

U-Series Isochron Dating of Evaporitic Deposits of Lakes

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Evaporitic deposits (e.g., halite, gypsum, and carbonate) of closed-basin saline lakes and salars record past changes in regional climates in terms of temperature, aridity, and hydrology. Dating these deposits for paleoclimate reconstructions is thus of great interest and importance. Here we show that for time intervals of ~10-350 ky, the dating can be done by measurements of the radioactive disequilibria among ^{230}Th , ^{234}U and ^{238}U . The ^{230}Th - ^{234}U disequilibrium occurs as a result of the vast difference in solubility between U and Th in natural waters. In contrast to the insoluble thorium, uranium in lakes is significantly in dissolved form and scavenged to the lake bed by sedimenting particles through adsorption, ion-exchange and co-precipitation, mostly in association with organic and Fe/Mn oxide phases attached to clay particles. While pure halite or gypsum crystals hardly co-precipitate U and Th, they often provide an effective enclosure for the U- and Th-bearing particles. The occurrence of authigenic U in this closed-system milieu provided by the primary evaporitic minerals forms the basis of U-series dating of these minerals, hence the evaporitic deposits.

As Th is mostly of detrital origin in lake sediments, authigenic lake deposits usually contain very low $^{232}\text{Th}/^{238}\text{U}$ and $^{230}\text{Th}/^{238}\text{U}$ ratios when formed. In principle, they can be dated based on the extent of ^{230}Th -growth by assuming initial $^{230}\text{Th}/^{234}\text{U} = 0$. However, for most evaporitic sediments, this assumption is negated by the presence of allochthonous (detrital) material admixed therein. As this detrital material is difficult to be removed completely by physical and chemical means from the authigenic phases, a total sample dissolution (TSD)-isochron method has been devised to correct for the detrital (hence initial) ^{230}Th (Bischoff et al., 1991; Luo and Ku, 1991). The method calls for measurements of U and Th isotopes on three or more coeval subsamples of different Th/U ratios (hence detrital contents) and assuming that these subsamples have an identical initial $^{230}\text{Th}/^{232}\text{Th}$ ratio. In some alkaline lakes, dissolved Th concentrations may not negligibly low and contribute further to the initial ^{230}Th . However, since this dissolved Th most likely originates from dissolution of detrital material in the lake, it should have a $^{230}\text{Th}/^{232}\text{Th}$ ratio similar to that of the detritus. Thus the assumption of constant initial $^{230}\text{Th}/^{232}\text{Th}$ should still hold.

The isochron method involves the plots of $^{230}\text{Th}/^{232}\text{Th}$ vs. $^{234}\text{U}/^{232}\text{Th}$ for a set of aliquots separated from a given sample. A better-defined "isochron" in these plots requires that the separated coeval subsamples exhibit a range of U/Th ratios. For this requirement, we took note of the following: The U/Th ratio in an evaporite differs significantly among various host phases of authigenic U: clays, organics, carbonates, and other minerals. Thus the subsampling basically involves the apportioning of these phases among the subsamples so as to achieve the widest spread of U/Th possible. Evaporites formed subaerially or under oxic shallow-water conditions contain sands and silts which

are low in authigenic U, not to mention their potential contribution to the non-uniformity of initial $^{230}\text{Th}/^{232}\text{Th}$ during the subsampling. They are to be avoided, so are clay-rich horizons which, being without the casing by massive halite crystals, may act as an open-system for U.

Using the isochron method, we have dated salt deposits from a number of locations including the Qaidam Basin in western China (2 cores), Death Valley in California (1 core), and the central Andes salars in S. America (4 cores). A given salt deposit was crushed into <0.5-cm-sized chunks with different degrees of detrital contents., and 3-4 coeval subsamples were assembled from them by hand-picking. Radiochemical analyses of U (^{234}U and ^{238}U) and Th (^{230}Th and ^{232}Th) isotopes were then performed on each of the subsamples by α -spectrometry.

In this presentation, we will show the general quality of the age data based on isochron determinations. The least-squares linear fits for the isochrons are good, with values for the correlation coefficient squared (R^2) mostly in the range 0.9-1.0. Within a given core the ages are consistent with stratigraphic succession. This stratigraphic consistency extends to different cores from the same basins. For instance, cores ZK2605 and ZK402 both show chronologies for the transition of climate from humid to arid conditions in the Qaidam Basin at 302 ± 56 ka, at 138 ± 6 ka, and at 16.3 ± 2.2 ka. The chronologies of the Salar de Atacama Basin cores also show consistent salt cyclicities, even though faulting in the basin has resulted in truncated sedimentation in some of these cores.

Independent estimates to cross-check the isochron ages have been available, including: (1) AMS- ^{14}C dating of organics in salts from Salar de Uyuni, Bolivia, (2) ^{36}Cl dating of the Qaidam Basin cores, and (3) U-series dating of tufas collected from the strandlines of Lake Manly. On the whole these cross-checks, though somewhat limited in scope and number, serve to validate the isochron dates well. For example, the tufa dates, which do not require corrections for the detrital ^{230}Th , yield information on Lake Manly history that is consistent with the late Pleistocene climatic history as revealed by our isochron dating of the evaporitic salts in a drill core from the Badwater Basin, Death Valley (Ku et al., 1998). Both the tufa and sediment core records indicate the existence of a perennial lake during ~10–35 ka and 120–185 ka, and the arid climate condition during the entire Holocene and the period 60-120 ka. The highest Lake Manly stand occurring between 160 and 185 ka appears to coincide with the period of coldest temperatures around 155 to 170 ka as registered by $\delta^{18}\text{O}$ signals of the Devils Hole calcites.

While the U-series dating of evaporitic lake sediments has shown promises thus far, the technique may extend to other late Pleistocene terrestrial deposits, such as rock vanish, peat, and various vein or sedimentary deposits of opaline, carbonate, phosphate, and sulfate compositions. The availability of high-precision instrumentations (e.g., TIMS and ICPMS) should further greatly facilitate the application of this dating method.

References Cited

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