DOUBLE BETA DECAY OF TELLURIUM-130: CURRENT STATUS. A. P. Meshik, C. M. Hohenberg, O. V. Pravdivtseva, and T. J. Bernatowicz, Laboratory for Space Sciences and Physics Department, Washington University, CB1105, One Brookings Drive, Saint Louis, MO 63130 (am@wuphys.wustl.edu).

Introduction: Geochemical determinations of radioactive decay rate are based on the measurement of daughter/parent ratios in a sample with known daughter accumulation time. Geochemically measured ^{130}Te double beta decay half-lives measured over decades in different laboratories tend to fall into two distinct groups: $2.5 \pm 0.4 \times 10^{21}$ years and $8 \pm 1 \times 10^{20}$ years, far beyond stated experimental uncertainties. The measured values do not seem to be correlated with the chemical composition, the mineralogy or the mass spectrometric facilities used (laboratory bias). The purpose of this work was to understand whether the spread in apparent ^{130}Te half-lives is real or an artifact of the geochemical properties of native Te.

Two explanations have been suggested from research groups advocating either "low" or "high" values for the ^{130}Te half-life: low age proponents [1] proposed that, since tellurides are "soft" low-temperature minerals, they may not retain Xe well, therefore the shorter half-life might provide the correct value; high age proponents [2] suggested that during telluride formation they inherited and trapped some mono-isotopic ^{130*}Xe from ores of a previous generation (similar to "parentless" ^{40}Ar), explaining the "low" measured ^{130}Te half-lives. We performed two different experiments to address each of these points of view.

Verification of Xe retention: Native Te samples from Colorado which previously yielded "long" ^{130}Te half-lives [2] were irradiated with thermal neutrons in order to produce ^{131}Xe from ^{130}Te by n-capture. Three months later, when all ^{131}I had decayed into ^{131}Xe, the isotopic composition of Xe released from the samples was measured in step-wise heating. After removal of trapped atmospheric and minor fission Xe components, ratios of ^{130*}Xe/^{131*}Xe were plotted *versus* the fractional release of ^{131*}Xe, similar to the "plateau" plot widely used in ^{39}Ar–^{40}Ar dating. Such plateau plots can reveal low temperature losses of radiogenic ^{40}Ar and, in our case ^{130*}Xe. However, the neutron-induced ^{131*}Xe correlates very well with the ββ ^{130}Xe for nearly all temperature fractions, proving that Xe loss is negligible (Fig. 1) over the geologic life of these samples.

Therefore, anomalously long half-lives cannot be attributed to poor ^{130}Xe retention. Assuming Xe retention ages for these two samples are equal to their model Pb-Pb ages, 1.66 and 1.60×10^9 y for the American and Good Hope mine samples, respectively [2], the measured ^{130}Xe* concentrations yield ^{130}Te half-lives of 3.0 and 2.8×10^{21} years, respectively, and thus belong to the "long" half-life group.

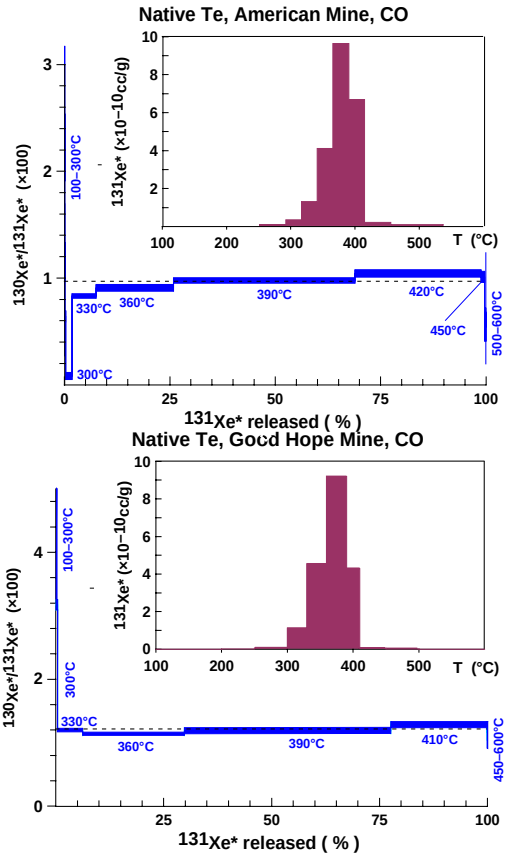

Fig. 1. Plateau plots demonstrate excellent ^{130}Xe* retention: ~ 100% in American Mine, and ~ 97% in Good Hope Mine, over the geologic lifetime of these samples. Also shown are Xe release patterns.

Detection of inherited ^{130*}Xe excess: If ^{130*}Xe has been inherited from a previous generation of ores, it would manifest itself as a low measured ^{130}Te half-life. Native Te from a gold-tellurium deposit Kochbulak, Uzbekistan turned out to be a suitable sample to address this possibility. Geological and paleographical studies [3] of this area set strong limits for ages and duration of ore formation, bracketed by the C_1 and P_3 epochs (61–89 Ma). We determined the ^{130*}Xe/Te in native Te from this deposit to be 10.5×10^{-12} cm^{3}STP/g. This implies a ^{130}Te half-life from 2.4×10^{20} to 3.5×10^{20} years, significantly lower even than "low" half-life group. A similar value (3.3×10^{20} y) was obtained earlier for Kalgoorlie krennerite [2]. These two samples therefore may be the best candidates to look for inherited ^{130*}Xe excesses.

To examine whether "parentless" ^{130*}Xe excesses are present, we examine the correlations between ^{130*}Xe and Xe produced by natural neutron capture reactions (^{129*}Xe or ^{131*}Xe), from cosmic ray muons or fission. Fig. 2 shows ^{129*}Xe/^{132}Xe *versus* ^{130*}Xe/^{132}Xe released from these two tellurides during step-wise extraction. Although differing in slope due to different environmental neutron exposures, both form mixing lines between trapped and Te-derived Xe, and indicate the same (atmospheric) trapped component. Inherited ^{130*}Xe should be visible as a departure from the line at low temperatures or, if well-mixed with trapped Xe, a apparent trapped component enriched in ^{130}Xe. Neither is observed.

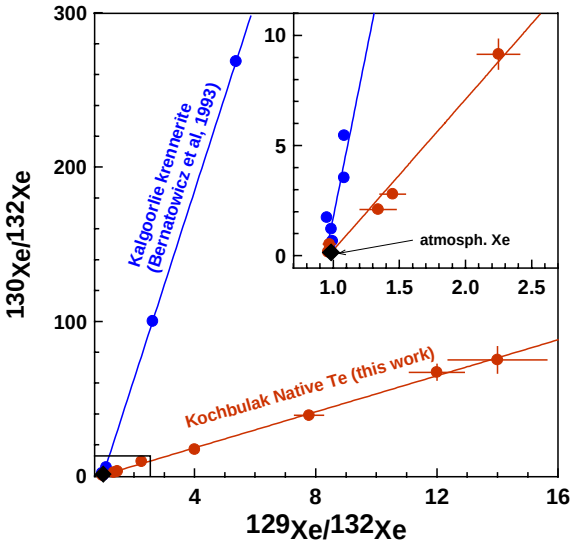

Fig. 2. Lines show simple mixing between a single Te-derived component (^{130*}Xe from ββ-decay and ^{129}Xe* from n-capture) and trapped Xe of atmospheric composition. No excess ^{130*}Xe is observed.

Discussion: We have found that neither Xe loss nor Xe inheritance are responsible for observed diversity of measured ^{130}Te half lives. There is an intriguing qualitative trend: the older the tellurium mineral, the higher the measured half-life seems to be. The same trend is also observed for the weak decay of ^{96}Zr, which has been measured both geochemically [4, 5] and in direct counting experiment [6]. Based upon this trend, it was proposed [4] that double beta decay might be a unique probe for testing whether certain fundamental constants (particularly Fermi constant G_F^4) are truly constant in time. However, if indeed, the weak interaction constant depends on time, it must not be unique to Te and Zr ores. There is very good agreement between the "present" ^{82}Se half-life measured by counting in the MEMO experiment [3] and those measured geochemically in the 4.5 Ga old Cape York meteorite [8], and in several samples of intermediate age [9]. We are left to conclude that the real problem in determining the ^{130}Te half life is the uncertainty in the Xe retention age, which is usually not included in published half-live. There is no reliable gas retention chronometer available for Te minerals. U-He, U-Xe, K-Ar are known to suffer variable losses of the noble gas daughter products. The Pb-Pb ages used in Te studies are model ages, useless for young samples and subjected to misinterpretation for disturbed samples where Xe and/or Pb diffusion has occurred.

One good candidate for accurate chronometry in Te minerals is ββ-decay itself, utilizing the ^{82}Se-^{82}Kr clock. Since the ^{82}Se half-life is relatively well established ($1.0 - 1.3 \times 10^{20}$ y is the range of published values), and it is possible to find minerals that contain both Se and Te, accumulation of ^{82*}Kr provides a reliable gas retention age. $^{130}T_{½}$ / $^{82}T_{½}$ ratio was determined to be 7.3 ± 0.9 from kitkaite (NiTeSe) [9], 10 ± 2 from tellurobismutite [10] and 12.5 ("best estimate") from selenokobellite [11], suggesting a ^{130}Te half-life between the "low" and "intermediate" groups. Clearly more analyses of these extremely rare Se-Te minerals are needed to resolve the mystery of the ^{130}Te half-life. Last decade several new Se-Te minerals have been identified [12,13], and we are currently making efforts to obtain some of them for further analyses.

We thank the stuff of the University Missouri-Rolla Research Reactor for sample irradiation and V. A. Kovalenker (IGEM, Russia) for providing the Kochbulach native Te. Supported by NASA grant NAG5-9442.

References: [1] Manuel O. K. (1991) *J. Phys G: Nucl. Part. Phys* **17**, 5221–9. [2] Bernatowicz T. et al. (1993) *Phys. Rev C*, 47(2), 806–25. [3] Kovalenker V. et al. *www.igem.ru/igem/ored/kovlnkr.htm* [4] Kawashima A. et al. (1993). *Phys. Rev. C*, **47**(6) R2452–6. [5] Wieser M. E. and De Laeter J. R. (2001) *Phys. Rev C*, **64** 243081–7. [6] Arnold R. et al. (1999) *Nucl. Phys. A* **A658**(4) 299–312. [7] Barabash A. S. (1998) *JETP Letters* **68**(1) 1–6. [8] Murty S. V. S and Marti K. (1987) *GCA* **51**, 163–72. [9] Lin W. J., Manuel O. K., Oliver L. L. (1986) *Nucl. Phys. A*, **A457**(2), 285–91. [10] Srinivasan B., Alexander E. C. Jr., Beaty R. D. et al. (1973) *Economic Geology* **68**, 252–7. [11] Kirsten T. *at al* (1986) In: *Nucl. Data decay and Neutrino*, 81–92. [12] Rudkosil T. *et al.* (2001) *Eur. J. Miner.* **13**(1) 177–85. [13] Bayliss P (1991) *Am. Miner.* **76**(1–2), 257–65.