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Our recent work on He, Ne, and Ar in Alpine gold samples [1,2] has demonstrated that gold is extremely retentive for He and could thus, in principle, be used for U/Th-^{4}He dating. For vein-type gold from Brusson, Northern Italy, we derived a U/Th-^{4}He age of 36 Ma, in agreement with the K-Ar formation age of associated muscovites and biotites [1,3]. However, in placer gold from the Napf area, Central Switzerland, we observed large excesses of both ^{4}He and radiogenic ^{40}Ar ($^{40}Ar_{rad}$, defined as $^{40}Ar - 295.5 \cdot {}^{36}Ar$). The gas release systematics [2] indicate two distinct noble gas components, one of which is released below about 800°C and the other one at the melting point of gold (1064°C). We now present results of He and Xe measurements in a 1 g placer gold sample from the river Krümpelgraben, as well as He and Ar data for Brusson vein-type gold and for gold from the Lily Gold Mine, South Africa [4]. We calculate reasonable U/Th-^{4}He as well as U-Xe ages based on those gases which are released at ≤800°C. Probably the low-temperature components represent in-situ-produced radiogenic He and fission Xe, whereas the gases evolving when gold melts have been trapped during gold formation. Therefore only the low-temperature components are relevant for dating purposes.

Table 1 gives the concentrations of ^{4}He, $^{40}Ar_{rad}$, and fission-type Xe (Xe_f) for the low-temperature (L) and the high-temperature (H) components separately. For Krümpelgraben and Lily gold, 80-90% of ^{4}He is released only when gold melts. In contrast, most ^{4}He and $^{40}Ar_{rad}$ in Brusson gold is outgassed below 800°C. $^{40}Ar_{rad}$ in Lily gold appears to be more abundant in the H than in the L component; however, since 40% of total $^{40}Ar_{rad}$ were released even above 1200°C, we suspect a major fraction of $^{40}Ar_{rad}$ to originate from silicate inclusions. In quartz associated with Lily gold we found huge amounts of $^{40}Ar_{rad}$: $(6090 \pm 110) \cdot 10^{-8}$ cm^3 STP/g. Therefore all $^{40}Ar_{rad}$ (H) may be from silicates. Fission-type Xe was observed in both the L and the H components for Krümpelgraben gold despite large uncertainties.

In order to find out which of the components, if any, represents in-situ-produced ^{4}He, $^{40}Ar_{rad}$, and Xe_f, we have calculated model gas retention ages based on the data from Table 1; they are presented in Table 2. For Krümpelgraben and Brusson gold, these ages can be compared with the estimated age of Alpine gold of ~32 Ma [3]. Since the H component of ^{4}He is almost completely missing for Brusson, we may assume that in-situ-produced ^{4}He is released below 800°C. As a matter of fact, the U/Th-^{4}He ages calculated from the L components are consistent with 32 Ma except for Brusson sample 1. This small (9.66 mg) sample may have contained more U than the other ones. The ^{238}U-^{134}Xe and ^{238}U-^{136}Xe ages for the L component agree also within the (very large) error limits with 32 Ma. On the other hand, the ages calculated from the H components of Krümpelgraben He and Xe are much too high, implying that ^{4}He (H) and Xe_f (H) were trapped by the forming gold from hydrothermal fluids which were already enriched in radiogenic and fissiogenic gases.

The low-temperature release of in-situ-produced gases indicates that U and Th are not homogeneously distributed in the gold, but may be concentrated in small inclusions around which radiogenic ^{4}He and Xe_f are found (α particles from U and Th decays have a range of ~10-40μm [5]). The low release temperatures might be a consequence of abundant radiation damages in these regions. In this way we can also explain variations of the U concentration between gold samples from the same location. U is actually incompatible with Au, i.e. it does not fit into the crystal lattice. On the other hand, trapped He may be sited within the crystal lattice of Au.

An interpretation of $^{40}Ar_{rad}$ (L) as being produced in situ is not valid, as demonstrated by the unreasonably high K-^{40}Ar model ages obtained for the Brusson samples (Table 2). Obviously most $^{40}Ar_{rad}$ was not produced in situ. A trapped $^{40}Ar_{rad}$ component released at low temperatures is expected to be accompanied by trapped ^{4}He and Xe_f components and, therefore, not all ^{4}He and Xe_f in the L component can be of in situ origin. However, we do not know the ratio $^4He/^{40}Ar_{rad}$ in the trapped component. On the other hand, for the placer gold samples studied in [2] we obtain U/Th-^{4}He ages which are considerably lower than 32 Ma based on the L components of ^{4}He, probably due to lower U and Th concentrations than assumed.

We conclude that the ^{4}He and Xe_f components released from gold at ≤800°C may represent in-situ-produced gases, whereas essentially all $^{40}Ar_{rad}$ and the He and Xe released at the melting point of gold were trapped during formation. Currently, the ^{238}U-^{136}Xe method seems to be most promising, if the large uncertainties can be reduced. From the isochron in a $^{136}Xe/^{130}Xe$ versus $U/^{130}Xe$ plot for several gold samples of the same age and the same trapped Xe composition, but with different concentrations of U or trapped Xe, we should be able to

correct for the trapped Xe_f component and derive the formation age. For this method it is, however, essential to analyze the noble gases and U in the same sample.

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References: [1] Eugster O., Hofmann B., Krähenbühl U. and Neuenschwander J. (1992) *Meteoritics* **27**, 219-220. [2] Eugster O., Hofmann B., Niedermann S. and Thalmann Ch. (1993) *LPS* XXIV (this issue). [3] Diamond L.W. (1990) *Am. J. Sci.* **290**, 912-958. [4] Anhaeusser C.R. (1986) *Min. Dep. of Southern Africa*, 187-196. [5] Friedlander G., Kennedy J.W., Macias E.S. and Miller J.M. (1981) Nuclear and Radiochemistry, John Wiley & Sons.

Table 1 Radiogenic and fissiogenic noble gases in Alpine and South African gold samples (He and Ar: 10^{-8} cm^3 STP/g; Xe: 10^{-12} cm^3 STP/g).

		Low-temperature component (≤800°C)				High-temperature component (>800°C)			
Sample	Weight[g]	^4He	^{40}Ar	^{134}Xe	^{136}Xe	^4He	^{40}Ar	^{134}Xe	^{136}Xe
Krümpelgraben	1.02	540 ±30	-	0.034 +0.024 -0.019	0.017 +0.031 -0.017	2740 ±200	-	0.064 ±0.028	0.031 ±0.012
Brusson 1	0.00966	458 ±40	116 ±11	-	-	-	-	-	-
Brusson 2	0.0205	179 ±18	54 +35 -17	-	-	-	-	-	-
Brusson 3	0.0509	201 ±11	46.0 ±2.7	-	-	7.5 ±0.4	8.7 ±0.9	-	-
Lily GM2	0.00549	97.4 ±4.5	20.8 ±2.8	-	-	905 ±48	140 ±16	-	-

Table 2 Model formation ages (Ma) of Alpine gold calculated from the low- and high-temperature components of ^4He, $^{134}Xe_f$, $^{136}Xe_f$, and $^{40}Ar_{rad}$, respectively. The following concentrations of K, Th, and U were assumed [1]: Krümpelgraben 25 ppm K, 0.1 ppm Th, 1.3 ppm U; Brusson 40 ppm K, 0.9 ppm Th, 0.4 ppm U.

	Low-temperature component (≤800°C)				High-temperature component (>800°C)			
Sample	U/Th-^4He	U-^{134}Xe	U-^{136}Xe	K-^{40}Ar	U/Th-^4He	U-^{134}Xe	U-^{136}Xe	K-^{40}Ar
Krümpelgraben	34 +15 -8	67 +51 -43	28 +52 -28	-	169 +72 -41	126 ±65	51 ±25	-
Brusson 1	62 +30 -17	-	-	2990 +560 -400	-	-	-	-
Brusson 2	24 +12 -6	-	-	1970 +780 -520	-	-	-	-
Brusson 3	27 +14 -7	-	-	1780 +440 -290	1.0 +0.5 -0.3	-	-	500 +180 -110