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Rb-Sr and K-Ar studies on rocks from the Suretta Nappe; Eastern Switzerland

by *G. Steinitz* * and *E. Jäger* **

Abstract

New Rb-Sr age determinations on whole rocks from the frontal part of the Pennine Suretta nappe substantiate an early Alpine metamorphic event (118 ± 8 m.y.). Whole rock systems in areas to the south did not equilibrate during this event. Rb-Sr phengite-whole rock ages (35–40 m.y.) occuring in the low grade part of the Lepontine aureole basically reflect white mica formation ages and as such date the conditions near the peak of metamorphism. K-Ar apparent ages of phengites are probably also Lepontine ages with varying amounts of inherited ^{40}Ar in the system.

Introduction

The Suretta nappe, occuring in the eastern part of the Central Alps, is one of the middle Pennine nappes exposed in eastern Switzerland. This tectonic unit has been studied in varying detail from geologic, petrographic, structural and geochronologic aspects (e.g. GRÜNENFELDER, 1956; HANSON et al., 1969; STREIFF et al., 1971/1976; MILNES and SCHMUTZ, 1978). The southern part of this tectonic unit is a heterogeneous crystalline complex which is assumed to be derived from pelitic sediments and tuffs. This complex was intruded by, presumably, a granite porphyr some 350 m.y. ago (Zircon ages, HANSON et al., 1969). This granite porphyr now constitutes the Roffna Gneiss of the frontal (northern) part of the Suretta nappe. Both these, prealpine amphibolite facies crystalline units, compose the core of the Suretta nappe, which is enveloped in a mesozoic («Triassic») parautochthonous cover composed of quartzites and carbonates.

The aim of the present work is to contribute age data on phengite-gneisses of this unit and test the existing Alpine geochronologic models within the realm of the Suretta. The latter is especially interesting as:

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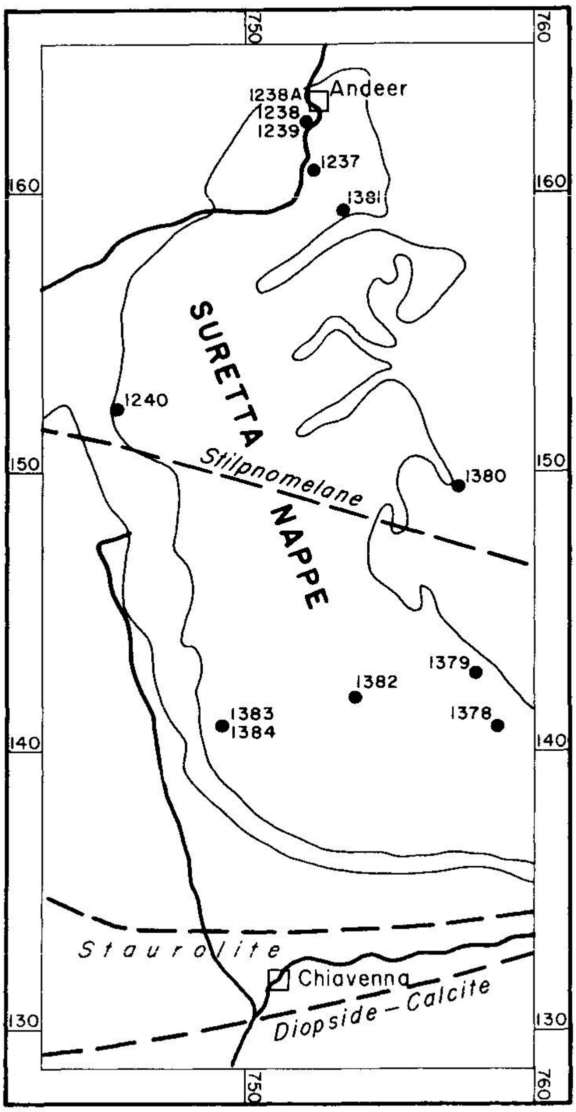

Fig. 1 Map showing location of samples within the Suretta nappe and the Lepontine mineral isograds.

a) The Suretta nappe is the highest Pennine nappe on the eastern edge of the Lepontine aureole. The low grade Tertiary (Lepontine) metamorphic event is noted throughout as a greenschist facies overprint (Metamorphic map of the Alps, 1 : 1 000 000, 1973). The area discussed here lies to the north of the staurolite mineral isograd and is traversed by the stilpnomelane-out isograd (fig. 1). In such an area Lepontine white mica formation ages are to be expected.
b) An Eoalpine metamorphic event (HANSON et al., 1969) has been recorded from the frontal part of the Suretta nappe, being developed as a relatively high pressure greenschist facies (OBERHÄNSLI, 1977).
c) Four Alpine deformation phases (thrusting and folding) have been recognised within this unit (MILNES and SCHMUTZ, 1978).

Eleven samples from the crystalline core of the nappe and one from the parautochthonous cover were chosen for investigations on whole rock and mineral separates. Seven of the samples are originating from the area to the north of the

Lepontine stilpnomelane zone, the rest to the south of it, towards the staurolite zone (fig. 1).

Petrography

Detailed petrographic descriptions of the crystalline core of the Suretta nappe are given by GRÜNENFELDER (1965) and by HANSON et al. (1969).

The Roffna Gneiss (samples KAW 1237–1239, 1381) is basically an augengneiss of granitic composition. The augen are mostly composed of perthithic microcline and quartz, having rounded and corroded outlines. The matrix is composed of fine, recrystallized quartz, phengite, K-feldspar and plagioclase (in varying proportions) with minor amounts of epidote, chlorite, calcite and garnet (KAW 1239). Different degrees of mylonitization followed by recrystallization determine the observed textural variations. The prominent schistosity is mainly due to the compositional layering of phengite versus quartz and feldspar within the sample.

The samples belonging to the southern crystalline complex of the Suretta nappe show basically the same petrographic features (KAW 1240, 1378–1379, 1382–1384). Their mineralogy is similar to the above described samples. In some of the samples (KAW 1383, 1384) deformed and recrystallized plagioclase is observed. Abundant chlorite and relicts of deformed (brittle) garnets are found in KAW 1379. The textures observed are recrystallized mylonitic textures. Schistosity in these rocks is determined by compositional layering of the phengite versus quartz and feldspar as well as elongation of quartz and phengite (KAW 1240, 1378, 1379).

Sample KAW 1380 is a recrystallized quartzite. The prominent schistosity is due mainly to the preferred orientation of phengite and quartz with only a slight tendency towards compositional layering.

All white micas analyzed have been determined as phengites (FREY et al., in preparation) having the 2M modification except for the phengite of KAW 1378 which is a mixture of the 2M and 3T modifications.

Methods

Large (30 kg and more) samples were taken from fresh looking outcrops. All samples were crushed in a jaw crusher and a representative whole rock split was ground in an agate mortar for 10 hours under suprapure alcohol. Mineral separation followed with the aid of vibrating table, Wilfley table and magnetic separators. Special care has been taken in the separation of the very fine mica

Sample/ locality	Coordinates		87Rb ppm	Sr rad ppm	% rad	Sr com. ppm	87Sr/86Sr	87Rb/86Sr	Age m. y. (1)	Corr. age m. y. (2)
KAW 1237	752. 26/160. 80	Total	72. 4	0. 2747	4. 72	79. 92	0. 7450	9. 268	267 ± 111	
Roffla		Phengite	215. 6	0. 1737	10. 16	22. 12	0. 7902	99. 65	57 ± 10	35. 2 ± 2. 7
		KF	92. 6	0. 6992	4. 57	210. 4	0. 7439	4. 498	530 ± 227	
KAW 1238	752. 10/162. 43	Total	68. 8	0. 2335	4. 50	71. 43	0. 7433	9. 855	238 ± 104	
Andeer		Phengite	179. 0	0. 1819	7. 70	31. 42	0. 7691	58. 25	71 ± 17. 9	38 ± 4. 8
		KF	87. 2	0. 3865	3. 95	135. 2	0. 7391	6. 595	312 ± 154	
KAW 1239	752. 10/162. 43	Total	64. 7	0. 2690	4. 24	87. 48	0. 7413	7. 564	292 ± 135	
Andeer		Phengite	174. 2	0. 1729	7. 64	30. 08	0. 7686	59. 22	69 ± 18	37. 3 ± 4. 5
		KF	83. 2	0. 5137	3. 81	186. 8	0. 7380	4. 551	434 ± 224	
KAW 1240	745. 40/152. 15	Total	76. 0	0. 2680	6. 11	59. 33	0. 7561	13. 10	247 ± 79	
Splügen		Phengite	237. 3	0. 4723	7. 01	90. 23	0. 7634	26. 89	140 ± 38	37 ± 17
		KF	119. 3	0. 4636	5. 30	119. 4	0. 7496	10. 21	273 ± 100	
KAW 1378	758. 90/140. 90	Total	78. 9	0. 2485	6. 96	47. 85	0. 7630	16. 85	222 ± 61	
Madriser Tal		Phengite	333. 2	0. 1394	23. 05	6. 704	0. 9225	508. 1	29. 5 ± 2. 3	22. 8 ± 0. 7
		KF	104. 0	0. 2776	6. 72	55. 53	0. 7610	19. 14	187 ± 54	
KAW 1379	758. 15/142. 80	Total	34. 5	0. 1828	3. 43	74. 12	0. 7351	4. 765	372 ± 212	
Madriser Tal		Phengite	122. 6	0. 1820	4. 87	51. 18	0. 7463	24. 50	105 ± 41	39. 3 ± 11. 4
		Chlorite	0. 869	0. 01536	3. 55	6. 010	0. 7360	1. 478		
KAW 1380	757. 40/149. 40	Total	6. 78	0. 02529	0. 147	246. 9	0. 7109	0. 2807	262 ± 3560	
Gröt/Avers		Phengite	94. 1	0. 05326	5. 85	12. 34	0. 7540	77. 96	39 ± 13. 5	39. 3 ± 2. 9
KAW 1381	753. 35/159. 35	Total	73. 9	0. 2459	4. 95	68. 03	0. 7468	11. 11	234 ± 92	
N. Ausser		Phengite	207. 8	0. 1281	19. 72	7. 51	0. 8843	282. 9	43. 4 ± 3. 9	35. 2 ± 1. 1
Ferrera		KF	94. 8	0. 3716	4. 75	107. 4	0. 7453	9. 022	275 ± 113	
KAW 1382	753. 85/141. 95	Total	73. 0	0. 2294	10. 63	27. 22	0. 7944	26. 88	220 ± 39	
Val di Lei		Phengite	167. 2	0. 1961	17. 47	13. 34	0. 8602	128. 2	83 ± 8	45. 5 ± 2. 7
		KF	76. 9	0. 8272	6. 95	159. 6	0. 7629	4. 927	754 ± 209	
		Plag. +qz.	29. 9	0. 1059	10. 41	13. 14	0. 7923	23. 28	249 ± 46	
KAW 1383	749. 20/140. 90	Total	20. 5	0. 1302	1. 44	128. 2	0. 7203	1. 634	446 ± 612	
E. Frasiscio		Phengite	113. 9	0. 07613	3. 85	27. 39	0. 7383	42. 50	46. 7 ± 23. 8	31. 1 ± 5. 4
		KF	45. 7	0. 1119	1. 46	108. 7	0. 7204	4. 300	172 ± 234	
KAW 1384	749. 20/140. 90	Total	23. 4	0. 1048	1. 32	112. 5	0. 7194	2. 131	313 ± 471	
E. Frasiscio		Phengite	110. 5	0. 08713	2. 64	46. 28	0. 7291	24. 41	56 ± 41	30. 7 ± 9. 7
		KF	47. 5	0. 1625	1. 62	142. 4	0. 7216	3. 413	240 ± 295	
		Plag. +qz.	7. 01	0. 09352	1. 85	71. 62	0. 7232	1. 001	934 ± 1002	

Fig. 2 Rb-Sr analytical data.
(1) Age calculated with «common» Sr, $^{87}Sr/^{86}Sr = 0.71014$
(2) Phengite age calculated with whole rock parameters.

Sample	40Ar rad cm3 x 10^{-6} g^{-1} STP	% rad	% K	40K/36Ar x 10^3	40Ar/36Ar	"age" m. y.
KAW 1237 Pheng.	14.76	82.42	8.88	558.61	1681.74	41.9 ± 1.5
KAW 1238 Pheng.	14.14	78.49	8.86	452.47	1373.88	40.3 ± 1.5
KAW 1238A Pheng.	16.64	85.71	9.26	660.85	2068.75	45.3 ± 1.6
KAW 1238A Stilpnom.	1.3718	31.94	1.22	82.62	434.31	28.5 ± 2.7
KAW 1239 Pheng.	17.51	83.45	8.93	509.07	1786.26	49.4 ± 1.7
KAW 1240 Pheng.	15.32	88.49	8.69	863.09	2568.08	44.5 ± 1.5
KAW 1378 Pheng.	14.56	86.58	9.33	817.80	2203.03	39.5 ± 1.4
KAW 1379 Pheng.	58.55	88.78	8.66	231.68	2634.24	165.1 ± 5.6
KAW 1379 Chlorite	0.3678	7.15	0.15	6.21	318.30	61.7 ± 25.9
KAW 1380 Pheng.	14.25	70.75	9.38	315.16	1010.58	38.4 ± 1.6
KAW 1381 Pheng.	14.38	52.43	9.43	143.01	621.16	38.5 ± 2.2
KAW 1382 Pheng.	17.56	89.32	9.33	880.34	2769.40	47.4 ± 1.6
KAW 1383 Pheng.	14.02	84.55	8.69	671.42	1913.93	40.7 ± 1.44
KAW 1384 Pheng.	14.27	91.47	9.10	1352.56	3464.86	39.6 ± 1.3

Fig. 3 K-Ar analytical data.

which is closely intergrown with chlorite and epidote. K-feldspar and plagioclase were separated with heavy liquids.

Rb and Sr contents and the isotopic composition of Sr were measured, with standard isotope dilution methods, on an Avco mass spectrometer. K was measured by flame photometry and Ar was determined with an improved GD-150 mass spectrometer (PURDY, 1972).

Errors on $^{87}Rb/^{86}Sr$ are estimated at ± 2% and on $^{87}Sr/^{86}Sr$ as ± 0,2%. The error on the determination of K is estimated at ± 1% and on the argon content and composition as ± 3%. Isochrons were calculated according to YORK (1967). All constants used are according to STEIGER and JÄGER (1977).

Whole rock systems

Evaluation of the existing whole rock Rb-Sr data from the Suretta nappe are given in figures 4 and 5.

As HANSON et al. (1969) already indicated, samples from the frontal part (northern part) of the nappe manifest the opening of the whole rock system. This event has been attributed by some as to a purely tectonic event (e.g. FREY et

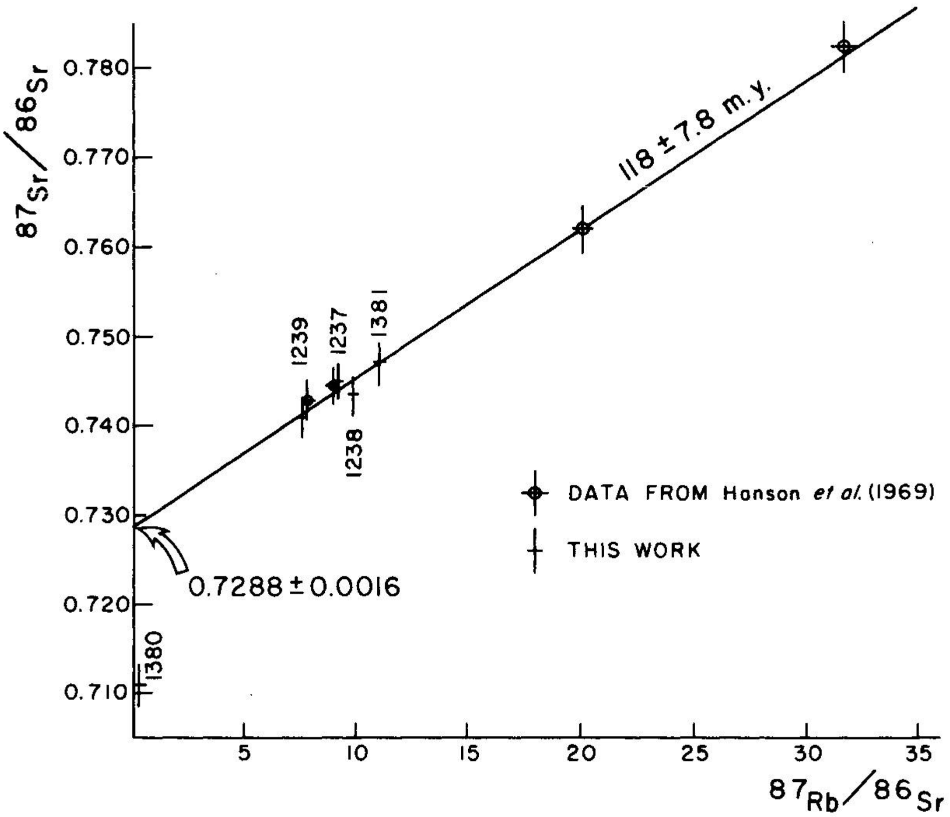

Fig. 4 Rb-Sr evolution diagram for whole rock samples from the frontal part of the Suretta nappe. The sample from the «Triassic» quartzites is also shown.

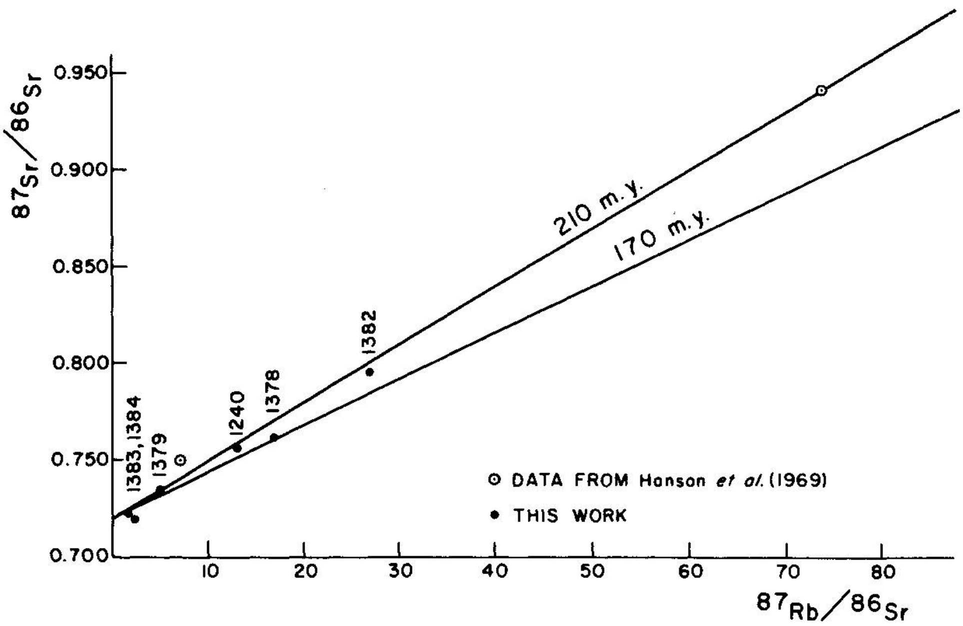

Fig. 5 Rb-Sr evolution diagram for whole rock samples from the southern part of the Suretta nappe. Two lines, corresponding to ages of 170 m.y. and 210 m.y., have been added for comparison.

al., 1974) or as a true (high P, low T) metamorphic event in which new minerals are formed (e.g. HANSON et al., 1969; OBERHÄNSLI, 1977). Assuming an open system model for this part of the Suretta nappe the age of the early Alpine event can be placed at 118 ± 8 m.y. (fig. 4). The isotopic composition of Sr at the time of homogenization was $^{87}Sr/^{86}Sr$ = 0.7288 ± 0.0016. MILNES and SCHMUTZ (1978) tend to correlate the first folding phases with this Eoalpine event. Consideration of the whole rock data from the southern part of the Suretta nappe, depicted in a Rb-Sr evolution diagram (fig. 5) clearly shows that these samples do not belong to the afore mentioned early Alpine open system. It would rather seem that the presented pattern reflects a disturbed older system (Hercynian, c.f. HANSON et al., 1969) having a lower initial strontium composition (0.720). Still these samples are probably influenced, although not completely reset, by the early Alpine event.

The autochthonous to parautochthonous «Triassic» quartzite sample (KAW 1380 - shown in fig. 4) does also seem to be basically unaffected by the early Alpine event. It probably still retains a Sr isotopic value which is close to its original marine sedimentary value. Thus it certainly did not form an open system with the «frontal» crystalline core of the nappe. This result indicates that further work on the isotopic systematics of similar rocks of the cover, tightly infolded into the frontal part of the Suretta nappe (MILNES and SCHMUTZ, 1978) could throw light on the nature of the contact of the cover and the basement versus its behaviour during the early Alpine metamorphism. It may well be that the cover, due to its relatively high water content, did form an independent open whole rock system at some stage of the Alpine metamorphic history. This is especially promising since HAMMERSCHMIDT (1980) could show that such rocks did reset their Rb-Sr whole rock system, under similar geologic conditions, within the framework of the Alpine events.

Mineral age systematics

Rb-Sr ages of the phengites, calculated with common Sr, show a very large spread (29–140 m.y.). A much narrower age spread is obtained if every phengite is assumed to be in equilibrium with the Rb-Sr-isotopic parameters of its whole rock. Most mica ages, calculated by this method are in the range of 35–40 m.y. The concordance of the white mica ages arrived at by assuming equilibration, to a first order, within the sample system reflects therefore a small scale homogenization event.

All samples analyzed originate from an area well outside the staurolite zone of the Lepontine metamorphic aureole, i.e. in an area in which Lepontine temperatures were below 500–550 °C. So far the dating of the peak of metamorphism has been based mainly on the interpretation of Rb-Sr phengite ages from the western periphery of the Lepontine aureole (HUNZIKER 1970; JÄGER 1970, 1973). The assumption underlying this interpretation is that Rb-Sr ages of white micas formed in areas where temperatures were below 500°C are formation ages (PURDY and JÄGER 1976, JÄGER 1979). With this model in mind the Rb-Sr ages of the phengites from the Suretta are considered to be formation ages reflecting the progressive part near the peak of the Lepontine metamorphic event.

Petrographic examination shows that the fine white micas in these samples define a prominent penetrative schistosity within the Suretta rocks. Thus it is appealing to suggest that a major «Lepontine» deformation phase is also dated in this case. It is possible that this phase can be correlated with the major structural Niemet phase defined by MILNES and SCHMUTZ (1978). Verification of this point merits further investigations.

In four samples deviations from this age pattern are found: a) the two adjacent samples (actually from one block) KAW 1383 and 1384 from Frasicio are from a very inhomogeneous phengite gneiss rich in coarse quartz veins. It may well be that the samples are too small to get a true age by calculation with the total rock parameters. In this case calculation of a phengite (KAW 1383)-phengite (KAW 1384) age results in an age of 36 m.y.; b) The phengite of KAW 1378 gives a younger age which may be a cooling age as it is the closest sample to the Alpine staurolite zone; c) the high age (45.5 m.y.) of sample KAW 1382 is probably a case which reflects disequilibrium.

A further justification of the assumed model is arrived at by consideration of the Rb-Sr systematics in the K-feldspars. The relevant Rb/Sr and $^{87}Sr/^{86}Sr$ parameters are given in fig. 6. The phengite-whole rock line with the corresponding age is shown for each sample. The K-feldspars are connected with tie lines to their appropriate whole rocks. The samples are grouped into those which are assumed to reflect the Lepontine event (through the phengite-whole rock age, fig. 6A) and those whose ages deviate considerably (fig. 6B). It is significant that in the first group the K-feldspars all have Rb/Sr ratios which are low relative to the Rb/Sr ratio of the whole rock and that they are close to the phengite-whole rock line. In the other cases (fig. 6B) the K-feldspars are either farther away from the phengite-whole rock line or they have Rb/Sr ratios which are higher than the whole rock. It is thus concluded that only in those samples which yield phengite-whole rock Lepontine ages the K-feldspars are also completely or almost completely reset within the sample system.

K-Ar ages of most phengites are 2–17 m.y. higher than the corresponding Rb-Sr ages. In one case we even have an alpine phengite (KAW 1379) yielding a K-Ar age of 165 m.y. It seems that these higher apparent ages must be interpreted as due to an inherited overpressure of ^{40}Ar in the system. The case of the three phengites yielding K-Ar ages of 40, 45 and 49 m.y. (KAW 1238, 1238A and 1239), originating from one quarry, also implies such a situation. This rea-

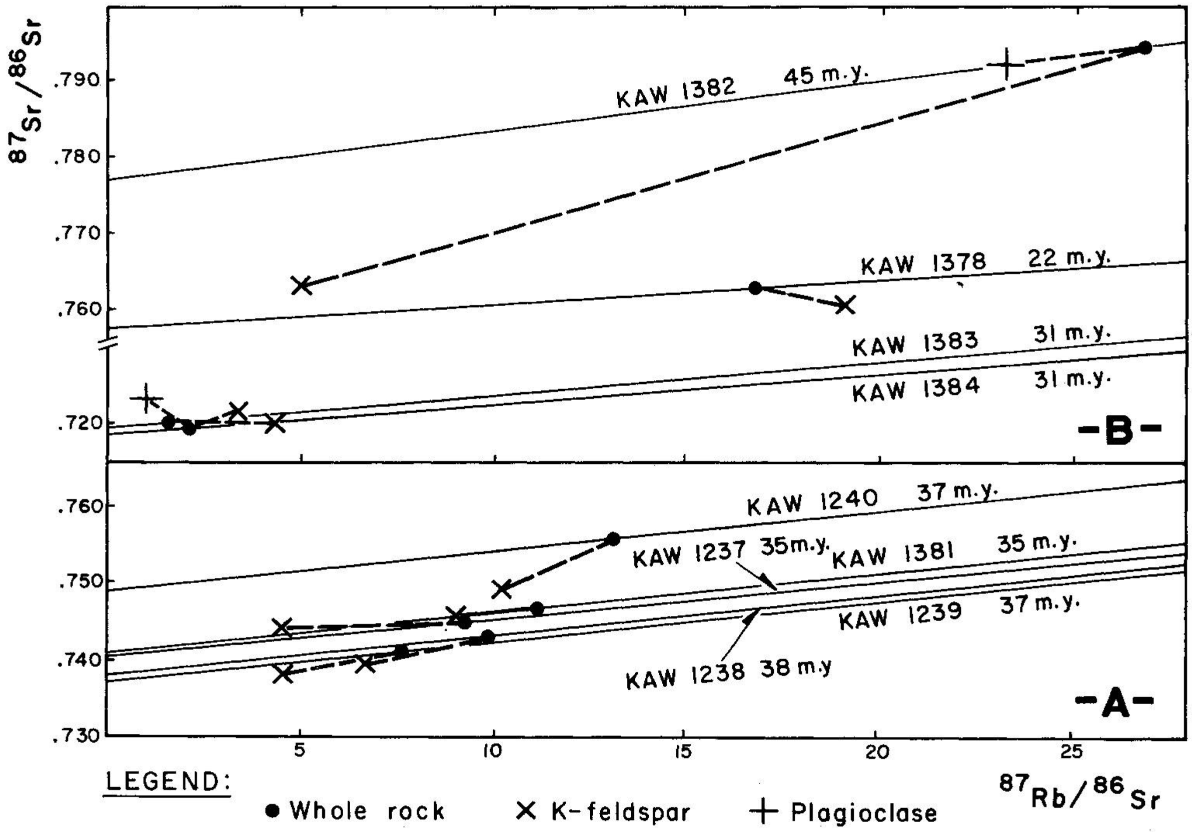

Fig. 6 Rb-Sr evolution diagrams for mineral systems. The phengite-whole rock reference lines, with the associated ages, are shown as thick lines. The K-feldspars are connected, by a broken line, to their appropriate whole rocks. Fig. 6A shows those samples which are assumed to be equilibrated and fig. 6B shows the disequilibrium cases. See text for further details.

soning is further supported by the most concordant age (Rb-Sr versus K-Ar) which is found for the phengite separated from the «Triassic» quartzites (KAW 1380). This last feature could, again, be easely explained if it is assumed that the quartzites behaved as a system which was chemically independent from the crystalline core during the Lepontine event and which was opened relatively easely due to its relatively high water content. On the whole, although disequilibrium probably exists, the K-Ar ages of the phengites still do reflect the effect of the Lepontine phase in this area.

The age of 28.5 m.y. (K-Ar) for the only stilpnomelane separated could well be a cooling age; biotite has not been detected in our samples.

Hanson et al. (1969) report an exceptional low Rb-Sr phengite-total rock age of 14 m.y. We could not confirm this result, it needs further attention.

Conclusions

Different Alpine metamorphic events are recorded within the Suretta nappe by the various radioactive isotope systems. An early Alpine event (118 ± 8 m.y.) is recorded by part of the whole rock system and the Lepontine metamorphic event (35–40 m.y.) is clearly documented in the phengite-whole rock system.

Clear indications exist that the timing of the various metamorphic events can be elucidated by careful investigation of the different isotopic systems at various scales. Even in areas of relatively low metamorphic grade procedures and criteria can be set up for recognizing Rb-Sr systems which did equilibrate - and thus do date an event - from systems which did not do so.

The elucidation of the timing of penetrative structural metamorphic events seems to be possible in the Alpine regime. This would have to be done on chosen test cases and would require a multidiciplinary approach, in which structural, mineralogic-petrographic and isotope systematics are combined.

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