RETRIEVING PALEO-ATMOSPHERIC SIGNALS FROM ANCIENT HYDROTHERMAL QUARTZ: A CASE STUDY ON QUARTZ FROM THE HIMALAYA AND THE ALPES. G. Avicè1, F. Vayrac1, M. Naumenko-Dézes1,2 and R. Melis3, 1Université Paris Cité, Institut de physique du globe de Paris, CNRS, France, avicè@ipgp.fr. 2Now at: Bureau de recherches géologiques et minières (BRGM), 3 av. Claude-Guillemin, Orléans, France. 3Laboratoire de Géologie de Lyon: Terre, Planètes et Environnement, CNRS UMR 5276, Université Claude Bernard Lyon 1, ENS Lyon, Université de Lyon 69622 Villeurbanne, France

Introduction: The composition of the Earth's atmosphere evolved over time under the influence of important processes such as magmatic degassing, atmospheric escape, geodynamics including subduction and various bio-geochemical cycles [1]. Noble gases and nitrogen are excellent tracers of such processes [2]. Following the evolution of the composition of the Earth's atmosphere allows thus to follow the evolution of the entire planet [3]. Previous research indicates that hydrothermal quartz samples (up to several Ga-old) have preserved noble gases from the ancient Earth's atmosphere [4-6]. However, the atmospheric signal detected in quartz is often blurred by the presence of noble gas isotopes produced inside the Earth's crust by radioactivity. In this study, we measured the elemental and isotopic composition of noble gases released from fluid inclusions trapped in relatively recent (<20Ma) hydrothermal quartz in order to evaluate the quality of the atmospheric signal in presence of significant nucleogenic, radiogenic and fissiogenic contributions.

Samples & Analytical Methods:
Samples Quartz samples come from syn-kinematic, post-foliation and late (~12-18 Ma) hydrothermal veins sampled in the Himalaya mountain range (see details given by ref. [7]). Other samples come from late (<15 Ma) veins located in the Alpes with samples from Aiguilles Rouges, Mont-Blanc and Belledonne mountains [8]. Oxygen and hydrogen isotope measurements conducted on fluids released from fluid inclusions revealed that water trapped in these quartz samples has a strong meteoric origin [7].
Methods: Noble gases were extracted from quartz samples by stepwise crushing in vacuum allowing to release gas contained in different generations of fluid inclusions. Reactive chemical species were removed from the gas phase using series of getters. Noble gases were then trapped on charcoal cooled down to 10 K by a cryogenic pump. They were sequentially released and admitted into a static noble gas mass spectrometer (Noblesse, High Resolution 3F6M, NuInstruments) for the determination of the elemental abundance and isotopic composition of Ne, Ar, Kr and Xe. All data have been corrected for mass discrimination of the instrument, blank contribution, and reproducibility of standard measurements. Additional details of the analytical methods are provided in [6].

Results: The elemental and isotopic compositions of noble gases reveal that gases trapped in fluid inclusions consist in a mixing between air and crustal gases enriched in nucleogenic, radiogenic and fissiogenic isotopes.
Neon. For neon, data define a clear trend (Fig. 1) between atmospheric neon and nucleogenic neon produced inside the Earth's crust [9]. The well-defined correlation line obtained for samples from the Alpes allows to compute a 20Ne/22Ne ratio of 9.82 ± 0.06 (1σ) for atmospheric neon trapped in these samples (considering a trapped atmospheric 21Ne/22Ne ratio of 0.029). Neon in Himalaya samples is less nucleogenic with a minimum 20Ne/22Ne ratio of about 9. The fact that data for Himalaya samples are more scattered might reflect the presence of two distinct nucleogenic components.

Figure 1: Isotope composition of neon released from fluid inclusions contained in quartz samples from the Himalaya and Alpes. Crushing steps define a mixing line between Air and nucleogenic neon produced in the crust. Errors are at 1σ, smaller than the size of symbols.

Argon. Results are typical of quartz containing significant amounts of crustal fluids. 36Ar/38Ar ratios are close to the atmospheric value. 40Ar/36Ar ratios range from 1,200 to about 30,000 signing the presence of parentless radiogenic 40Ar [10].

Xenon. Xenon contained in both series of sample consist in a mixing between atmospheric xenon and fissiogenic xenon produced by the spontaneous fission of 235U (Fig. 2 & 3). Like neon, the correlation is extremely well defined with a fissiogenic production ratio matching the one reported in the literature [11] and passing through the composition of modern air (Fig. 3),
even for samples from the Himalaya which show elevated isotope ratios for heavy xenon isotopes (maximum $^{136}\text{Xe}/^{130}\text{Xe}$ ratio of about 16 (!)).

Figure 2: Three-isotope plot of xenon released from fluid inclusions contained in quartz samples from the Himalaya and Alpes. Crushing steps reveal a clear contribution from fissionogenic xenon from the spontaneous fission of $^{238}\text{U}$. Errors are at 1σ, smaller than the size of symbols. Extrapolation of the correlation line passes through "Air" (see figure below).

Figure 3: Close-up view of the graph above showing that extrapolation of the correlation line computed on datapoints passes through the composition of modern atmospheric xenon without forcing. Errors are at 1σ.

Elemental ratios. For most crushing steps, results plot close to the seawater line corresponding to elemental ratios of atmospheric noble gases dissolved in seawater (Fig. 4). However, data show significant scatter. This means that deducing the elemental ratio of the original atmospheric component trapped in fluid inclusions in hydrothermal quartz remains very challenging.

Interpretations and perspectives: Samples analyzed in this study show various contributions from nucleogenic (Ne), radiogenic (Ar) and fissionogenic (Kr, Xe) noble gas isotopes produced in the Earth's crust over time. The key finding of this study is that despite the presence of significant amounts of noble gas isotopes produced by radioactivity, our method allows retrieving with accuracy and precision the composition of the atmospheric end-member.