Data repository item 2003086
APPENDIX

Laser instruments and VULKAAN laserprobe characteristics

The laser used for analysis in this study is the VULKAAN argon laserprobe at the Vrije Universiteit of Amsterdam, Faculty of Earth and Life Sciences. The VULKAAN argon laserprobe is characterised by a laser with typical wavelenghts of 488 and 514.5mm, which fall in the visible light range (blue(-green) and green light, respectively). For further and more detailed information refer to Wijbrans *et al.* (1995). The VULKAAN argon laserprobe consists of a 24W argon ion laser, beam optics, a low volume UHV gas inlet system, and a MAP 215-50 noble gas mass spectrometer. The inlet system consists of sample house with up to 156 positions for individual samples, a central water-cooled getter cross fitted with two Fe-V-Zr internally heated alloy getter elements operating at about 250 °C. A Pyrex cold finger and a filament heated Zr-Al getter cartridge can be included in the sample house segment of the extraction line. The getter cross is pumped with a Balzers TPU062 hybrid turbo/drag pump, backed-up by a 20 l/s triode ionpump, to vacuum levels of Ω<x10^{-9} mbar. The turbo pump pumps any gas into a 10 l expansion volume that is pump in turn by an Alcatel dragpump to better that 1.0x10^{-3} mbar. The foreline vacuum is pumped to levels lower than 2 mbar with a Vacuubrand MD4 diaphragm pump. The total volume of the inlet line is around 100ml. Because the mass spectrometer volume is ca 1500ml, expansion of the gas ensures transfer of more than 90% of the gas into the mass spectrometer for isotopic measurements. The mass spectrometer is fitted with a Nier type electron bombardment source, that operates at 75eV electron energy, 200σA trap current and 3kV acceleration voltage. The source housing is pumped for reactive gases with a SAES NP50 getter pump fitted with a Zr-Al alloy cartridge at room temperature, and for all gases with a 30 l/s triode ionpump using a VAT all metal pneumatically operated valve. The isotopic composition of the argon gas was measured using a double focussing noble gas mass spectrometer (MAP 215-50) in static mode. Beam intensities were measured on a secondary electron multiplier detector (gain 60,000) and switchable preamplifier resistor settings (10, 100 and 1000 MOhm) by peak jumping at half mass intervals down from mass 40 to 35.5.

Irradiation facility

The irradiation facility used for this project was the cadmium-lined CLICIT facility of the TRIGA reactor of the Oregon State University Reactor Center. Irradiation times were 7hrs for three different irradiations V32, V36, VU41. Correction factors for interferences of Ca and K isotopes were 0.1869 for $^{38}Ar/^{36}Ar$, 0.000673 for $^{39}Ar/^{37}Ar$, 0.000264 for $^{36}Ar/^{37}Ar$ and 0.00086 for $^{40}Ar/^{39}Ar$ respectively. These values were determined using zero age K-feldspar and anorthite glass. As flux monitor standards for this project we used TCs (Taylor Creek sanidine; for VU32) and DRA2 sanidine (for VU36-41)(Steenbrink *et al.*, 1999), with an age of 28.34 and 25.26 Ma respectively. These values are compatible with the set of Renne *et al*. (1998), based on biotite GA1550 (at K/Ar age of 98.79 ∂#0.69 Ma).

References cited

Steenbrink, J., van Vugt, N., Hilgen, F.J., Wijbrans, J.R. & Meulenkamp, J.E., 1999, Sedimentary cycles and volcanic ash beds in the lower Pliocene lacustrine succession of Ptolemais (NW Greece); discrepancy between $^{40}Ar/^{39}Ar$ and astronomical ages: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 152(3-4), p. 283-303.

Renne, P.R., Swisher, C.C., Deino, A.L., Karner, D.B., Owens, T.L., De Paolo, D.J., 1998, Intercalibration of standards, absolute ages and uncertainties in $^{40}Ar/^{39}Ar$ dating: Chemical Geology, v. 145, p. 117-152.

Wijbrans, J., Pringle, M.S., Koppers, A.A.P. & Scheveers, R. 1995, Argon geochronology of small samples using the Vulkaan argon laserprobe: Proceedings Koninklÿke Nederlandse Akademie van Wetenshappen, v. 98(2), p. 185-218.

Table DR1. COMPLETE SAMPLE INFORMATION

CODE	N	FIELD N	Formation	Step H.	Total F.	LAB CODE	Depositional time	DA	GPS (UTM, 32T, EU 1950)
D	42	24-3	Molare		X	99M0183+99j0119	Chattian (Gelati et al., 1993)	23.8	423639-491334
D	60	4,4	Molare		X	99M0140+99M0143	Rupelian (section 12, Mutti et al., 1995)	28.5	453834-492276
D	67	4,4	Molare	X		99M0287	Rupelian (section 12, Mutti et al., 1995)	28.5	453834-492276
D	80	54-4	Molare		X	99M0144	Rupelian (Gelati et al., 1993)	28.5	465800-493815
B	1	2,2	Molare		X	00M0061	Rupelian (section 12, Mutti et al., 1995)	28.5	453834-492276
B	21	64-2	Molare		X	00M0070	Rupelian (Gelati et al., 1993)	28.5	461620-492711
B	33	108-9	Molare		X	00M0085	Rupelian (Gelati et al., 1993)	28.5	477478-494043
B	42	72	Molare		X	00M0258+01M0258L	Rupelian (Gelati et al., 1993)	28.5	448500-491220
B	45	83	Molare		X	00M0276	Rupelian (Gelati et al., 1993)	28.5	455600-492890
B	47	90	top Molare		X	01M0029	Rupelian (Gelati et al., 1993)	28.5	445850-493190
B	40	77	Molare		X	00m0257	Rupelian (Gelati et al., 1993)	28.5	442125-491480
B	52	86	Molare		X	00M0277+01M0277	Rupelian (Gelati et al., 1993)	28.5	446500-493195
B	36	70-1	Molare		X	00M0088	Chattian (N2, Gelati & Gnaccolini, 1996)	28.5	414965-491319
D	45	16-16	Rocchetta		X	99m0148	Lower Oligocene-Aquitanian	20.5	445238-493171
D	46	25-4	Rocchetta		X	99m0149+99m0186	Aquitanian (section Ceva, Gelati 1968)	20.5	424250-491619
D	52	21-21	Rocchetta		X	99m0197+0199	Aquitanian (Mazzurrini body, Gelati & Gnaccolini, 1998)	20.5	443750-493646
D	57	18-18	Rocchetta	X		99m0403	Chattian (Noceto system, Cazzola & Fornaciari, 1990)	23.8	44507-4932356
D	59	18-18	Rocchetta		X	99m0185	Chattian (Noceto system, Cazzola & Fornaciari, 1990)	23.8	44507-4932356
D	61	27-6	top Rocchetta Fm.-base Monesiglio Fm.	2X		99m0301, 99m0300	Aquitanian (Gelati, 1968)	20.5	424250-491619
D	62	27-6	Rocchetta		X	99m0155	Aquitanian (Gelati, 1968)	20.5	424250-491619
D	66	12,12	Rocchetta		X	99m0159	Aquitanian (top Mioglia system, Cazzola & Rigazio, 1982)	20.5	452159-492792
D	71	15-15	Rocchetta		X	99m0167	Lower Oligocene-Aquitanian (Gelati, 1968)	20.5	445540-423183
D	72	10,10	Rocchetta	X		99m0299	Chattian-Aquitanina (Mioglia system, Cazzola & Rigazio, 1982)	20.5	452502-492717
D	74	10,10	Rocchetta		X	99m0168	Chattian-Aquitanina (Mioglia system, Mutti et al., 1995)	20.5	452502-492717
D	77	57-7	Cassinelle Sandstones		X	99m0175	Rupelian (d'Atri et al., 1997)	28.5	465454-493862
D	69	20-20	Monesiglio	X		99m0370	Burdigalian (Piantivello body, Gelati & Gnaccolini, 1998)	16.4	443360-493583
D	70	20-20	Monesiglio		X	99m0192+190	Burdigalian (Piantivello body, Gelati & Gnaccolini, 1998)	16.4	443360-493583
B	7	29-8	top Monesiglio		X	00m0064	Burdigalian-Langhian (Gelati, 1968)	14.8	424170-491830
B	10	34-13	Monesiglio		X	00m0076	Aquitanian (Gelati, 1968)	20.5	433929-492018
B	23	76-7	Monesiglio		X	00m0079	Chattian (N2, Gelati et al., 1996)	23.8	414788-491567
D	76	30-9	top Paroldo Marls		X	99m0193+195	Langhian (Gelati, 1968)	14.8	425280-491956
B	20	63-1	Paroldo Marls		X	00m0078	Burdigalian-Langhian (Gelati, 1968)	14.8	426400-492110
D	43	37-2	base Cortemilia		X	99m0241	Aquitanian (Gelati, 1968)	20.5	436475-493307
D	47	38-3	top Cortemilia		X	99m0212	Langhian (Gelati, 1968)	14.8	434343-493702
D	56	61-11	Cortemilia		X	99m0246	Aquitanian (Gelati, 1968)	20.5	458183-494519
D	81	19-19	Cortemilia		X	99m0247	Burdigalian (Gelati, 1968)	16.4	442307-493503
D	48	31-10	base Murazzano		X	99m0255	Langhian (Gelati, 1968)	14.8	426250-492180

B	9	32-11	Murazzano		X	00m0074	Langhian-Serravallian (Gelati, 1968)	11.2	421529-492661
B	29	87-18	Murazzano		X	00m0082	Serravallian (Gelati, 1968)	11.2	427842-493809
D	40	46-11	Cassinasco	X		99m0371	Serravallian (section type of Gelati 1968)	11.2	44403-4948162
D	41	46-11	Cassinasco		X	99m0200+202	Serravallian (section type of Gelati 1968)	11.2	44403-4948162
D	49	45-10	Cassinasco		X	99m0122+184	Serravallian (section type of Gelati 1968)	11.2	443982-494878
D	50	47-12	base Cassinasco	X		99m0373	upper Langhian-lower Serravallian (Gelati, 1968)	14.8	423854-490674
D	51	47-12	base Cassinasco		X	99m0203+0208	upper Langhian-lower Serravallian (Gelati, 1968)	14.8	423854-490674
D	54	39-4	Cassinasco	X		99m0402	Langhian-Serravallian (Gelati, 1968)	11.2	431926-493473
D	55	39-4	Cassinasco		X	99m0210+209	Langhian-Serravallian (Gelati, 1968)	11.2	431926-493473
D	64	62-12	Cassinasco		X	99m0211	Langhian-Serravallian (Gelati, 1968)	11.2	462191-494965
D	65	62-12	Cassinasco	X		99m0404	Langhian-Serravallian (Gelati, 1968)	11.2	462191-494965
B	11	42-7	top Cassinasco		X	00m0073	Serravallian (Gelati, 1968)	11.2	430993-494386
B	24	81-12	top Cassinasco-Murazzano base		X	00m0072	Serravallian (Gelati, 1968)	11.2	419966-492936
B	27	84-15	Cassinasco		X	00m0081	Serravallian (Gelati, 1968)	11.2	429263-493713
B	34	121-7	Serravalle Sst. (Cassinasco)		X	00m0087	Langhian-Serravallian (Gelati, 1968)	11.2	451790-495200
B	26	82-13	Lequio		X	00m0080	Serravallian (Gelati, 1968)	11.2	418495-493108
B	30	89-20	Lequio		X	00m0083	Tortonian (Gelati, 1968)	7.1	422410-493902
A	2	80-11	Lequio		X	01M0383	Serravallian-Tortonian (Gelati, 1968)	7.1	419141-4930859
A	4	83-14	Lequio		X	01M0415	Serravallian-Tortonian (Gelati, 1968)	7.1	427669-493806
A	6	Mondovi' 4	Lequio		X	01M0368	Serravallian-Tortonian (Gelati, 1968)	7.1	408000-491670
A	5	88-19	Lequio		X	01M0416	Serravallian-Tortonian (Gelati, 1968)	7.1	424127-493865
B	13	Maira	present sands		X	00M0067	Present	0	Dronero
A	34	Maira	present sands		X	01M0387	Present	0	Dronero
B	14	Maira	present sands	X		00M0089	Present	0	Dronero
B	15	Tanaro	present sands		X	00M0068	Present	0	Ceva
A	31	Tanaro	present sands		X	01M0388	Present	0	Ceva
B	16	Tanaro	present sands	X		01M0044	Present	0	Ceva
B	17	Stura	present sands		X	00M0069	Present	0	Borgo S. Dalmazzo
A	33	Stura	present sands		X	01M0423	Present	0	Borgo S. Dalmazzo
B	18	Stura	present sands	X		01M0039	Present	0	Borgo S. Dalmazzo

Complete data information for samples used in Fig. 2; for the complete age dataset see Carrapa (2002) while for ages used to construct Fig. 3 see Tab. DR2

Step H.=step heating analysis; Total F.=total fusion analysis. DA=minimum depositional ages (top limit) used in Tab. DR2 and Tab. 1 according to the time scale of Bergrren et al. (1995) (in the text).

For lab code see Carrapa (2002) (in the text).

References cited

Cazzola, C., and Fornaciari, M., 1990, Geometry and Facies of the Budroni and Noceto Turbidite systems (Tertiary Piedmont Basin): Atti Ticinesi di Scienze della Terra, v. 33, p. 177-190.

Cazzola, C., and Rigazio, G., 1982, Sedimentology of Valla and Moglia turbidites, Rochetta Formation (Oligocene-Miocene) of Piedmont Tertiary basin: Giornale di Geologia, v. 45, p. 87-100.

d' Atri, A., Piana, F., Tallone, S., Bodrato, G., and Roz Gastaldi, M., 1997, Oligo-Miocene tectonics of the Alto Monferrato stratigraphic succession (Tertiary Piedmont Basin) and of tne Northwestern part of the Voltri Group (Acqui Terme-Cassinelle, Al): Atti Ticinesi di Scienze della Terra, v. 5, p. 85-100.

Gelati, R., 1968, Stratigrafia dell'Oligo-Miocene delle langhe tra le valli dei fiumi Tanaro e Bormida di Spigno: Rivista Italiana di Paleontologia e Stratigrafia, v. 74, p. 865-967.

Gelati, R., and Gnaccolini, M., 1996, The Stratigraphic record of the Oligocene-Early Miocene events at the south-western end of the Piedmont Tertiary Basin: Rivista Italiana di Paleontologia e Stratigrafia, v. 102, p. 65-76.

Gelati, R., and Gnaccolini, M., 1998, Synsedimentary tectonics and sedimentation in the Tertiary Piedmont Basin, Northwestern Italy: Rivista Italiana di Paleontologia e Stratigrafia, v. 104, p. 193-214.

Gelati, R., Gnaccolini, M., Falletti, P., and Catrullo, D., 1993, Stratigrafia sequenziale della successione Oligo-Miocenica delle Langhe, Bacino Terziario Ligure-Piemontese: Rivista Italiana di Paleontologia e Stratigrafia, v. 98, p. 425-452.

Mutti, E., Papani, L., Di Biase, D., Davoli, G., Mora, S., Segadelli, S., and Tinterri, R., 1995, Il Bacino Terziario Epimesoalpino e le sue implicazioni sui rapporti tra Alpi ed Appennino: Memorie di Scienze Geologiche di Padova, v. 47, p. 217-244.

Table DR2. AGE DATA USED TO CONSTRUCT FIGURE 3

Formation	lab code	ages	errors
Molare			
	D42b	44.16	± 0.41
	B1	40.83	± 0.68
		43.3	± 0.72
		42.54	± 0.26
		43.12	± 0.32
		42.94	± 0.34
		42.17	± 0.39
	B21	37.1	± 0.84
		36.75	± 0.65
		37.25	± 0.86
		34.89	± 0.91
	B33	43	± 0.28
		39.44	± 0.65
		44.42	± 0.48
		41.57	± 0.33
	B42	42.47	± 0.72
	B45	41.11	± 1.01
		40.16	± 0.90
		39.64	± 1.56
		39.67	± 1.28
	B47	44.31	±1.65
		41.08	±1.21
		37.75	±1.30
		33.98	±2.25
		37.52	±3.06
		36.40	±1.99
	B40	38.12	±0.97
	B52	31.04	± 9.67
		31.63	**± 1.66**
	B36	36.75	± 0.67
		36.58	± 5.66
		37.59	± 0.52
		36.22	± 0.76
	B47	44.31	± 1.65
		41.08	± 1.21
		37.75	± 1.30
		33.98	± 2.25
		37.52	± 3.06
		36.4	± 1.99
Rocchetta	D45	40.89	± 5.61
	D46	**22.72**	**± 0.41**
		37.58	±1.14
		22.78	±0.55
		40.33	±1.14
	D52(199ef)	36.42	± 1.74
	D52(199gh)	43.86	± 1.14
	D59(mn)	42.73	± 1.02
	D71	40.8	± 0.84
		43.23	± 0.61
		37.45	± 1.10
		43.91	± 2.68
	D74	43.26	± 1.45
Cassinelle Sst.	D77	33.66	± 5.74
		40.47	± 10.17
		37.62	± 0.69

Formation	lab code	ages	errors
Monesiglio	D70(190ab)	42.08	± 0.56
	D70(190lm)	40.44	± 0.52
	B7	**37.25**	**± 0.39**
		39.66	± 0.88
	B10	37.45	± 0.49
		38.41	± 10.64
Paroldo Marls	B20	**36.97**	**± 0.88**
		37.43	± 0.96
		38.26	± 9.10
		38.21	± 7.29
Cortemilia	D43	41.78	± 14.43
		39.23	± 11.48
	D47	32.5	± 25.34
	D56	36	± 10.50
	D81	44.26	± 1.51
		44.46	± 1.73
Murazzano	D48	37.46	± 2.13
	B9	43.16	± 0.40
		37.69	± 1.93
		38.28	± 2.09
	B29	**37.54**	**± 1.10**
Cassinasco	B27	32.82	± 9.57
	D41	38.95	± 0.43
		42.66	± 1.16
	D49	38.76	± 4.10
	B24	44.5	± 1.19
		37.49	**± 0.79**
		38.34	± 0.56
		41.91	± 8.00
		42.84	± 0.40
Lequio	B26	39.01	± 0.76
		43.69	± 0.90
	B30	**38.24**	**± 0.52**
	A2	42.14	± 1.53
	B15	37.65	± 0.68
	A31	35.76	± 1.47
	B13	39.75	± 1.35
Present-day sands			
Tanaro			
	B15	37.65	± 0.68
	/	**35.76**	± 1.47
Maira			
	B13	**39.75**	±1.35

Ages <45Ma (used to construct Fig. 3) from a database based on a total in excess of 500 analyses (Carrapa, 2002). For lab code see Carrapa (2002) (in the text).

Note: 2σ# errors reported represent the analytical errors (errors in the regressions of the samples and blanks, in the mass discrimination factor and for correction of interfering nuclear reactions) excluding the uncertainties in J and age of the standards and uncertainties in the decay constant. Average of J related errors is in the order of 0.3%.

For sample datails see Table DR1 (data repository)

*only ages with errors<10% are considered as minimum depositional ages (in bold)