

ESS 460 – ESS 560 Cosmogenic Nuclides Homework Week 3

Take a look at the list of "meteoric" or "atmospheric" cosmogenic nuclides in Table 1 of Lal's 1988 article, handed out in class. The full reference is given below.

Select one nuclide other than ^{14}C , which is the best known and most widely used (*hopefully* not everyone will choose ^{10}Be). Read at least one of the papers in the list below dealing with the nuclide of your choice and its use or uses. Research and answer the following:

- (1) What is the half-life?
- (2) What is the production reaction (or reactions) in the atmosphere?
- (3) What is the principal target element?
- (4) Give an approximate estimate of the production rate.
- (5) What are the geochemical affinities of the element? i.e. Is this an element normally found in the atmosphere (*atmosphile*), rivers, lakes, oceans or groundwater (*hydrophilic*), rocks (*lithophile*) or in biological materials (*biophilic* or *nutrient element*)? Briefly summarise the types of chemical processes the element participates in.
- (6) If the nuclide you chose is a *lithophile*, *hydrophilic* or *biophilic* element, how is it removed from the atmosphere? How does it disperse thereafter? What geochemical cycles does it enter into?
- (7) How is the nuclide useful to geochemists? For example, how is it used to fingerprint the source of a geologic material? Track a geochemical or biological process? Or trace the exchange of material between geochemical reservoirs? Date a geologic or biologic material? Answers to this question will depend on which nuclide you chose – for example, the uses of ^{32}P and ^{36}Cl are very different.

Putting this together should take about 1/2 a page to 1 page. Be concise and use note-form answers where appropriate. Write more if you get fascinated. Feel free to discuss your choice of nuclide with me, or others in the class. Let me know if I've omitted important reference material, and I will add it to the web page.

Suggested reading material organised by topic

This is mostly from the pre-pdf era. Look for it on the website “reading” page, or visit the library and browse through the old paper journals ...

General references concerning meteoric (“garden variety”) cosmogenic nuclides:

- P. Fritz and J.-C. Fontes (Editors), Handbook of Environmental Isotopes. Elsevier, New York, pp. 422-480. Other articles deal with ^7Be , ^3H , and other less commonly used isotopes.
- Lal, D. and Peters, B., 1967. Cosmic ray produced radioactivity on the earth. In: S. Flugg (Editor), Handbuch der Physik. Springer, Berlin, pp. 551-612.
- Beer, J. et al., 2002. Cosmogenic nuclides during Isotope Stages 2 and 3. Quaternary Science Reviews, 21, 1129-1139.
- Lal, D., 1999. An overview of five decades of studies of cosmic ray produced nuclides in oceans. Science of the Total Environment, 238 (Special Iss. SI): 3-13.

Meteoritic ^{10}Be in subduction-related volcanic rocks:

- Brown, L., Klein, J., Middleton, R., Sacks, I.S. and Tera, F., 1982. Be-10 in Island-Arc Volcanos and Implications for Subduction. Nature, 299(5885): 718-720.
- Tera, F. et al., 1986. Sediment incorporation in island-arc magmas: Inferences from ^{10}Be . Geochim. Cosmochim. Acta, 50: 535-550
- Morris, J.D., 1991. Applications of cosmogenic ^{10}Be to problems in the earth sciences. Ann. Rev. Earth Planet. Sci., 19: 313-350.

Meteoritic ^{10}Be and ^{36}Cl in ice cores:

- Baumgartner, S. et al., 1998. Geomagnetic modulation of the Cl-36 flux in the GRIP ice core, Greenland. Science, 279(5355): 1330-1332.
- Steig, E.J., Polissar, P.J., Stuiver, M., Grootes, P.M. and Finkel, R.C., 1996. Large amplitude solar modulation cycles of ^{10}Be in Antarctica; implications for atmospheric mixing processes and interpretation of the ice core record. Geophysical Research Letters, 23(5): 523-526.
- Beer, J. et al., 1990. Use of ^{10}Be in polar ice to trace the 11-year cycle of solar activity. Nature (London), 347(6289): 164-166.

An unusual approach to reconstructing paleomagnetic field variations using ^{36}Cl :

- Plummer, M.A. et al., 1997. Chlorine-36 in fossil rat urine: An archive of cosmogenic nuclide deposition during the past 40,000 years. Science, 277, 538-541.

Use of meteoritic ^{10}Be to estimate erosion rates:

- Brown, L., Pavich, M.J., Hickman, R.E., Klein, J. and Middleton, R., 1988. Erosion of the eastern United States observed with ^{10}Be . Earth Surf. Processes Landf., 13: 441-457 (IMO possibly the best cosmogenic nuclide paper ever written).

Hydrologic applications and use of meteoritic ^{32}Si , ^{36}Cl , ^{129}I and ^{81}Kr in groundwater:

- Patterson, L.J. et al., 2005. Cosmogenic, radiogenic, and stable isotopic constraints on groundwater residence time in the Nubian Aquifer, Western Desert of Egypt. Geochemistry Geophysics Geosystems, 6.

Bentley, H.W., Phillips, F.M. and Davis, S.N., 1986. Chlorine-36 in the terrestrial environment. In: P. Fritz and J.-C. Fontes (Editors), Handbook of Environmental Isotopes. Elsevier, New York, pp. 422-480.

Collon, P. et al., 2000. Kr-81 in the Great Artesian Basin, Australia: a new method for dating very old groundwater. Earth and Planetary Science Letters, 182(1): 103-113.

Knies, D.L. et al., 1994. Be-7, Be-10, and Cl-36 in Precipitation. Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms, 92(1-4): 340-344.

Use of meteoric ^{32}Si to date glacier ice and young groundwater:

Morgenstern, U., Taylor, C.B., Parrat, Y., Gaggeler, W.H. and Eichler, B., 1996. Si-32 in precipitation: Evaluation of temporal and spatial variation and as dating tool for glacial ice. Earth and Planetary Science Letters, 144, 289-296.

Use of ^7Be as an atmospheric tracer:

Koch, D. and Rind, D., 1998. Beryllium-10/beryllium-7 as a tracer of stratospheric transport. Journal of Geophysical Research-Atmospheres, 103(D4): 3907-3917.

Kulan, A., Aldahan, A., Possnert, G. and Vintersved, I., 2006. Distribution of Be-7 in surface air of Europe. Atmospheric Environment, 40(21): 3855-3868.

Oceanographic tracing with $^{32,33}\text{P}$ (and ^7Be):

Benitez-Nelson, C.R. and Karl, D.M., 2002. Phosphorus cycling in the North Pacific Subtropical Gyre using cosmogenic P-32 and P-33. Limnology and Oceanography, 47(3): 762-770.

Lee, T., Barg, E. and Lal, D., 1991. Studies of Vertical Mixing in the Southern California Bight with Cosmogenic Radionuclides P-32 and Be-7. Limnology and Oceanography, 36(5): 1044-1053.

A more complete bibliography

General references

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- Lal, D., 1999. An overview of five decades of studies of cosmic ray produced nuclides in oceans. *Science of the Total Environment*, 238(Special Iss. SI): 3-13.
- Lal, D. and Peters, B., 1967. Cosmic ray produced radioactivity on the earth. In: S. Flugg (Editor), *Handbuch der Physik*. Springer, Berlin, pp. 551-612.

References to meteoric ³⁶Cl and its applications:

- Baumgartner, S. et al., 1998. Geomagnetic modulation of the Cl-36 flux in the GRIP ice core, Greenland. *Science*, 279(5355): 1330-1332.
- Baumgartner, S. et al., 1997. Chlorine 36 fallout in the Summit Greenland Ice Core Project ice core. *Journal of Geophysical Research Oceans*, 102(C12): 26659-26662.
- Cresswell, R.G., Jacobson, G., Wischusen, J. and Fifield, L.K., 1999. Ancient groundwaters in the Amadeus Basin, Central Australia: evidence from the radio-isotope Cl-36. *Journal of Hydrology*, 223(3-4): 212-220.
- Davis, S.N., Cecil, L.D., Zreda, M. and Moysey, S., 2001. Chlorine-36, bromide, and the origin of spring water. *Chemical Geology*, 179(1-4): 3-16.
- Elmore, D. et al., 1982. (super 36) Cl bomb pulse measured in a shallow ice core from Dye 3, Greenland. *Nature (London)*, 300(5894): 735-737.
- Finkel, R.C., Nishiizumi, K., Elmore, D., Ferraro, R.D. and Gove, H.E., 1980. (super 36) Cl in polar ice, rainwater and seawater. *Geophysical Research Letters*, 7(11): 983-986.
- Knies, D.L. et al., 1994. Be-7, Be-10, and Cl-36 in Precipitation. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms*, 92(1-4): 340-344.
- Lippmann, J. et al., 2003. Dating ultra-deep mine waters with noble gases and Cl-36, Witwatersrand Basin, South Africa. *Geochimica Et Cosmochimica Acta*, 67(23): 4597-4619.
- Patterson, L.J. et al., 2005. Cosmogenic, radiogenic, and stable isotopic constraints on groundwater residence time in the Nubian Aquifer, Western Desert of Egypt. *Geochemistry Geophysics Geosystems*, 6.
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- Scheffel, C. et al., 1999. Cl-36 in modern atmospheric precipitation. *Geophysical Research Letters*, 26(10): 1401-1404.
- Wagner, G. et al., 2000a. Chlorine-36 evidence for the Mono Lake event in the Summit GRIP ice core. *Earth and Planetary Science Letters*, 181(1-2): 1-6.
- Wagner, G. et al., 2001. Reconstruction of the paleoaccumulation rate of central Greenland during the last 75 kyr using the cosmogenic radionuclides Cl-36 and Be-10 and geomagnetic field intensity data. *Earth and Planetary Science Letters*, 193(3-4): 515-521.

Wagner, G. et al., 2000b. Reconstruction of the geomagnetic field between 20 and 60 kyr BP from cosmogenic radionuclides in the GRIP ice core. *Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms*: 597-604.

References to meteoric ⁷Be and its applications:

Brown, L., Stensland, G.J., Klein, J. and Middleton, R., 1989. Atmospheric deposition of ⁷Be and ¹⁰Be. *Geochim. Cosmochim. Acta*, 53: 135-142.

Goel, P.S., Jha, S., Lal, D., Rhadakrishna, P. and Rama, 1956. Cosmic ray produced beryllium isotopes in rainwater. *Nucl. Phys.*, 1: 196-201.

Graham, I., Ditchburn, R. and Barry, B., 2003. Atmospheric deposition of Be-7 and Be-10 in New Zealand rain (1996-98). *Geochimica Et Cosmochimica Acta*, 67(3): 361-373.

Koch, D. and Rind, D., 1998. Beryllium 10 beryllium 7 as a tracer of stratospheric transport. *Journal of Geophysical Research-Atmospheres*, 103(D4): 3907-3917.

Kulan, A., Aldahan, A., Possnert, G. and Vintersved, I., 2006. Distribution of Be-7 in surface air of Europe. *Atmospheric Environment*, 40(21): 3855-3868.

Lee, T., Barg, E. and Lal, D., 1991. Studies of Vertical Mixing in the Southern California Bight with Cosmogenic Radionuclides P-32 and Be-7. *Limnology and Oceanography*, 36(5): 1044-1053.

Nagai, H., Tada, W. and Kobayashi, T., 2000. Production rates of Be-7 and Be-10 in the atmosphere. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms*, 172: 796-801.

Rehfeld, S. and Heimann, M., 1995. Three dimensional atmospheric transport simulation of the radioactive tracers Pb-210, Be-7, Be-10, and Sr-90. *Journal of Geophysical Research-Atmospheres*, 100(D12): 26141-26161.

Smith, A.M. et al., 2000. Be-7 and Be-10 concentrations in recent firn and ice at Law Dome, Antarctica. *Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms*: 847-855.

References to meteoric ¹⁰Be and its applications:

Barg, E., Lal, D., Pavich, M.J., Caffee, M.W. and Southon, J.R., 1997. Beryllium geochemistry in soils: evaluation of Be-10/Be-9 ratios in authigenic minerals as a basis for age models. *Chemical Geology*, 140(3-4): 237-258.

Beer, J. et al., 1990. Use of ¹⁰Be in polar ice to trace the 11-year cycle of solar activity. *Nature (London)*, 347(6289): 164-166.

Beer, J. et al., 1988. Information on past solar activity and geomagnetism from ¹⁰Be in the Camp Century ice core. *Nature (London)*, 331(6158): 675-679.

Brown, E.T. et al., 1992. Beryllium Isotope Geochemistry in Tropical River Basins. *Geochimica Et Cosmochimica Acta*, 56(4): 1607-1624.

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- Yiou, F. et al., 1997. Beryllium 10 in the Greenland Ice Core Project ice core at Summit, Greenland. *Journal of Geophysical Research Oceans*, 102(C12): 26783-26794.

References to meteoric ^{129}I and its applications:

- Cooper, L.W. et al., 1998. Iodine-129 and plutonium isotopes in Arctic kelp as historical indicators of transport of nuclear fuel-reprocessing wastes from mid-to-high latitudes in the Atlantic Ocean. *Marine Biology*, 131, 391-399.

References to meteoric $^{32,33}\text{P}$ and their applications:

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- Benitez-Nelson, C.R. and Karl, D.M., 2002. Phosphorus cycling in the North Pacific Subtropical Gyre using cosmogenic P-32 and P-33. *Limnology and Oceanography*, 47(3): 762-770.
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References to meteoric ³²Si and its applications:

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References to meteoric ⁸¹Kr and its applications:

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