

# FORECAST OF DEVELOPMENT OF SEA COASTS ON THEIR MORPHODYNAMIC

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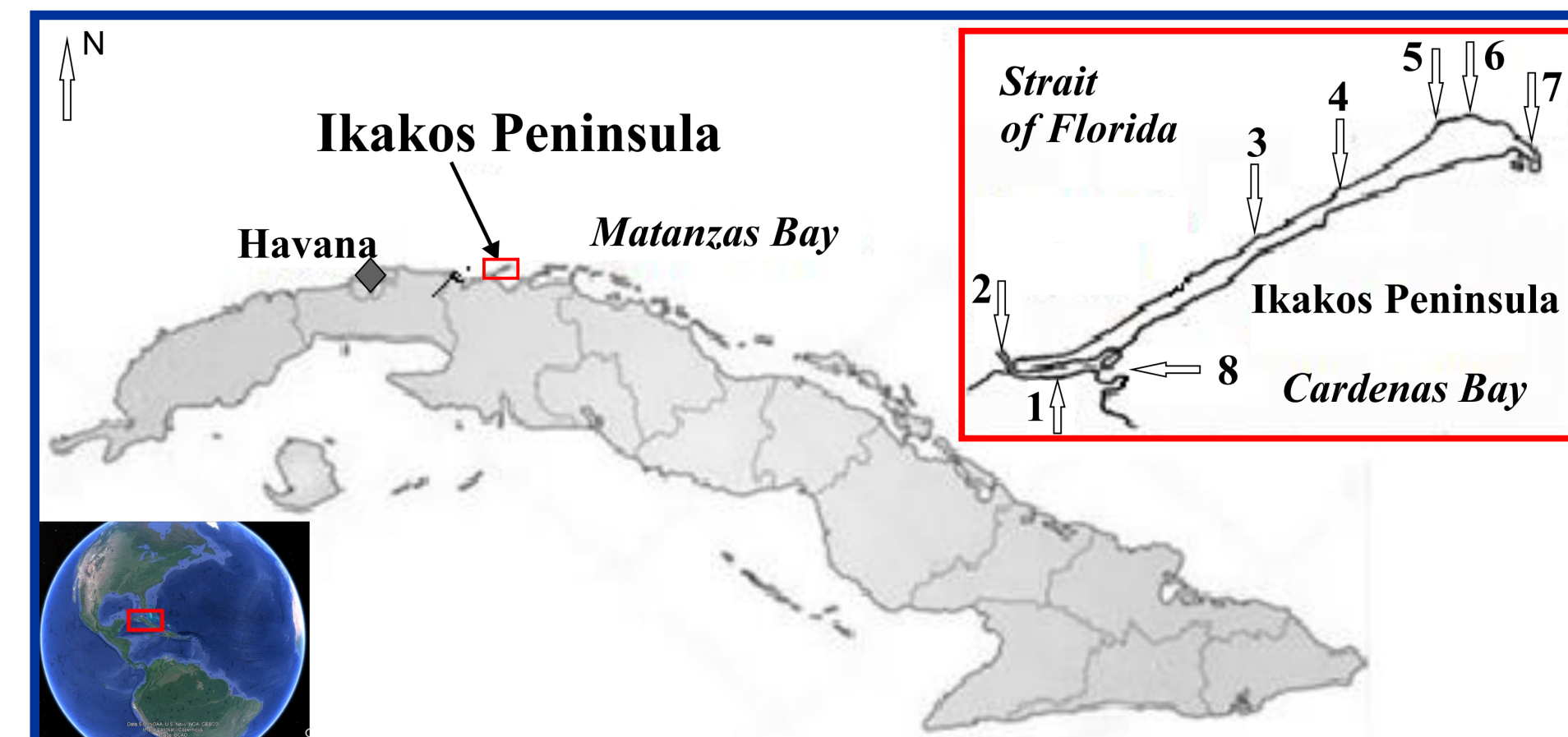
## STATE ACCORDING TO THE RESULTS OF DECRYPTION OF SPACE IMAGES

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### 1. The location of the research area

The choice of the object of study is due to the alarming problem of the stability of its shores and, above all, the sandy beaches of the recreational and tourist complex of international importance Varadero, Ikakos Peninsula.

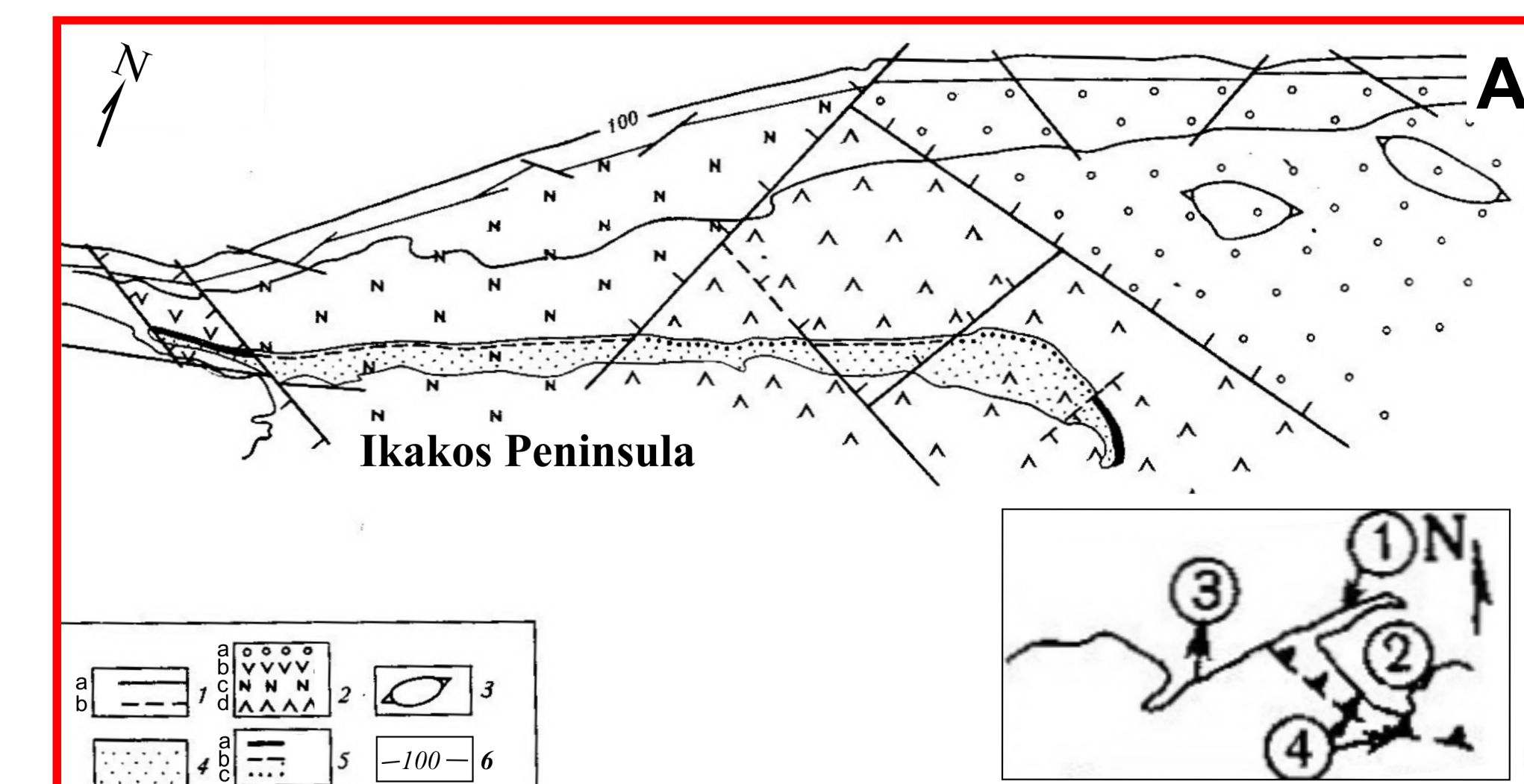


Relief of the Ikakos Peninsula is represented by a low (on average 10 m) abrasion-accumulating plain with several remnants of indigenous carbonate rocks of calcarenites, the maximum elevation of which is 27 m.

1- Paso Malo lagoon, 2- Paso Malo canal (was built in 1956), 3- Bernardino cape, 4- Chapelin cape, 5- Frances cape, 6 - Hicacos cape, 7- Molas cape, 8- Kawama canal

### 2. The latest tectonics and structure of the coastal zone

In tectonic terms, the Ikakos Peninsula is represented by a fault-block structure complicating the centreline of the neotectonic trough of Remedios, bordering about Cuba island. Its relief is represented by a low (on average 10 m) abrasion-accumulating plain with several remnants of indigenous carbonate rocks of calcarenites, the maximum elevation of which is 27 m. Holocene deposits of the Peninsula on the western side are represented by marine organogenic sand of beaches, limited by organogenic conglome breccia of the Seboruko terrace and cliffs of Miocene calcareous sandstones, and on the eastern side, where mangrove vegetation is widely developed. mainly by sediments of marshes and small shallow lagoons.



#### A. Map of the latest tectonics of the Ikakos Peninsula and adjacent shelf

Legend: 1 - discontinuous violations (a - identified by geological and geomorphological or seismoacoustic data, b - assumed by geomorphological features); 2 - a generalized distribution of amplitudes of elevations from the smallest (a) to the largest (g); 3 - local uplifts; 4 - land; 5 - a generalized characteristic of the dynamic state of the coasts (a - quasistatic, b - weak uplift, c - moderate uplift), 6 - isobaths. Inset: 1 - Ikakos Peninsula, 2 - Cardenas Bay, 3 - Matanzas Bay, 4 - southern boundary of the Remedios Trough

#### B. Lineaments identified by geomorphological features in field research and interpretation of satellite images (red lines)

### 5. Dynamics of the western coast of the Ikakos Peninsula in 2003-2013

The current coastal dynamics is estimated by comparing satellite images Landsat from December 31, 2003 and December 15, 2013 (the spatial resolution 15 m) and Quick Bird (the spatial resolution better than 1 m) (https://www.google.com/earth/).

#### Coastline shift, m / year

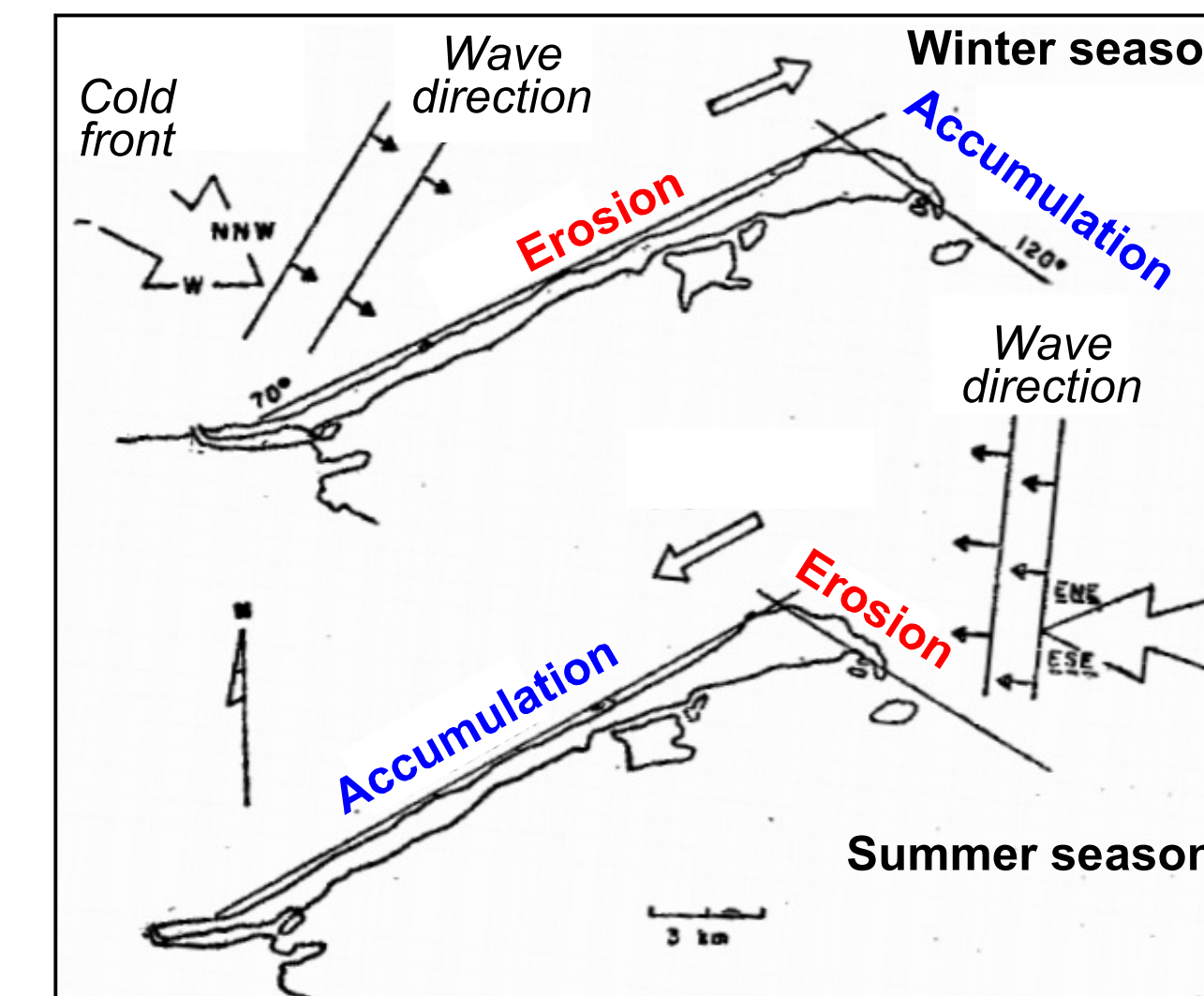
(shown by the color of the lines):

- Insignificant or absent – green;
- Retreat:
  - light-blue - less than 1,
  - blue - 1-2;
- Promotion:
  - yellow - less than 1,
  - orange - 1-3,
  - red - 3-10

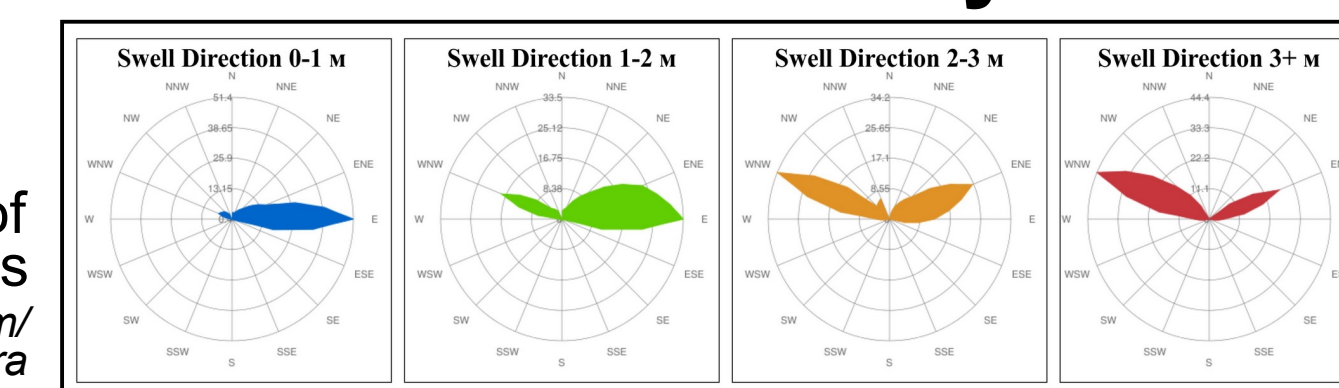


The distal part of the Ikakos Peninsula advanced about 250 m, blocking the strait. The width of the spit increased here by 50-70 m. In the 2013 photograph, the green line shows the position of the beach base in 2003.

### 3. Wave mode and lithodynamics



Roses of excitement for different gradations of wave heights (http://wisuki.com/statistics/649/vara)



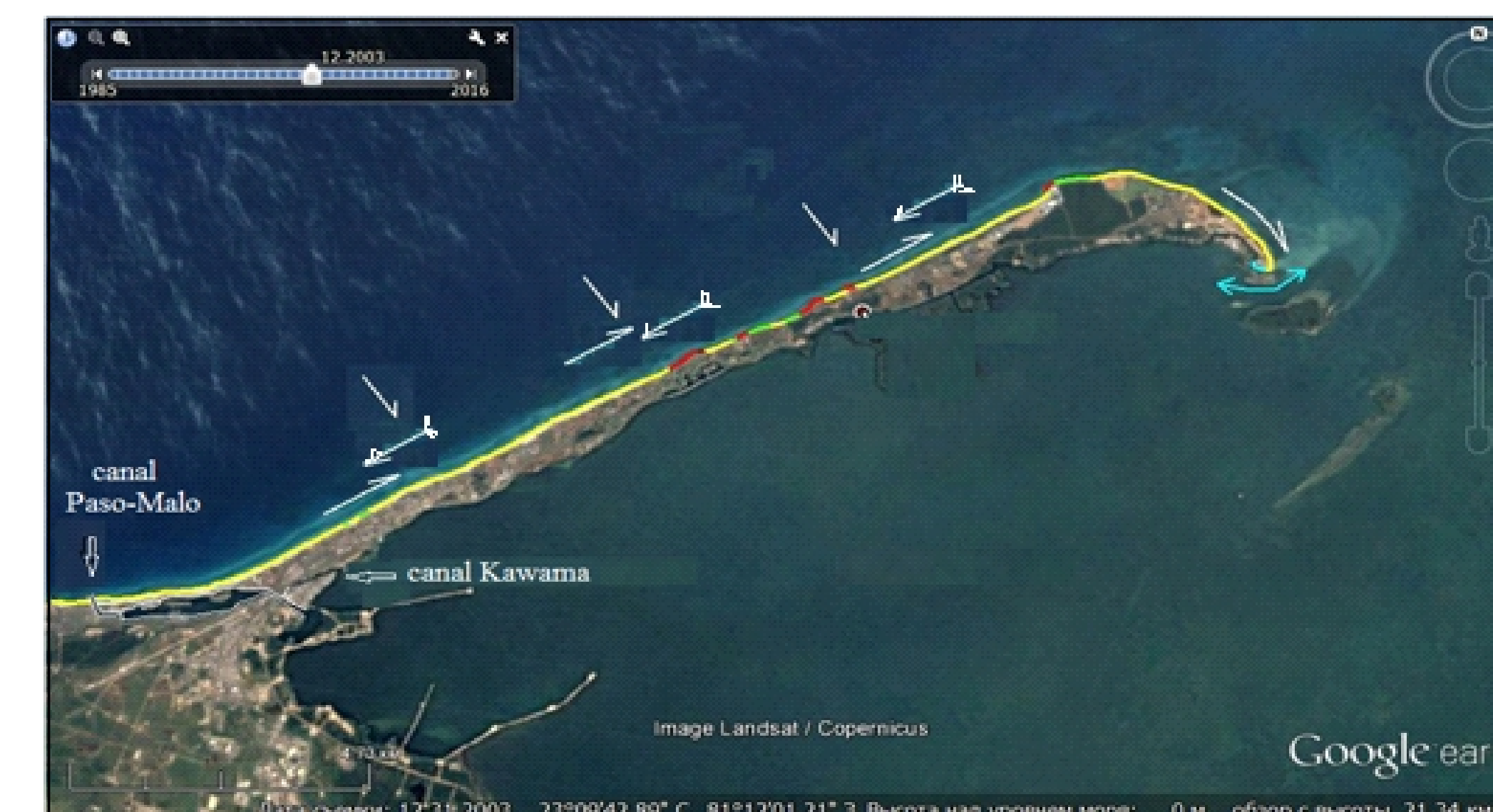
The erosion ledge in the sediments of the beach.

NNE coast of the Peninsula. February 2020



- The height and directions of the approach of waves in winter and summer are different. As a result, beach sands in winter move to NNE, and in the summer to the SSW. At the same time, the Paso-Malo channel impedes the movement of sediment to the NNE.
- To maintain the beaches, mainly over 12 km south-west of the Chapelin cape, sand is added. In 1987-2019 about 3 million cubic meters were dumped here m of sand.

### 4. Types of the western coast of the Ikakos Peninsula



The basis is a Landsat satellite image taken on December 31, 2003 (https://www.google.com/earth/).

#### Shore types (shown by line color):

- yellow - accumulative sandy beaches;
- green - abrasive-accumulative, with sandy beaches and limestone benches;
- red - abrasive, with coastal ledges developed in limestone sandstones (calcarenites);
- blue - erosive, formed by tidal currents.

The white arrows show the prevailing sediment flow directions, the blue arrows indicate the reversal tidal currents.



Accumulative sandy beach

On the abrasive-accumulative coasts of the benches

- during the erosion season are almost naked
- in the season accumulations are covered with sand



Abrasive-accumulative coast



Abrasive coast

### 6. Conclusions

- Most part of the western coastline is stable. For the accumulative part of it, this is obviously a consequence of artificial sanding, and for the abrasive part, it is a consequence of the expansion of benches with a boulder block.
- The beaches are most stable in the middle part of the peninsula, probably because migrating alongshore sediment fluxes from both the southern and northern sides of the peninsula rush here.
- The most mobile were the basal and distal parts of the peninsula.
- In the short term, the morpholithodynamics of the coastal geosystem of the Ikakos Peninsula will be determined mainly by its latest tectonics and sea-level kinematics.
- The western margin will be determined by sand reserves in the coastal shelf zone.
- If the peninsula maintains a tendency toward a weak and moderate uplift, the abrasion of the coasts formed by calcarenite will slow down. On sandy coastal areas with increased flotation of beach-forming material, the amount of material will be reduced. Therefore, to maintain the beaches, it will be necessary to carry out competent and timely sanding and provide measures to extinguish the energy of storm waves at a submerged slope. The distal part of the peninsula will increase. On low-lying mangrove shores, lagoons and bogging will shrink, and halophilic, mainly mangrove, vegetation will advance into the Gulf of Cardenas waters.

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