Morphodynamic types of postglacial cliffs of the Southern Baltic

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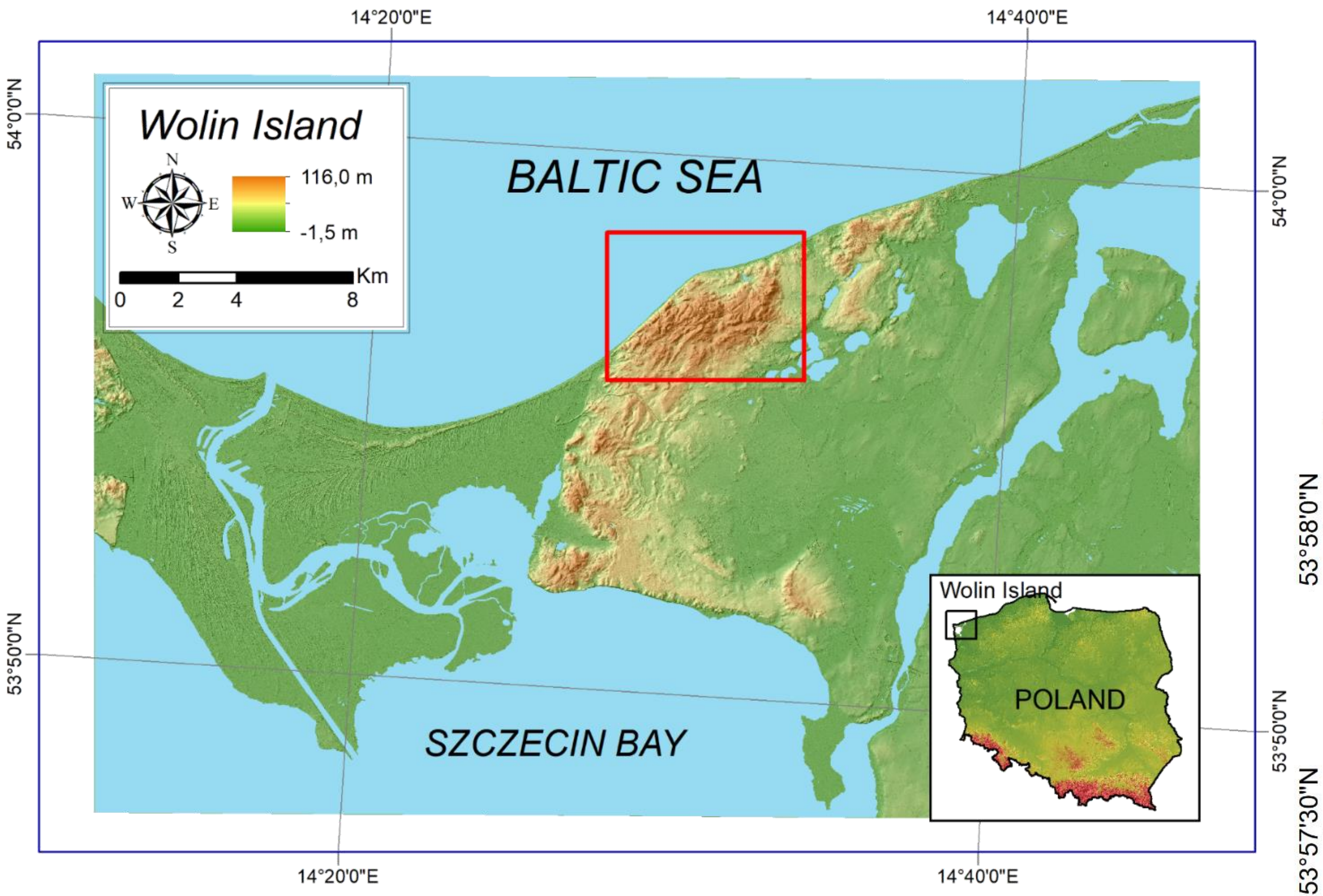
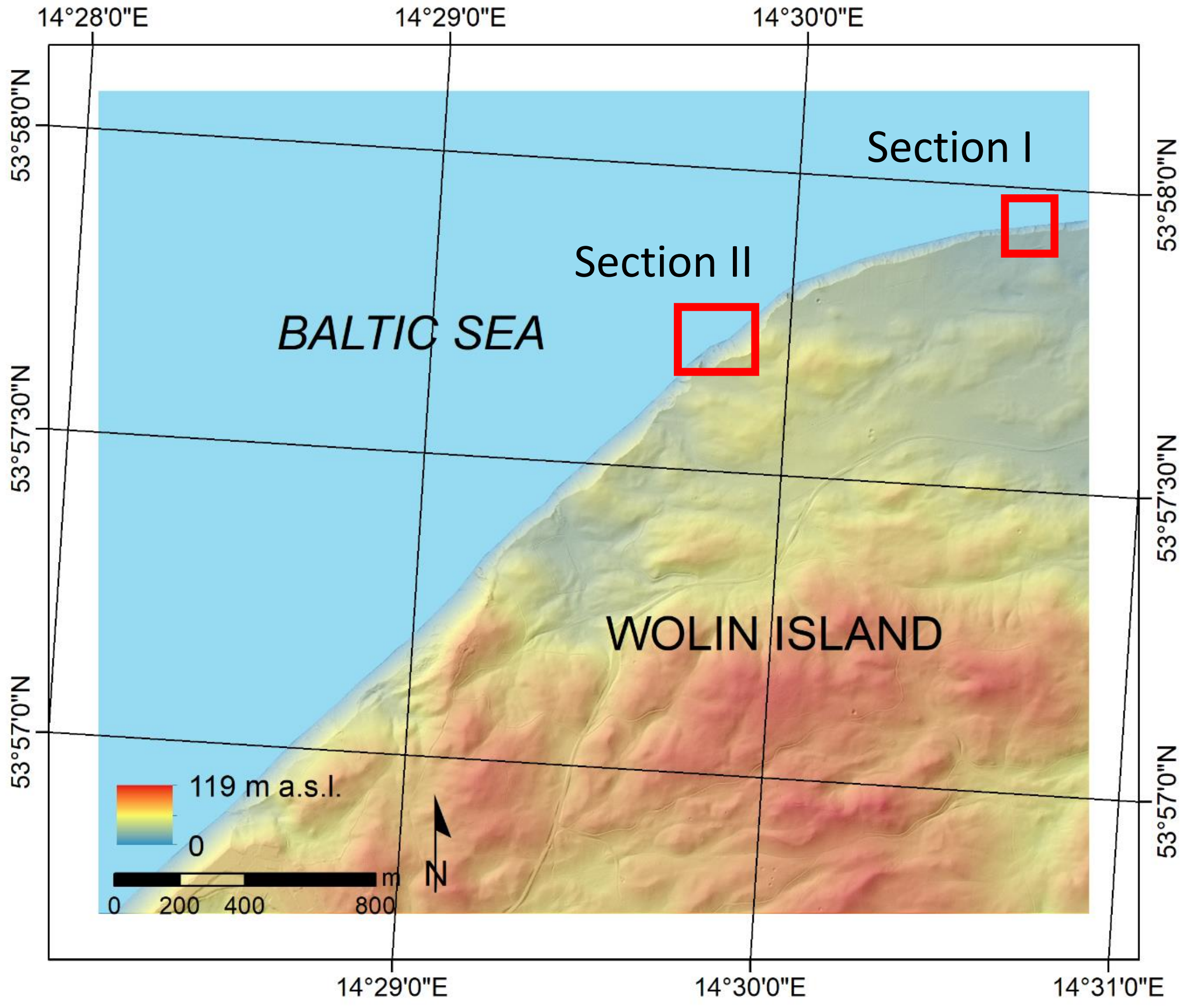
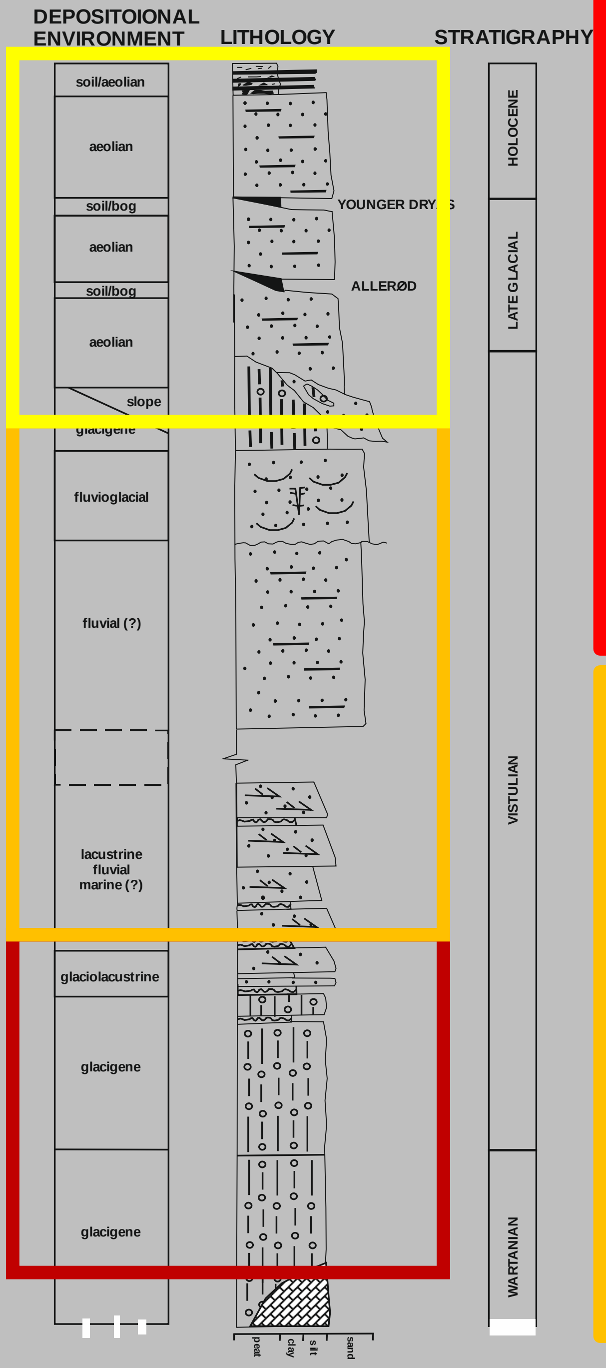
Study area

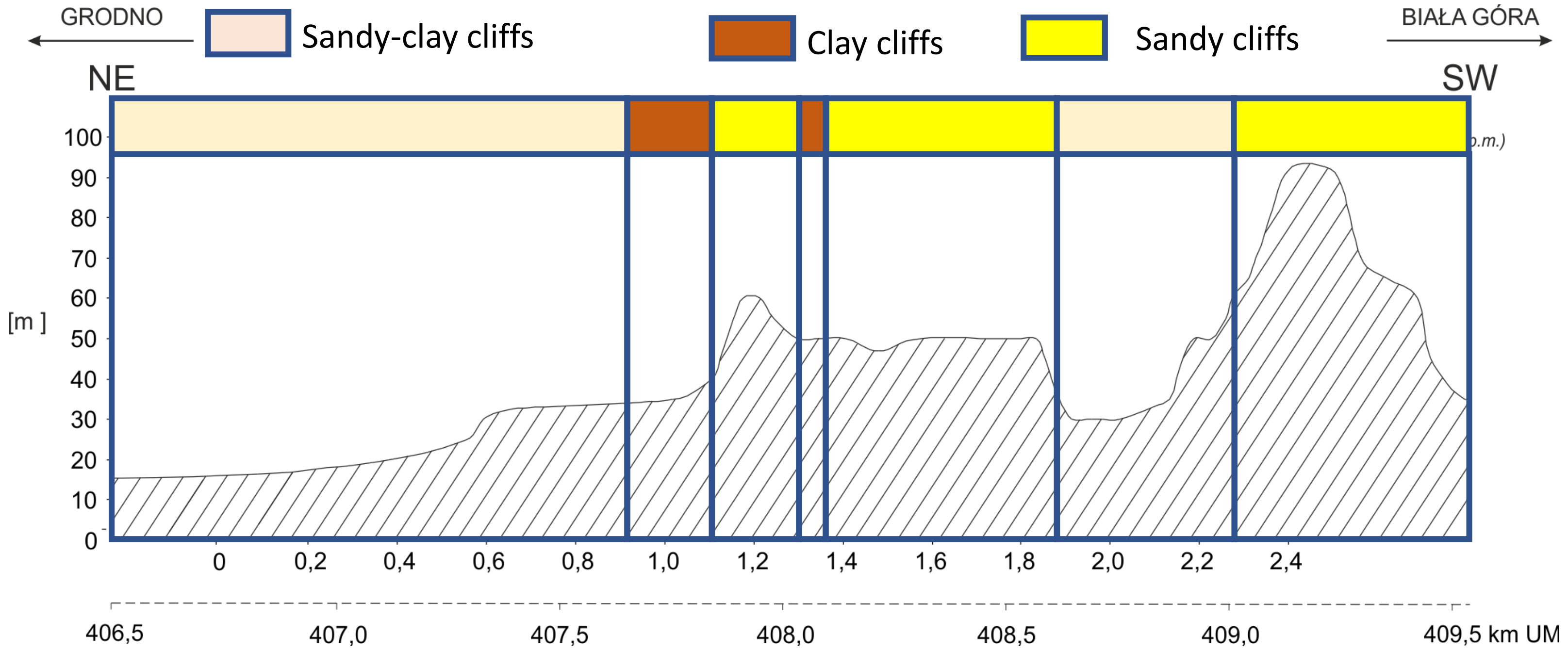

14°20'0"E
14°40'0"E
54°0'0"N
53°50'0"N
Wolin Island
N
S
W
E
116,0 m
-1,5 m
Km
0
2
4
8
BALTIC SEA
SZCZECIN BAY
Wolin Island
POLAND

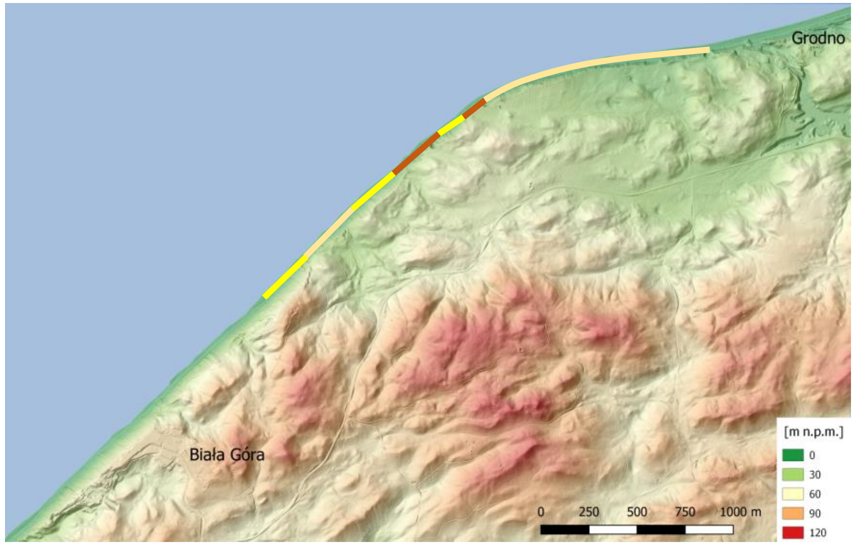

14°28'0"E
14°29'0"E
14°30'0"E
14°31'0"E
53°58'0"N
53°57'30"N
53°57'0"N
Section I
Section II
BALTIC SEA
WOLIN ISLAND
119 m a.s.l.
0
m
0
200
400
800
N

GRODNO - GOSAŃ



Borówka et al. 1999


GRODNO
Sandy-clay cliffs
Clay cliffs
Sandy cliffs
BIAŁA GÓRA
NE
SW
[m]
100
90
80
70
60
50
40
30
20
10
0
0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
2,2
2,4
406,5
407,0
407,5
408,0
408,5
409,0
409,5 km UM


Grodno
Biała Góra
[m n.p.m.]
0
30
60
90
120
0
250
500
750
1000 m

Typology of cliff coasts

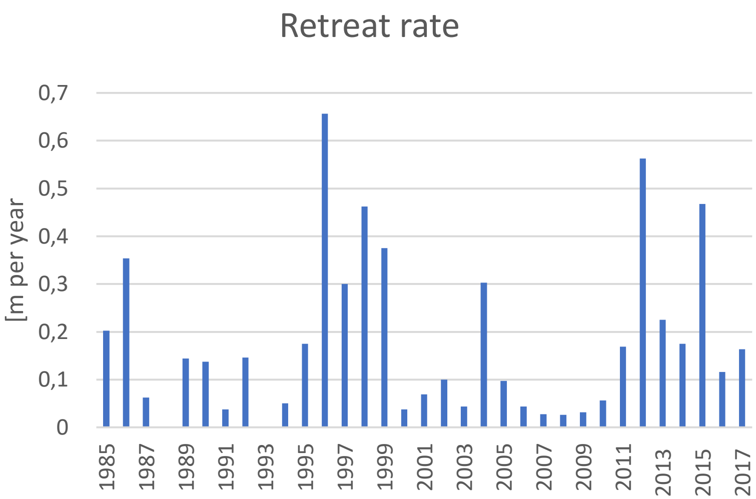
- **<u>Lithological criterion:</u>**
  - ✓ Clay-type cliffs
  - ✓ Sandy-type cliffs
  - ✓ Sandy-clay-type cliffs

- **<u>Morphogenetic criterion:</u>**
  - ✓ Fall-type cliffs
  - ✓ Flow-type cliffs
  - ✓ Talus-type cliffs
  - ✓ Landslide-type cliffs
  - ✓ Fall-landslide-type cliffs
  - ✓ Landslide-flow–type cliffs

Moraine cliffs (Wolin Island, Poland)

Clay cliffs

- Slope <80°,
- Resistance:
  - ✓ τ_{fu}-100-150kPa
  - ✓ ρ – 2,0-2,3 g/cm^3
  - ✓ W_P – 10-14%
  - ✓ W_L – 14-23%
- Low recession rate
  - ✓ 0,10 – 0,18 m/a
  - ✓ Long response time

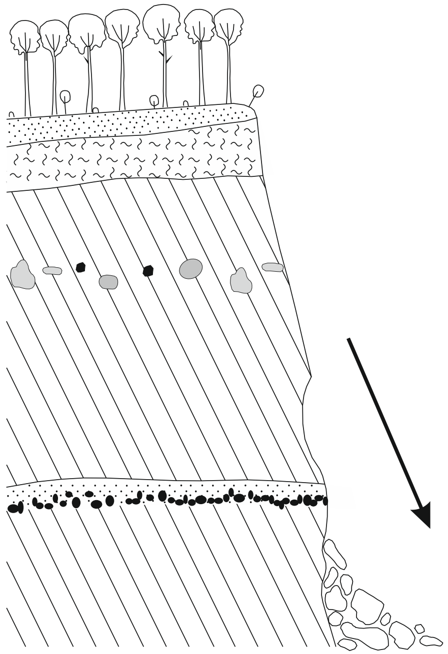


Clay cliffs

- Weathering (30-40 cm):
  - ✓ Mechanical
  - ✓ Chemical
  - ✓ Biological
- Clay flacking– susceptibility to fall

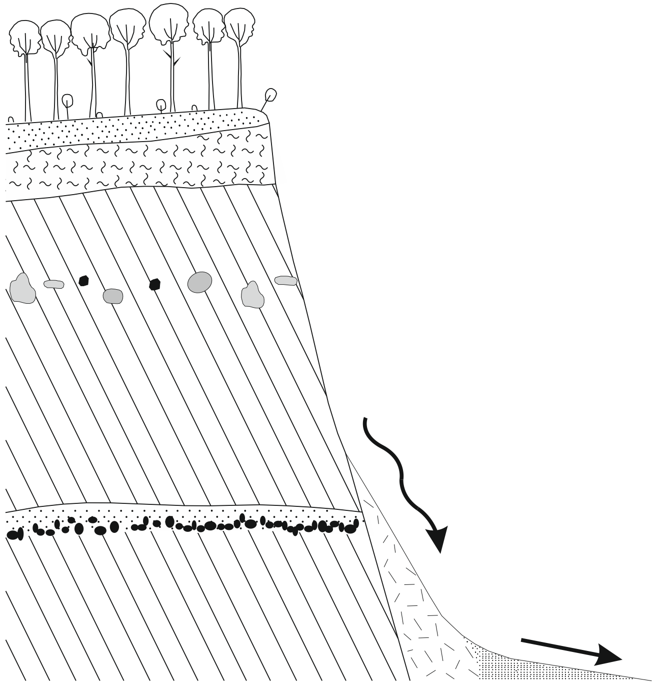
Clay cliffs – fall-type

- Fall processes:
  - ✓ Strong storm surges
  - ✓ Heavy rains episodes
  - ✓ High ground humidity – increased weight of weathered sediments
  - ✓ Intensive soil drying.



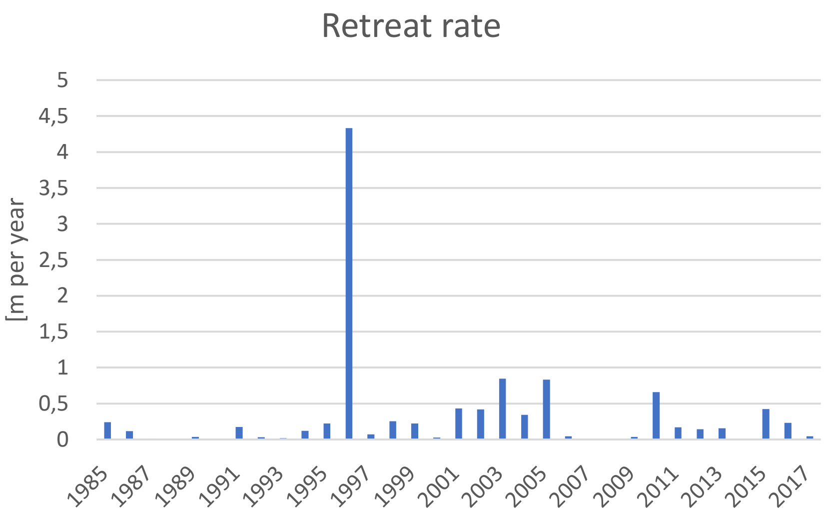
Clay cliffs – flow-type

- Flow processes:
  - ✓ Rainy episodes – heavy rainstorms
  - ✓ Thawing episodes
  - ✓ Crossing liquidity limit (14-23%)
  - ✓ Uat the foot of the cliff – flow covers and cones



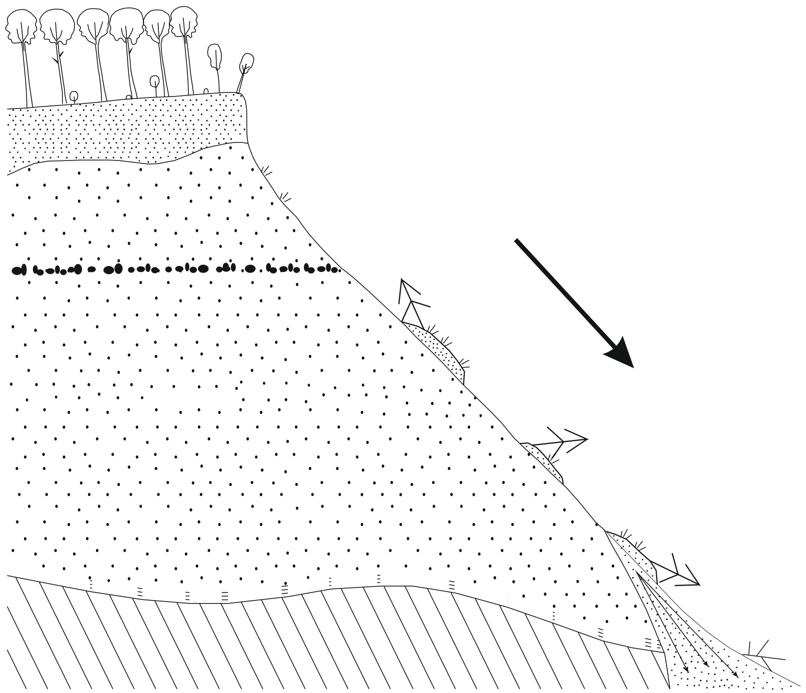
Sandy cliffs

- Slope <40º
- Low resistance:
  - ✓ τ_{fu}- 40-80 kPa,
  - ✓ ρ – 1,7-1,8 g/cm^3
  - ✓ I_D – 0,2-0,6
- Short response time
- High recession rate
  - ✓ 0,30-0,35 m/a



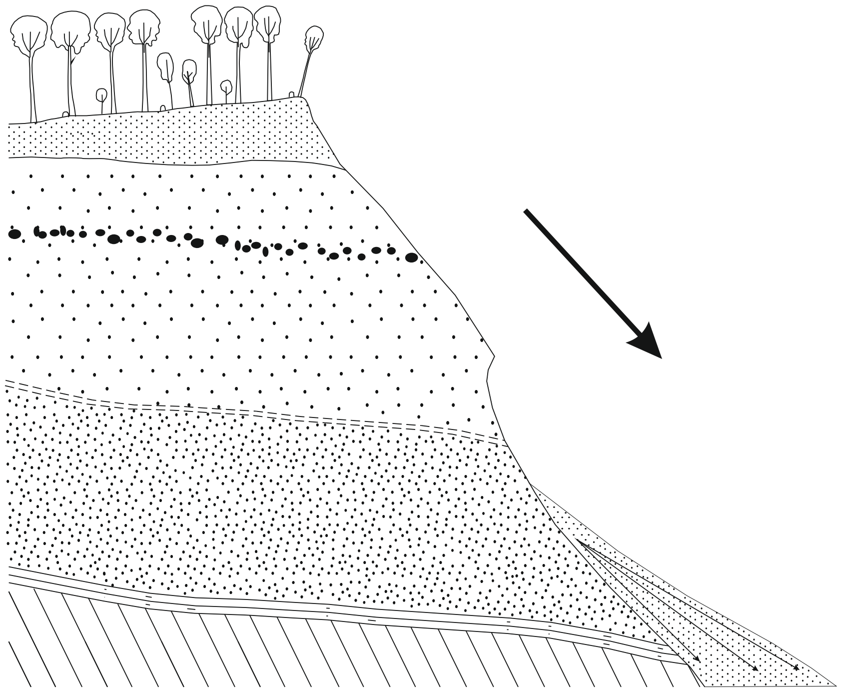
Sandy cliffs – talus-type

- Talus processes:
  - ✓ Dry periods + wind
  - ✓ Vegetation
  - ✓ Initiation in the top of the cliff area
  - ✓ At the foot of the cliff – talus cones
  - ✓ Landforms with the shortest survival time



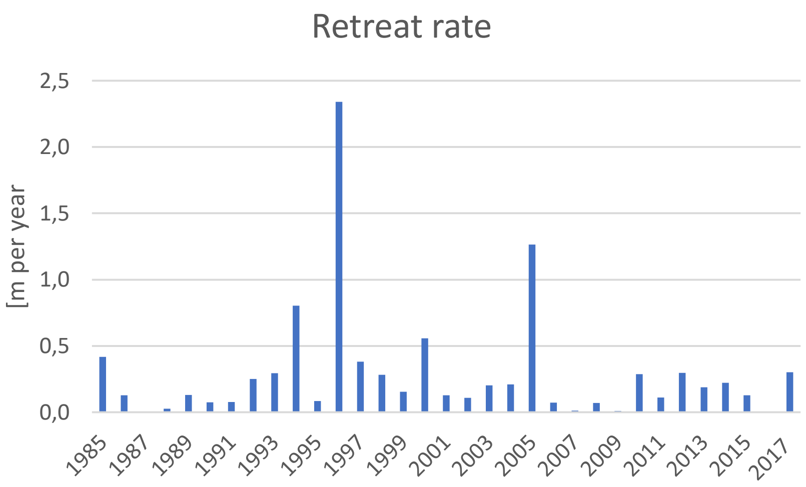
Sandy cliffs – landslide-type

- Landslide processes
  - ✓ Local occurrence of heavily concentrated deposits
  - ✓ Periods of high dynamics of sea
  - ✓ Abrasion of the foot of the cliff – loss of slope suport
  - ✓ Sliding a significant part of the slope - depending on the size of the undercut
  - ✓ Large local cliff top loss (up to 10 m)
  - ✓ Landslide cones (at the foot of the cliff)



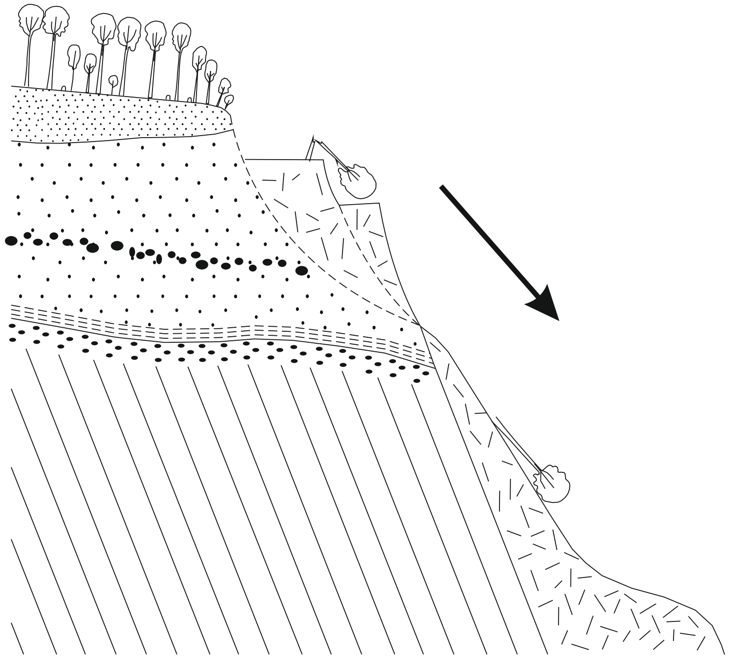
Sandy-clay cliffs

- Clay in the lower part, sand in the upper part
- Varied cliff profile
- Varied resistance sediments
- High recession rate
  - ✓ 0,3 m/a
  - ✓ Violent processes



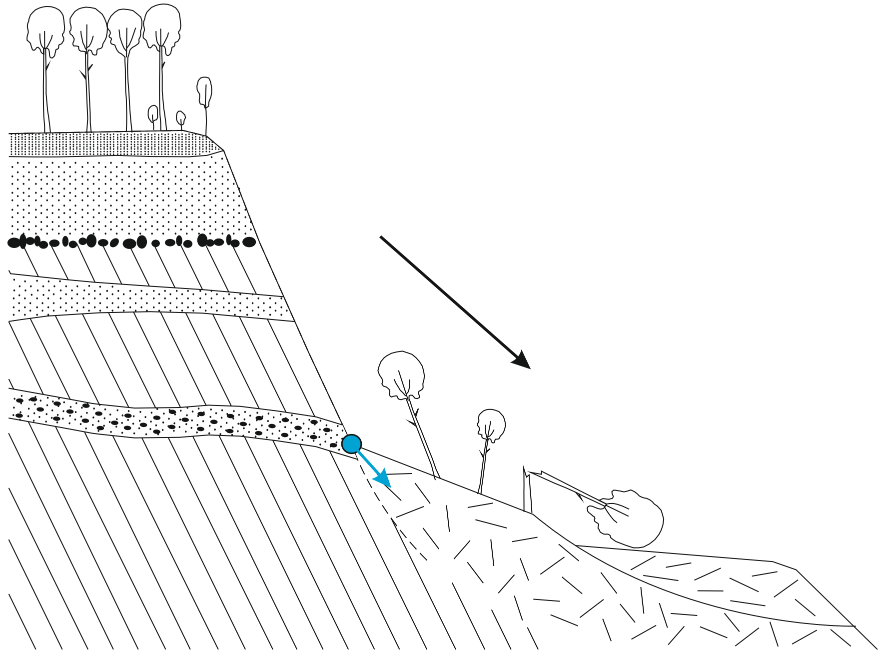
Sandy-clay cliffs – fall-landslide - type

- Periods of high sea dynamics – abrasion of the foot cliff
  - ✓ Abrasive niches and undercuts, cavitation boilers
  - ✓ Initiation of fall processes at the clayey foot of the cliff
  - ✓ Initiation of landslide processes in the upper (sandy) part of the cliff
    - ➢ Translational landslides
    - ➢ Rotational landslides



Sandy-clay cliffs – landslide-flow - type

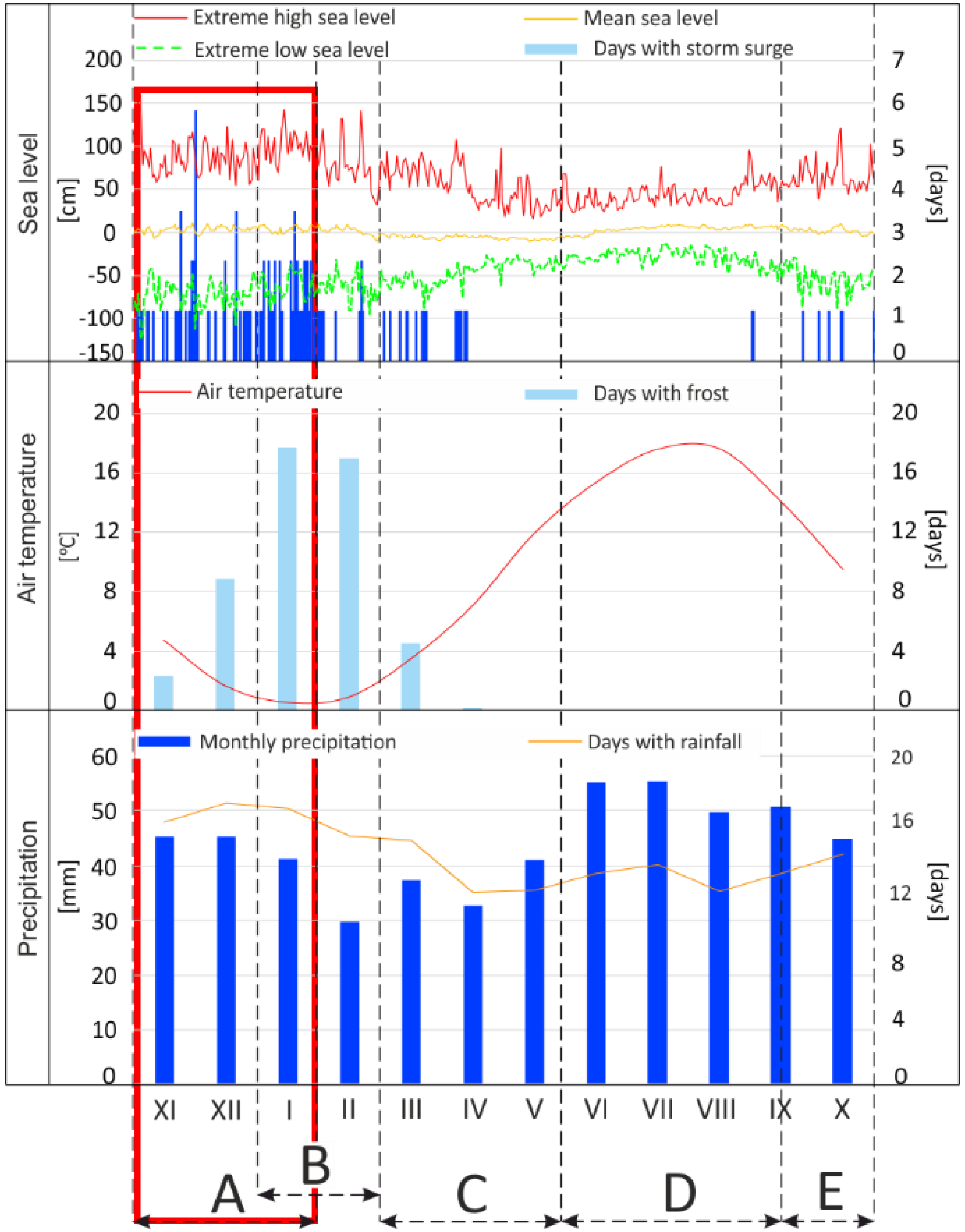
- Cliffs with groundwater outflows
  - ✓ Melting and liquefying deposits of clay sediments
  - ✓ As a result of abrasive undercutting, landslides are formed in the form of extensive tongues (much waterlogged)
  - ✓ In periods of strong rain liquidate deposits - intensification of flowing processes - degradation of colluvium landslides



Seasonal variability of cliff types

A – Autumn-winter season (November 1 – January 31):

- Increased sea dynamics (XI – 17,5%, XII – 23,5%, I – 32%)
  - ✓ Domination of abrasion processes
- Precipitation at the annual average level, reduced evaporation - increased soil moisture
  - ✓ Often the liquidity limit of moraine clay is exceeded - initiation of runoff processes

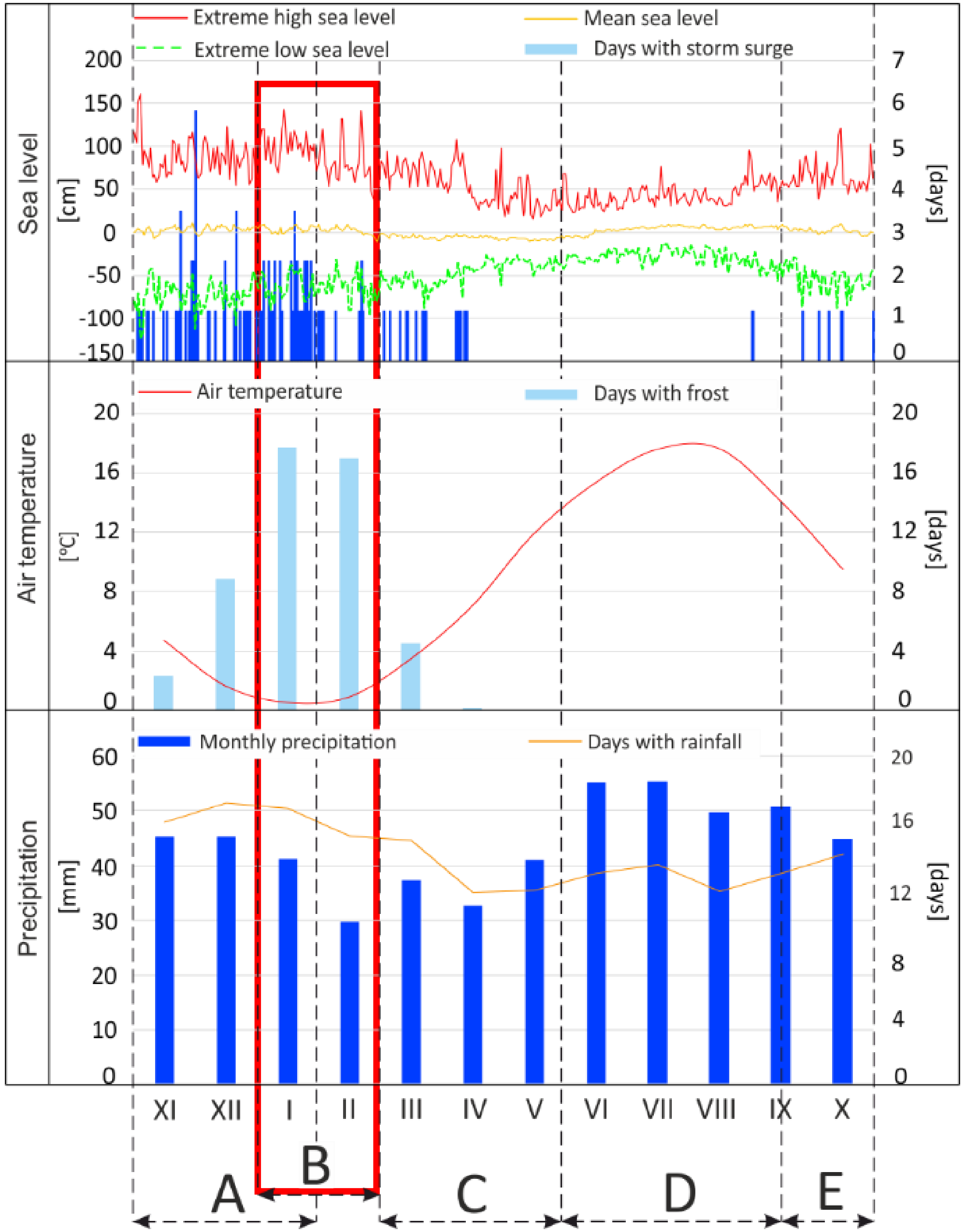


* Data for 1973-2009; IMGW Świnoujście

Seasonal variability of cliff types

B – Winter season (February 1 – February 28):

- Increased sea activity (I – 32%; II – 7%) - abrasion
- Most days with frost (I – 18 days, II – 17 days)
  - ✓ Limitation of processes related to the impact of water on the slopes
  - ✓ In the coldest periods it is possible to freeze the sea and build up ice shafts on the beach

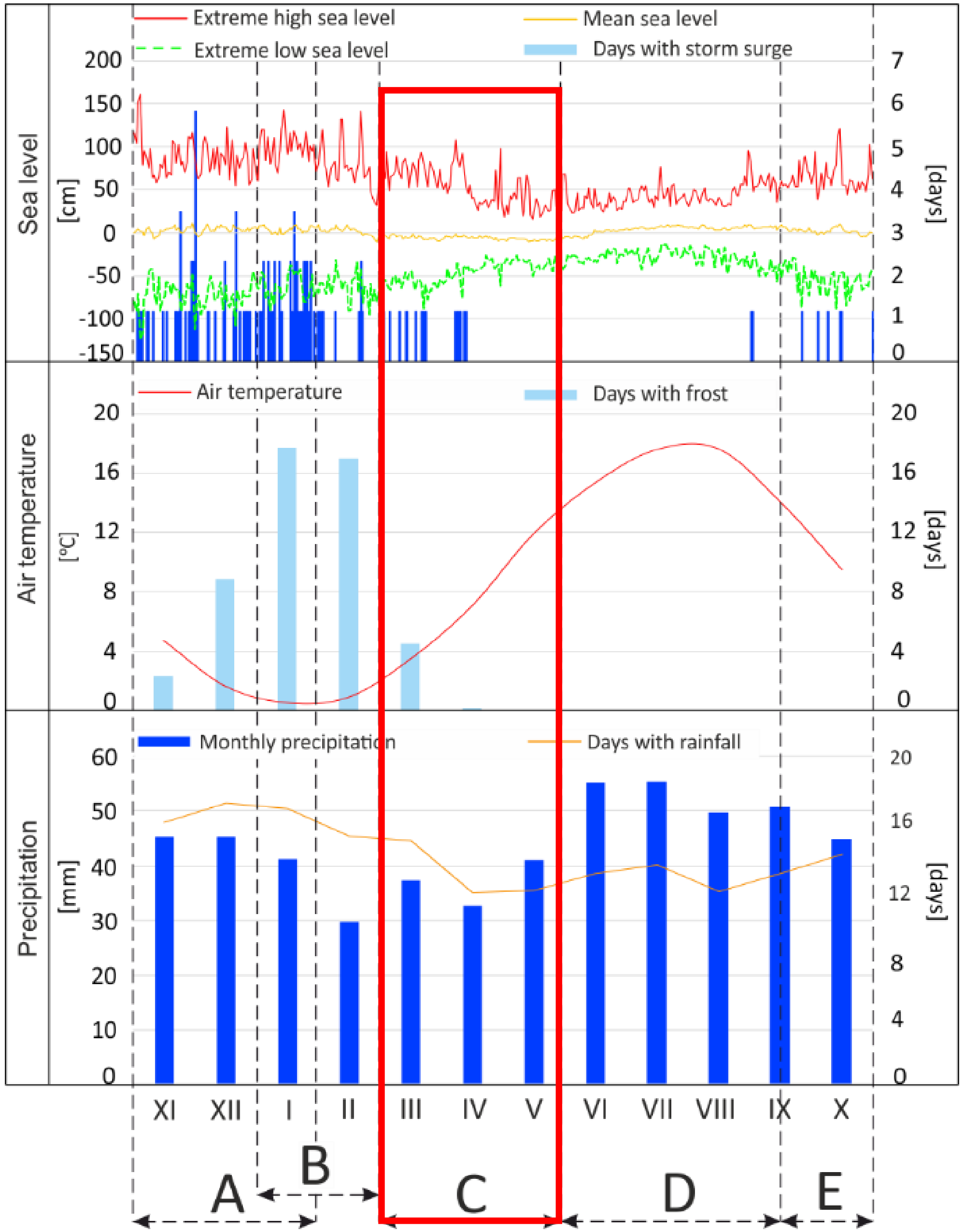


* Data for 1973-2009; IMGW Świnoujście

Seasonal variability of cliff types

C – Spring season (March 1 – May 31):

- Decreased sea activity (III – 8%, IV – 4%, V – 1%)
  - ✓ Optimal conditions to rebuild the beach
  - ✓ Increased temperature – few frost days (III – 4,5 day)
  - ✓ soil thawing and snow melting
- Reduced precipitation and increased evaporation
  - ✓ Increased susceptibility to deflation processes

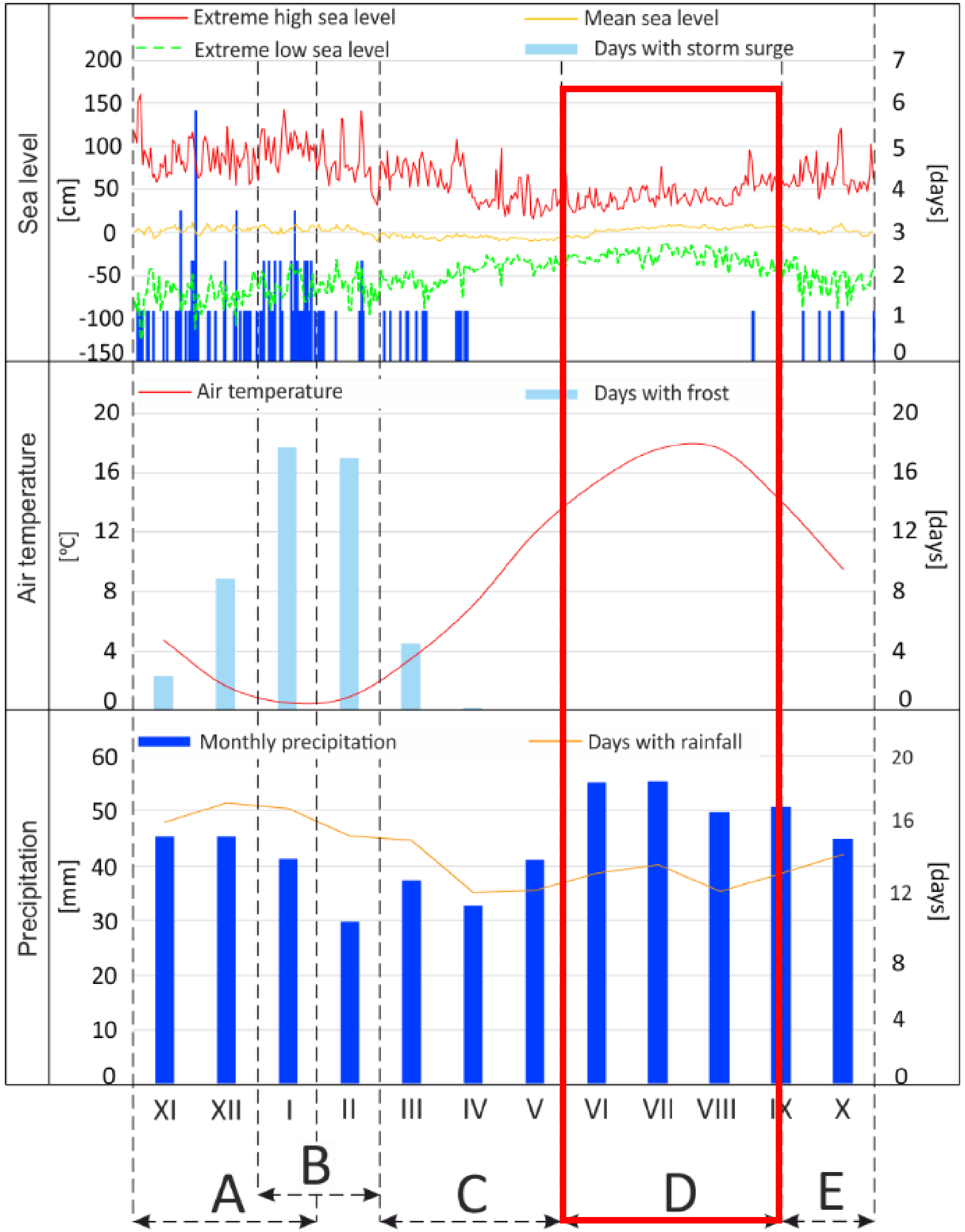


* Data for 1973-2009; IMGW Świnoujście

Seasonal variability of cliff types

D – Summer season (June 1 – September 15):

- No sea impact on the cliff
- High air temperature, high evaporation
- During sunny weather clear breeze system
  - ✓ dry soil susceptible to deflation processes
- Periods of heavy rainfall often – initiation of runoff processes,
  - ✓ intensification of water erosion processes and cutting of the slope

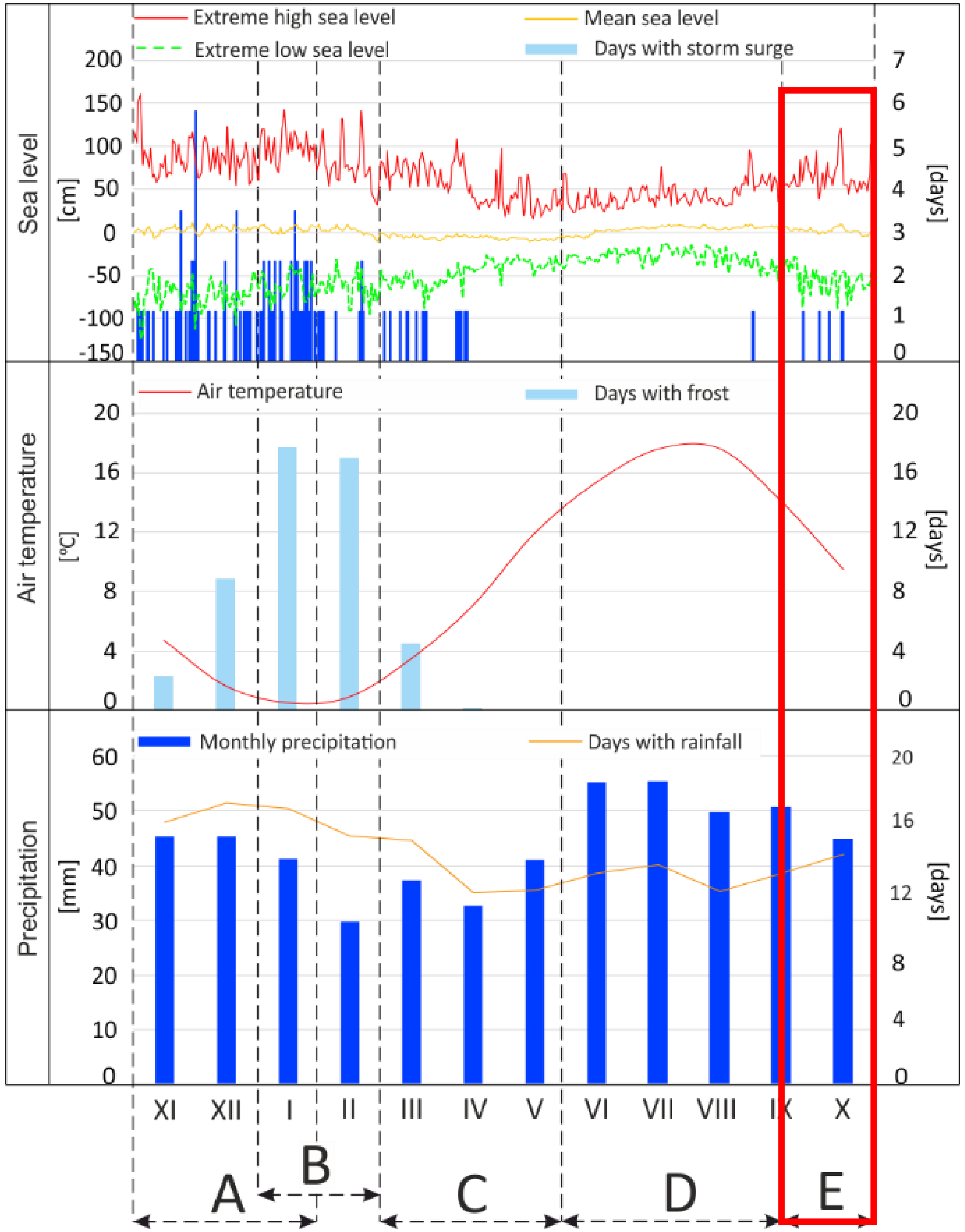


* Data for 1973-2009; IMGW Świnoujście

Seasonal variability of cliff types

E – Fall season (September 16 – October 31):

- Slight increase of sea activity (IX – 4%, X – 4%)
- Reduce of air temperature
- Reduced precipitation
  - ✓ Small cliff morphodynamics



* Data for 1973-2009; IMGW Świnoujście

Conclusions

- As a result of many years of observations of the Wolin island cliff coast, a new typology of cliff coasts was presented,,
- Based on the assumed criteria, morphodynamic types of the coast were separated, which spatial distribution is strictly determined by the geological structure of the cliffs,
  - ✓ Clay cliffs - fall type and flow type,
  - ✓ Sandy cliffs - talus type and landslide type,
  - ✓ Sandy-clayey cliffs - landslide type and landslide-flow type
- On the other hand, the temporal variability of the separated morphodynamic types is determined by the activity of hydro-meteorological conditions, which on an annual basis form the seasonal system: autumn-winter, winter, spring, summer and autumn,
- In the longer time scale, morphodynamic types are an important indicator feature of the cliff development stage on the Southern Baltic Cliff coasts.

Thank you for your attention