Bringing the Mid-Atlantic region to the light: a summary of published luminescence ages (OSL, IRSL, TL) from the area, what we have learned and new utilities of the technique in regional geomorphology and archaeology

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Introduction to luminescence dating –OSL/IRSL/TL

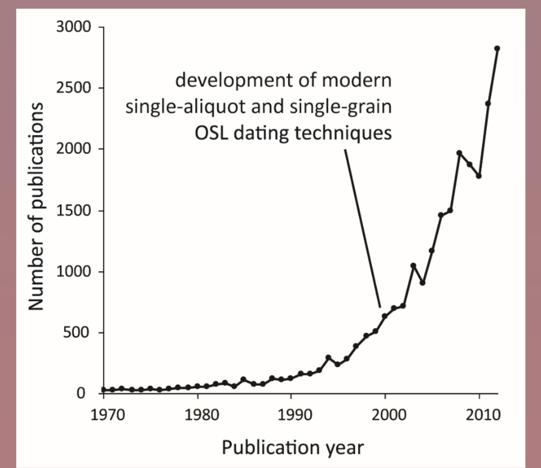
Luminescence dating provides an age estimate of the last time quartz or feldspar minerals were last exposed to sufficient light or heat (> 450°C). After removal from heat or from sunlight, electrons accumulate in defects in the crystal lattice of minerals by exposure to ionizing radiation (Aitken, 1998).

$$Age\ (ka) = \frac{Equivalent\ Dose,\ D_E\ (Gy)}{Dose\ Rate,\ D_R\ (Gy/ka)}$$

D_E - Amount of absorbed radiation since last exposure to light or heat, measured in the lab.
D_R - Rate in which electrons accumulate in traps, and is proportional to the flux of radiation from radioelemental decay of K, U, Th, and Rb, in addition to cosmogenic nuclide radiation.

Dating range is typically ~100 - 200,000 years, or greater depending on dose rate environment.

Recent technological advances and the development of single-aliquot (Murray and Wintle 2000; Wallinga et al. 2000) and single-grain dating capabilities (Bøtter-Jensen et al. 2000; Duller et al. 1999) have greatly expanded archaeological and geological applications



Nelson et al., 2015

Where would you collect a luminescence sample in the outcrops below?

Paleoseismic trench central VA

Basin-fill southern AZ

Geomorphic ?'s:

- What was the depositional environment?
- Was there sufficient sunlight exposure to reset a previous luminescence signal?
- Has the deposit experienced post-depositional mixing?
- How homogenous is the dose rate environment?
- Has there been recent erosion or aggradation of the geomorphic surface?
- Is the in-situ water content representative of average conditions over burial history?

Mineralogical ?'s:

- Is it the correct grain size?
- What is the primary mineralogy?
- Is there enough quartz or feldspar?
- Do the grains have sedimentary history, or are they recently eroded from igneous or metamorphic rocks?
- Are the grains heavily chemically weathered?
- Are there abundant micaceous minerals?
- Are volcanic grains and minerals present?
- Is there carbonate coating on the grains/gravels/cobbles?

Champlain Sand Sea, Quebec, Canada

Ideal sampling conditions, considerations for best practices:

Equivalent dose (D_E)

- Grain size range: 63-250µm or 4-11µm
- Avoid active soil processes and stratigraphy with indicators of bio-, cryo-, pedoturbation
  - Vertical mixing of grains can cause age over or underestimation
- Requires sufficient exposure to light or heat to reset any previous signal
  - Partial bleaching is caused by incomplete solar resetting upon burial
  - Can be mitigated with single-grain dating and minimum age modeling
- Grains with long sedimentary history, i.e. derived from sedimentary rocks are generally most susceptible to acquiring a luminescence signal
  - Grains with igneous/volcanic or metamorphic origin may have dim signals or strong non-fast components of total signal

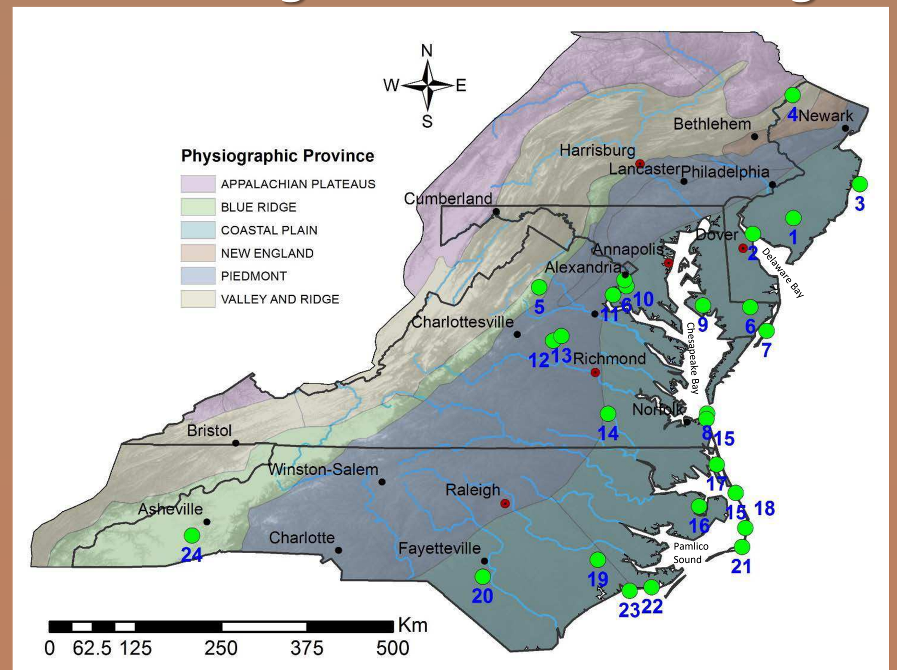
Dose Rate (D_R)

- Homogeneity of grain size and mineralogy within 15-cm radius preferred
- Consistent or average water content conditions over time, as variation may lead to non-linear attenuation of dose rate or radioelemental disequilibrium
  - Estimate of site variability is important and may require dose rate modeling if extreme fluctuations assumed
- Chemical and physical weathering can add or remove radioelements
- Recent/modern erosion or aggradation can change burial depth
  - Burial depth influences magnitude of cosmogenic radiation received

Luminescence dating in archaeology – ceramics, building materials:

- Requires single-grain dating
- Separate D_R sample needed for specimen and surrounding sediment
- Abundant quartz or feldspar in temper or paste required
- Sherds should be >5mm thick, >2cm in diameter and heated to >450°C
- Wildfires can reset signal acquired since ceramic construction (Ideker et al., *in press*)

Studies utilizing luminescence dating in the Mid-Atlantic region



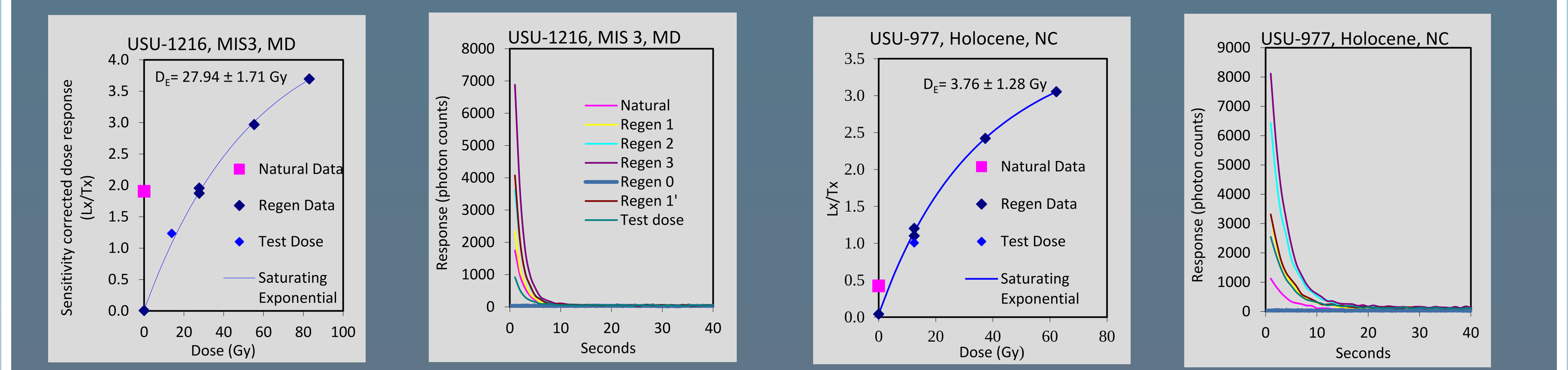
Study ID #	Region	Deposit type or geomorphic feature	Technique	# samples	Ref
1	Pine Barrens, NJ	sand wedges, permafrost and thermokarst	multi-grain Qtz OSL SAR and polymineral IRSL	12	French et al., 2007
2	Quaternary Cape May formation Jones Island, southern NJ	MIS 5 high stand	multi-grain Qtz MAAD	3	O'Neal and Dunn, 2003
3	Pine Barrens, NJ	cover sands over permafrost features	multi-grain Qtz OSL SAR	2	Demitroff, 2016
4	Northern Delaware River Valley, NJ	floodplain and terrace alluvium	multi-grain Qtz pIR-OSL SAR	4	Bitting, 2013
5	SE MD east of Chesapeake Bay region	Late Pleistocene eolian features	multi-grain Qtz OSL SAR	7	Markewich et al., 2009
6	SE MD east of Chesapeake Bay region, Delmarva DE and MD	Late Pleistocene eolian features	multi-grain Qtz OSL SAR	5	Markewich et al., 2015
6	Delmarva Peninsula DE and MD	Late Pleistocene eolian features	multi-grain Qtz OSL SAR	5	Markewich et al., 2015
7	Assateague Island, MD	relict tidal inlet along wave-dominated barrier island	multi-grain Qtz OSL SAR	3	Seminack and Buynevich, 2013
8	eastern shore VA (southern Delmarva Peninsula) and south side VA	MIS 5 and MIS 3 coastal deposits	multi-grain Qtz OSL SAR	8	Scott et al., 2010
9	Chesapeake Bay (MD)	MIS 5 and MIS 3 coastal deposits: paleoshorelines, tidal-dominated channels, estuarine facies	multi-grain Qtz OSL SAR	28	DeJong et al., 2015
10	Hybla Valley, northern VA	25-100ka sands with interbedded mud	multi-grain Qtz OSL SAR	6	Litwin et al., 2013
11	Kent Island, Chesapeake Bay MD and other around Chesapeake Bay	estuarine sands and silts	multi-grain Qtz OSL SAR	>5	Pavich et al., 2006; 2009
12	Virginia Piedmont, South Anna River	fluvial terraces	multi-grain Qtz OSL SAR and Feld IRSL	9	Pazzaglia et al., 2015; Malenda, 2015
13	Central VA Seismic Zone	terrace, floodplain, colluvial	multi-grain Qtz OSL SAR and Feld IRSL	>5	Burton et al., 2015; Harrison et al., 2012
14	Cactus Hill, VA (between Richmond and Emporia VA)	culturally stratified dune on alluvial terrace along Nottoway River in Sussex County, VA	single-grain and multi-grain Qtz OSL SAR	13	Feathers et al., 2006
15	Albemarle embayment , VA and NC	Holocene back-barrier coastal dune	multi-grain Qtz OSL SAR	7	Havholm et al., 2004
15	Albemarle embayment , NC	Holocene back-barrier coastal dune	multi-grain Qtz OSL SAR	7	Havholm et al., 2004
16	Albemarle embayment , VA and NC - Pamlico and Talbot coastal terraces	estuarine and marine interfluve deposits	multi-grain Qtz OSL SAR	23	Parham et al., 2013
17	Currituck and Kitty Hawk, NC	paleoshoreline ridges/ beach ridge complex	multi-grain Qtz OSL SAR	27	Mallinson et al., 2008
18	Outer Banks around Pamlico Sound, NC - Hatteras and Ocracoke islands	paleoinlet channels; inlet fills	multi-grain Qtz OSL SAR	26	Mallinson et al., 2011
19	Squires Ridge, Owens Ridge and other sites along the Tar River, upper NC coastal plain	occupational stratigraphy in aeolian dune along paleo Tar River braidplain	multi-grain Qtz OSL SAR	5	Daniel et al 2013; Moore 2009
20	Herdon Bay SE NC near Cape Fear River	sand rim of Herndon Bay	single-grain Qtz OSL SAR	3	Moore et al., 2016
21	Cape Hatteras, NC	flood deposits from collapsing barrier island	multi-grain Qtz OSL SAR	11	Peek et al., 2014
22	Croatan Beach Ridge Complex, Bogue Banks, and Bogue Sound, NC	inner shelf/ open shelf/ lagoon/spit complex	multi-grain Qtz OSL SAR	11	Lazar et al., 2016
23	Bogue Banks, NC - southern-most island in the Outer Banks barrier island chain	landward-most beach ridge dune	multi-grain Qtz OSL SAR	3	Timmons et al., 2014
24	Blue Ridge Mtns, NC - southern Appalachian Mtns	Pleistocene periglacial colluvium west side of Pisgah Ridge	multi-grain Qtz TL	3	Shafer, 1988

Broad conclusions:

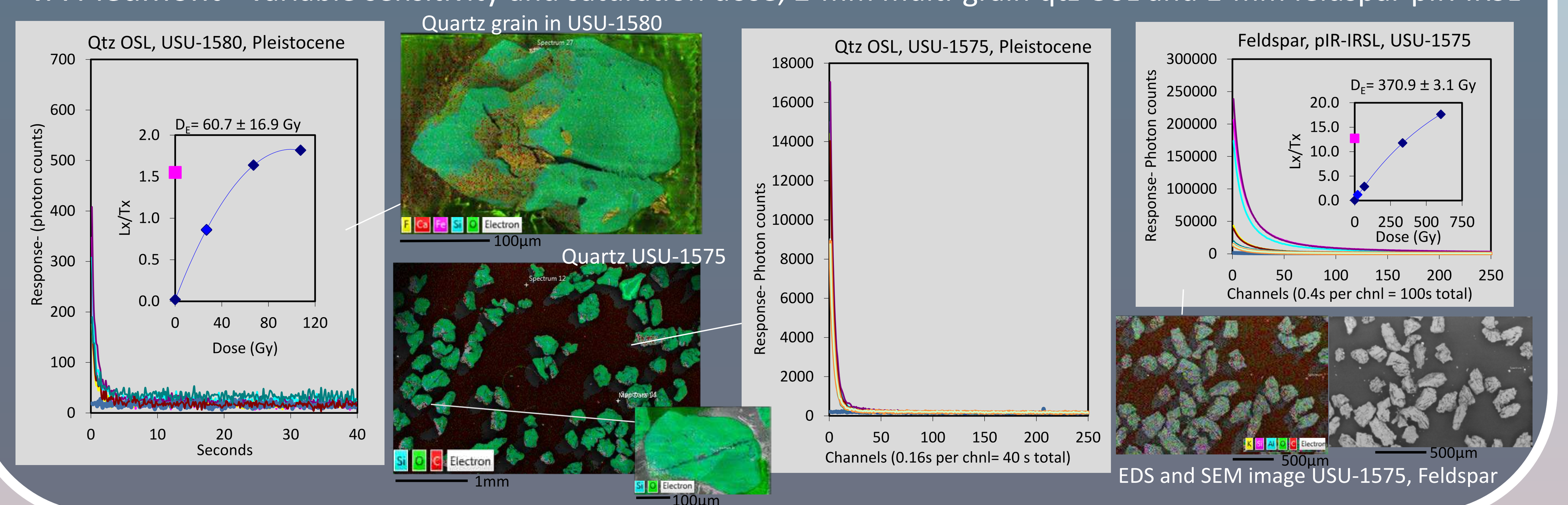
1. Most dates in the area are from multi-grain quartz OSL
2. Generally OSL supports other age control
3. Systematic OSL/IRSL work needed in other physiographic provinces aside from coastal plain
4. More eolian and fluvial features could be dated with OSL and correlated to ice and shoreline records
5. Unusual amount of OSL lab collaboration amongst various projects

Luminescence characteristics – examples from MD, NC, VA

Coastal MD and NC- generally highly-sensitive quartz OSL @ 1-2mm multi-grain- aliquot



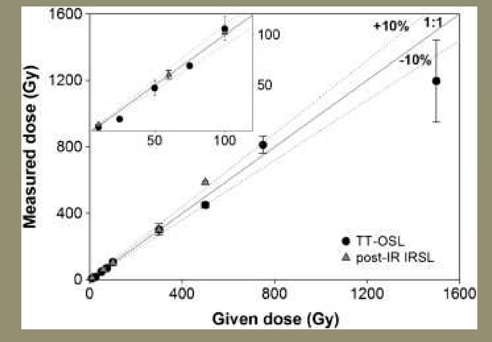
VA Piedmont - variable sensitivity and saturation dose, 2-mm multi-grain qtz OSL and 1-mm feldspar pIR-IRSL



EDS and SEM image USU-1575, Feldspar

Emerging Applications

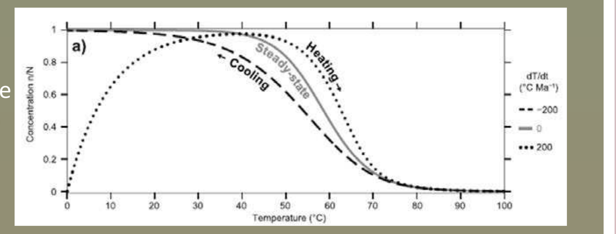
- Age Range extension: Thermal Transfer OSL – TT OSL



Thiel et al 2012: Figure 3 – Dose Recovery test results

- Low temperature thermochronology of bedrock

Guralnik et al., 2015: Figure 3a - Evolution of trap filling n/N of the fast OSL component in a set of representative linear cooling (dashed), heating (dotted) and thermal steady-state (solid grey) scenarios.



- Portability for in-situ and extraterrestrial measurements (McKeever et al., 2003)

Sanderson and Murphy, 2010

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