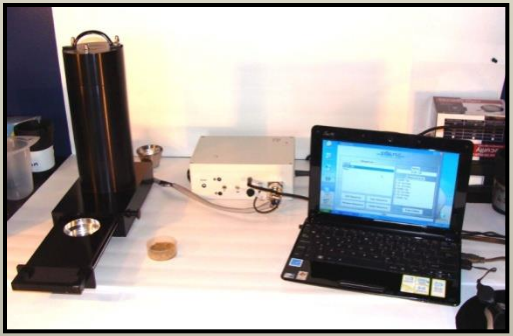
The utility of portable optically stimulated luminescence (OSL) readers in providing temporal contexts in clastic depositional systems: opportunities in geomorphology



Ken Munyikwa
Athabasca University, Alberta
Selena Brown
Evan Plumb
University of Alberta

NSERC CRSNG

Athabasca University

Overview

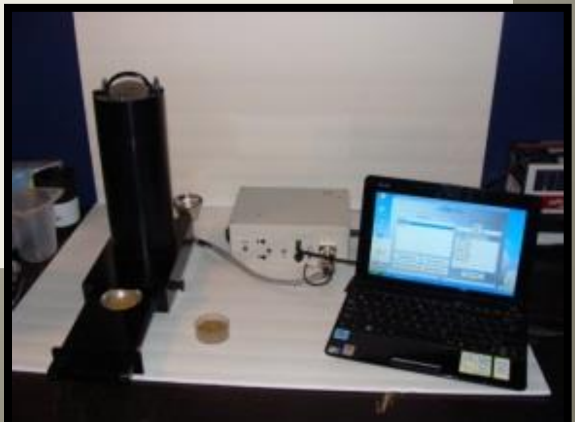
- Introduction
- Portable OSL readers
- Luminescence profiling
- Examples of applications from Alberta, Canada
  1. Approximating relative ages of depositional units in a stratigraphic sequence
  2. Delineating stratigraphic breaks at bases of eolian dunes to aid sample collection
  3. Identifying post-depositional sediment mixing in a stratigraphic sequence.
- Conclusions

Introduction

- Portable OSL readers in geomorhpology
  - The recent invention has ushered in new capabilities in field geomomrphological studies[1]
    - enhance overview of temporal context
    - disentangles complex depositional systems
    - aids sample collection for luminescence dating

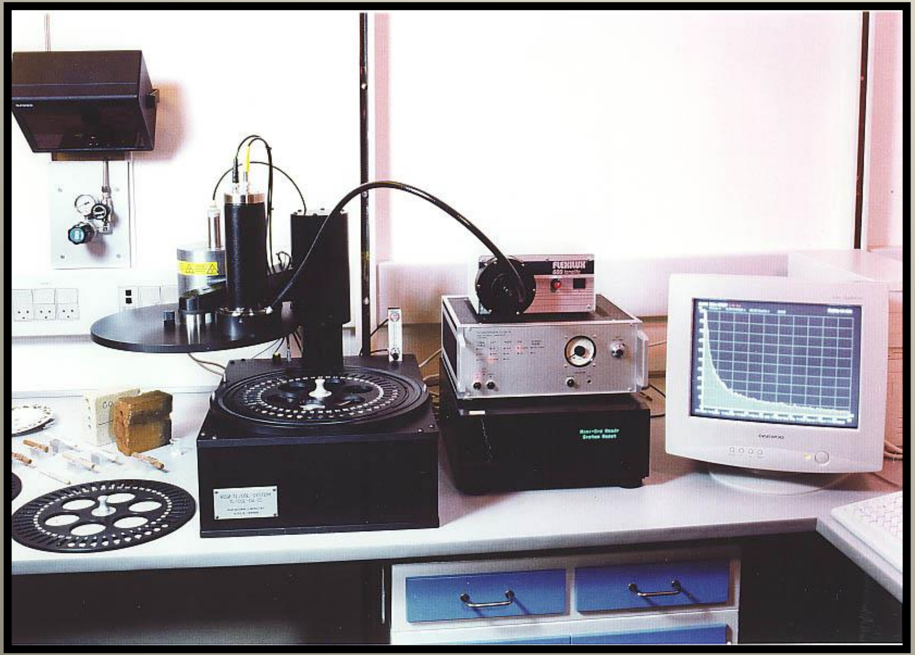
Portable OSL readers

- Portable readers
  - measure luminescence signals of clastic sediments
  - functional readers developed in the last 5-6 yrs
    - Scottish Universities Environmental Research Centre (SUERC) developed one since 2005
    - RISØ have been working on developing one
    - a few other developers are working on the same concept

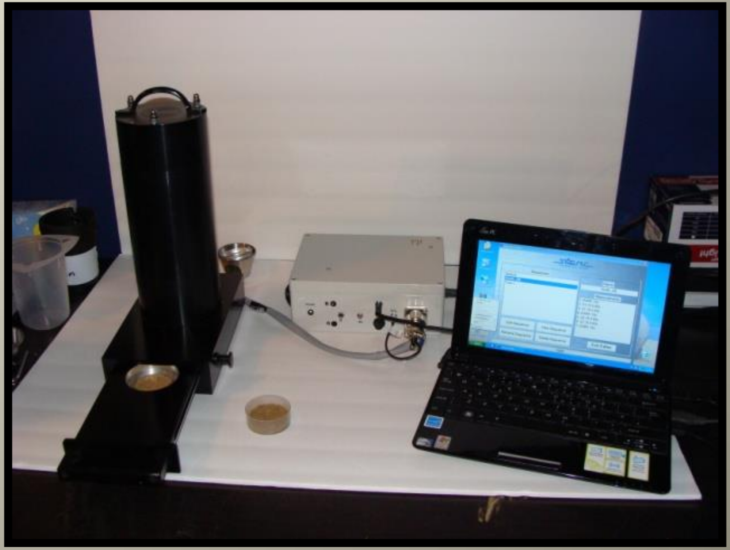


Portable OSL reader

Portable vs. lab-bound OSL reader



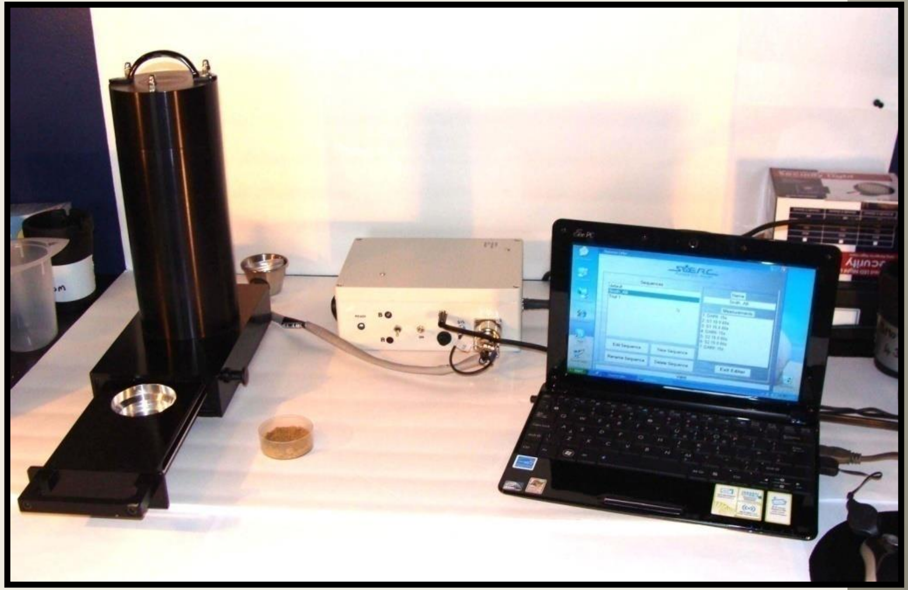
Lab-bound OSL Reader (RISO)



Portable OSL Reader (SUERC)

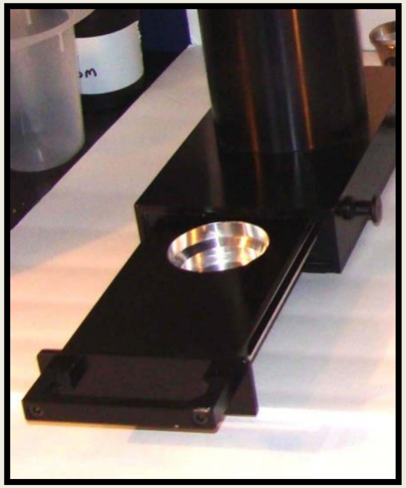
Portable OSL Reader

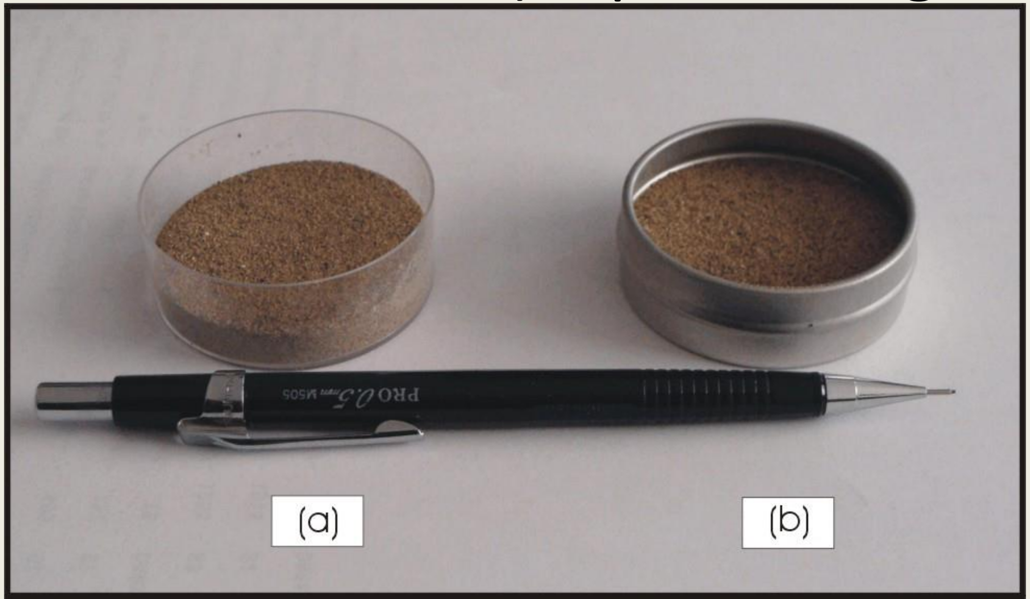
- Ideal instrument for rapid measurement of luminescence signals[1]
  - lightweight and portable (can be taken to field)
  - can be battery operated when mains unavailable
  - can measure signal on bulk (polymineralic samples)



Portable OSL reader

- Samples are introduced into machine in holder on tray
- Sample containers
  - can be plastic petri dish (5 cm diameter)
  - metallic (stainless steel or aluminum) if preheating is required.



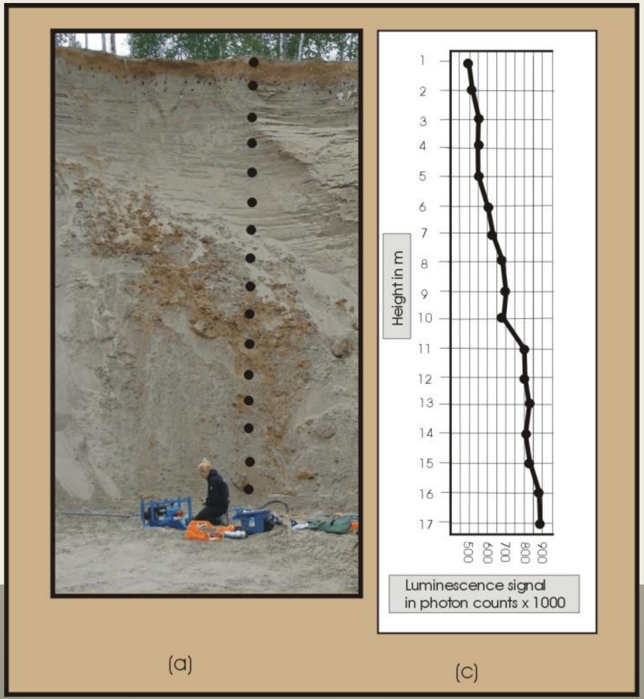


Portable OSL Reader

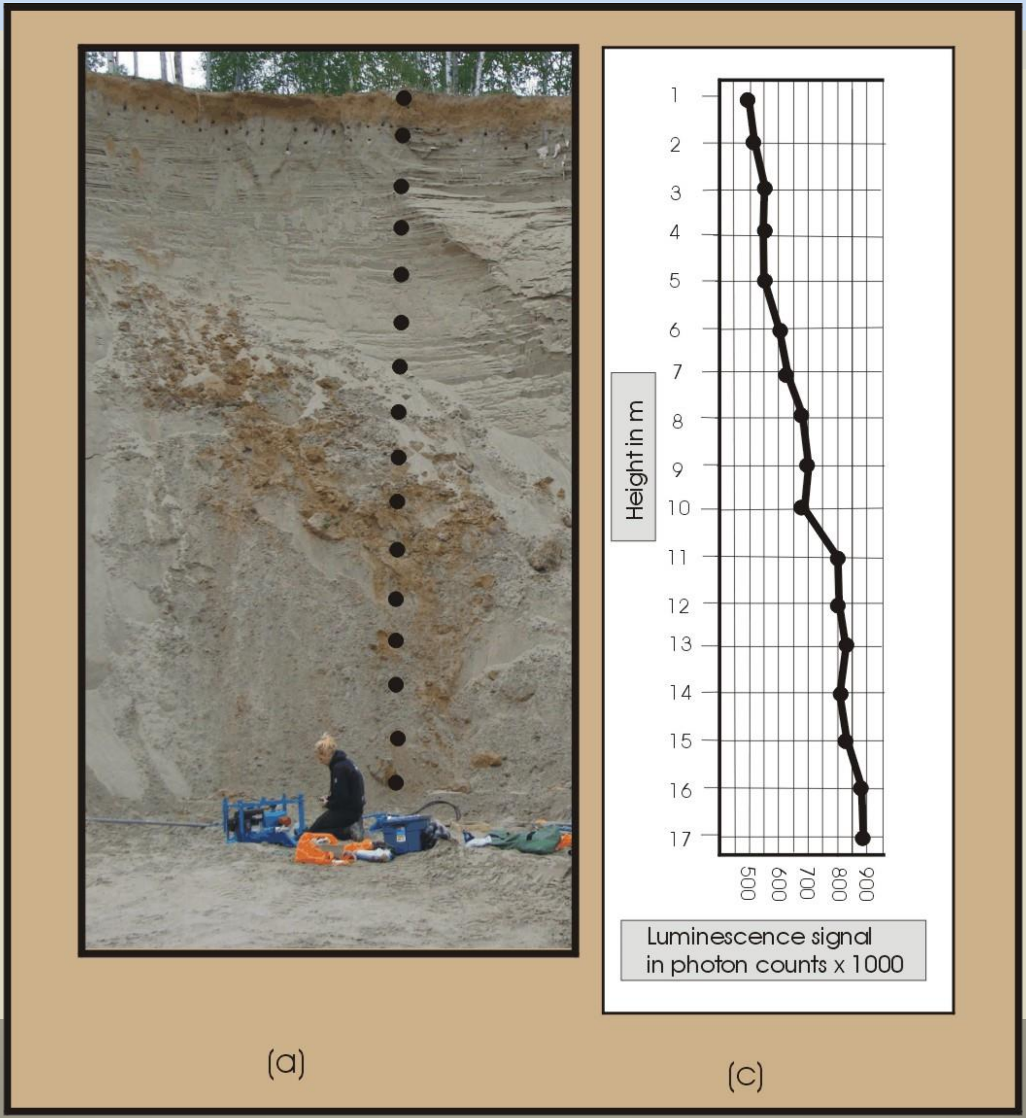
- Operational Mode
  - Analysis can be performed on bulk (untreated) polymineralic coarse grain samples
    - unlike regular OSL dating , sample pre-treatment is not necessary to separate pure quartz of feldspar
    - necessary to separate feldspar and quartz signals
      - IRSL stimulation yields feldspar signal
      - Post IR- blue OSL yields quartz dominant signal

Portable OSL reader

- Luminescence signal intensities:
  - Once obtained, signals can be plotted to show:
    - variation with depth or luminescence profile



Luminescence Profile

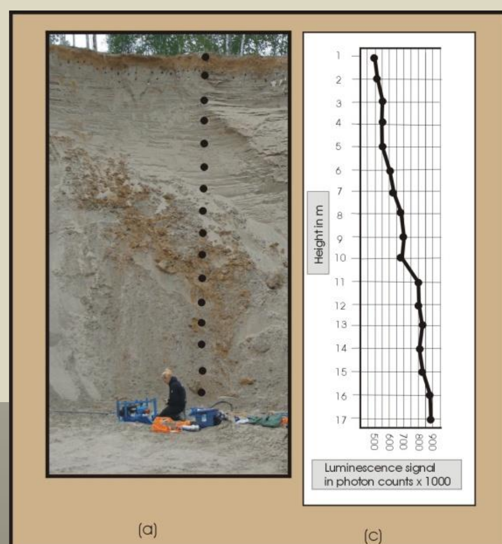


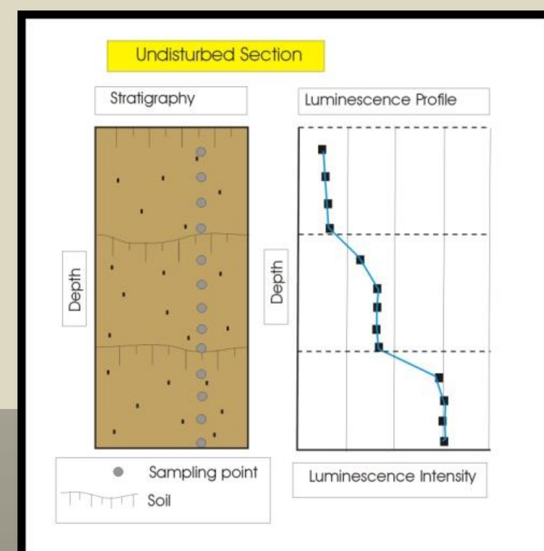
Luminescence Profiling

- Signal intensities depend on
  - sensitivity of mineral
  - burial age
  - sample mineralogy
  - dose rate
    - When all these variables are held constant, apart from burial age, the luminescence profile is a proxy for the chronostratigraphy

Luminescence Profiling

- When luminesrecence profiles have a chronostratigraphic role, it allows:
  - relative depositional rates to be approximated
  - relative ages of units to be ascertained
  - temporal gaps in depositional sequences to be detected



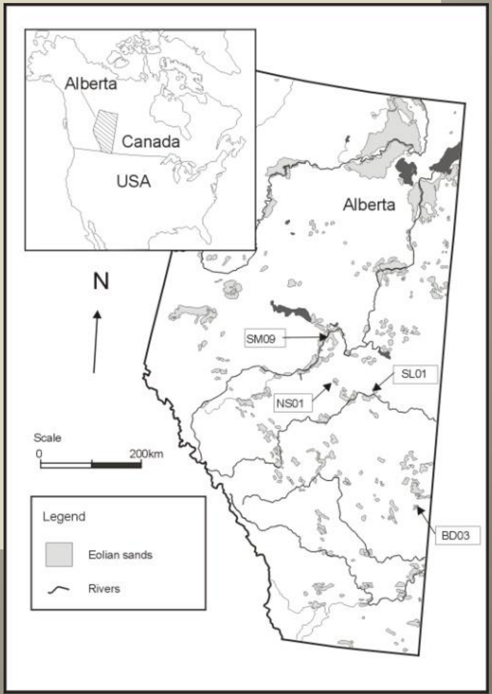


Overview

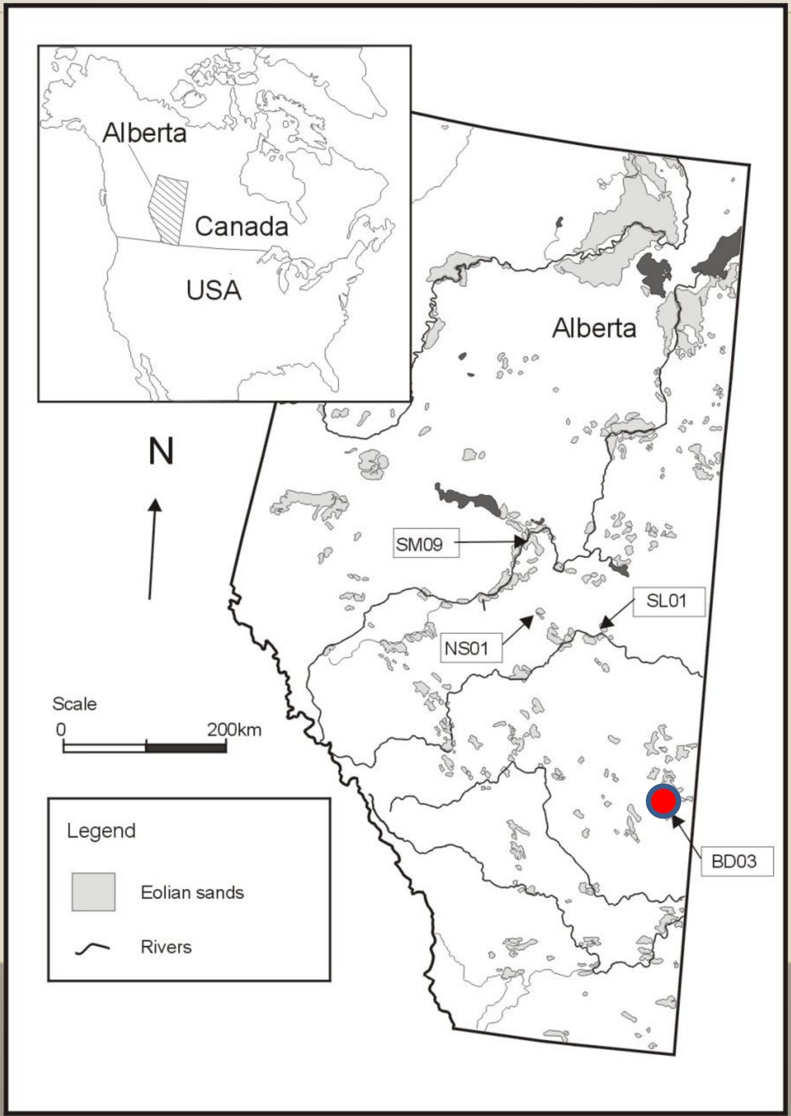
- Introduction
- Portable OSL readers
- Luminescence profiling
- Examples of applications from Alberta, Canada
  1. Approximating relative ages of depositional units in a stratigraphic sequence
  2. Delineating stratigraphic breaks at bases of eolian dunes to aid sample collection[2]
  3. Identifying post-depositional sediment mixing in a stratigraphic sequence[3].
- Conclusions

Case Study 1

- Holocene dune landscape
  - Recurrent eolian activity over last 10 ka
    - early human settlements found in places
    - study aimed to compare age of archaeologically productive units with underlying strata



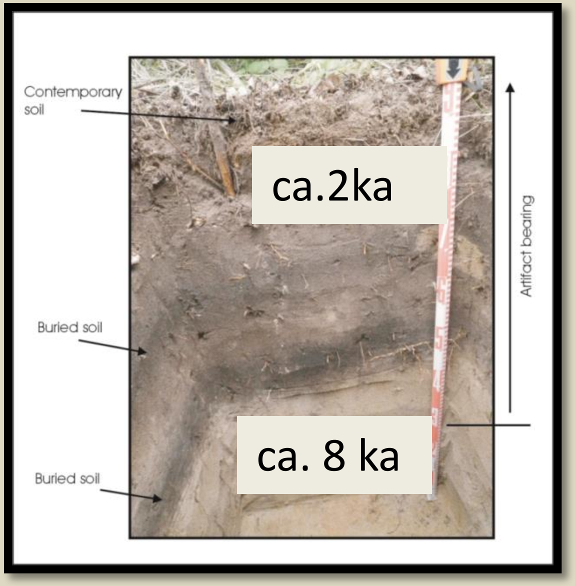
Case Study 1

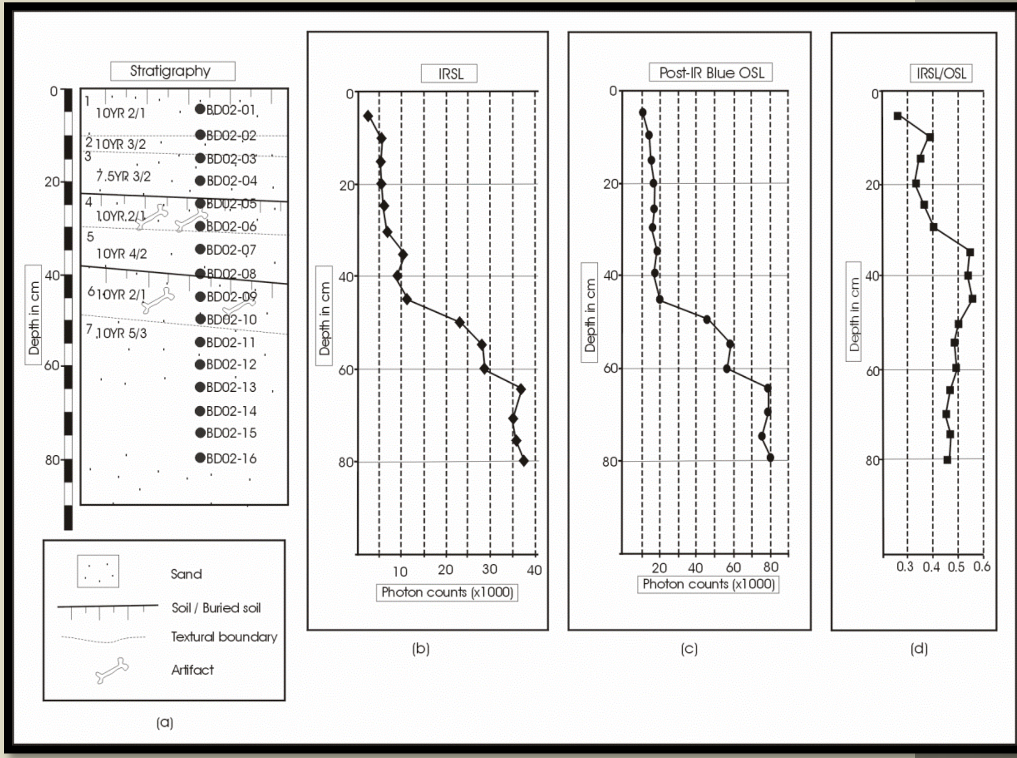


Alberta
Canada
USA
Alberta
N
SM09
SL01
NS01
Scale
0
200km
BD03
Legend
Eolian sands
Rivers

Examples from Alberta, Canada

- Approximating relative ages of depositional units: case study 1





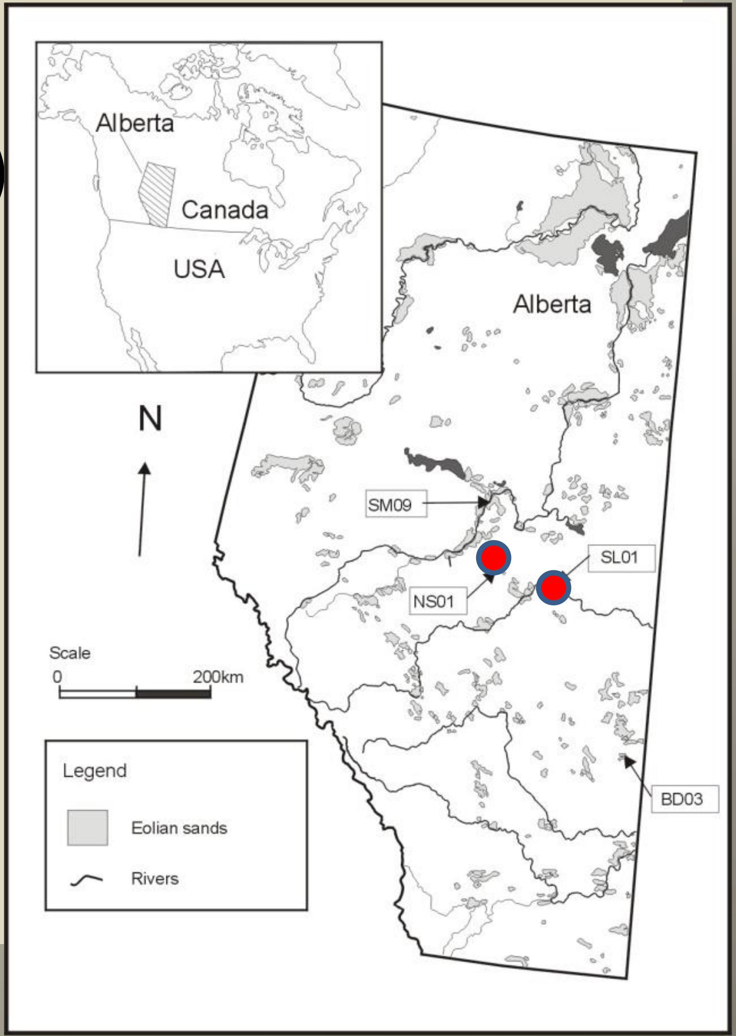
Luminescence signal of lower unit approximately 4 times higher than that of upper unit.

Case Study 2[2]

- Over 100 eolian dune fields in western Canada
- Most of the dune fields are located in Alberta
- Dunes are postglacial in age
  - Derived from glaciofluvial and lacustrine sands
    - in many places, the eolian dunes overlie glaciofluvial sands
    - to facilitate sampling for OSL dating it is important to delineate dune base prior to sampling.
      - Resolved to use portable reader to demarcate dune bases,

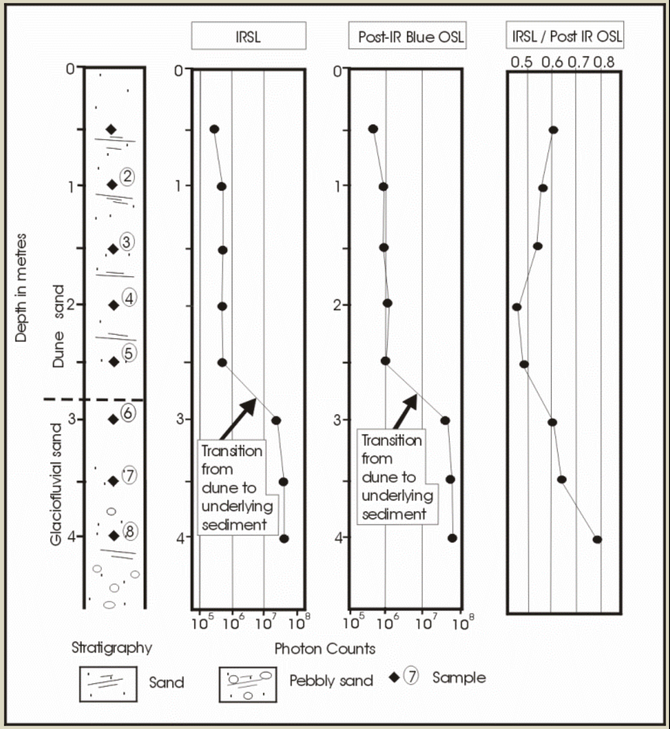
Luminescence profiling of dunes in Alberta

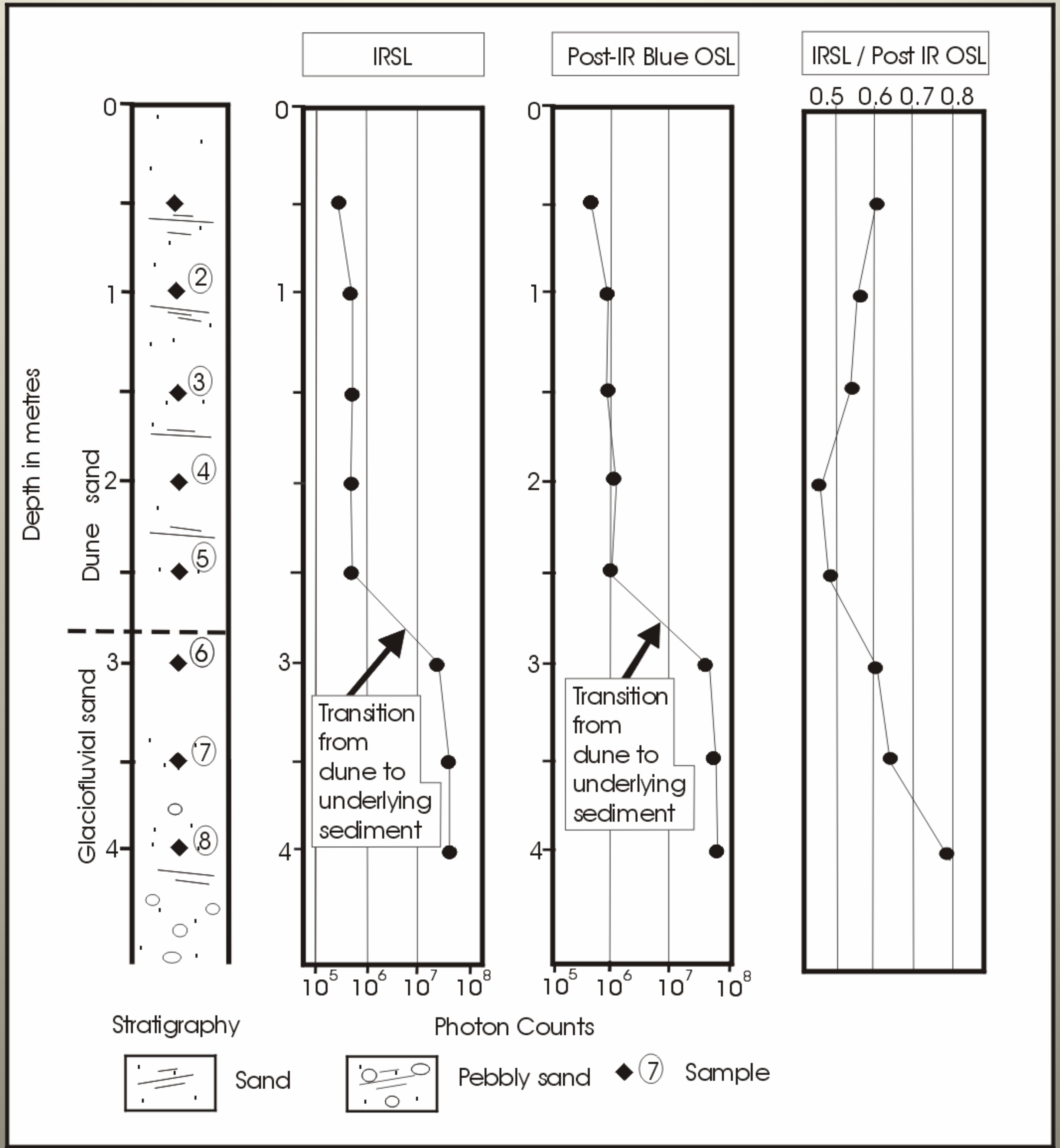
- Test cases
  - Smoky Lake dune field (SL01)



Luminescence profiling of dunes in Alberta

- Smoky Lake dune field - results[2]
  - Sharp rise in (x50) both IRSL and blue OSL signals around 3m
    - too old to be eolian
    - partially bleached glaciofluvial sediments



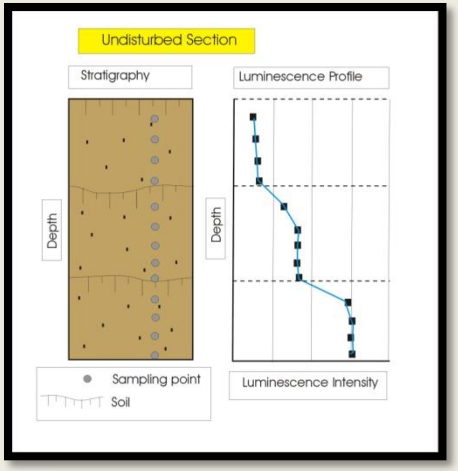

IRSL
Post-IR Blue OSL
IRSL / Post IR OSL
0.5 0.6 0.7 0.8
Depth in metres
Dune sand
Glaciofluvial sand
0
1
2
3
4
2
3
4
5
6
7
8
Transition from dune to underlying sediment
Transition from dune to underlying sediment
10^5 10^6 10^7 10^8
10^5 10^6 10^7 10^8
Stratigraphy
Photon Counts
Sand
Pebbly sand
7 Sample

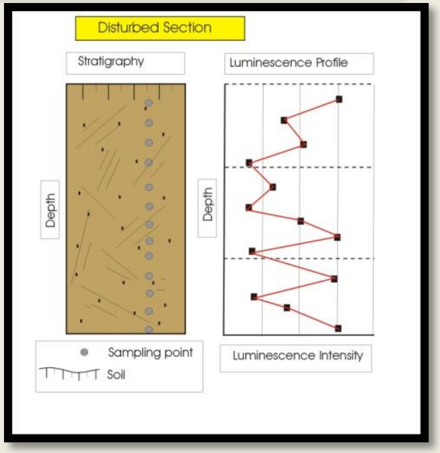
Case Study 3

- Illustrates the use of a portable OSL reader to differentiate between areas whose stratigraphy has been disturbed from those that are still intact[3]
  - the integrity of a depositional sequence is central to the accuracy of stratigraphic interpretations in archaeological studies
  - test site is the Bodo Archaeological Site in southern Alberta.

Case Study 3

- Luminescence Profile
  - proxy for chronostratigraphy
    - signal intensity increases with age
    - intact stratigraphy
      - Signal increases with depth





    - disrupted or mixed stratigraphy
      - Signal fluctuates with depth or is inverted

Case Study 3 - Study Site[3]

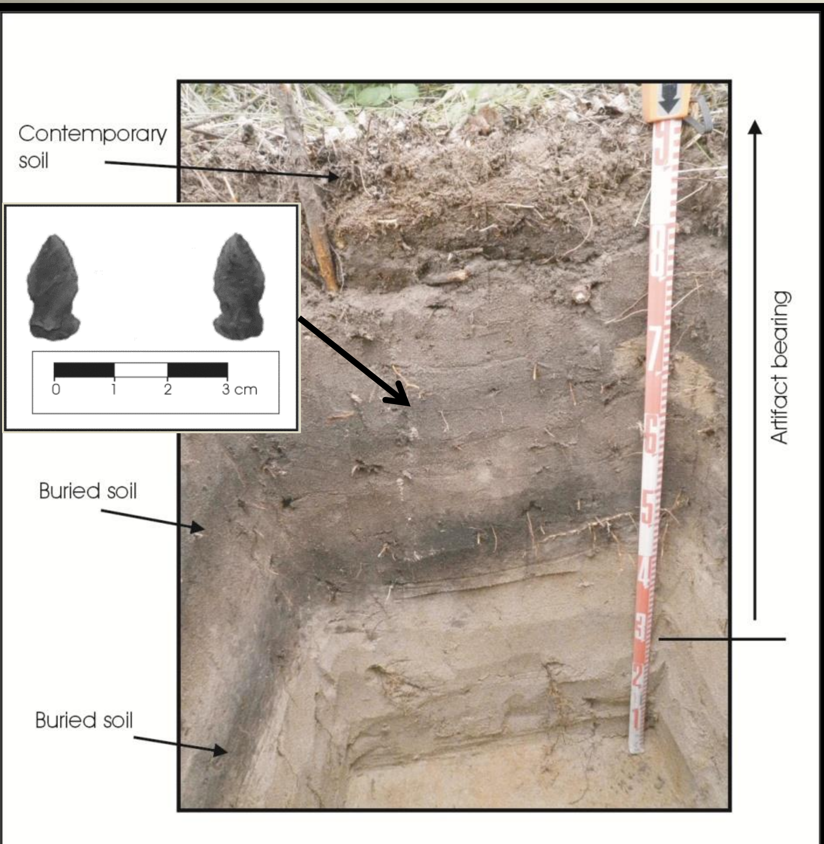
- Bodo Archaeological Locality
  - one of the largest precontact sites in western Canada
  - located on Holocene dune landscape in southern Alberta

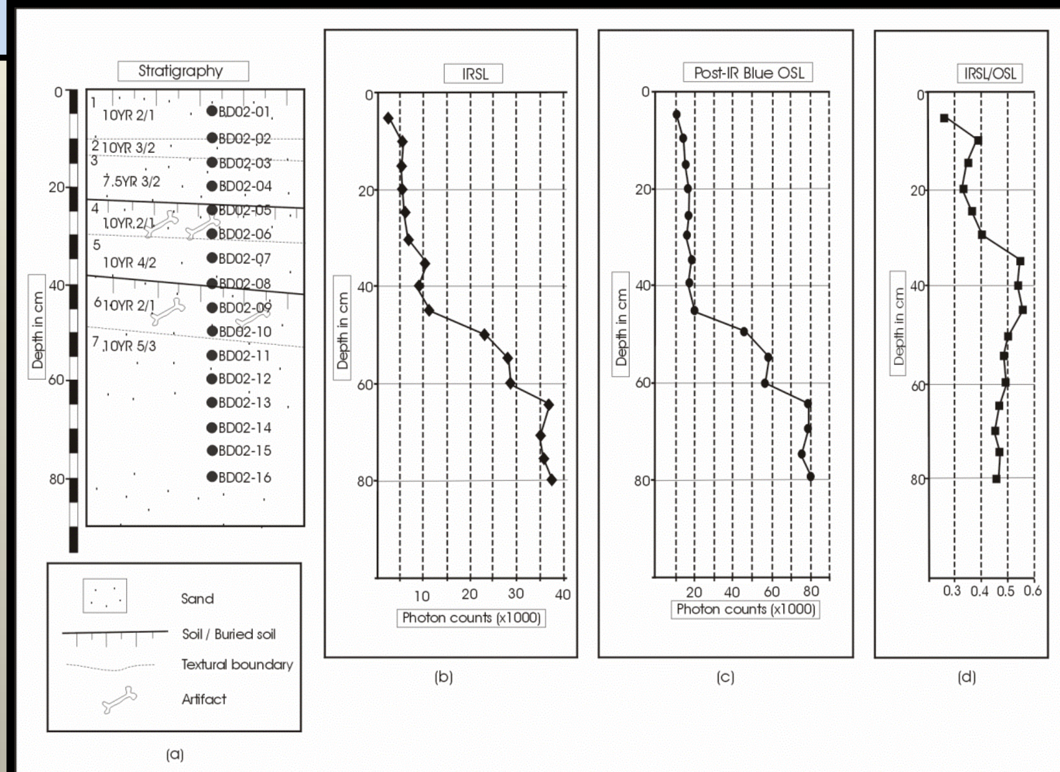
Case Study 3 - Study Site

- Oilfield activity initiated at site several decades ago
  - archeological deposits unknowingly disturbed
  - bison skulls discovered in pipeline trench in subsequent work
    - site occupied by ancestral First Nations at various times during the Holocene
  - routine maintenance work now carefully monitored to protect heritage resources
  - critical part of this process is distinguishing areas that have previously been disrupted from those that are still intact

Case Study 3 - Results

- Site BD02[3]

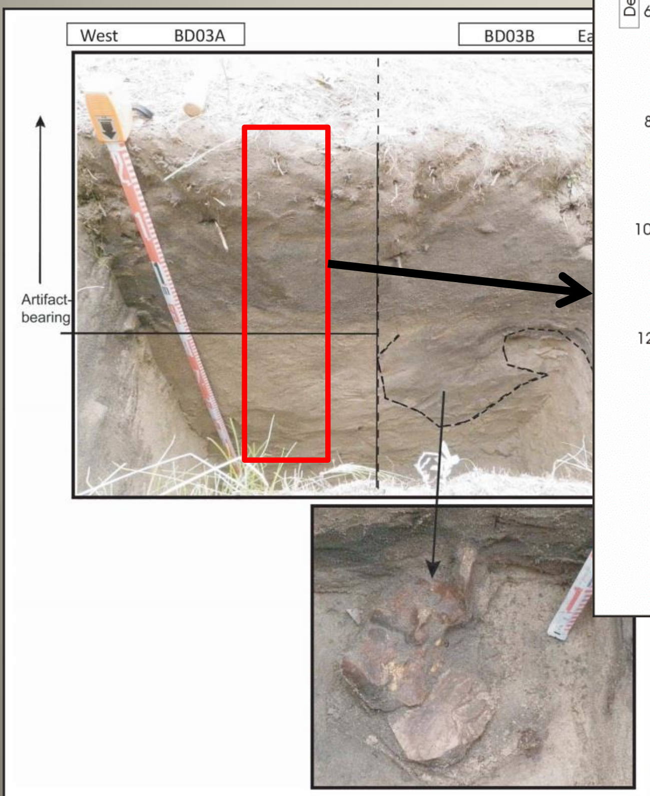


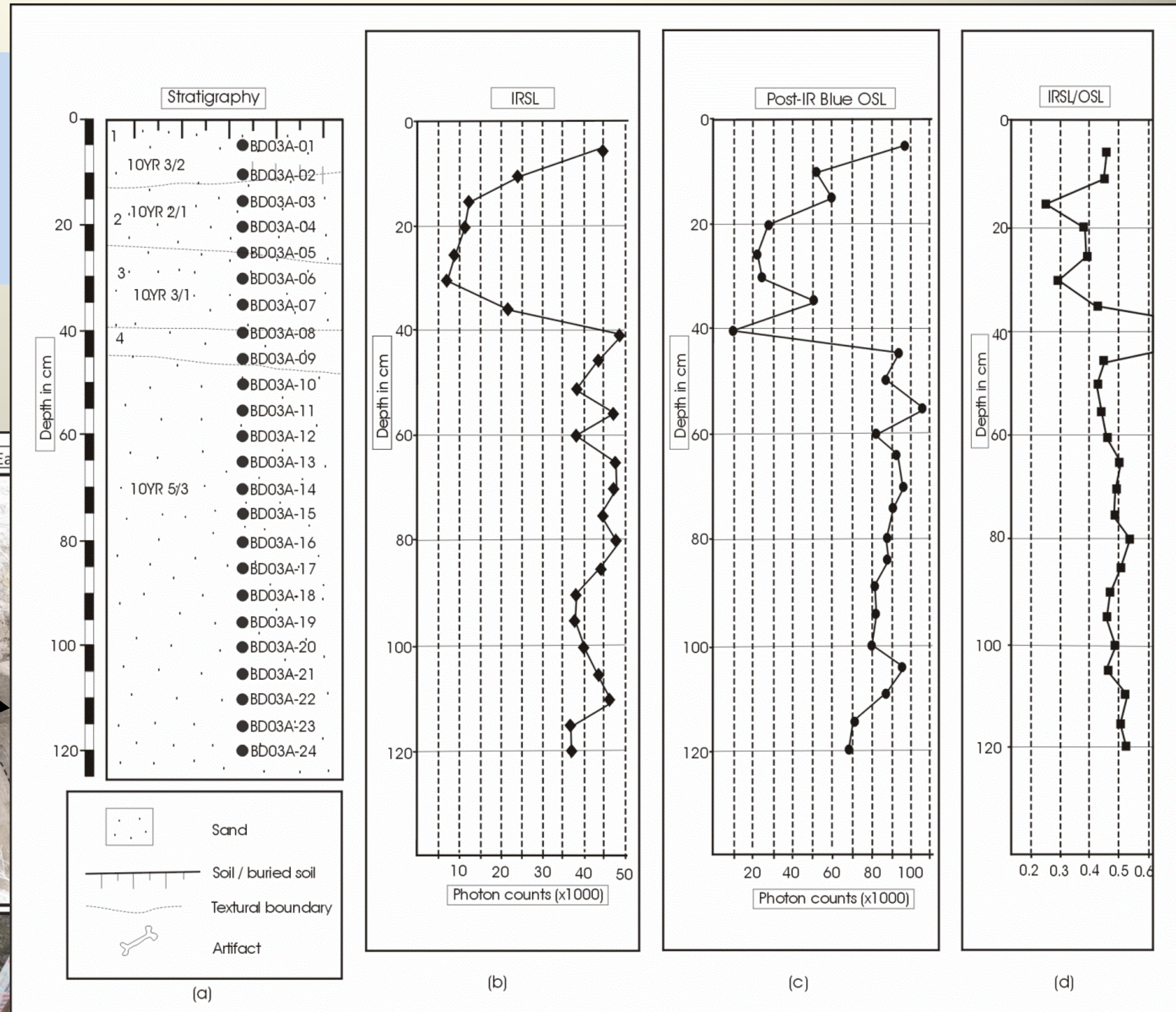


Luminescence profiles:
- both IRSL and post-IR blue-OSL increase with depth
- step-wise increase in signal intensity indicates increasing age of depositional units with depth
- results suggest section is intact

Results

Section BD03A[3]





Luminescence profiles:

- both IRSL and OSL signal intensities inverted in upper part; fluctuates below 40 cm.
- section most probably disturbed during pipeline works
- not easy to detect mixing with naked eye

Conclusions

- Portable readers are versatile devices that enable the rapid determination of luminescence signals of clastic sediments.
- Luminescence signals can be used to plot luminescence profiles; these in turn
  - allow the determination relative ages of strata
  - can be used to demarcate interfaces between depositional units or erosional contacts
  - enables the detection of sediment mixing
  - have potential for a range of other applications

References

- 1. Sanderson, D.C.W., Murphy, S. 2010. Using simple portable measurements and laboratory characterisation to help understand complex and heterogeneous sediment sequences for luminescence dating. Quaternary Geochronology 5, 299-305.

- 2. Munyikwa, K., Brown, S.T., Kitabwalla, Z. 2012. Delineating stratigraphic breaks at the bases of postglacial eolian dunes in central Alberta, Canada using a portable OSL reader. Earth Surface Processes and Landforms. DOI: 10.1002/esp.32

- 3. Munyikwa, Gilliland, K., Plumb, E., Gibson, T., 2012. Site characterization using a portable optically stimulated luminescence reader: delineating disrupted stratigraphy in Holocene eolian deposits on the Canadian Great Plains. American Geophysical Union, Fall Meeting, 2012.

Acknowledgements

- This work is funded through grants to KM from NSERC and Athabasca University