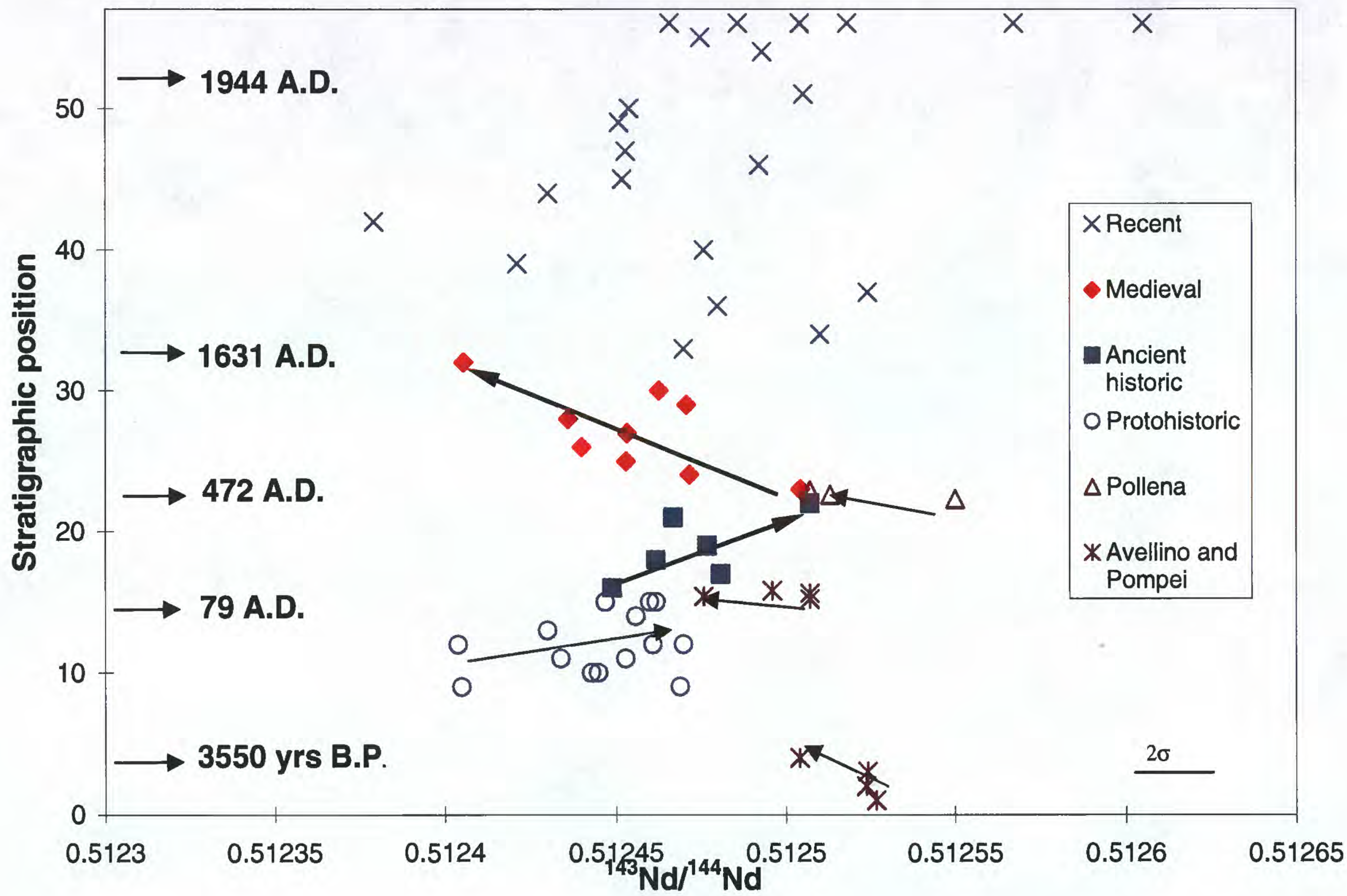

39.4
39.3
39.2
39.1
39
38.9
38.8
38.7
38.6
$^{208}Pb/^{204}Pb$
2σ
18.6
18.7
18.8
18.9
19
19.1
19.2
$^{206}Pb/^{204}Pb$
Recent
Medieval
Ancient Historic
Protohistoric
Somma cumulate
Ventotene xenoliths

Fig. 3b



15.74
15.72
15.7
15.68
15.66
15.64
15.62
15.6
$^{207}Pb/^{204}Pb$
2σ
18.6
18.7
18.8
18.9
19
19.1
19.2
$^{206}Pb/^{204}Pb$

Fig. 4



Stratigraphic position
0
10
20
30
40
50
1944 A.D.
1631 A.D.
472 A.D.
79 A.D.
3550 yrs B.P.
0.5123
0.51235
0.5124
0.51245
0.5125
0.51255
0.5126
0.51265
143Nd/144Nd
Recent
Medieval
Ancient historic
Protohistoric
Pollena
Avellino and Pompei
2σ