

# **Sedimentary structures**

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**Stratification and bedforms – Part I**

# Introduction

- Goals for this lecture:
  - Identify common sedimentary structures.
  - The effect grain size has on creating sedimentary structures.
  - Connect sedimentary structures to depositional environment.

# Primary Bedforms

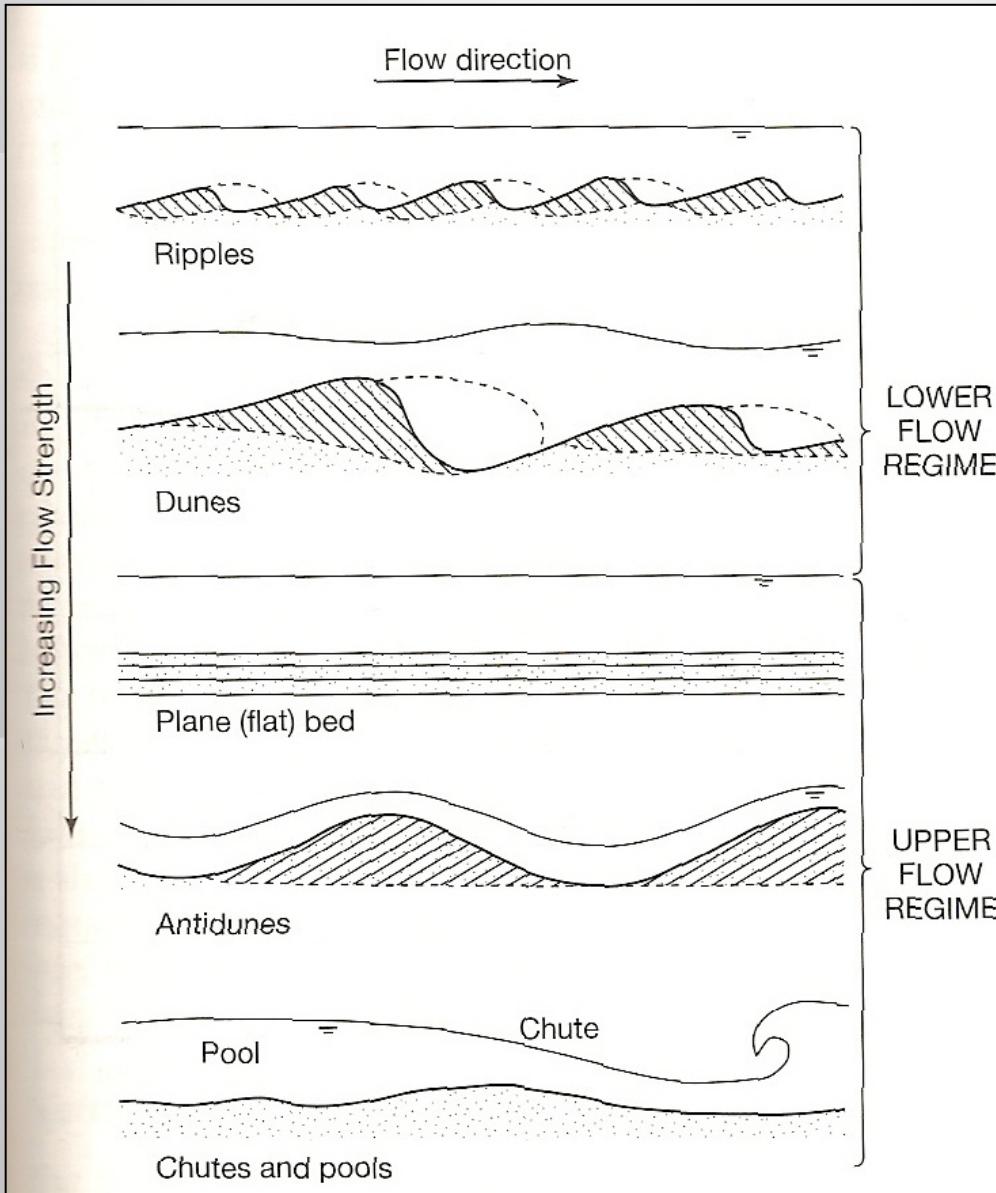
- Patterns formed by the deposition of sediments produced mechanically following transport by a fluid.

(Doesn't include changes from secondary processes such as post-depositional modification and biologic processes)

# Bedforms and flow regime

Froude  
numbers  
 $< 1$

Froude  
numbers  
 $> 1$



Under unidirectional flow conditions with sandy sediments (0.25 – 0.7 mm) along the streambed.

# Upper plane bed

- Upper plane bed flow occurs in fine and very fine sand when the flow velocity is increased above that needed for ripple formation (very fine sand) or dune formation (fine sand). Upper plane bed flow occurs in the upper flow regime ( $F_d > 1$ ). Basically, upper plane bed flow is intense sediment transport over a flat bed.

# Upper plane bed stratification



Modern beach deposit. Note that the 3D nature of the cut demonstrates the horizontal and planar aspect of this structure

# Parting lineation

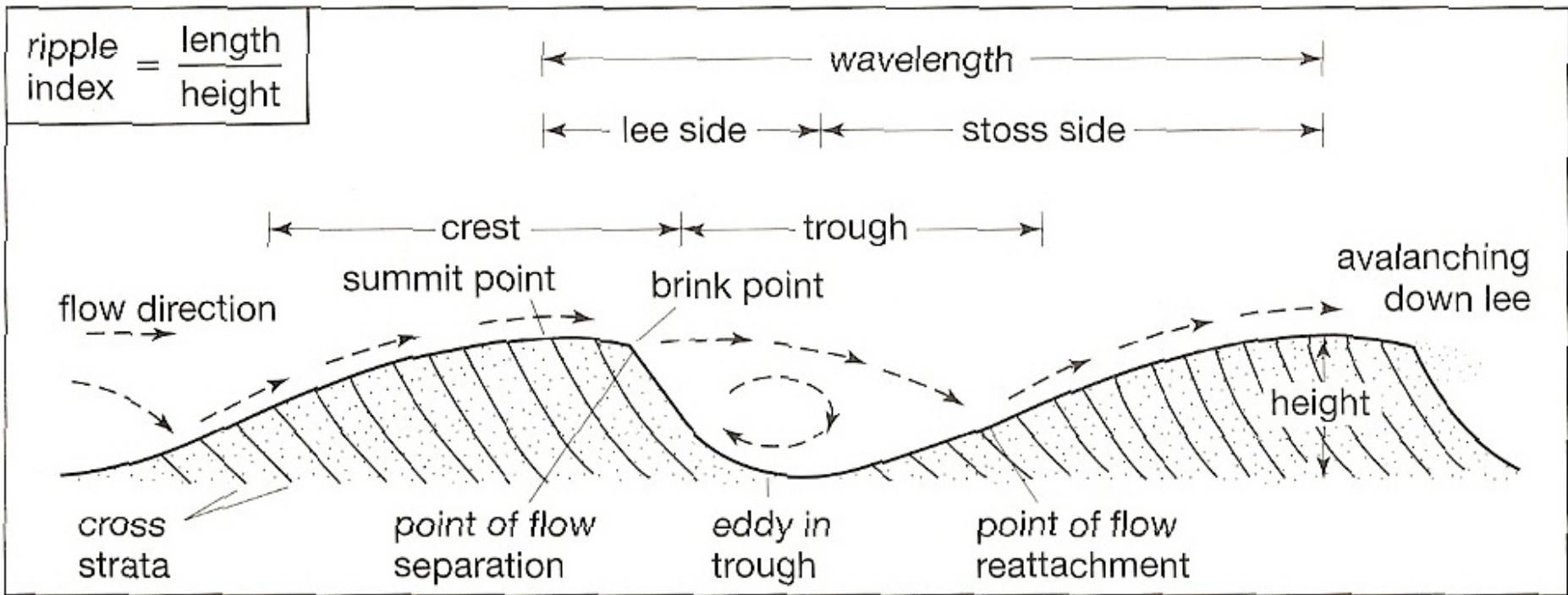


# Bedforms - Ripples



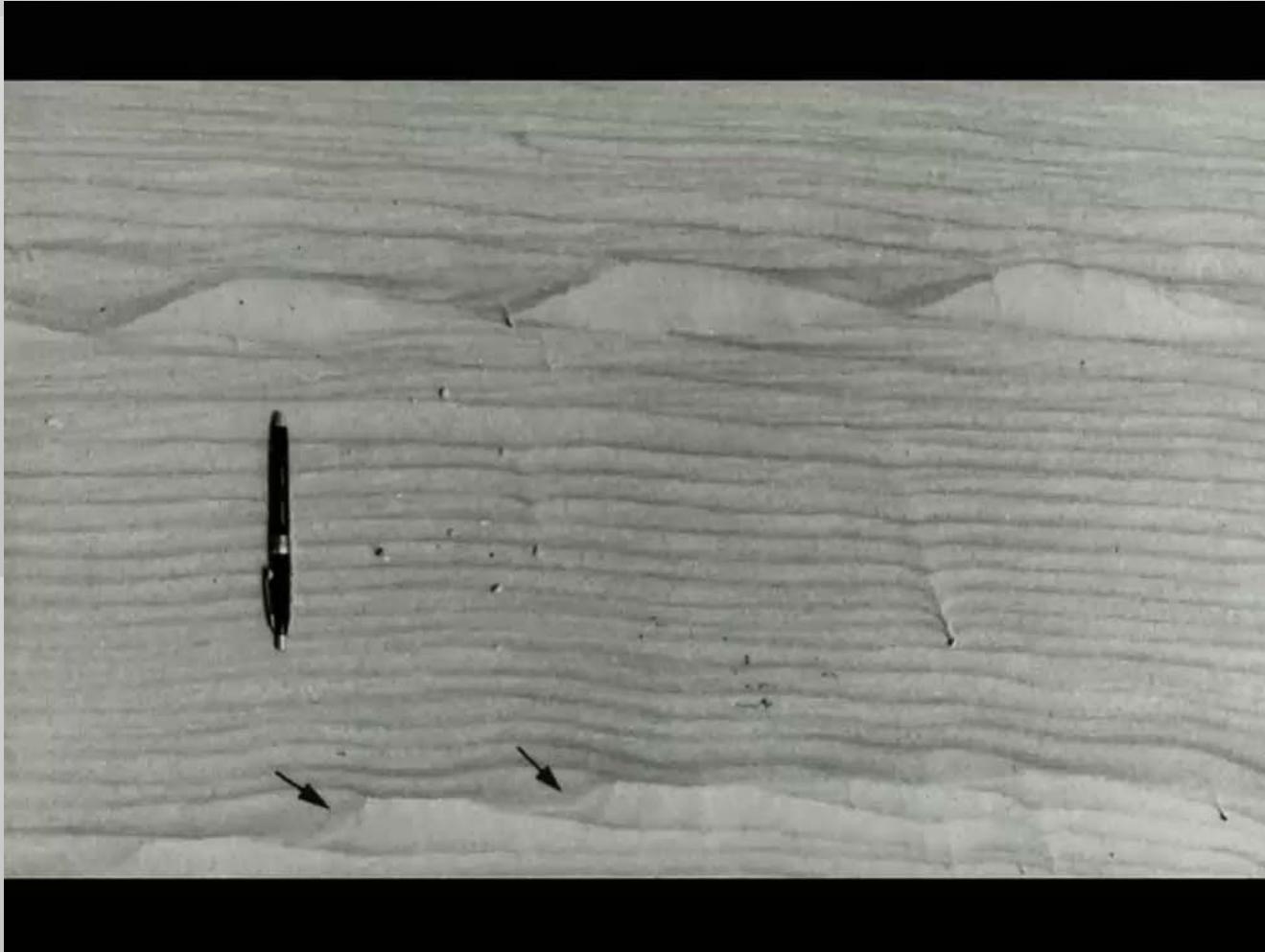
C.E. Jones, UPitt

# Asymmetric ripples



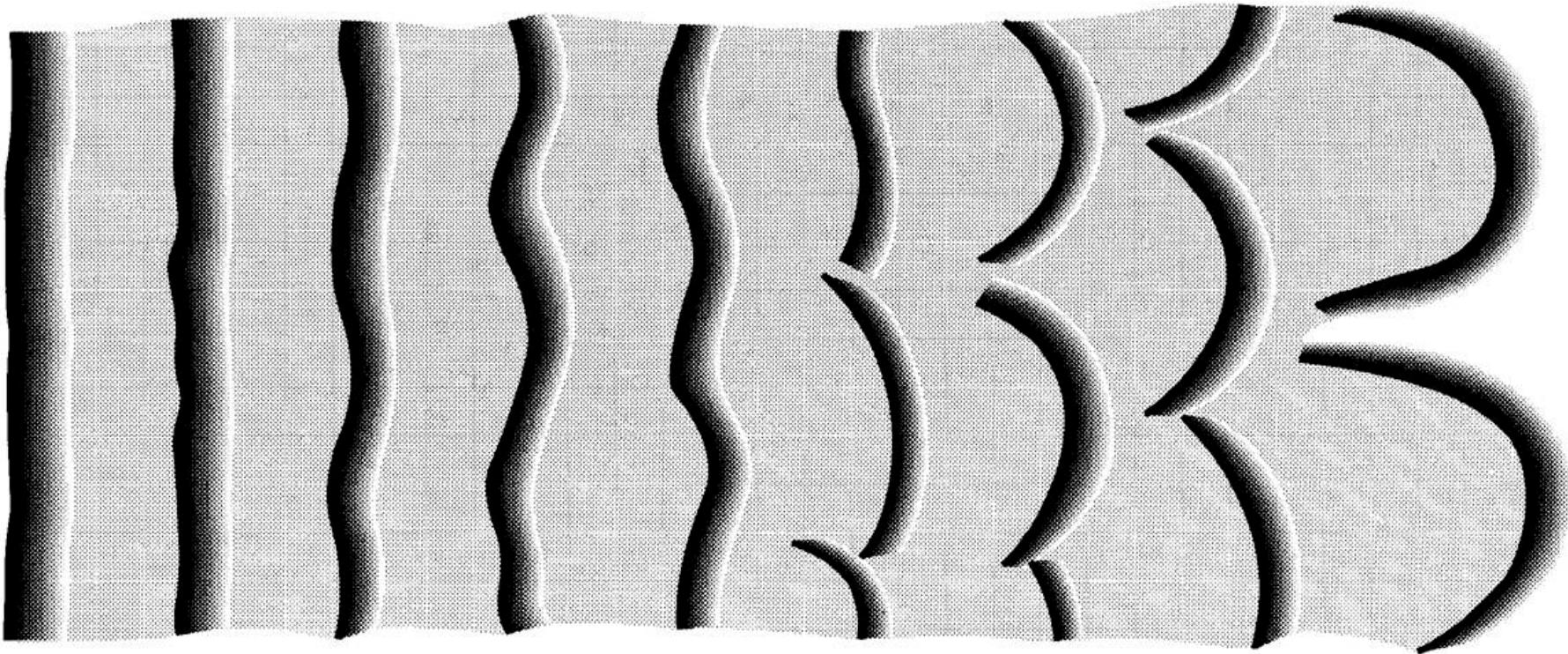
# Ripple formation

## (Unidirectional Flow)



# Ripple morphology

→ *Flow direction*



■ Straight

■ Sinuous

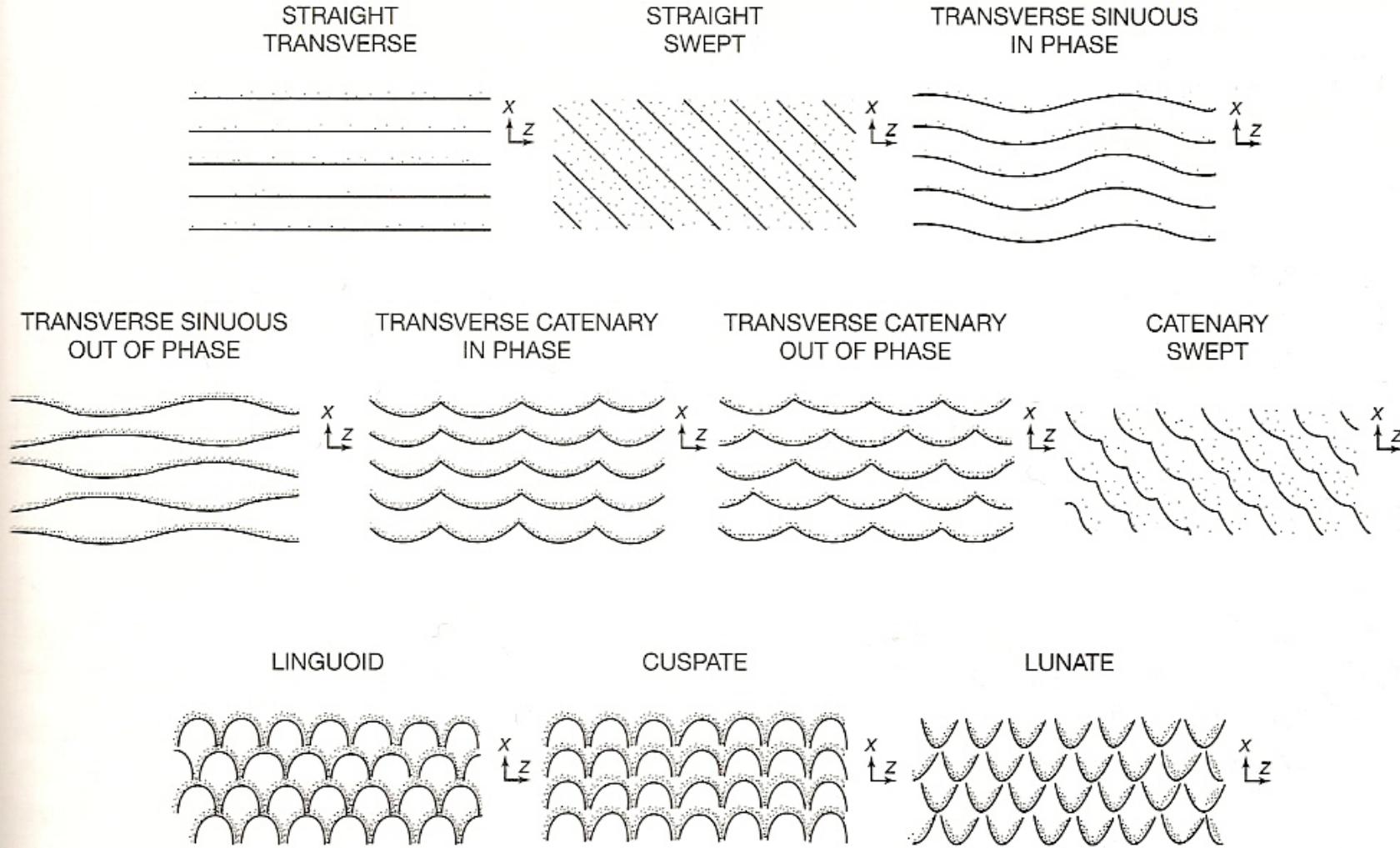
■ Isolated (linguoid)

M. Hendrix, Univ. of Montana

# Symmetric ripples



# Types of ripple crests



# Bedforms - Small-scale dunes



From fine sand to gravel



© M. Ross 1995

Porcupine River, Yukon

# **Large bedforms (landforms) - Eolian dunes**



Petawawa, ON

© M. Ross 2004

# Antidunes

- Antidunes are produced by in-phase, shallow flow at ca.  $Fr > 0.8$
- Antidunes migrate upstream, giving rise to low angle cross laminations that are dipping upstream
  - Faint (no grain sorting by avalanching)
  - Migration is due to grain accretion

# Antidunes

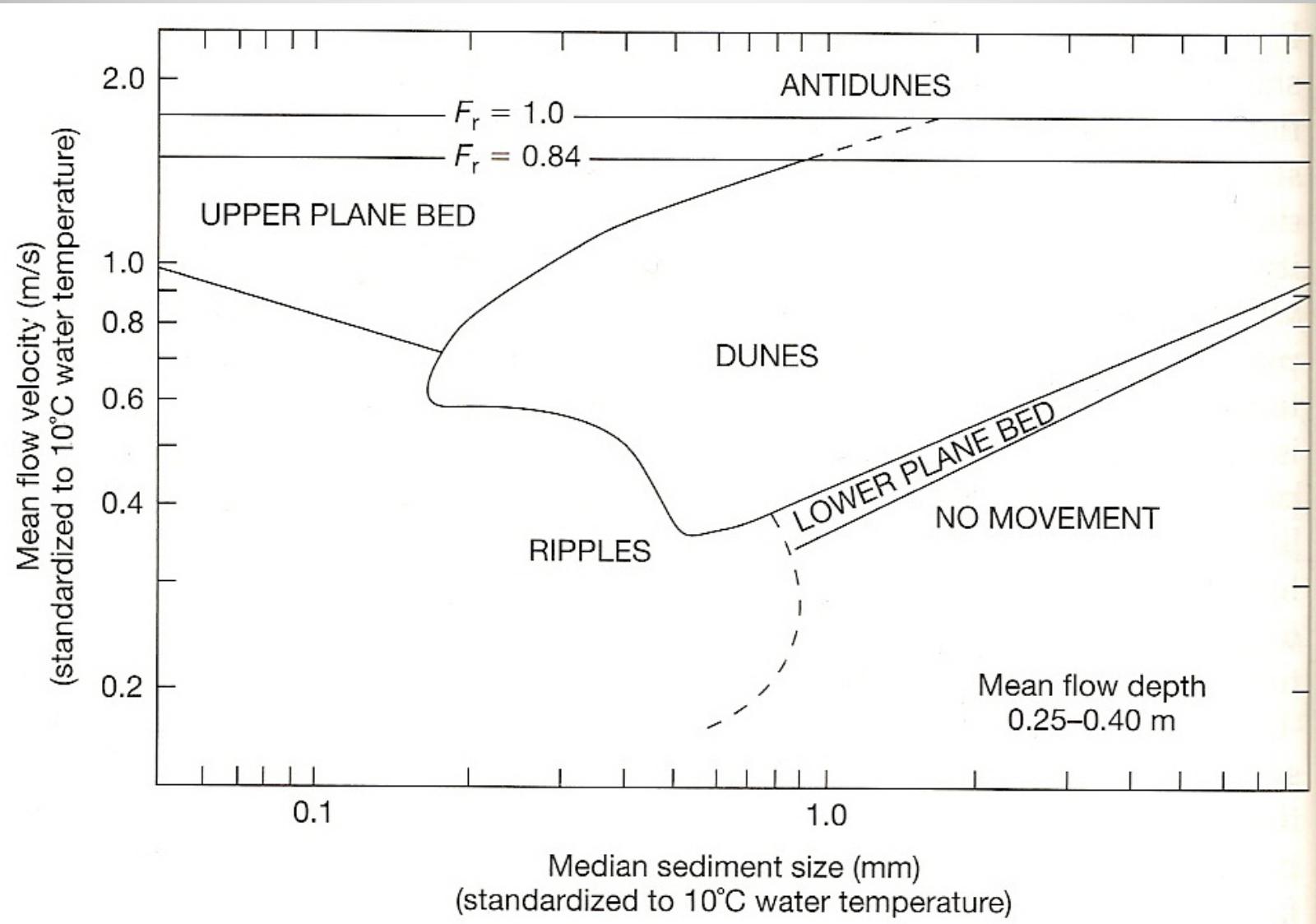


Antidunes forming in a small tidal channel  
on the California coast

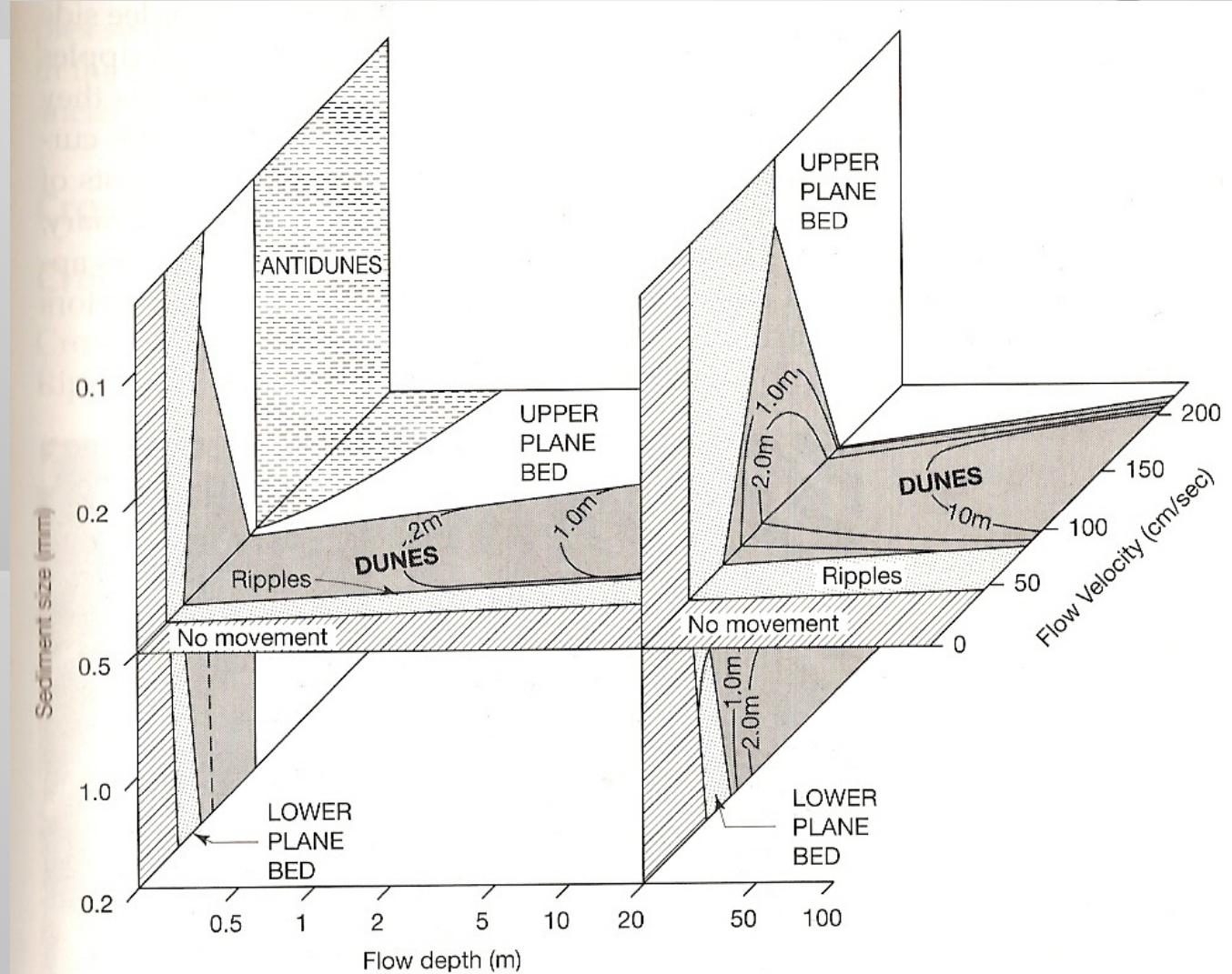


ca. 4 m  
A standing wave train with associated  
antidunes

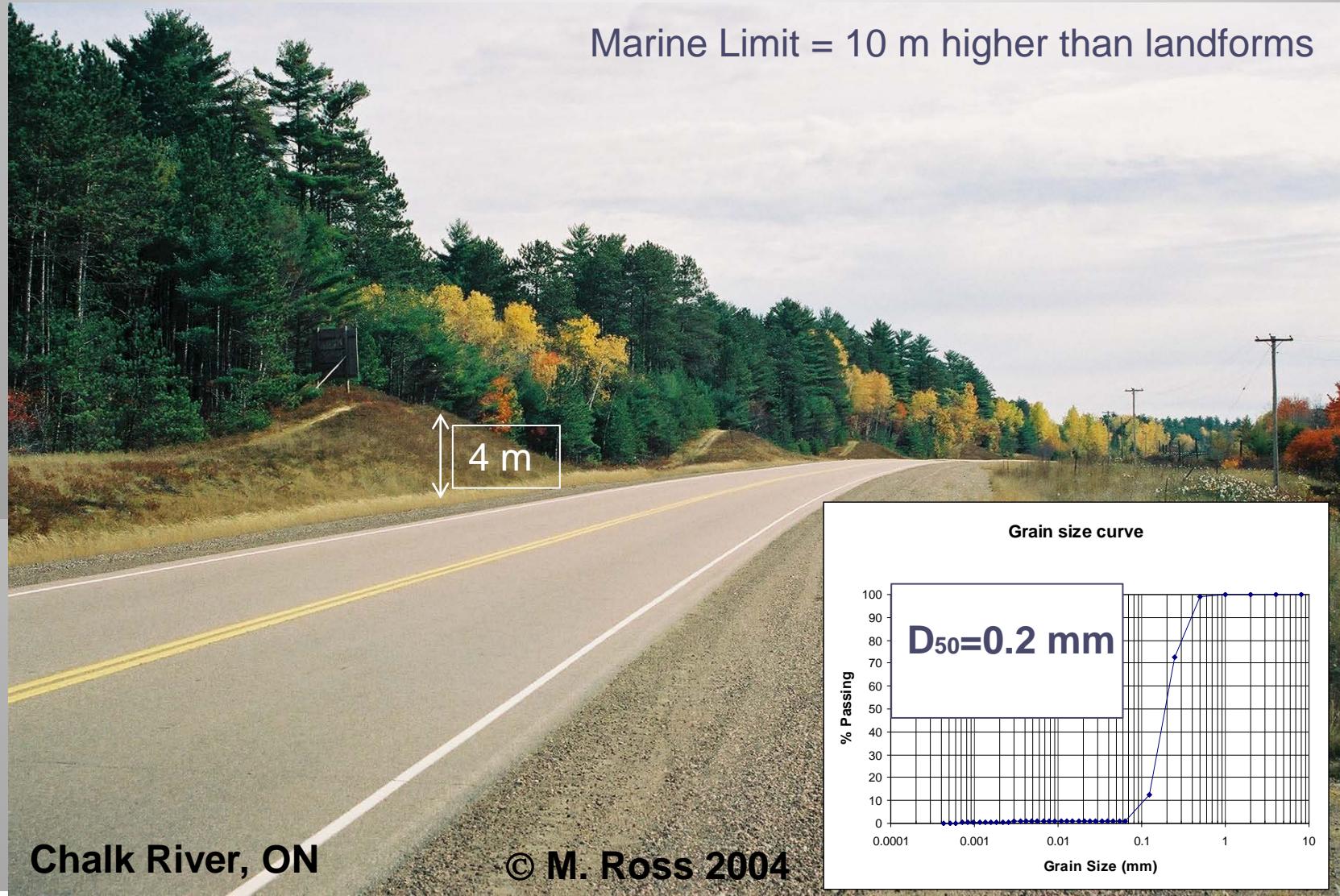
# Effect of grain size



# Depth-velocity-grain-size-bedform... relationships!

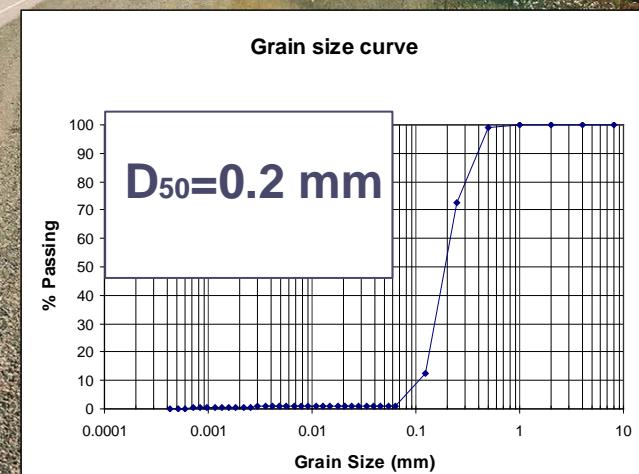


# Are they aeolian dunes or ‘giant’ subaqueous dunes?

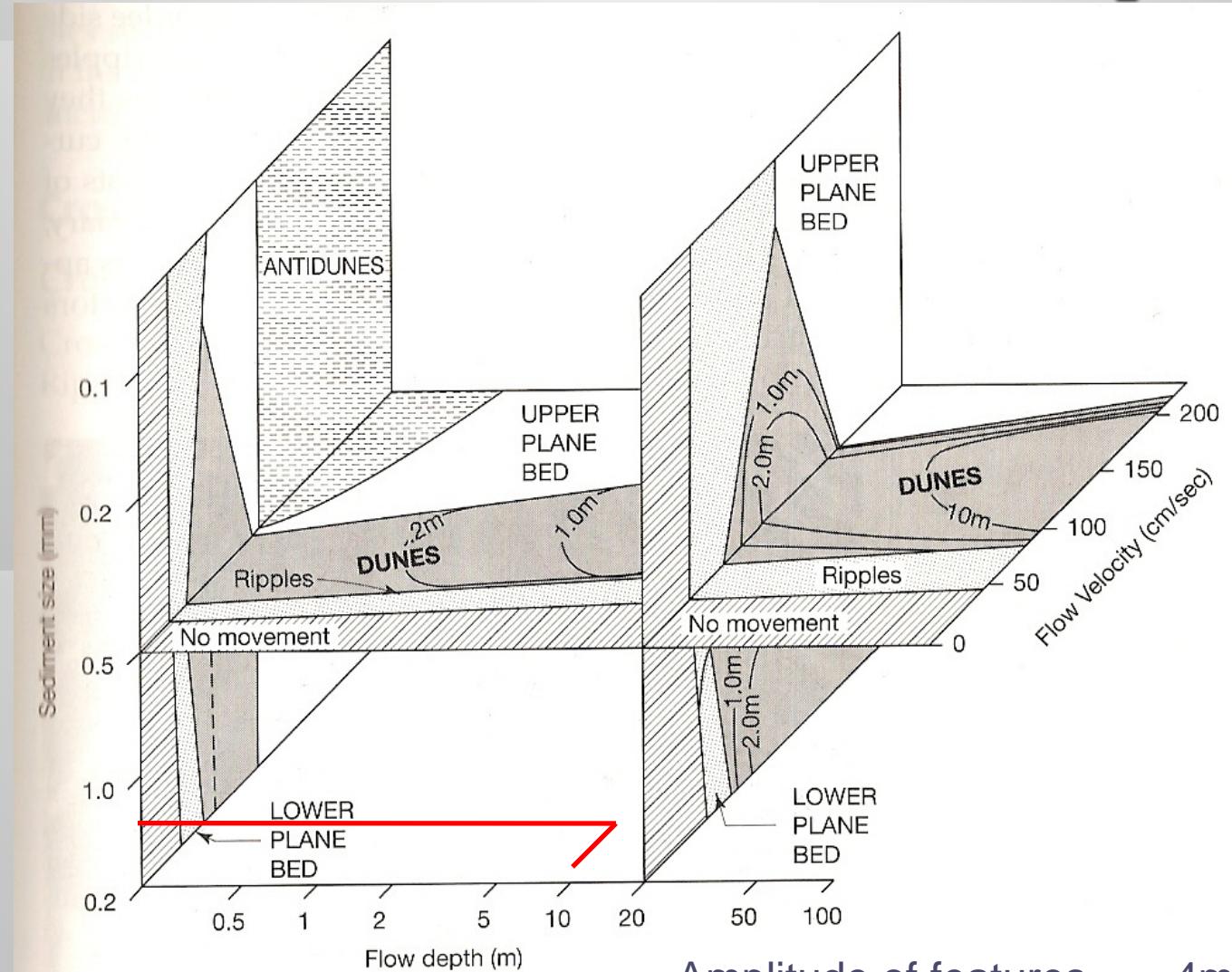


Chalk River, ON

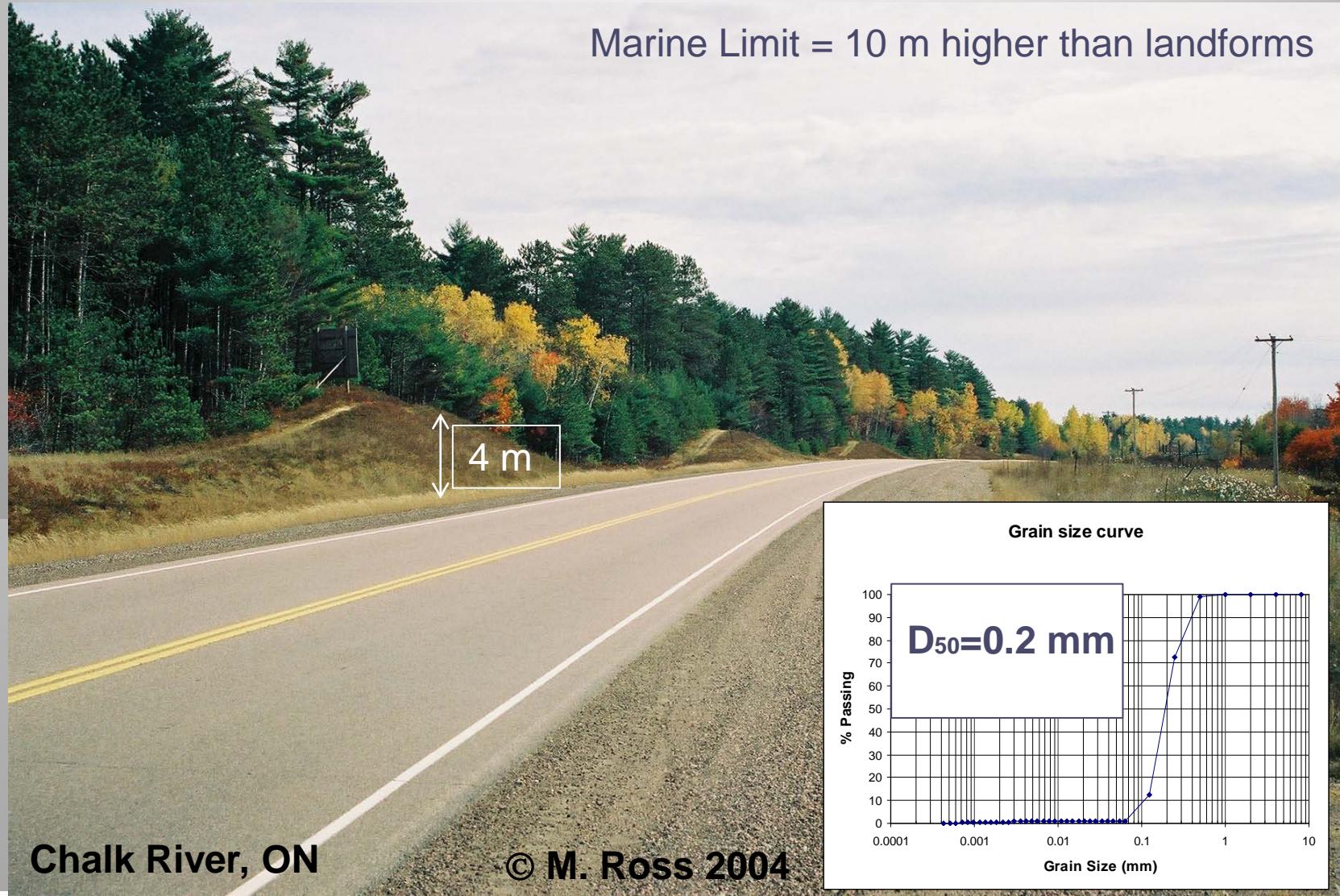
© M. Ross 2004



# Depth-velocity-grain-size-bedform... relationships!

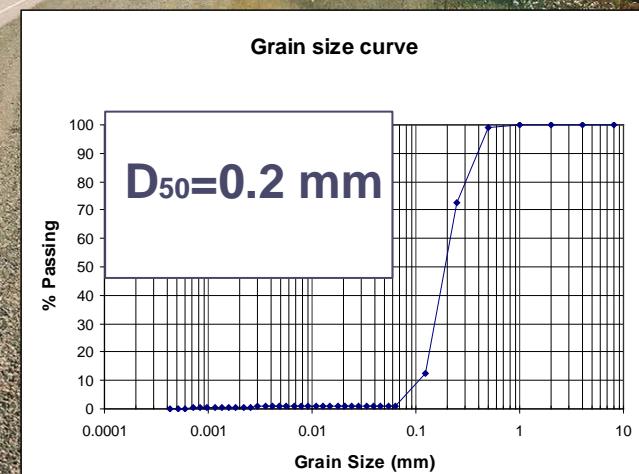


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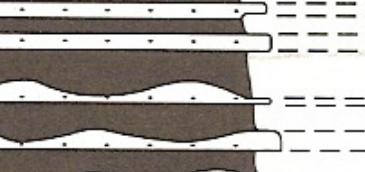
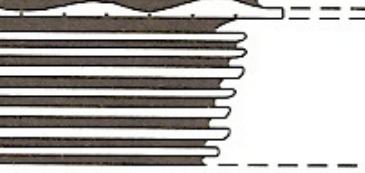


Chalk River, ON

© M. Ross 2004



# Bedding and lamination

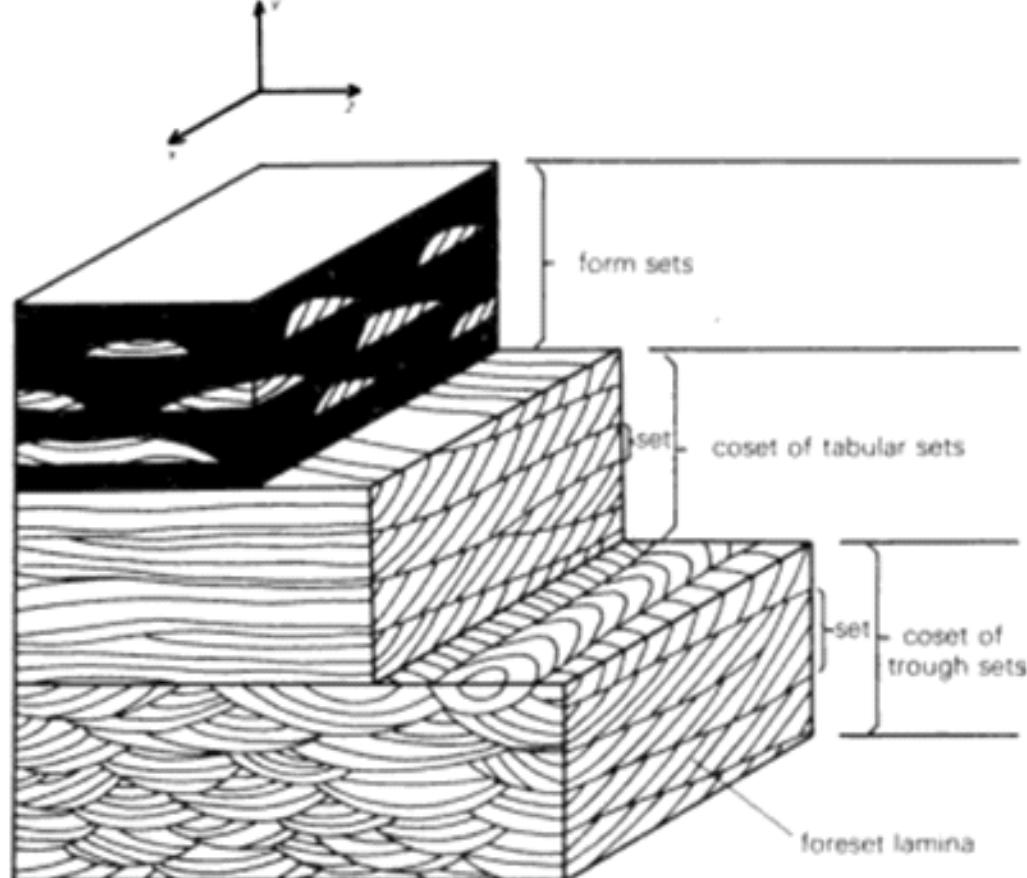
Grain size	Structure and features	Individual bed limits	Types of groups of beds (cosets or bedsets)	Bedding type
gravel	layers or strata		simple	simple layered gravel
sand	bedding planes and bounding surfaces layers and laminae erosional bounding surfaces		simple	plane laminated sand
	cross laminae cross strata		simple	simple cross-bedded or cross-laminated (ripple-bedded)
	nonerosional bounding surfaces		composite	interbedded sand/mud
sand – silty mud			composite	lenticular bedded sand
silt – mud	laminae		simple	laminated
		increasing grain size, mud → gravel		

coarsening upwards of several bedsets

# Coarse-grained strata

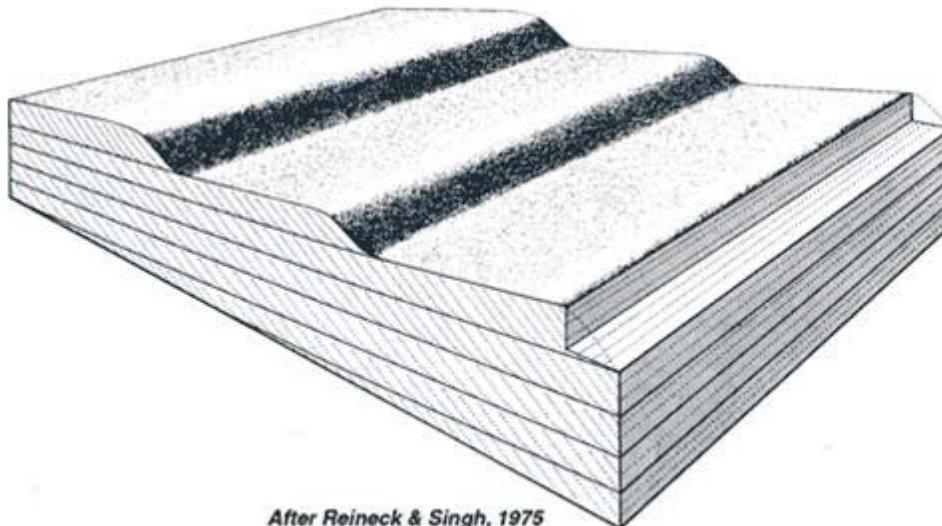


# Basic types of cross lamination

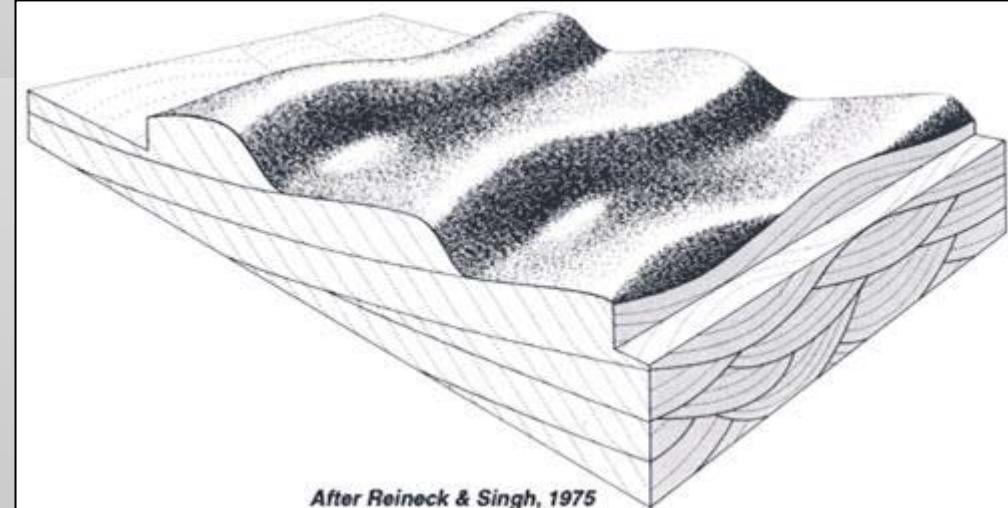


**Figure 6.9** Definition diagram for the basic types of **cross** lamination. The same terms apply at a larger scale to **cross** bedding (based on Allen 1968).

# 3D block model...



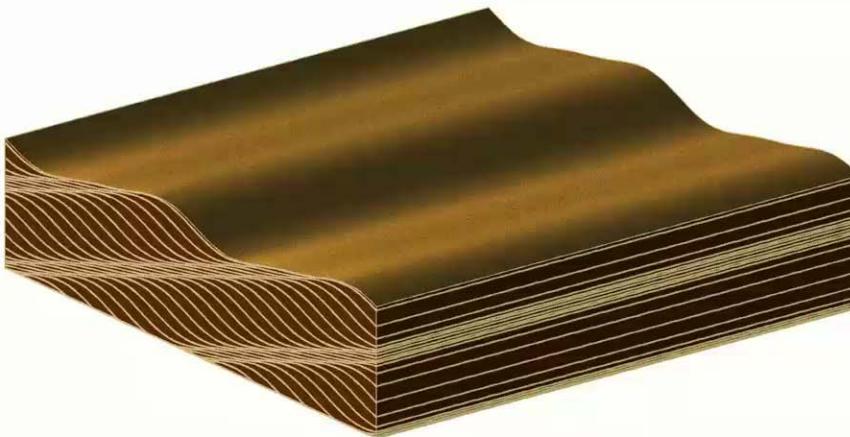
Planar cross beds created by straight crested ripples



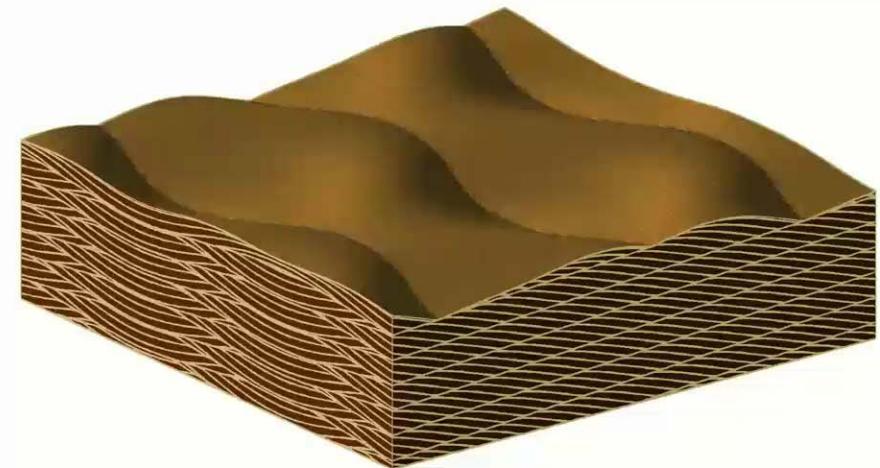
Trough cross beds created by sinuous crested ripples

# Basic types of cross lamination

Planar cross beds created by straight crested ripples



Trough cross beds created by sinuous crested ripples



# Cross-beds – Cross-strata



Zion National Park, Utah

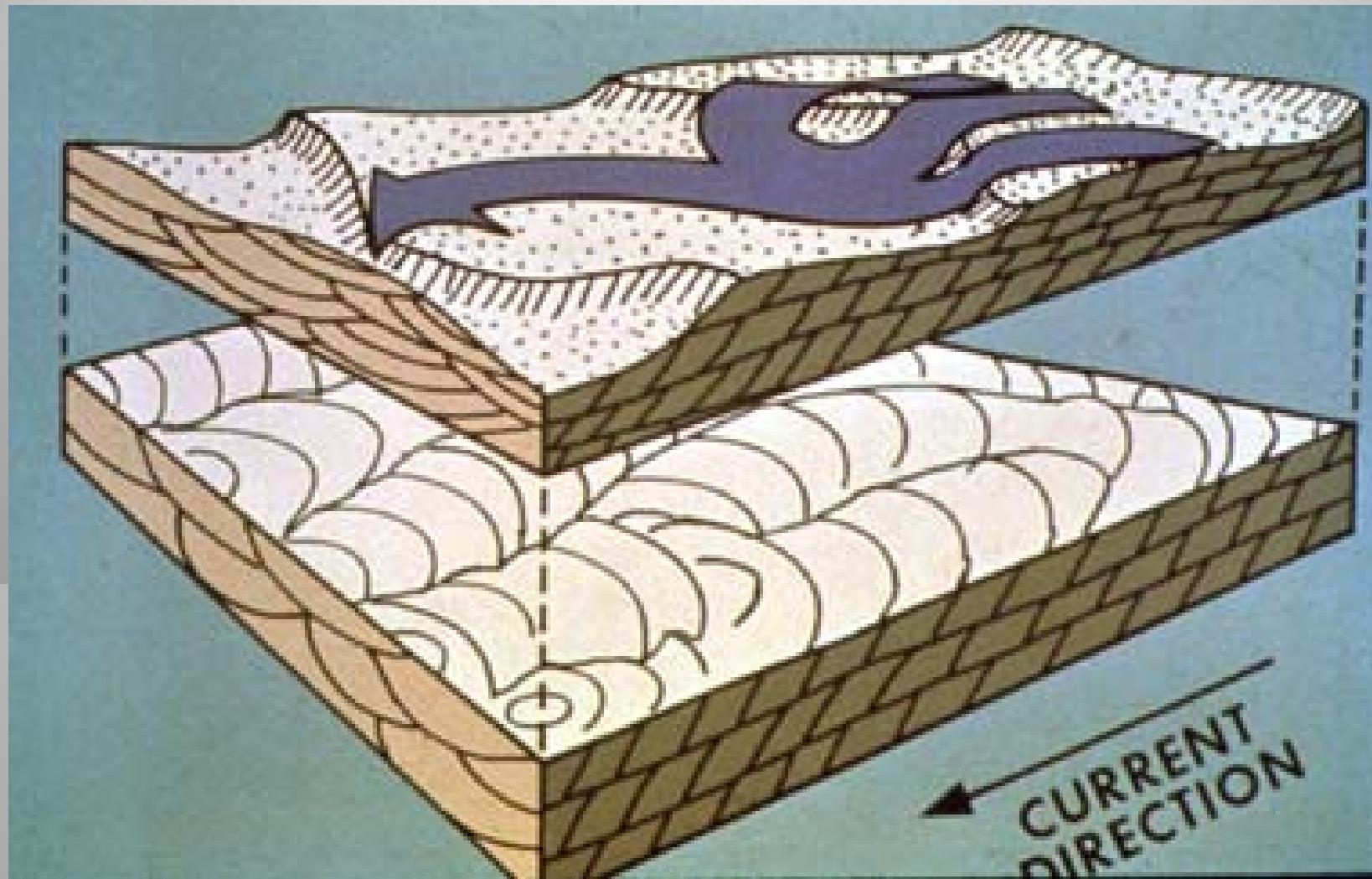
# Cross-beds – cross-laminations



Saint-Lazare, Qc

© M. Ross 1999

# Trough cross bedding

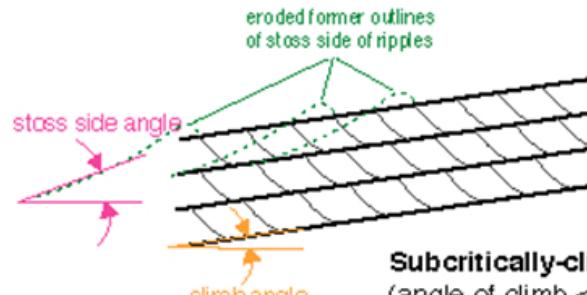
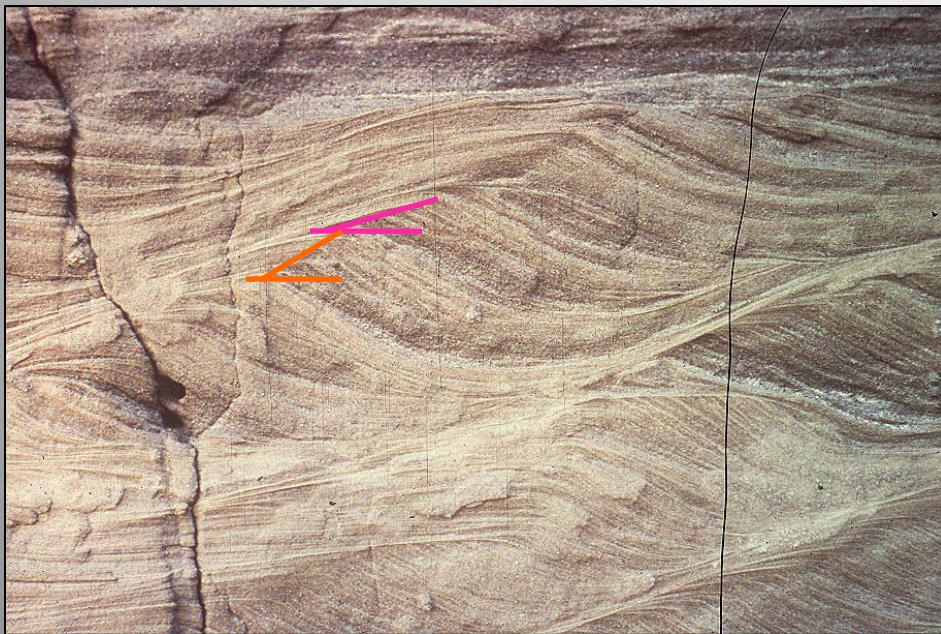


# Small-scale trough cross lamination



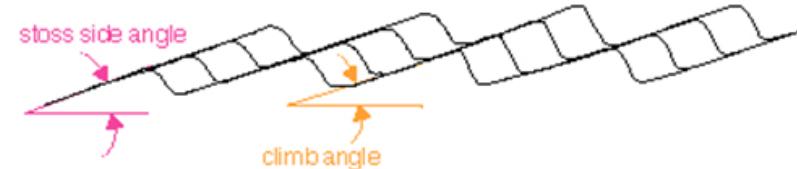
St. Lawrence Lowlands

# Climbing Ripples



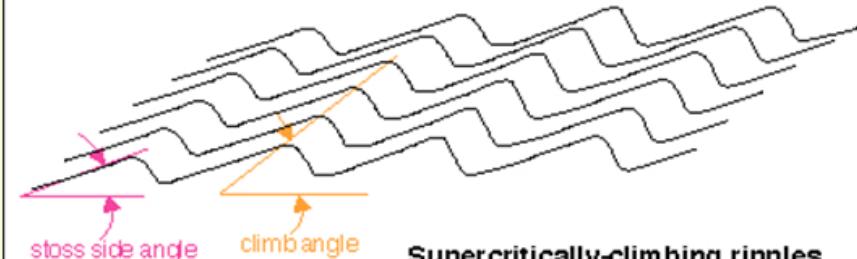
**Subcritically-climbing ripples**  
(angle of climb < stoss side angle)

Note that only toe of foresets is preserved;  
tops of foresets and entire stoss side is eroded



**Critically-climbing ripples**  
(angle of climb = stoss side angle)

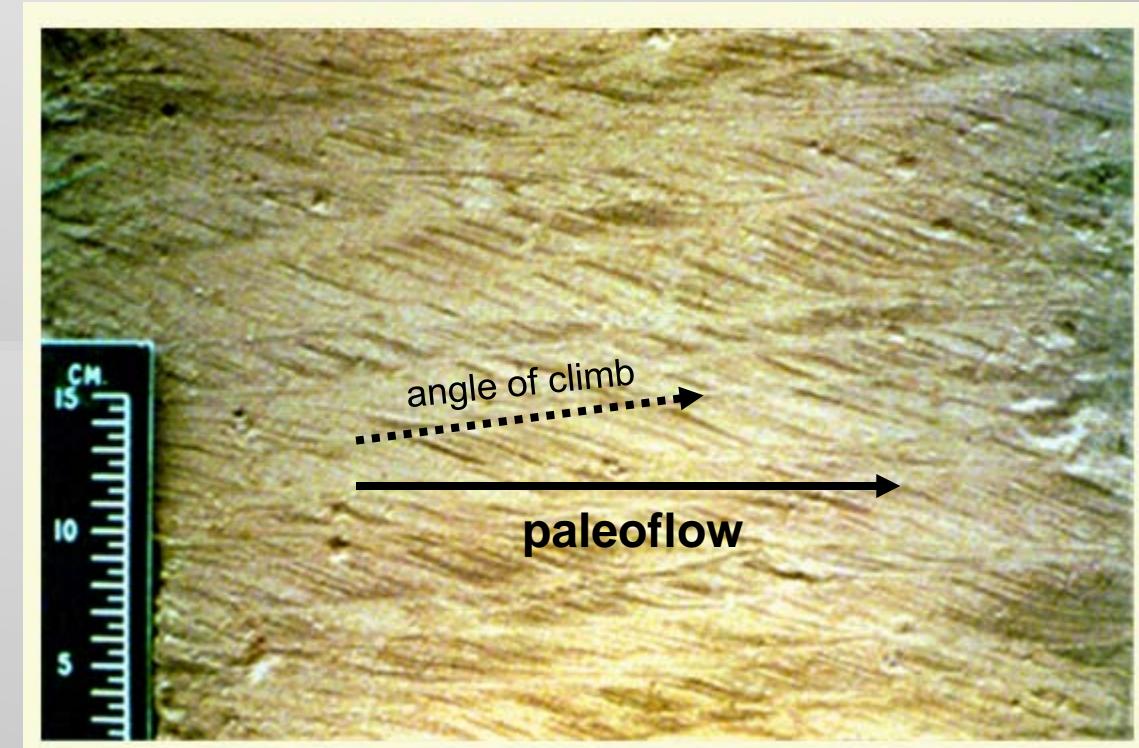
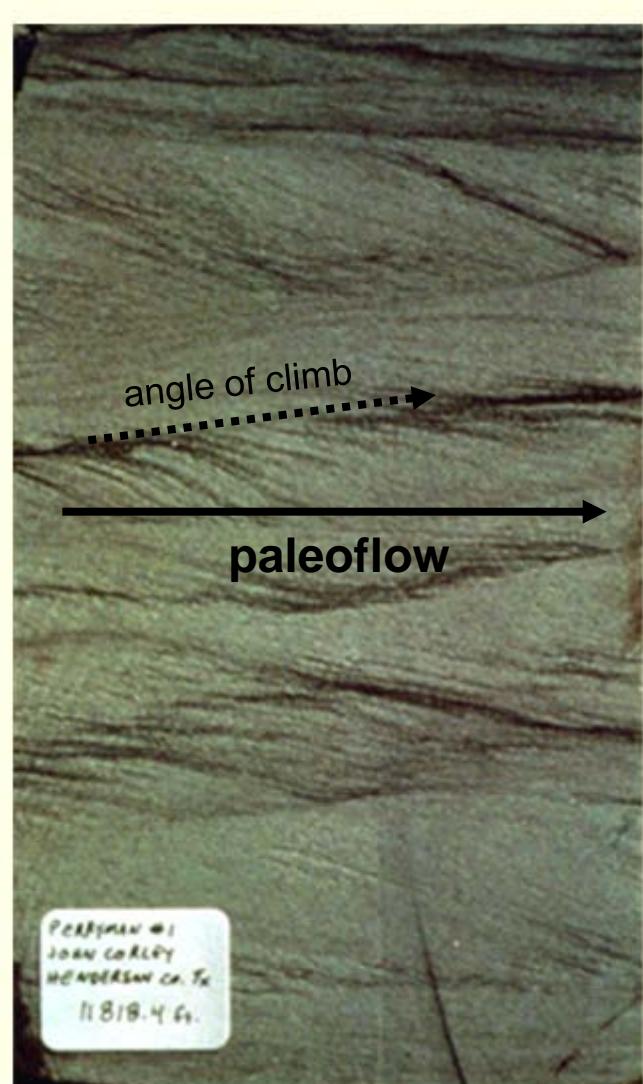
Note that entire lee side of ripples is preserved,  
and that stoss side of ripples is barely preserved.



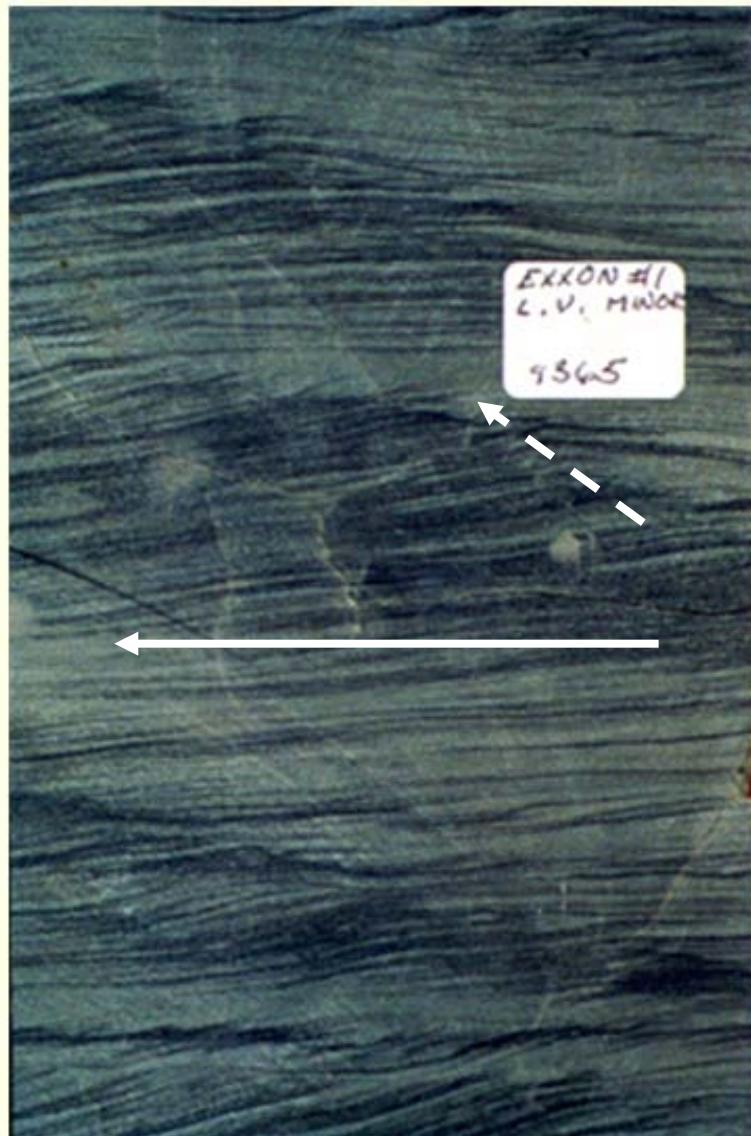
**Supercritically-climbing ripples**  
(angle of climb > stoss side angle)

Note that entire lee side and entire stoss side  
of ripples is preserved

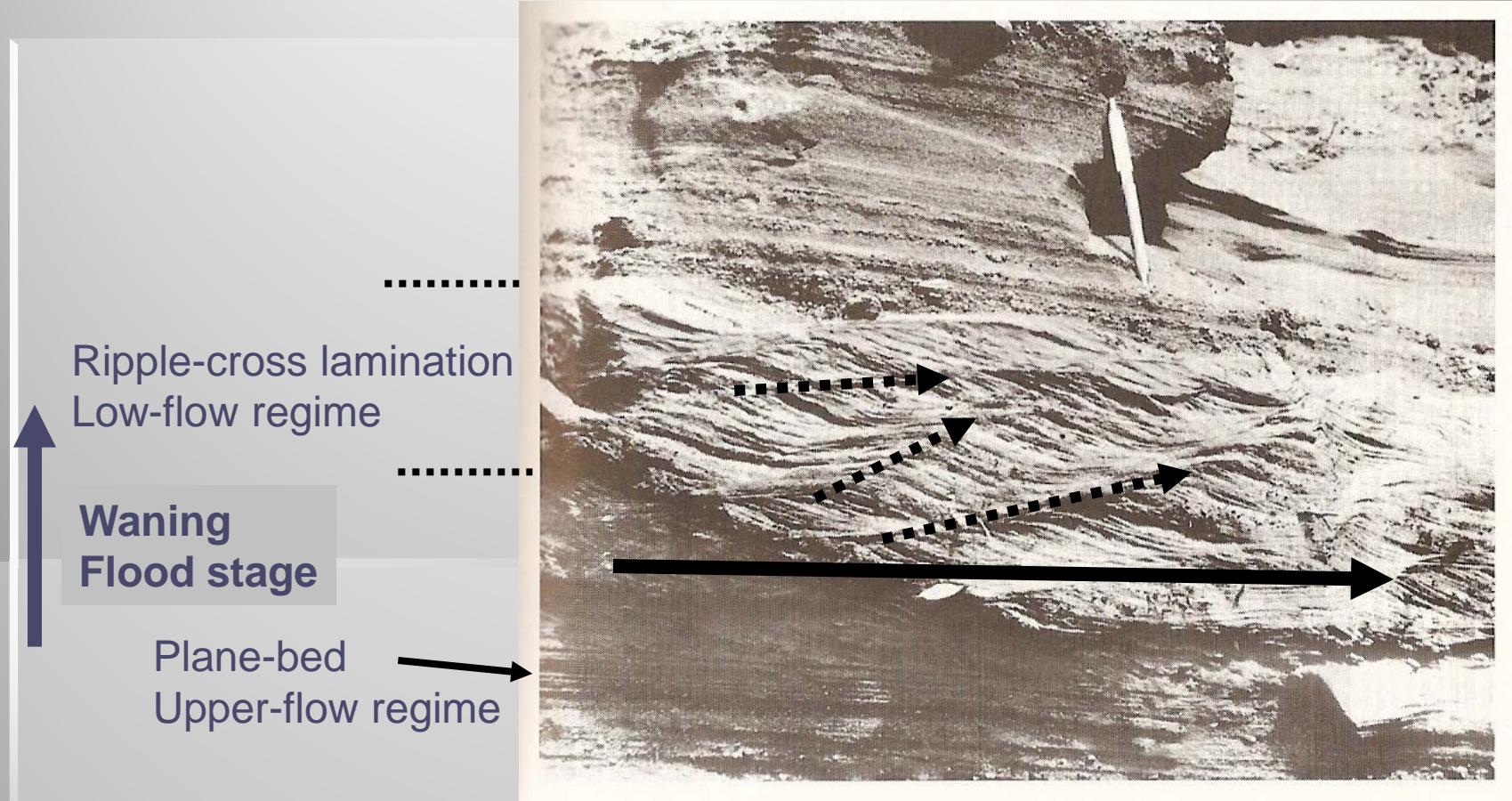
# What is the paleoflow direction?



# What is the paleoflow direction?



# Typical sequence...



Environments characterized by rapid sedimentation from suspension  
-Fluvial flood plains, point bars, turbidite sedimentation

# Type of bed and bedform? Paleoflow direction?



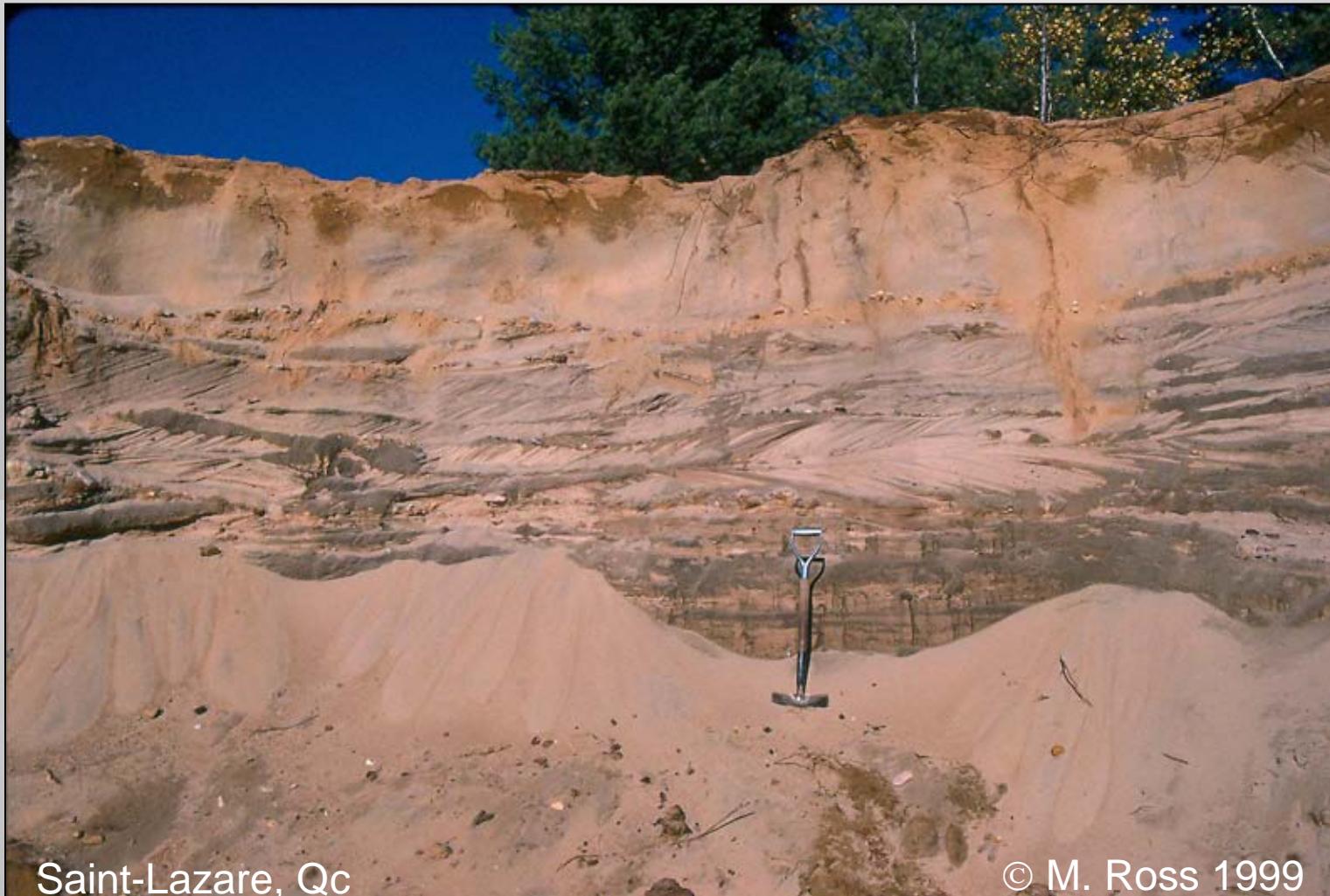
Subcritical climb

Overted foresets

ca. 4 m



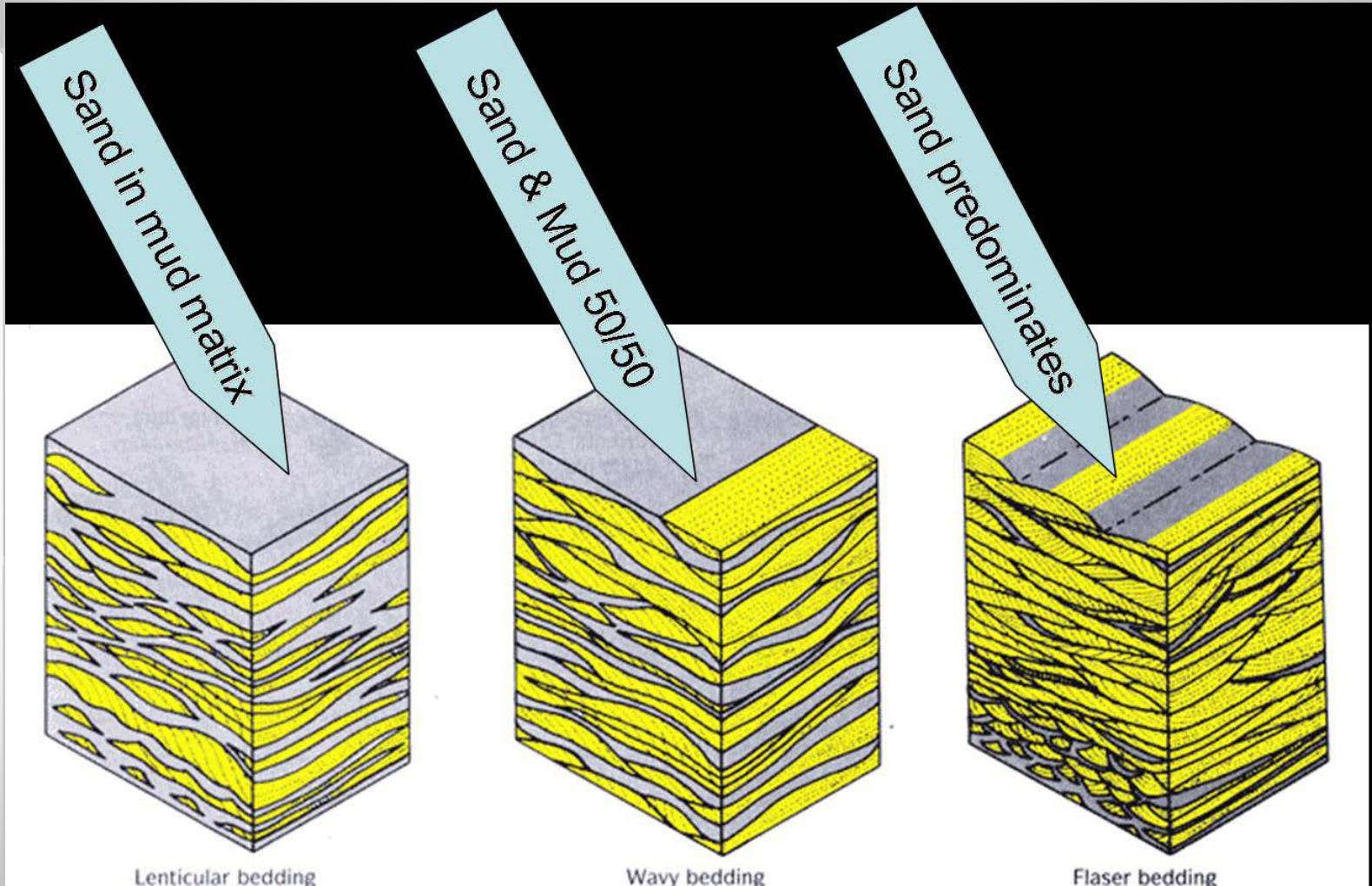
# Cross beds and “herringbone” structures



Saint-Lazare, Qc

© M. Ross 1999

# Variations in Grain Size

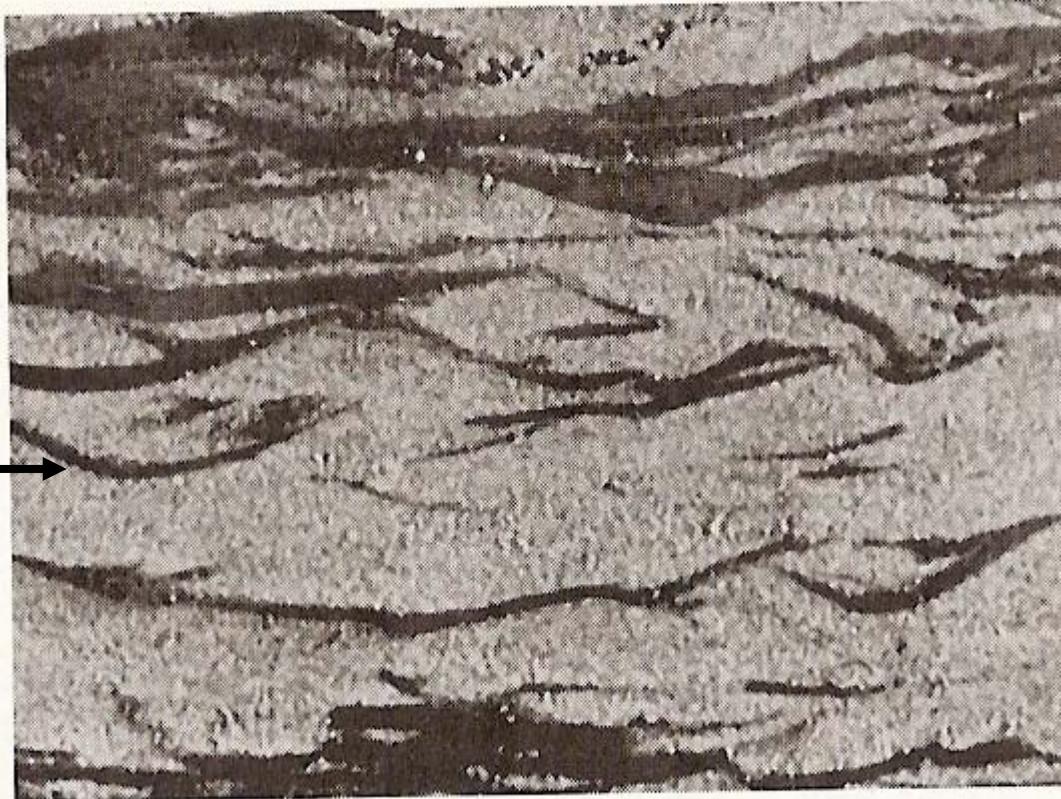


# Flaser bedding

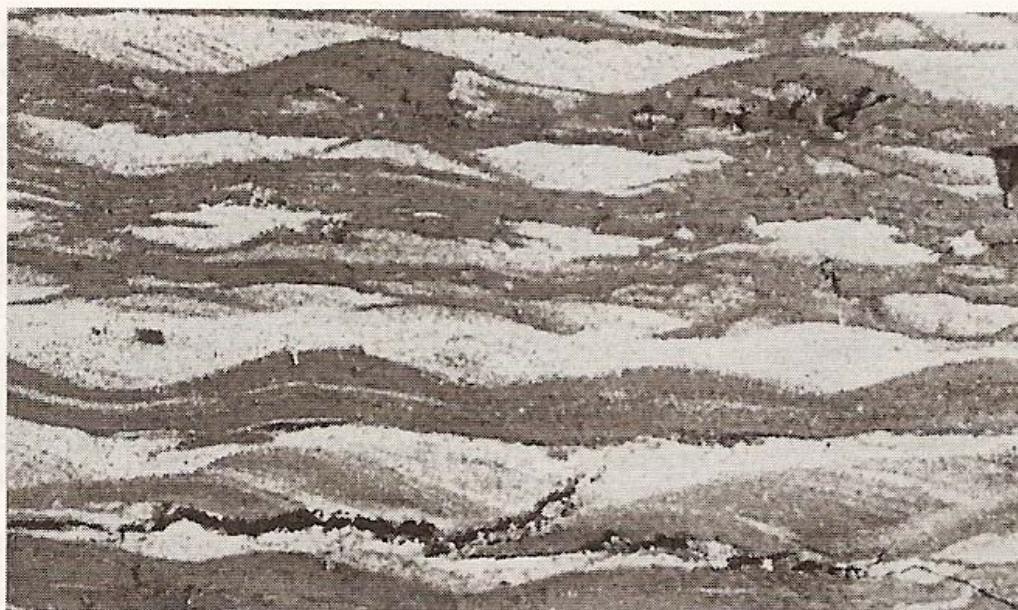
Thin streaks  
of mud

Fluctuating hydraulic conditions (current activity and periods of settling)  
Deposition and preservation of sand over mud is more favorable

Tidal flats



# Lenticular bedding



Interbedded mud and discontinuous ripple cross-laminated sand  
Deposition and preservation of mud over sand is more favorable

**Tidal flats**

# Hummocky cross-beds

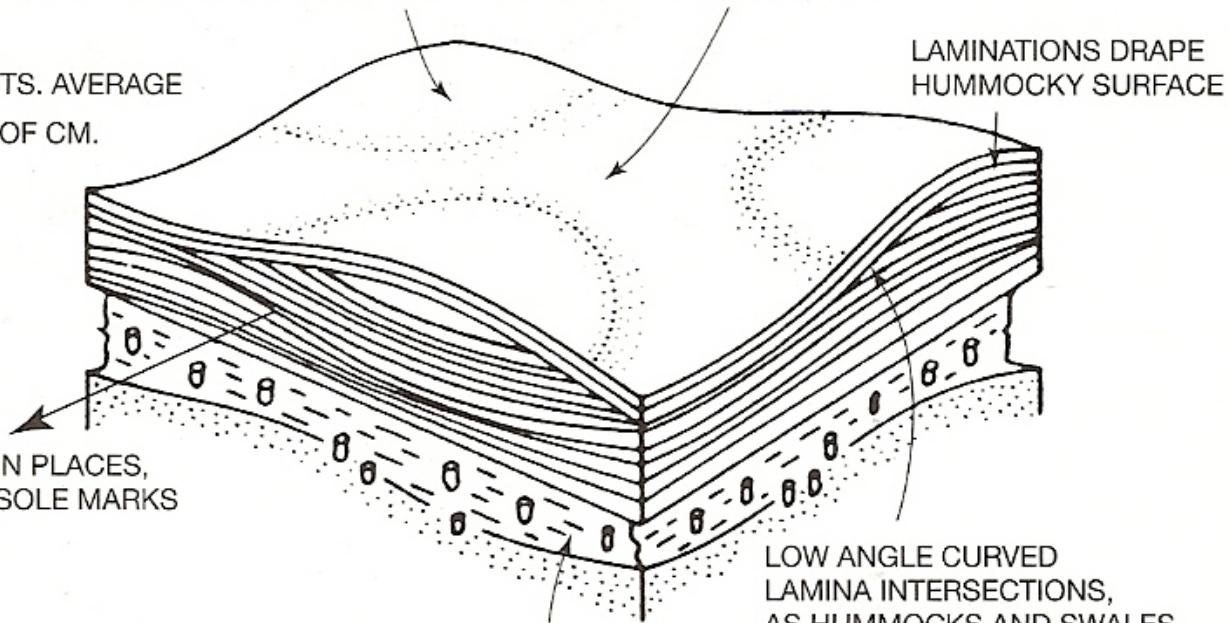
## HUMMOCKY CROSS STRATIFICATION - HCS

LONG WAVELENGTH, 1 - 5 M

LOW HEIGHT, FEW 10'S OF CM

HUMMOCKS AND SWALES CIRCULAR TO ELLIPTICAL IN PLAN VIEW

INDIVIDUAL SSTS. AVERAGE  
SEVERAL 10'S OF CM.



HCS CHARACTERIZED BY -

1. UPWARD CURVATURE OF LAMINATIONS
2. LOW ANGLE, CURVED LAMINA INTERSECTIONS
3. VERY LONG WAVELENGTHS, LOW HEIGHTS;  
LAMINA DIPS NORMALLY LESS THAN 10°



Tempestite beds with hummocky cross stratification, Comstock East outcrop. Note pen for scale. Many of the tempestite beds have concentrations of reworked oysters in the basal part.

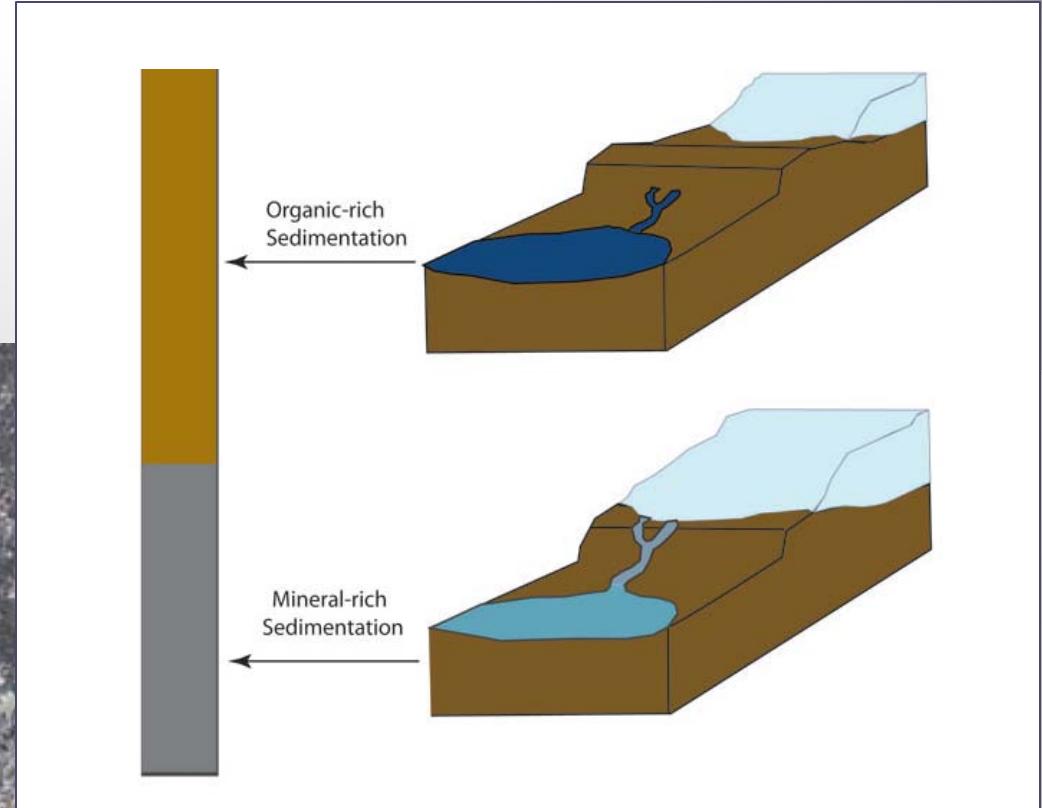
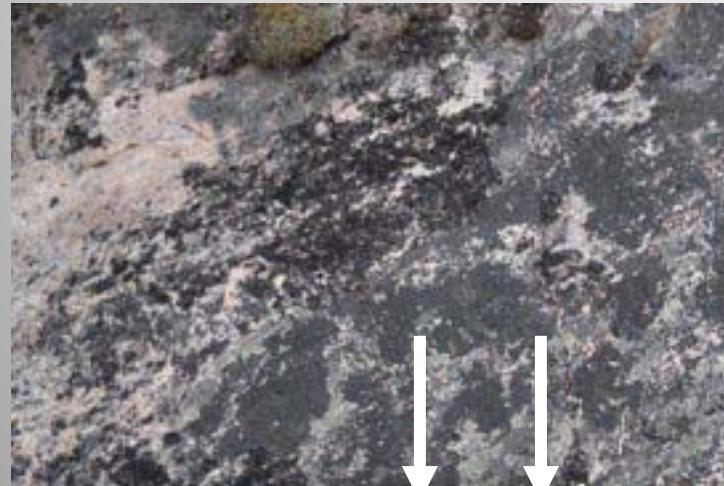
# **Interbedded sand/silt or (mud) beds**



Saint-Jérôme, Qc.

© M. Ross 2000

# Laminae



Deeper water

Fining-upward

Pro-fan/delta  
Marine deposition

Subaqueous fan  
deposition

Ripples  
(traction transport; bedload)  
and draping laminations  
(wavy grey laminae;  
particle settling)

Southampton Island,  
Nunavut

© M. Ross 2007

# Summary:

- Common Bedforms:

- Planar Beds



- Ripples

- Characteristics (scale, symmetry, orientation.)



- Dunes

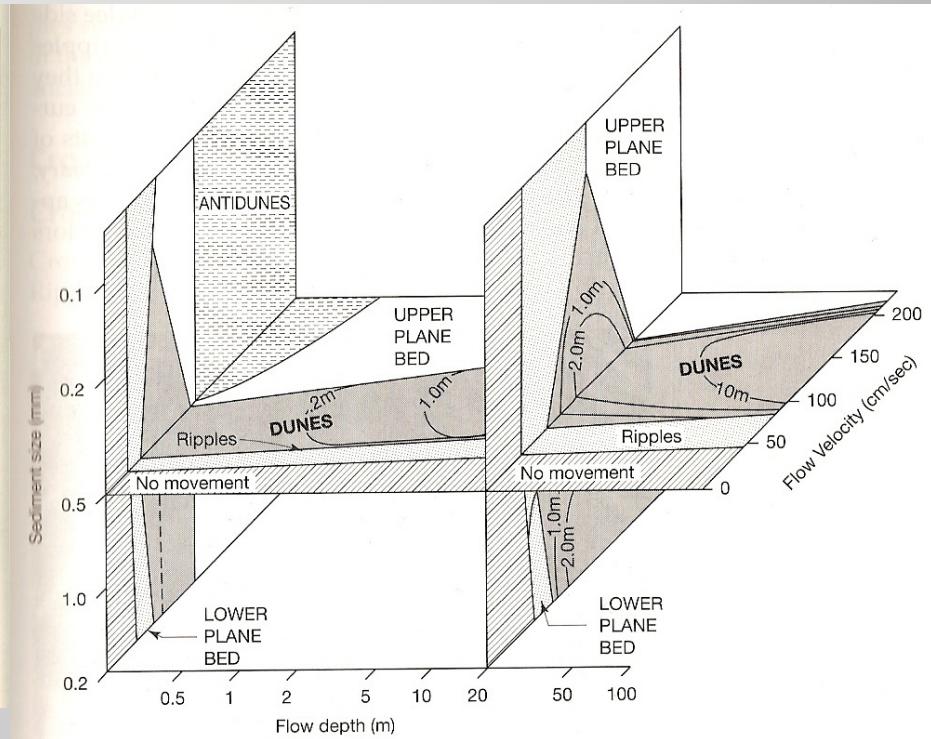
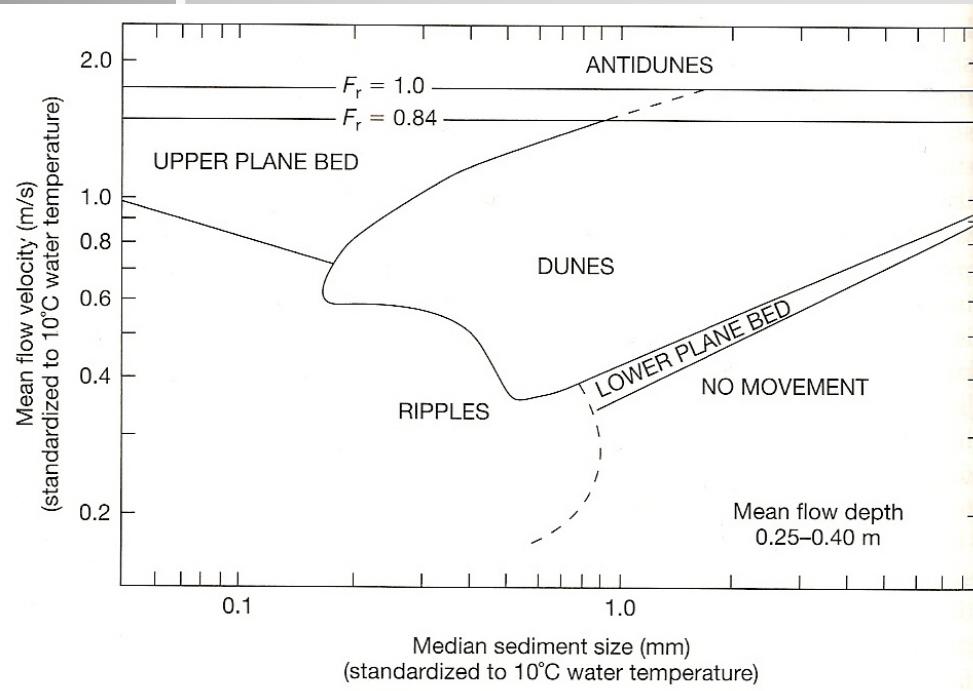


- Anti-Dunes



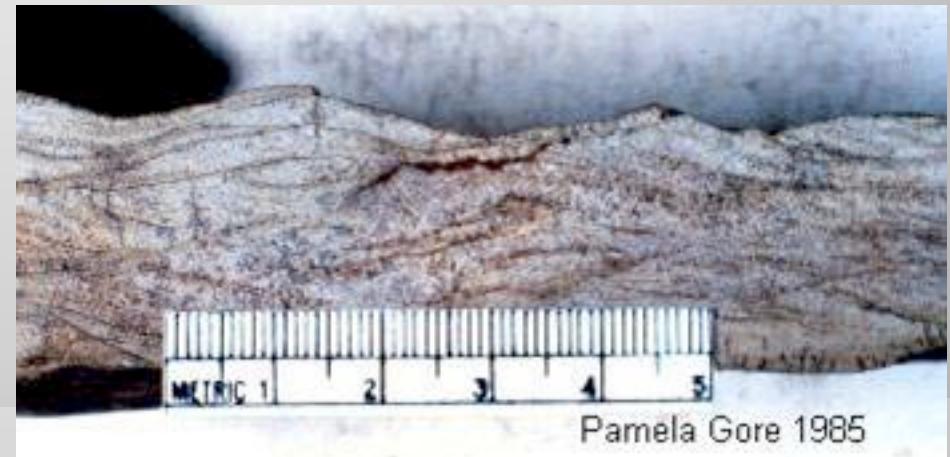
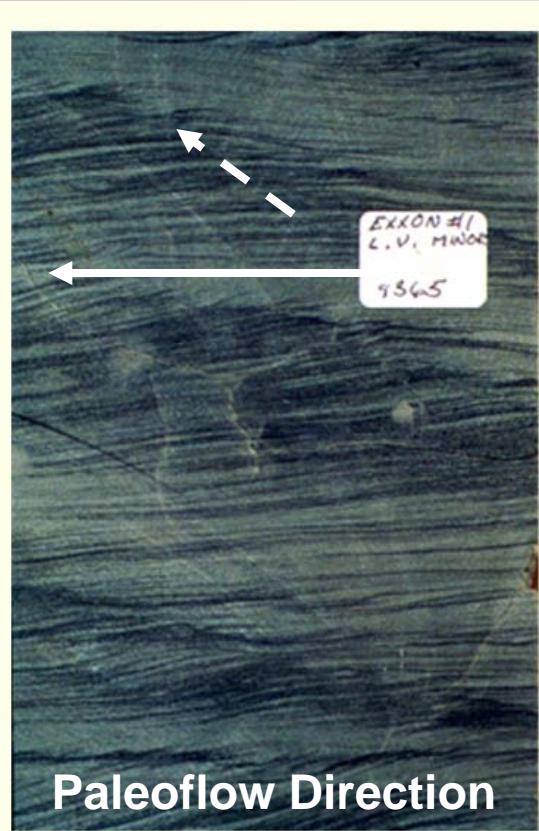
# Summary

- The effect of grain size and velocity on creating sedimentary structures.



# Summary

- Connect sedimentary structures to depositional environment.



Symmetric vs Asymmetric ripples



Talbot, W. Washington