ELEMENTS OF AQUIFER HETEROGENEITY, ORANGEVILLE MORAINE, SOUTHERN ONTARIO

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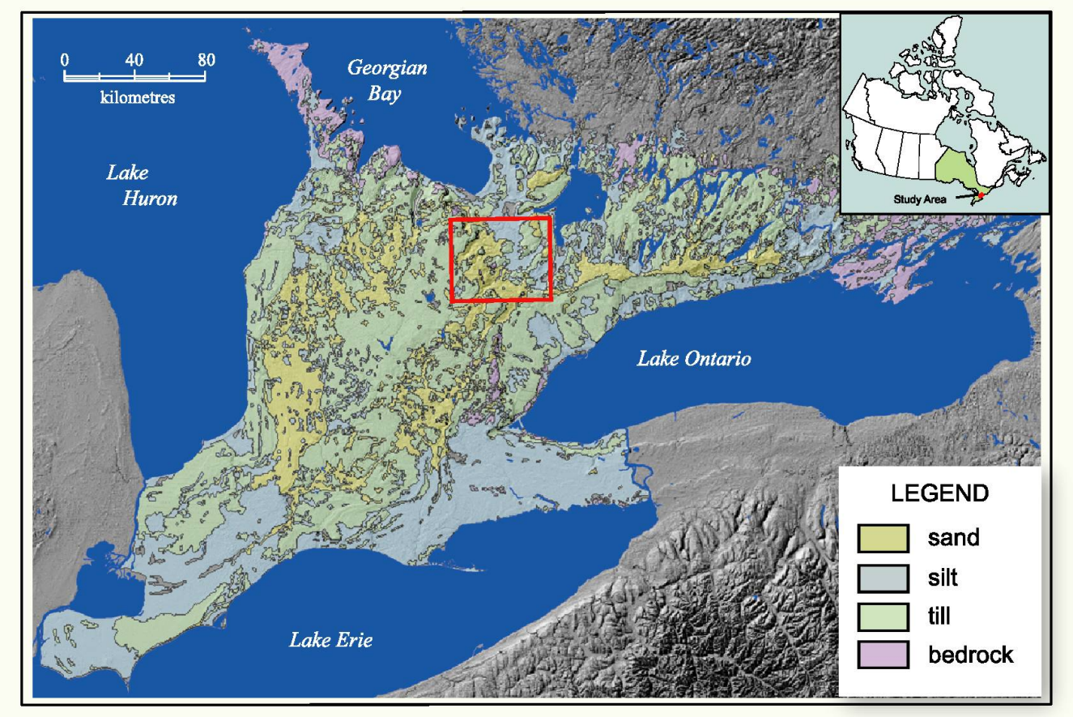

Figure 1. Southern Ontario showing the location of the study area (red rectangle). Geology modified from Barnett et al., (1991). Inset shows location of Ontario and study area in Canada.

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Introduction

- Hydrogeological understanding of Southern Ontario can be advanced by identifying local elements of the hydrogeological system that can provide regional insight.
- Most of Southern Ontario is covered by glacial sediment that controls groundwater recharge. Moraines in the area commonly form high recharge areas.
- An effective approach to improved understanding of hydrogeological characteristics of surficial deposits and landforms is the study of sediment facies and architecture in aggregate pits.
- This poster presents preliminary results of a study of the western part of the Nottawasaga River watershed, with an emphasis on observations from the Orangeville Moraine.

Regional Geological Setting

- The Orangeville Moraine occurs west of the Niagara Escarpment and north of the Guelph drumlin field.
- The Orangeville Moraine has been mapped previously by Cowan (1976) and Gwyn (1972) at 1:50,000 scale.
- The moraine consists of two distinct elements, i) a southern SW-NE trending ridge east of the Grand River and ii) a discontinuous N-S orientated ridge of ice-contact stratified sediment.
- The Orangeville Moraine overlies Newmarket / Catfish Creek tills and is overlain locally by silt and sandy silt tills known as Tavistock, Port Stanley, and Lower Northern tills (Fig 2; Cowan, 1976).
- The moraine has been recognized by Gwyn and Cowan (1978) to coalesce with the more easterly Singhampton moraine originally defined by Taylor (1913).
- The moraine consists of a cyclic succession of gravel and sand units (Cowan, 1976).

Geological Model

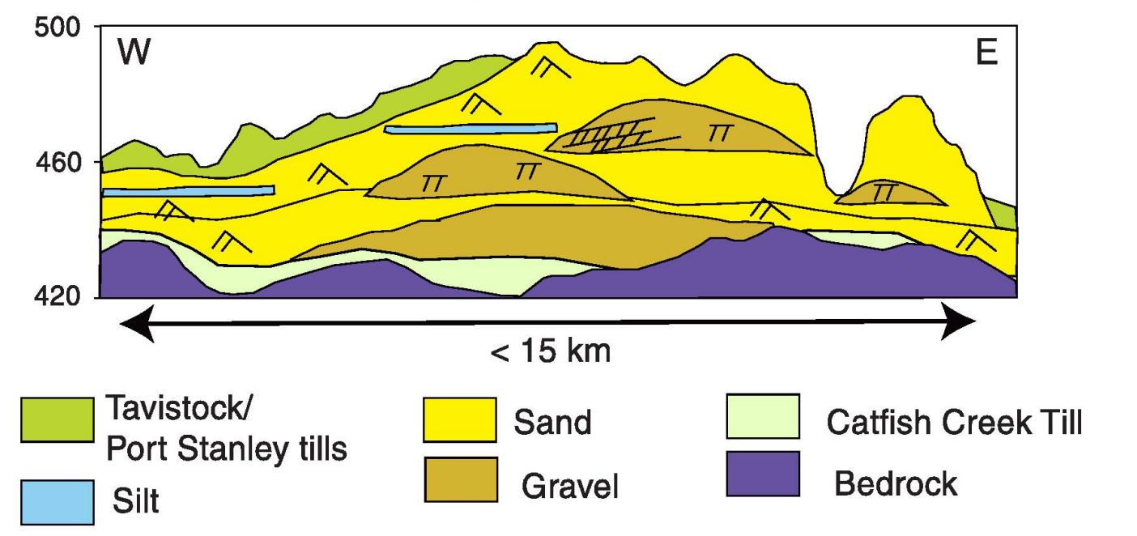


Figure 2. Conceptual geological model of the Orangeville Moraine. Note moraine is predominately sand and gravel with flanking diamicton onlapping the moraine.

Methods

Pit inventory:
Using provincial aggregate - pit licence maps and Google Earth images ~155 sites in the area were classified as, active, inactive or worked out. Of 25 sites visited (55 licences), 12 were in ice-contact-stratified-drift, 12 were in glacifluvial, and 1 was in alluvial map units (Cummings and Russell, 2008).

Site collection:
Data collected include sediment texture, bed thickness, sedimentary structure types, paleoflow measurements, and photo mosaics for architectural section analysis. This data from the unsaturated zone is synthesized and provides an analogue for aquifer properties.

Analysis:
Architectural analysis yields information on sediment facies that may form preferential flow units.

Sedimentary models:
The development of sedimentary depositional models provides a framework for development of predictive models of aquifer location, size, extent, and heterogeneity (Fig 3).

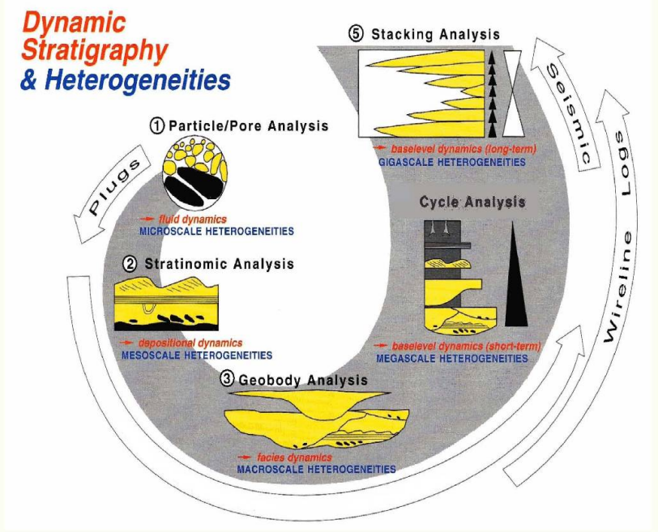
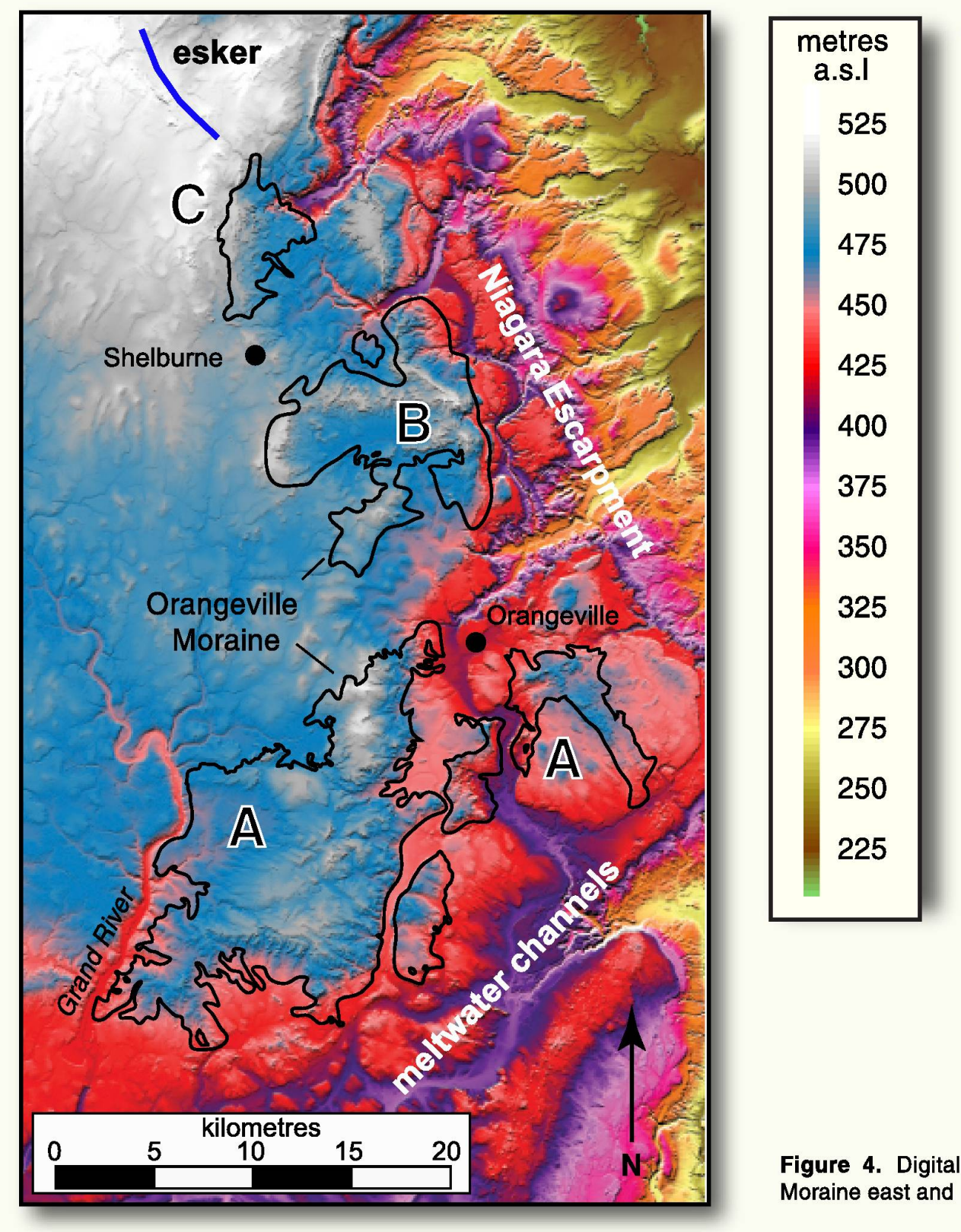


Figure 3. Conceptual diagram of relationship between various scales of aquifer heterogeneity and scales of investigation. Diagram from Aigner et al. (1998).

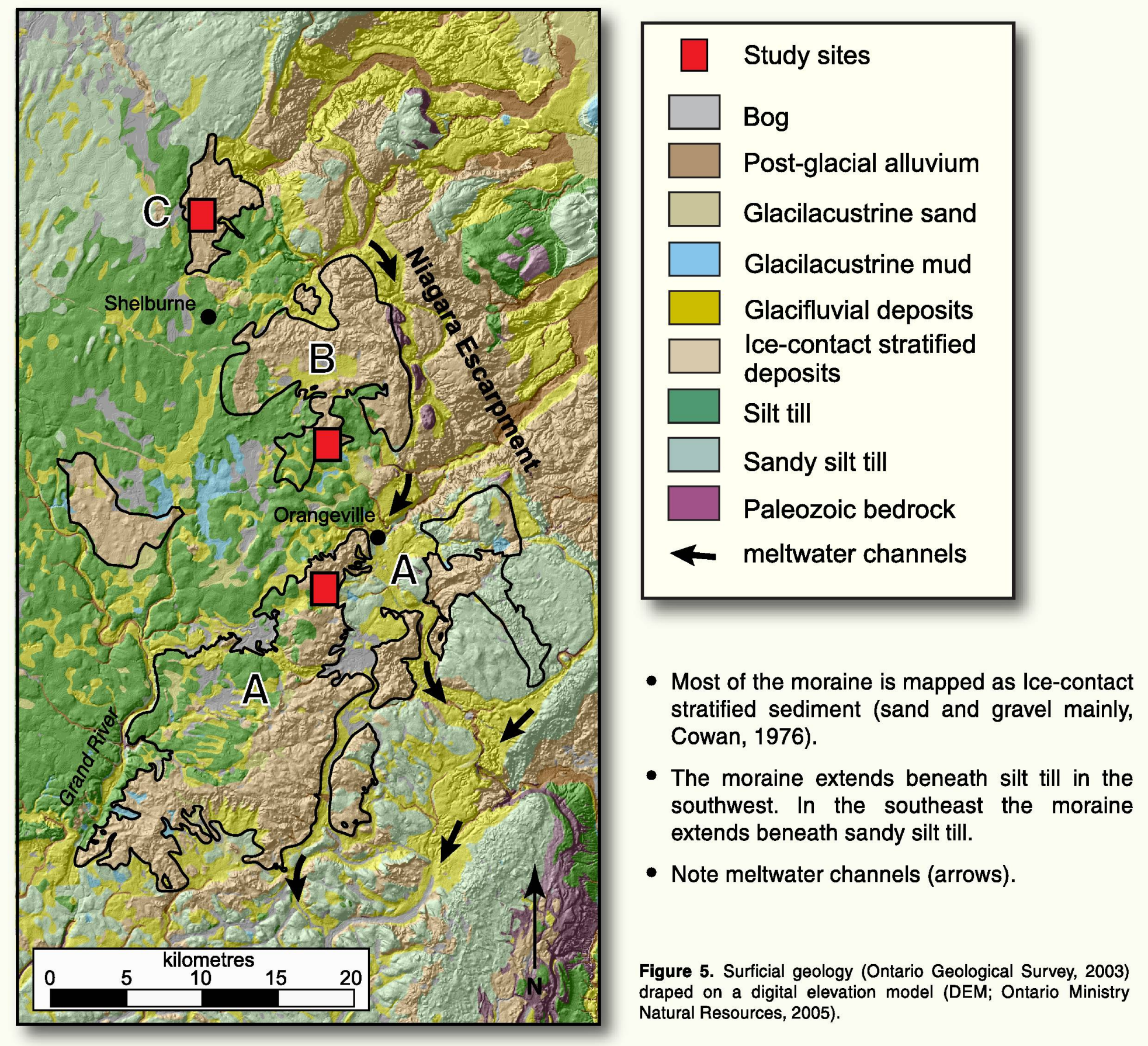
Orangeville Moraine Morphology



- Moraine extents were defined from topographic signature, surficial geology maps (Cowan, 1976; Gwyn, 1972) and a sediment thickness map (Gao et al., 2006). Three distinct depocentres are recognized, A) southern, B) Central, C) Northern.
- The north-south length of the moraine outlined is ~45 km and it is up to 20 km wide.
- In a number of places the eastern part of the moraine extends eastward and merges with a more easterly north-south trending ridge mapped as the Singhampton Moraine (Gwyn, 1972)
- The moraine has been incised and dissected locally by meltwater channels.

Figure 4. Digital Elevation Model (DEM) of the Orangeville Moraine east and north of the Grand River.

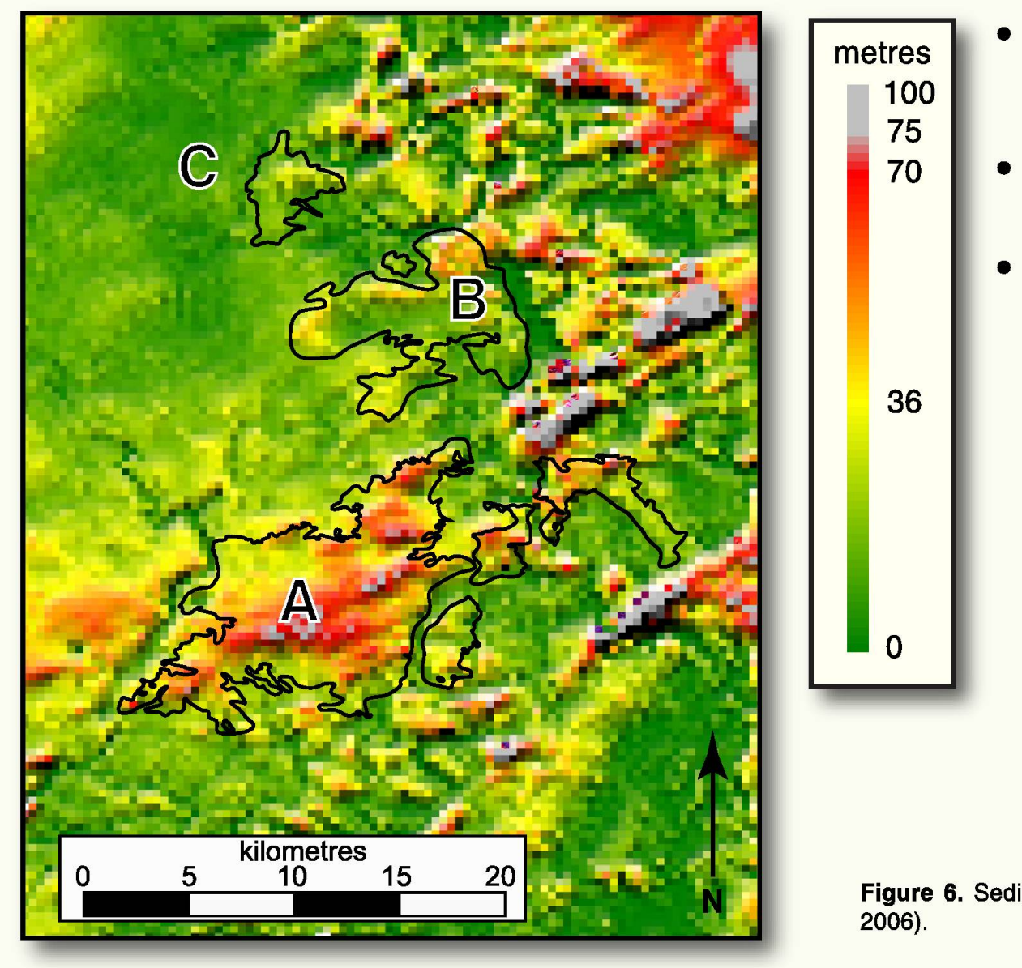
Orangeville Moraine Geology



- Most of the moraine is mapped as Ice-contact stratified sediment (sand and gravel mainly, Cowan, 1976).
- The moraine extends beneath silt till in the southwest. In the southeast the moraine extends beneath sandy silt till.
- Note meltwater channels (arrows).

Figure 5. Surficial geology (Ontario Geological Survey, 2003) draped on a digital elevation model (DEM; Ontario Ministry Natural Resources, 2005).

Sediment Thickness



- Note the decrease in absolute and average thickness of the moraine sediment from south to north.
- Note the extension of thick sediment corridors to the east.
- Thickest sediment corresponds to ice-contact stratified sediment map areas, particularly in the south.

Figure 6. Sediment isopach of the Orangeville area (Gao et al., 2006).

Orangeville South (A)

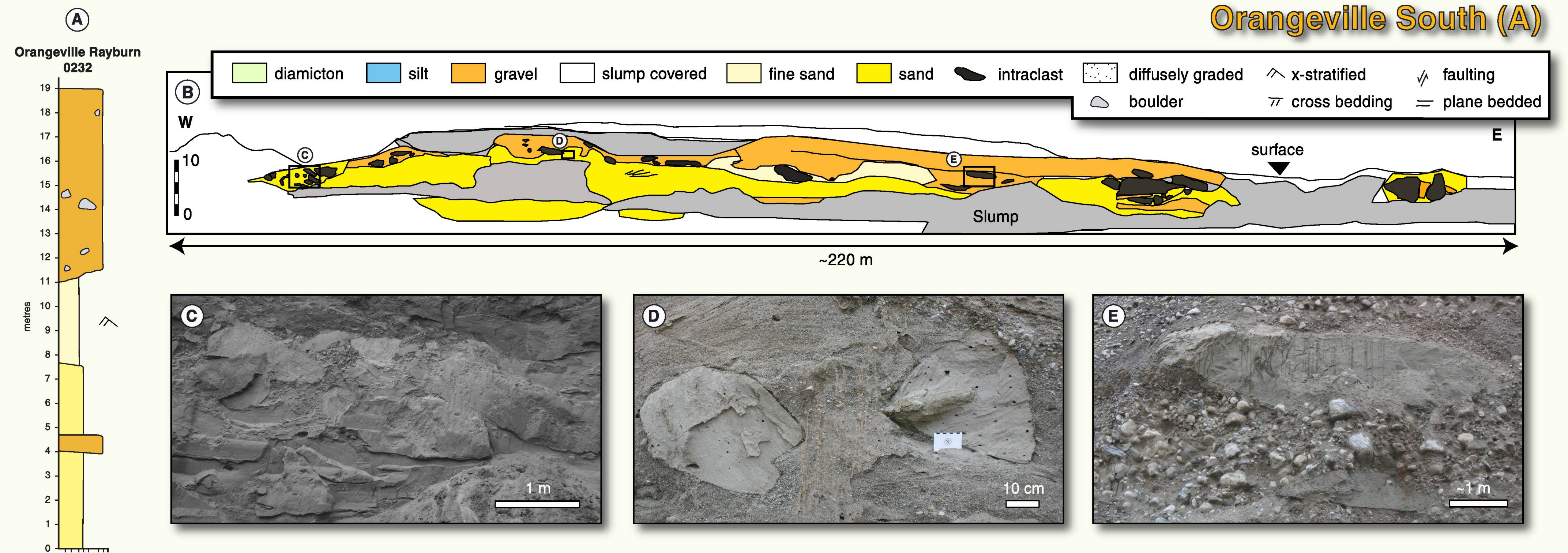


Figure 7. Data set from the Rayburn aggregate pit southwest of Orangeville. A) Summary graphic log from the western part of the pit face. B) Panel diagram of the east-west pit face showing cyclic succession of sand - gravel and intraclasts. Note that larger sand intraclasts exceed lengths of 6 metres and can be imbricated. C) Photo of sand breccia at western end of section. Intraclasts range in texture from fine to medium sand in a matrix of medium sand. Clasts have a range of sizes, shapes and angularity. D) Two subrounded fine sand intraclasts in a matrix of medium to coarse sand with pebbles. Note sharp clast boundary with no evidence of matrix grading perpendicular to clast margins. E) A large subhorizontal, ~ 6 m long fine sand intraclast within a bed of cobble gravel. Note variation in gravel texture suggesting possible cross-stratification within the gravel. Note smaller sand intraclasts below large intraclasts. General paleoflow is toward the west in all photos (right to left).

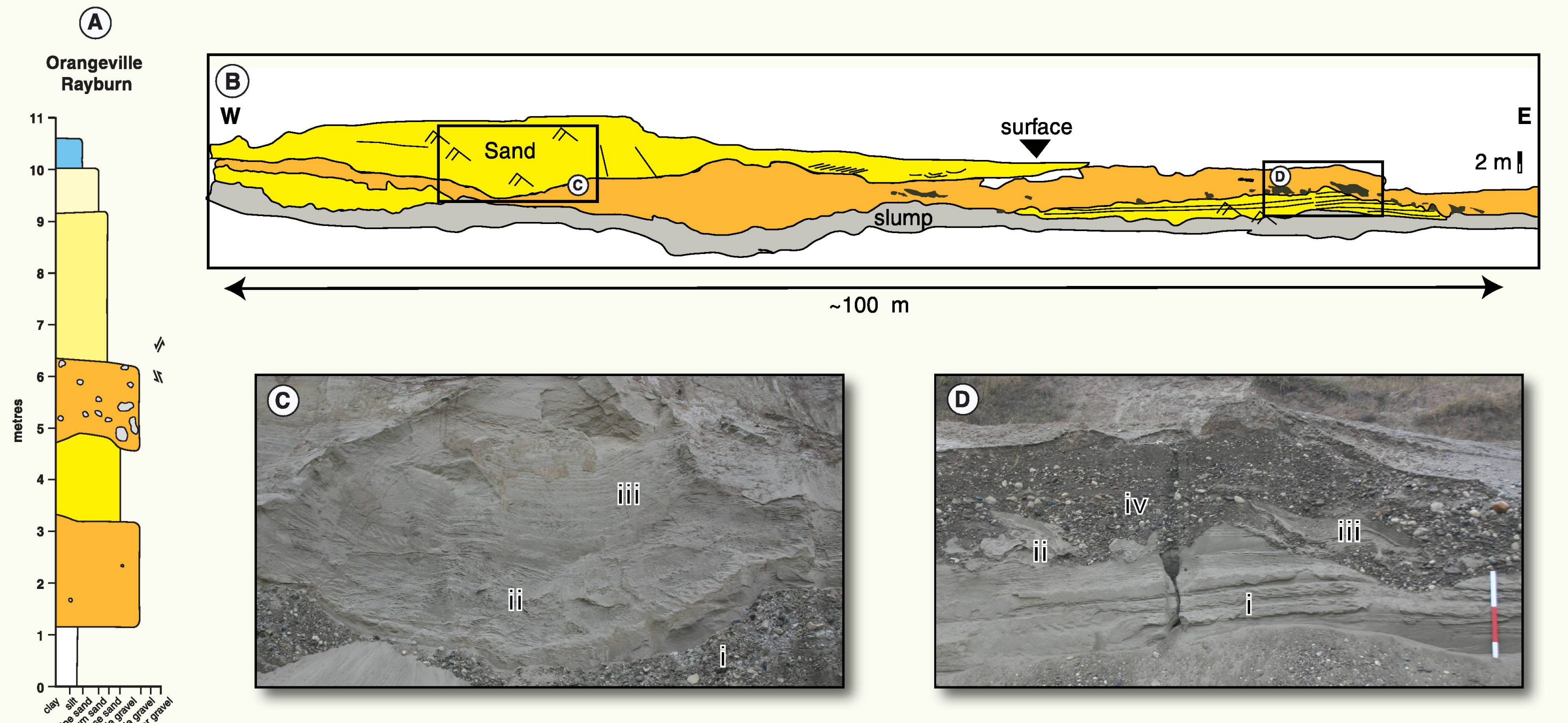


Figure 8. Data set from the Rayburn aggregate pit southwest of Orangeville. This section is immediately east (up-paleoflow) from Figure 7. A) Summary graphic log of the sediment succession. B) Panel diagram of the east-west pit face showing cyclic succession of sand – gravel with flame structures and intraclasts. Sand units are predominately ripple-scale cross-laminated with rare dune-scale cross-sets. C) Possible collapse structure with extensively faulted fine sand sagging into depression in gravel. Sand is locally dune-scale cross-stratified; however, it is predominantly ripple-scale cross-stratified: i) pebble-cobble gravel, ii) ripple-scale cross-stratification, and iii) high-angle reverse faults. D) Complex sand – gravel relationship; i) ripple-scale cross lamination, ii) incipient sand intraclasts, ii) apparent sand flame adjacent to gravel load structure, and iv) cobble gravel with horizontal stratification, weak imbrication, and interstratification of sand lens. Paleoflow right to left, scale stick in photo is 1.2 m long.

Orangeville South (A)

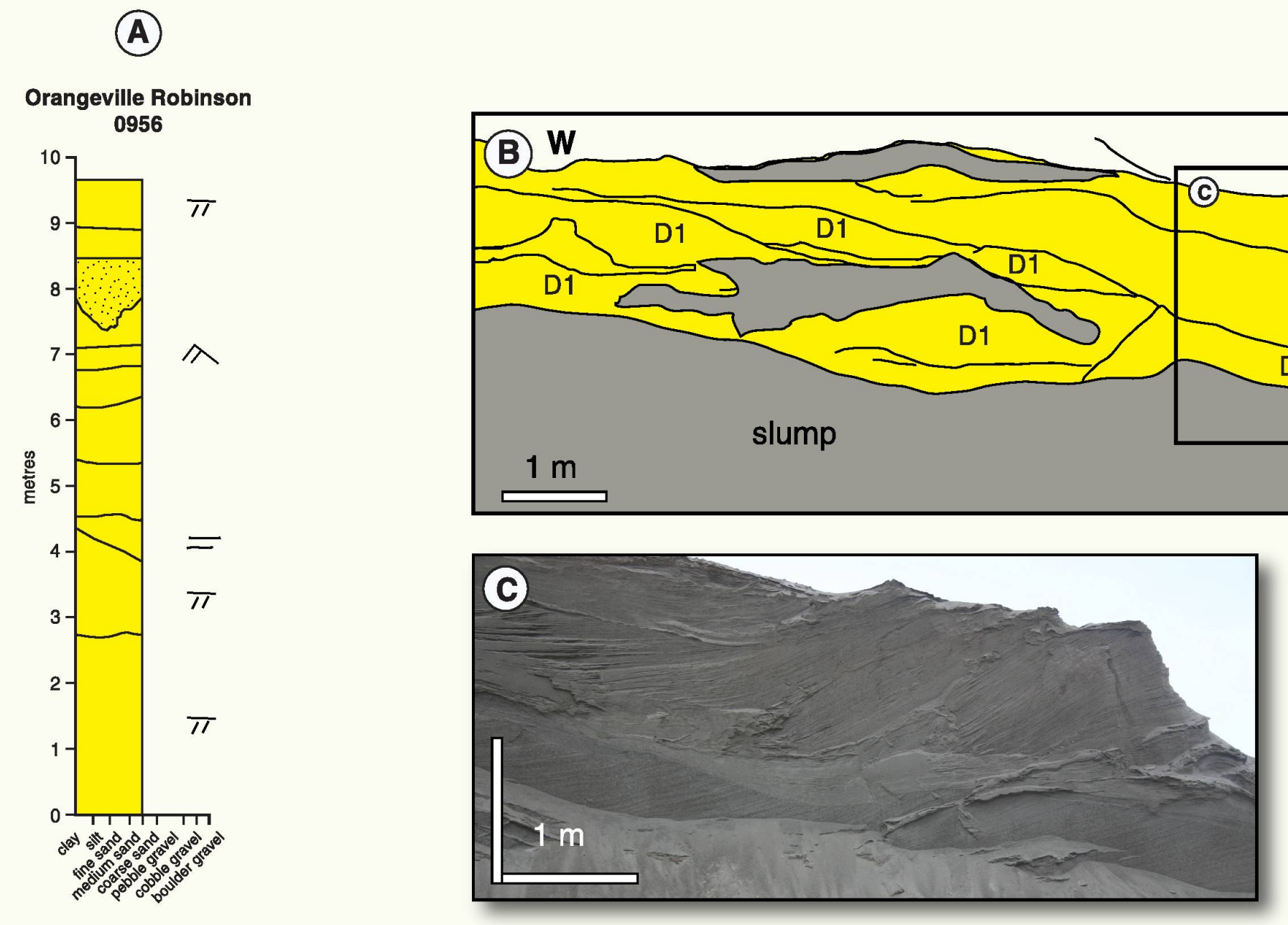


Figure 9. Data from the Robinson aggregate operation just north of Rayburn pit and stratigraphically higher. A) Summary graphic log of the most extensively exposed face illustrating interstratified nature of diffusely graded and cross-stratified fine and medium sand. B) Panel diagram of climbing dunes (D1) from the top of the exposure. C) Photo from (B) illustrating the largest and most well exposed climbing dune-scale cross-stratified medium sand. Paleoflow is from right to left.

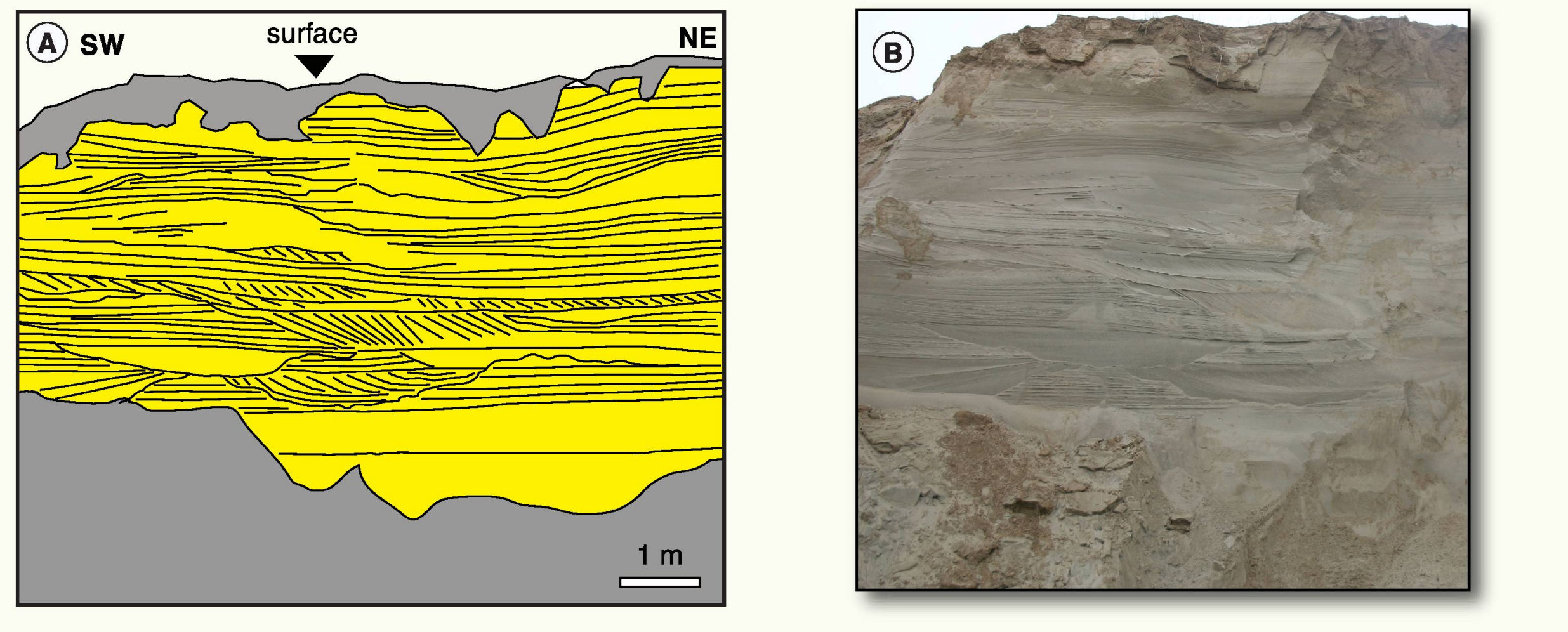


Figure 10. A) Panel diagram of dune-scale cross stratification dissected by scours filled with diffusely graded sand. B) Note the relatively uniform sediment calibre Paleoflow is obliquely into the face from left to right. Much of the apparent planar stratification is a strike view of cross-strata.

Orangeville Central (B)

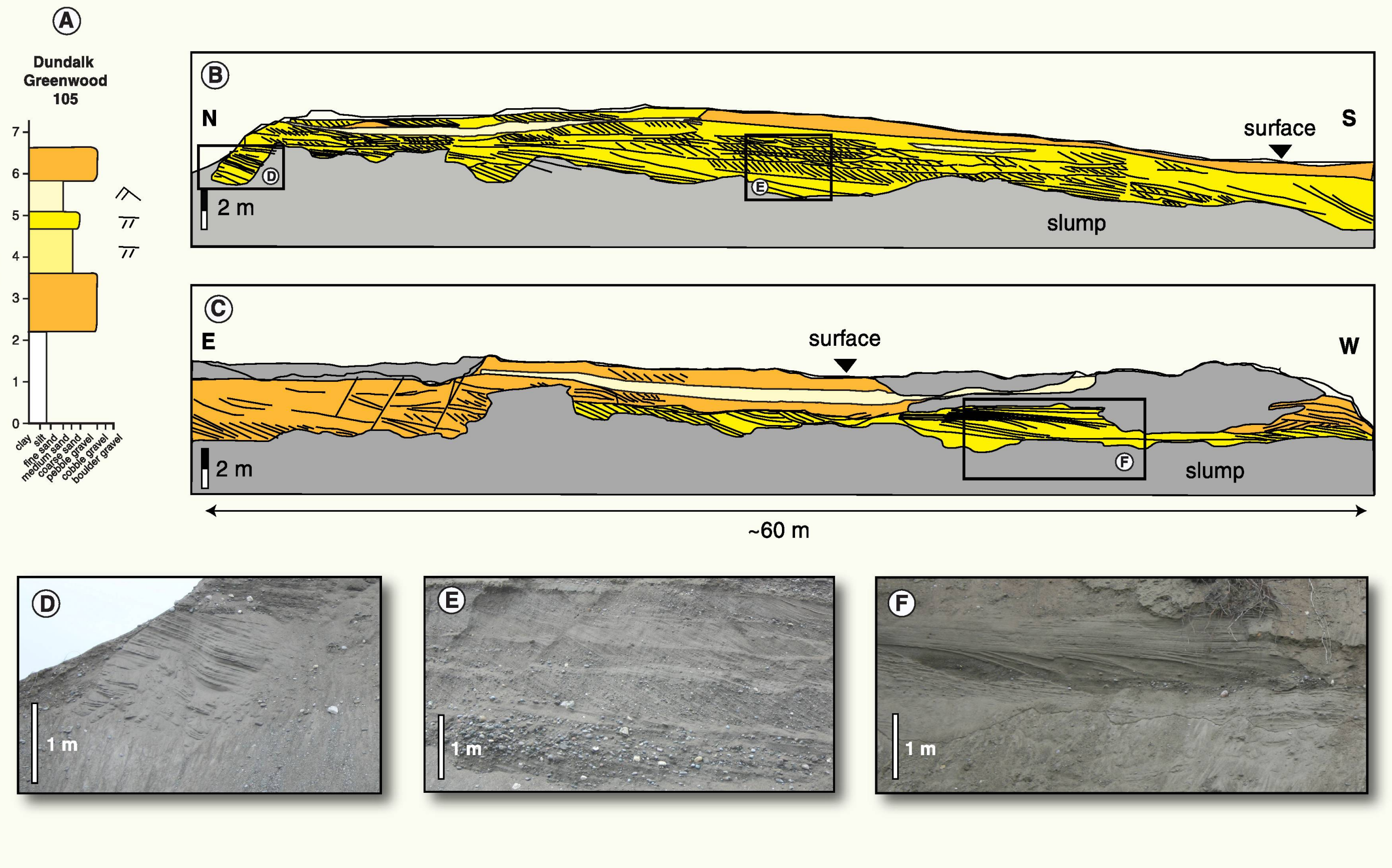


Figure 11. Data from the central part of the Orangeville Moraine (Fig. 4). A) Summary graphic log. B) Dip-section of sand and gravel succession with down climbing dune-scale cross-stratification in sandy gravel. Paleoflow is to the right. C) Strike-section of cross-stratified gravel over sand. Paleoflow is obliquely into the face toward the south-southwest. D) South dipping sandy clinoforms overlain by sandy gravel. E) Down climbing sandy gravel dune-scale cross strata in beds of 0.3 to 0.6 m thickness. F) Cross-stratified sand scour fill that grades upward to plane bedded sand.

Orangeville North (C)

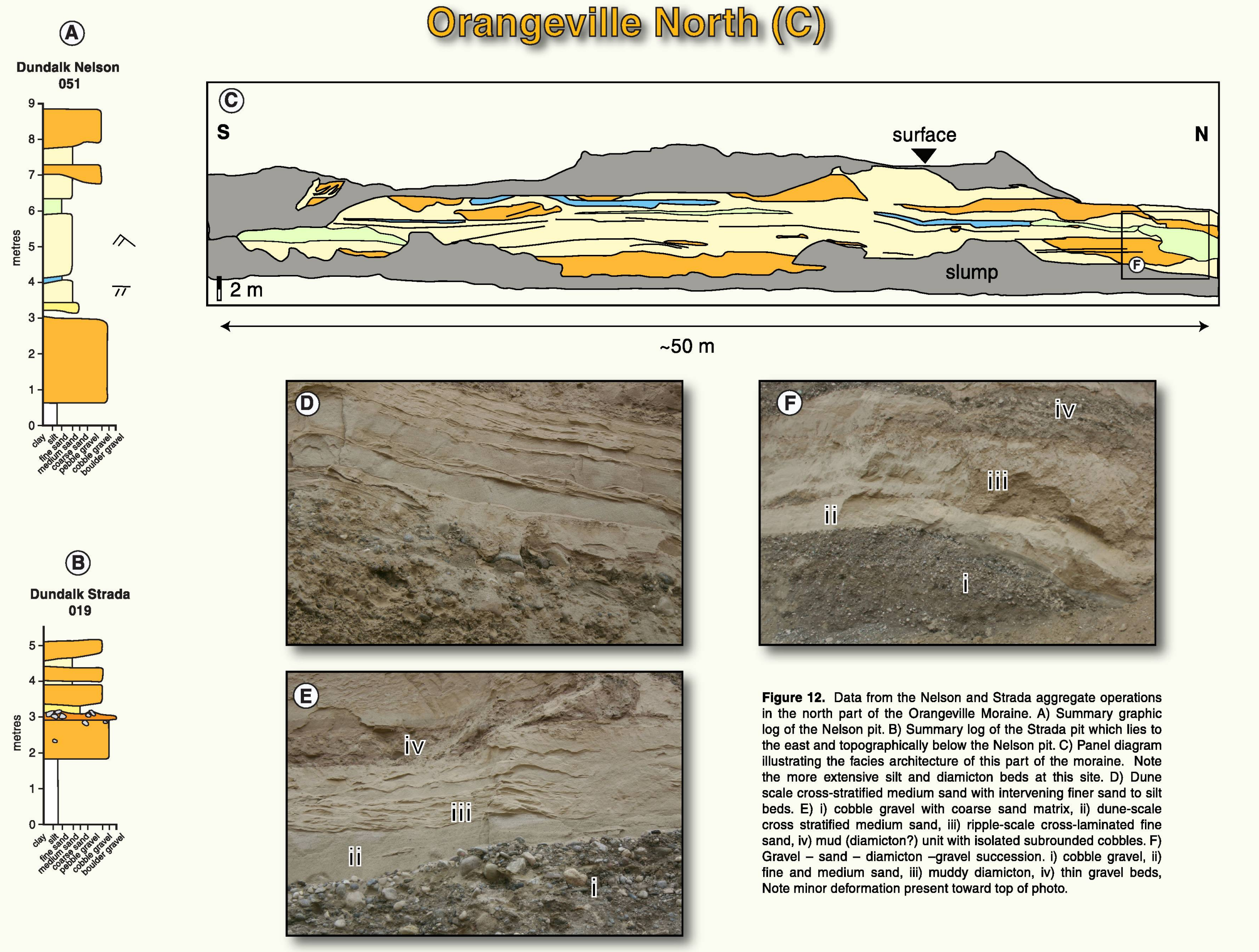


Figure 12. Data from the Nelson and Strada aggregate operations in the north part of the Orangeville Moraine. A) Summary graphic log of the Nelson pit. B) Summary log of the Strada pit which lies to the east and topographically below the Nelson pit. C) Panel diagram illustrating the facies architecture of this part of the moraine. Note the more extensive silt and diamicton beds at this site. D) Dune scale cross-stratified medium sand with intervening finer sand to silt beds. E) i) cobble gravel with coarse sand matrix, ii) dune-scale cross stratified medium sand, iii) ripple-scale cross-laminated fine sand, iv) mud (diamicton?) unit with isolated subrounded cobbles. F) Gravel – sand – diamicton –gravel succession. i) cobble gravel, ii) fine and medium sand, iii) muddy diamicton, iv) thin gravel beds, Note minor deformation present toward top of photo.

Summary

- A) Southern part of the moraine (Fig. 4, 5, 6 C).
  - Is the thickest area of the moraine.
  - Exhibits abundant evidence of rapid high-energy sedimentation (eg. scours, diffusely graded fills, large intraclasts, and climbing bedforms).
  - An esker-subaqueous model is most appropriate.
  - Aquifer heterogeneity is strongly controlled by highly transmissive gravel cores with expansive flanking reservoir sand.
- B) Central part of the moraine (Fig. 4, 5, 6 C) is
  - Is much thinner than the southern part of the moraine.
  - Has limited evidence for subaqueous fan deposition in sites visited; likely records a transition from deltaic – subaqueous fan to glacifluvial. Rates of deposition lower than to the south
  - Aquifer has less expansive aquifer sand and is thinner.
- C) Northern part of the moraine (Fig. 4, 5, 6 C).
  - This area is the thinnest part.
  - It has the most complex changes in sediment textures gravel – sand cycles, diamicton. It records changing depositional conditions and sediment fluxes, transitions from glacifluvial to subaqueous and debris flows.
  - Depositional setting is likely ice-proximal and meltwater flux is lowest of the three study areas.
  - Aquifer heterogeneity is high; likely has flow barriers and aquifer compartmentalization.
- Paleoflow measurements at all three sites support earlier observations (Chapman and Dell, 1963) that moraine sediment is derived from east of the Niagara Escarpment.
- Moraine morphology is most clearly associated with ice-contact stratified sediment on 1:50,000 maps.
- Sediment isopachs indicate that moraine sediment extends beneath flanking muddy Tavistock and sandy silt Port Stanley tills (see Cowan, 1976).
- Morphology and sediment thickness connects traditional moraine elements to the more eastern Singhampton moraine (see Gwyn & Cowan, 1978).
- Orangeville Moraine is probably a basin equivalent of the Singhampton moraine.
- Observations of this study support interpretation that the moraine is constructed of a cyclic succession of gravel and sand (see Cowan, 1976).
- Sediment facies show pronounced changes between the three study sites (A,B,C).

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