

# A case study to evaluate the environmental impact of relict sand dredging along the Tuscany continental shelf



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**Settore Protezione e Valorizzazione della Fascia costiera e dell'Ambiente marino**



**Tuscany**

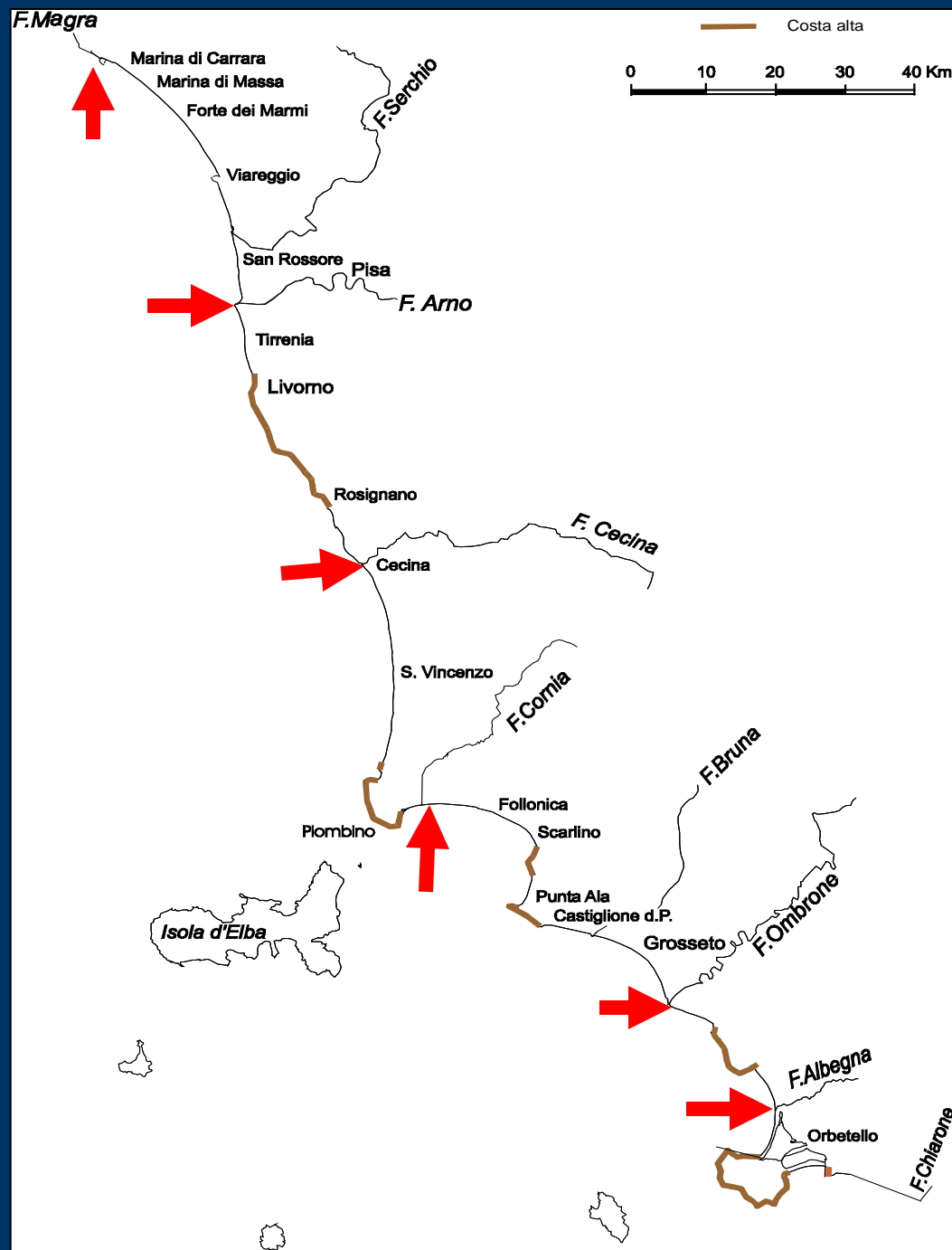
**Coastal length: 330 km**

**Beaches: 200 km**

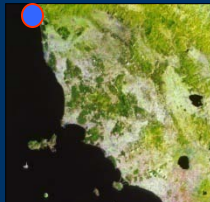
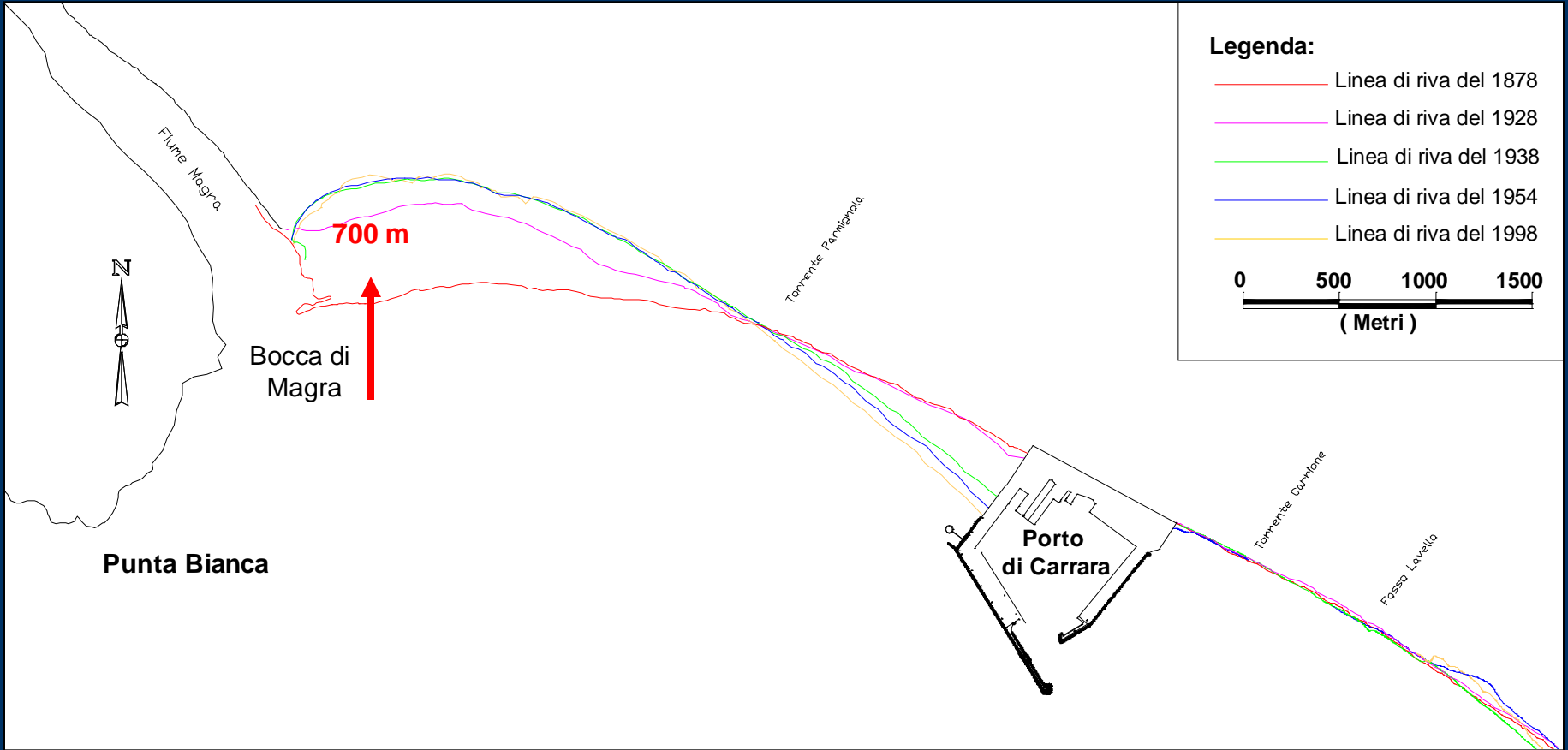
**Archipelago: 250 km**



Areas experiencing maximum shoreline retreat: **River deltas**, due to drastic reduction in sediment bed load in the last Century



# Magra River outlet

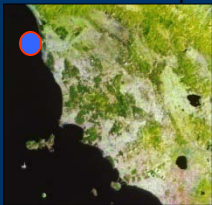




A day in the summer life  
of Marina di Massa (Tuscany)

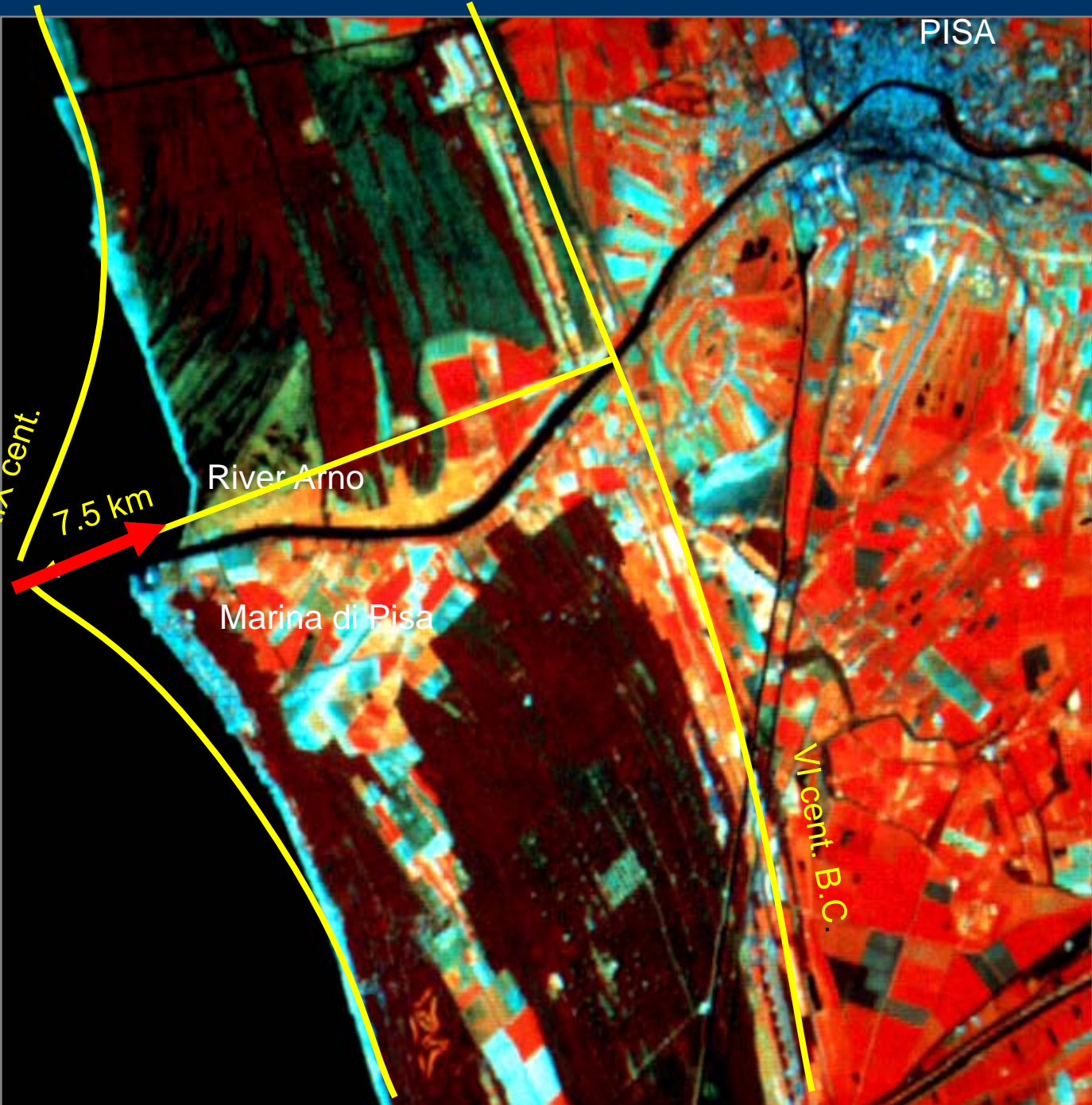
N.B. The beach is given in concession  
to private entrepreneurs

Location map





Location map



PISA

XIX cent.

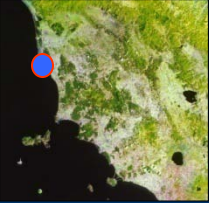
7.5 km

River Arno

Marina di Pisa

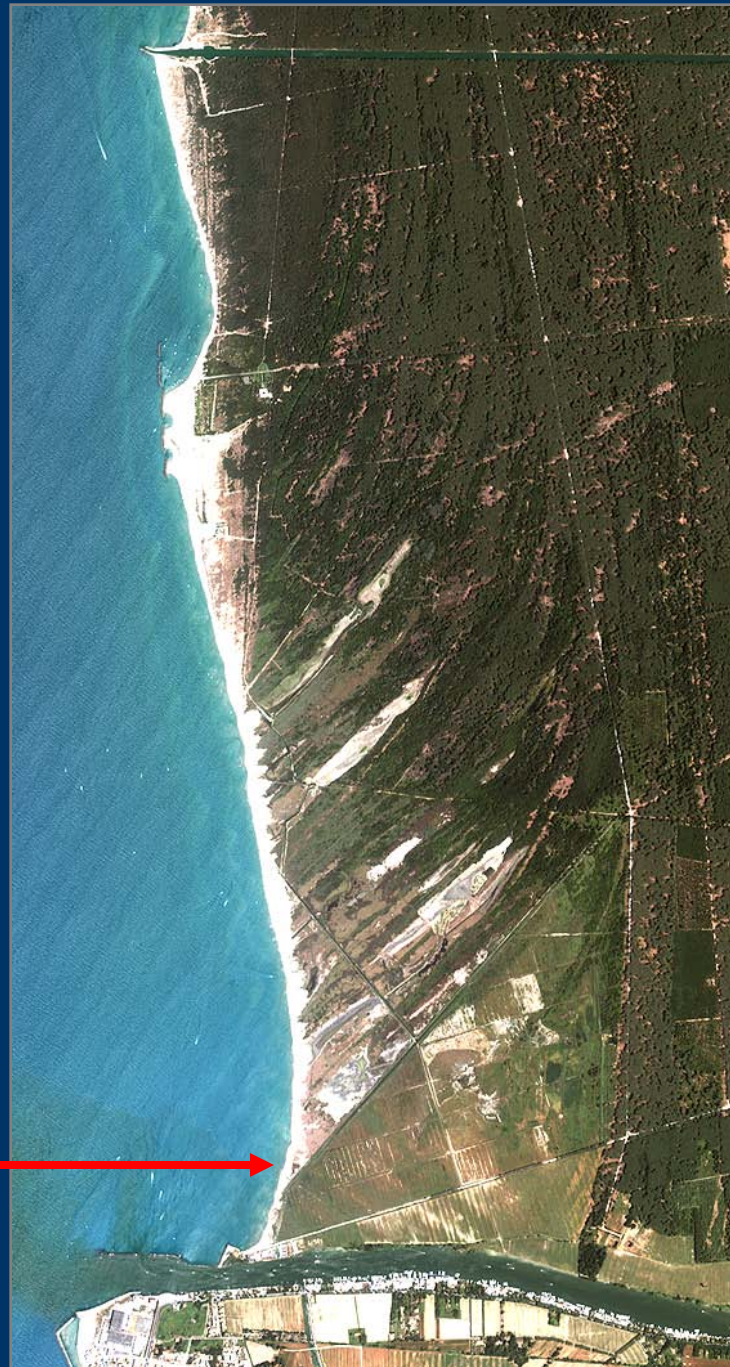
VI cent. B.C.

**Arno river  
Delta**

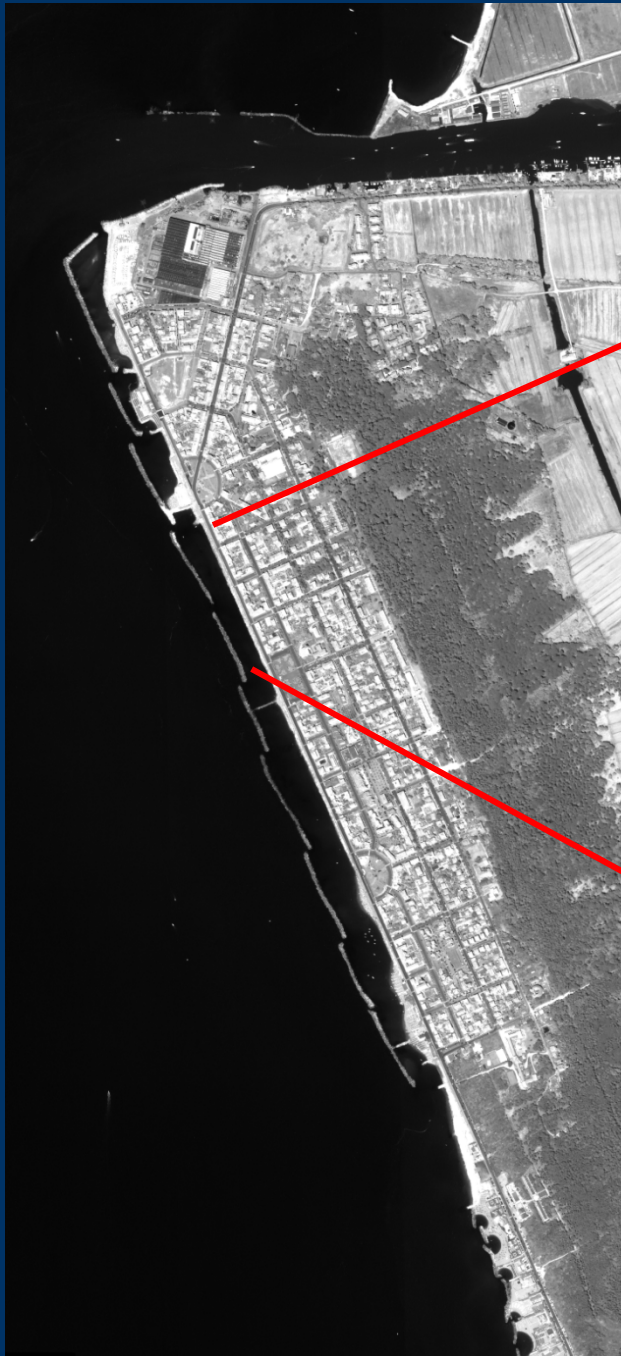


## Arno river delta northern wing

1.3 km

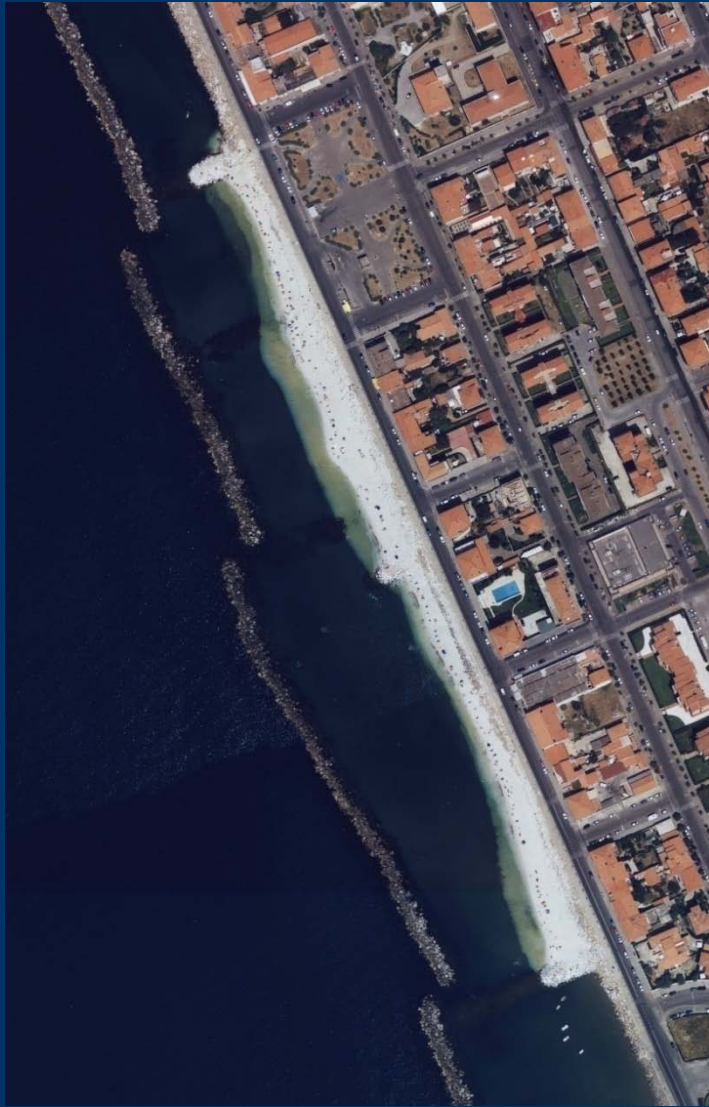


Marina di Pisa – Southern wing of the Arno River delta





**Coastal restoration project at Marina di Pisa – artificial coastal cells # 6 e 7  
(DCR 47/2003 Intervention # 5 – Province of Pisa – Territorial defense unit)**



**First phase**



**Second phase**

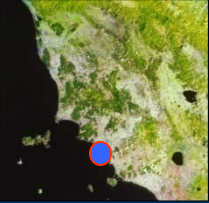
**Beach fill with marble gravel coming from Carrara quarries production reject**

**Before**



**After**

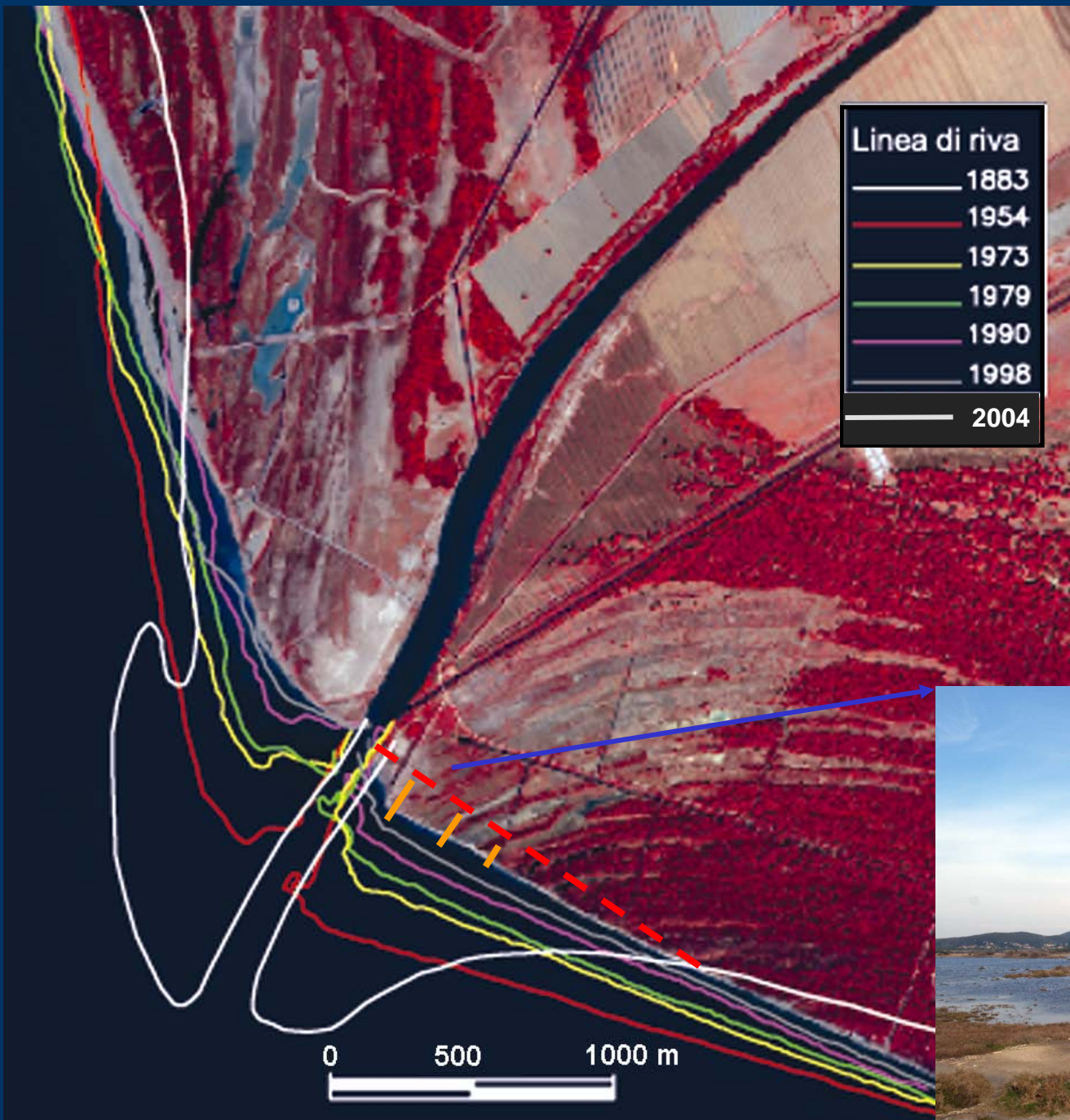




Ombro river delta



## Managed realignment at Bocca d'Ombrone (GR)







**Regione Toscana**

Diritti Valori Innovazione Sostenibilità



**Tuscany Regional Council in 2003 has approved and financed the following:**


**PROGRAMME OF PRIORITY INTERVENTIONS TO RESTORE ERODING BEACHES AND RESEARCH ACTIVITIES TO IMPLEMENT TUSCANY REGION ICZM PLAN**  
**€109.800.000**



**Research activities and restoration projects design**  
**€8.800.000**



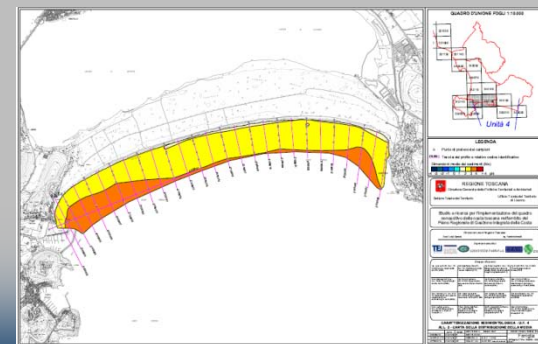
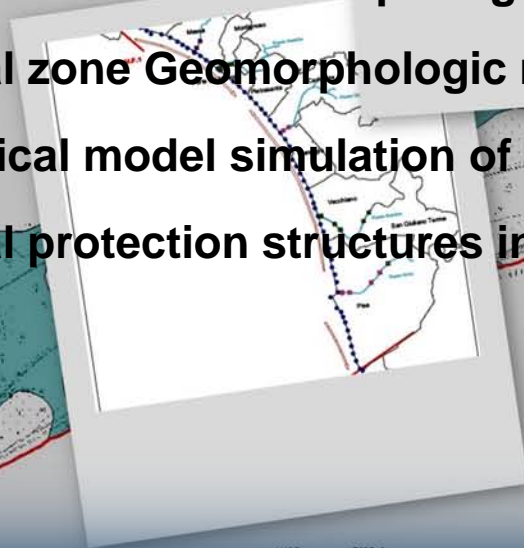
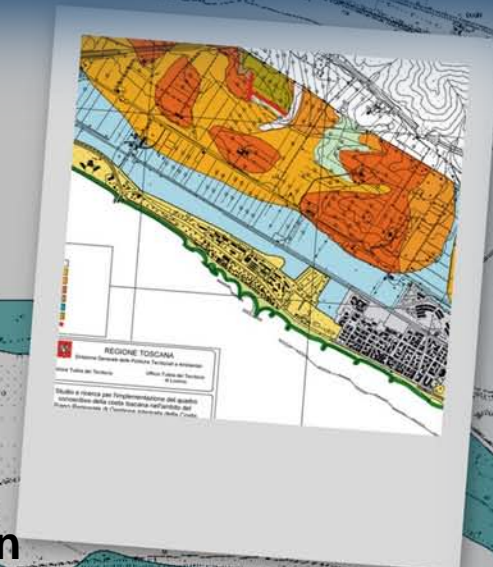
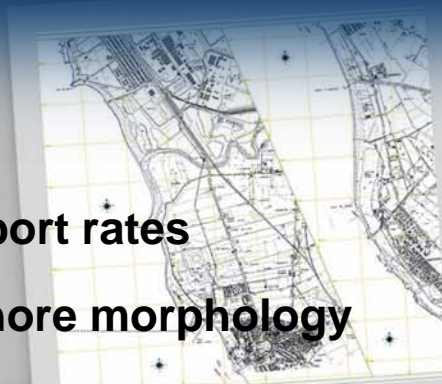
**Realization of coastal restoration works**  
**€96.000.000**



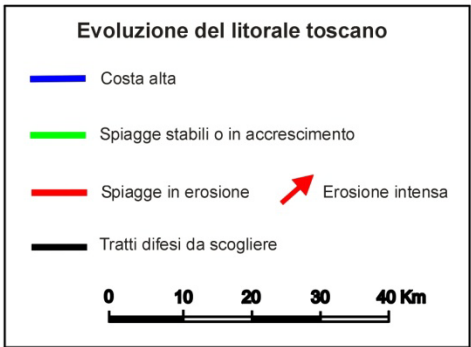
**Monitoring program to evaluate the effectiveness of the restoration projects**  
**€5.000.000**

# Study and research for the implementation of coastal zone database

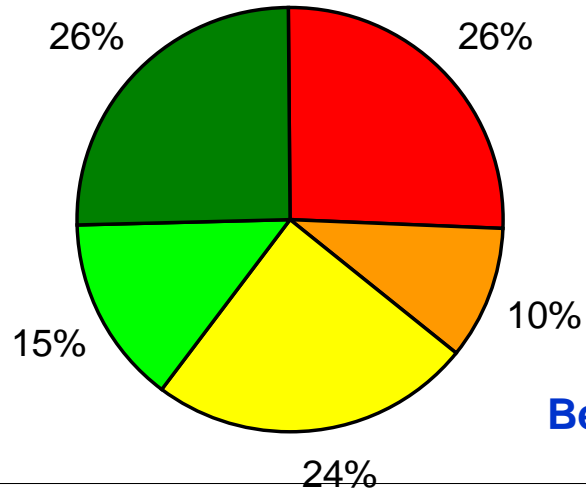
- River sediment transport rates
- Shoreface and nearshore morphology
- Beach sand texture and petrography
- Coastal zone Geomorphologic map
- Numerical model simulation of future evolution
- Coastal protection structures inventory





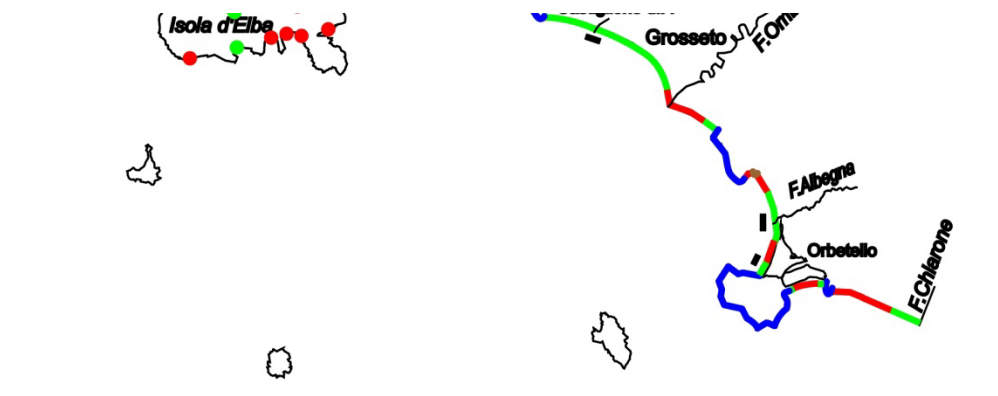


**Ultimo periodo ('90 - oggi)**



- Forte arretramento (<-5)
- Modesto arretramento (<-2)
- Stabile (tra -2,01 e +2,01)
- Modesto avanzamento (>+2)
- Forte avanzamento (>+5)

**Beach surface budget: - 178.000 m2**

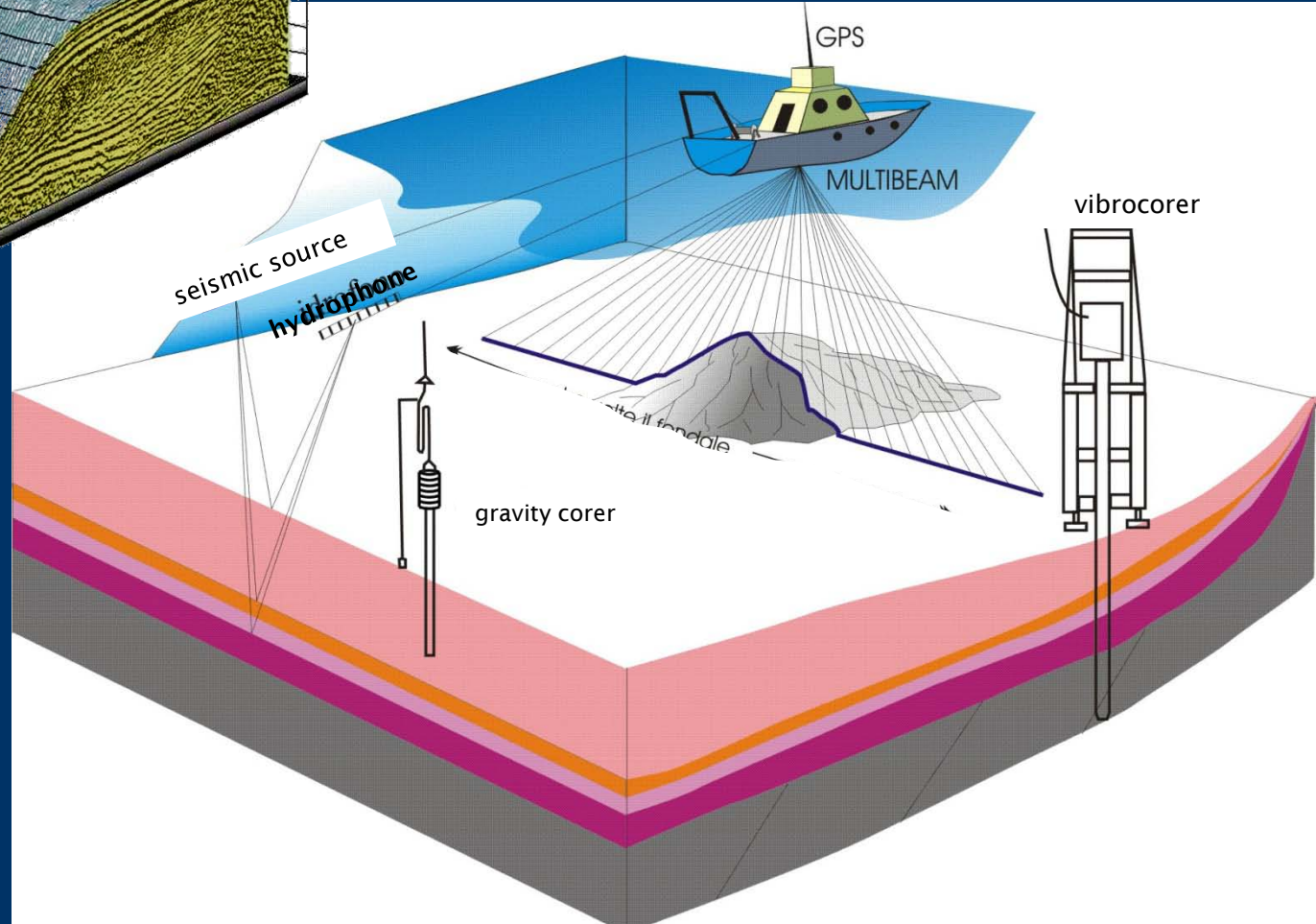
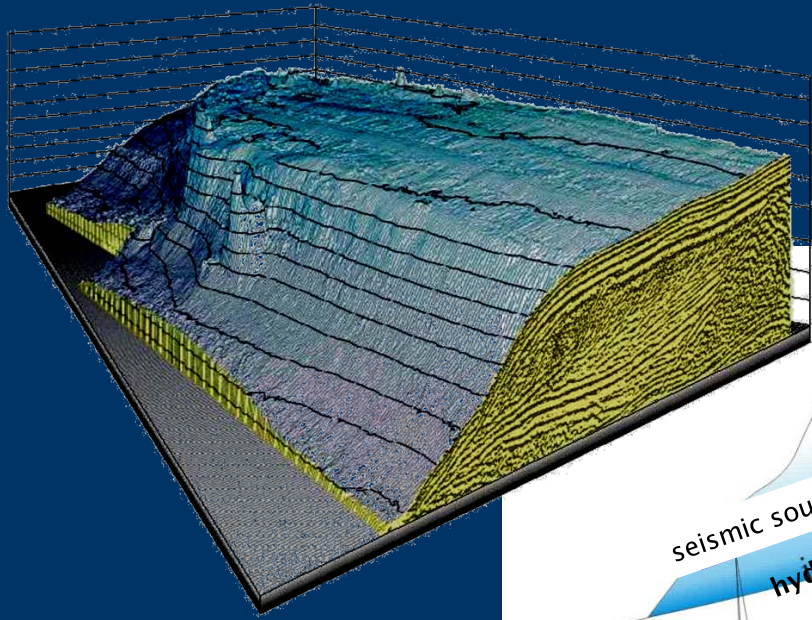


**2006 - 2008**

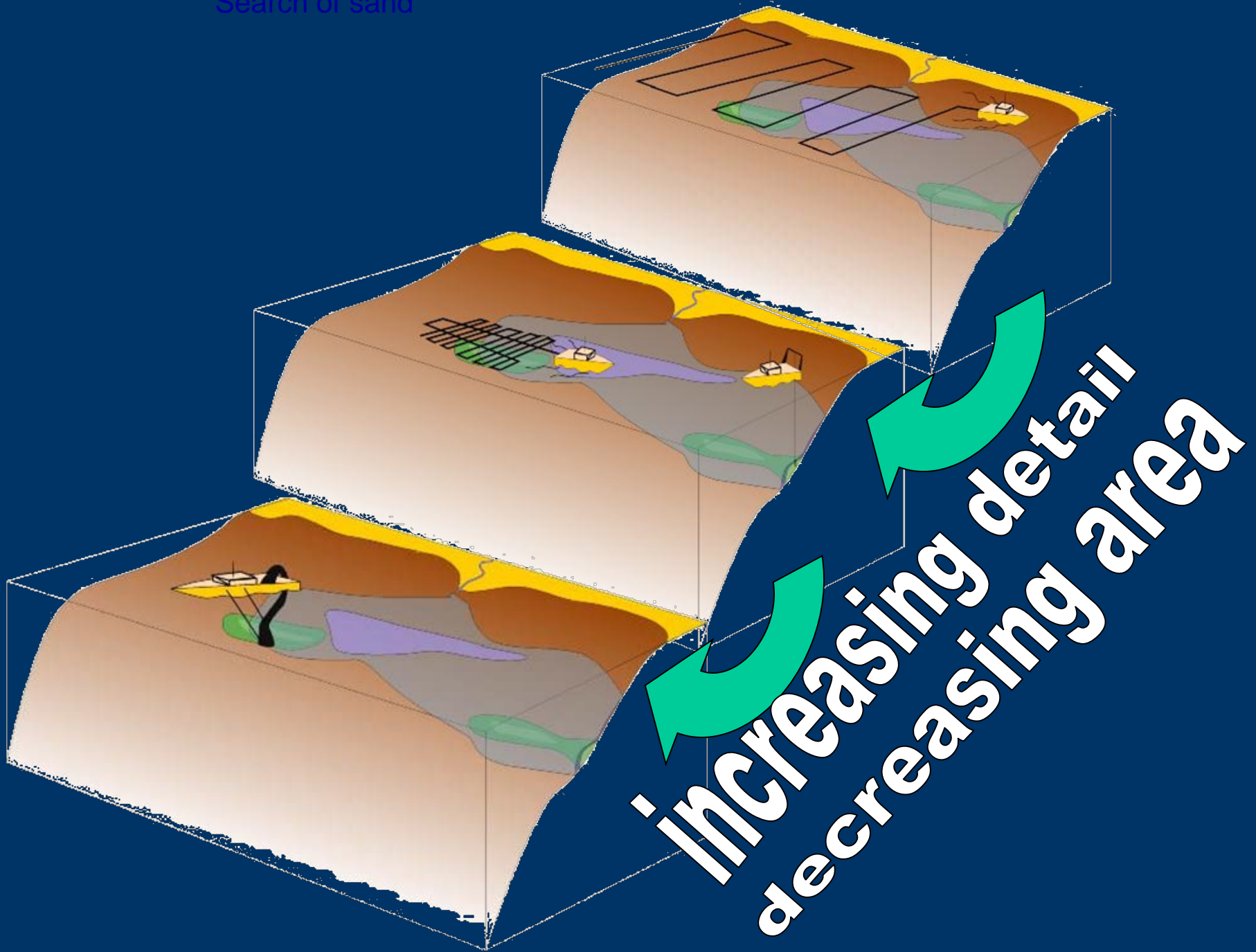


**Search and characterization  
of relict sand deposits  
in the Tuscany continental shelf  
for the artificial nourishment  
of eroding beaches**

Identification of sand bodies on the continental shelf is mainly based on the interpretation of geophysical data (seismics, side scan sonar, multibeam), groundtruthed by vibrocores



Search of sand



**Increasing detail**  
**decreasing area**

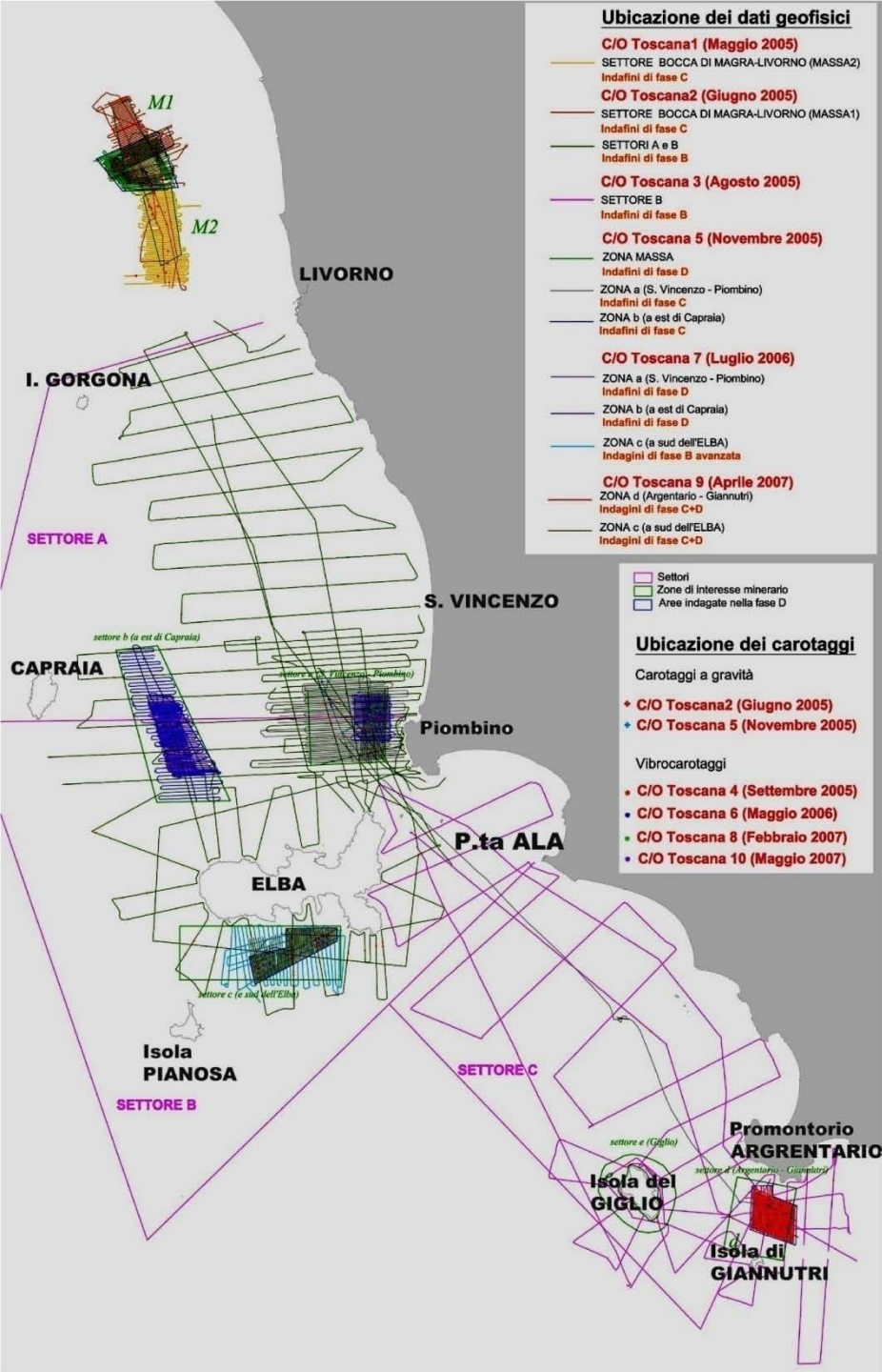
# Search of sand

- Phase “A” – building knowledge – Mining scientific literature, collecting and re-interpreting pre-existing data to define shelf sectors
- Phase “B” – shelf scouting in shelf sectors – low-density seismic survey to define promising mining zones
- Phase “C” – exploration in mining zones – high density seismic survey and coring to define exploitation sites

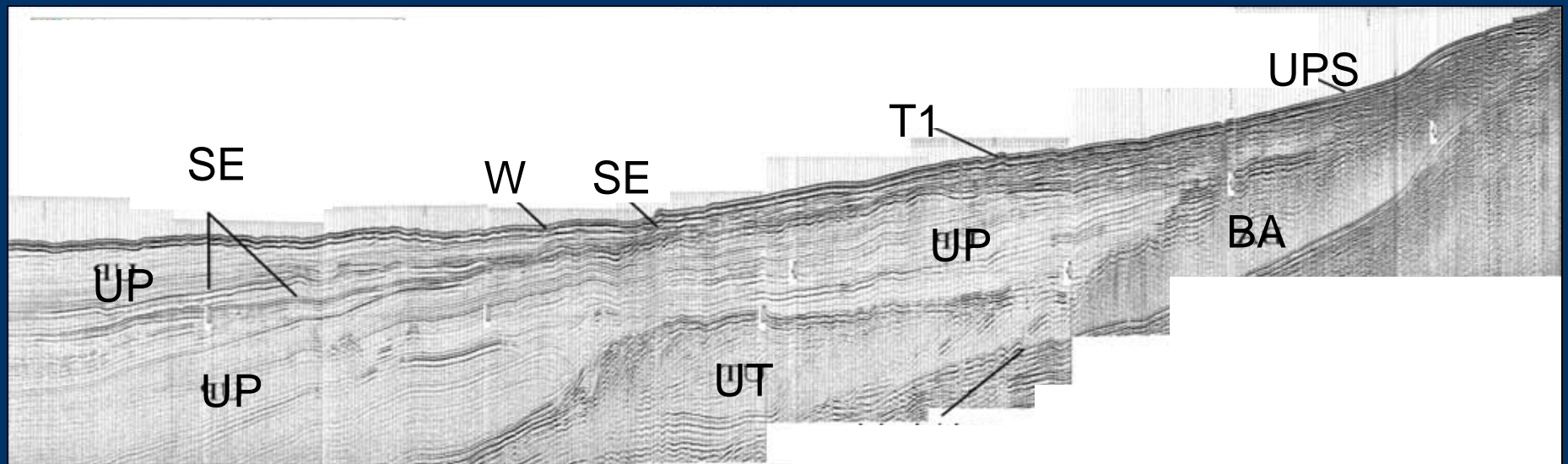
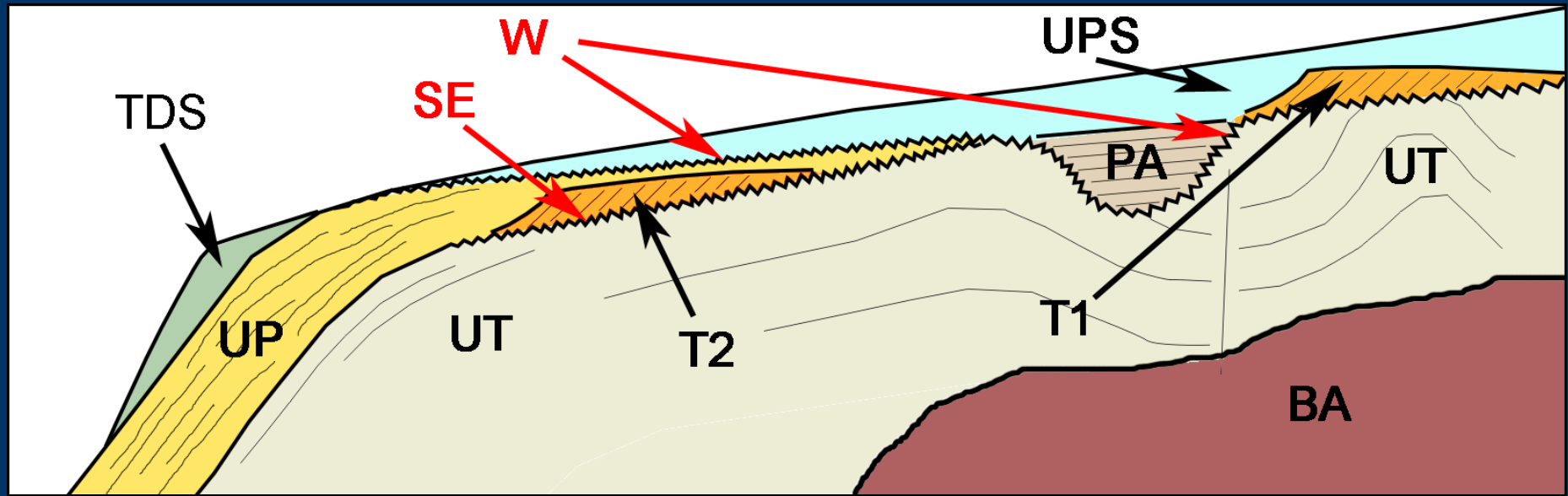
Phase “D” – exploitation in dredging sites - very high density seismic survey and narrow-spaced coring to define dredging corridor

## Total amount of collected data

- 6.800 km S.B.P.- Chirp profiles
- 6.500 km Sparker/Uniboom profiles
- 6.800 km multibeam bathymetry
- 33 gravity cores
- 195 vibrocores

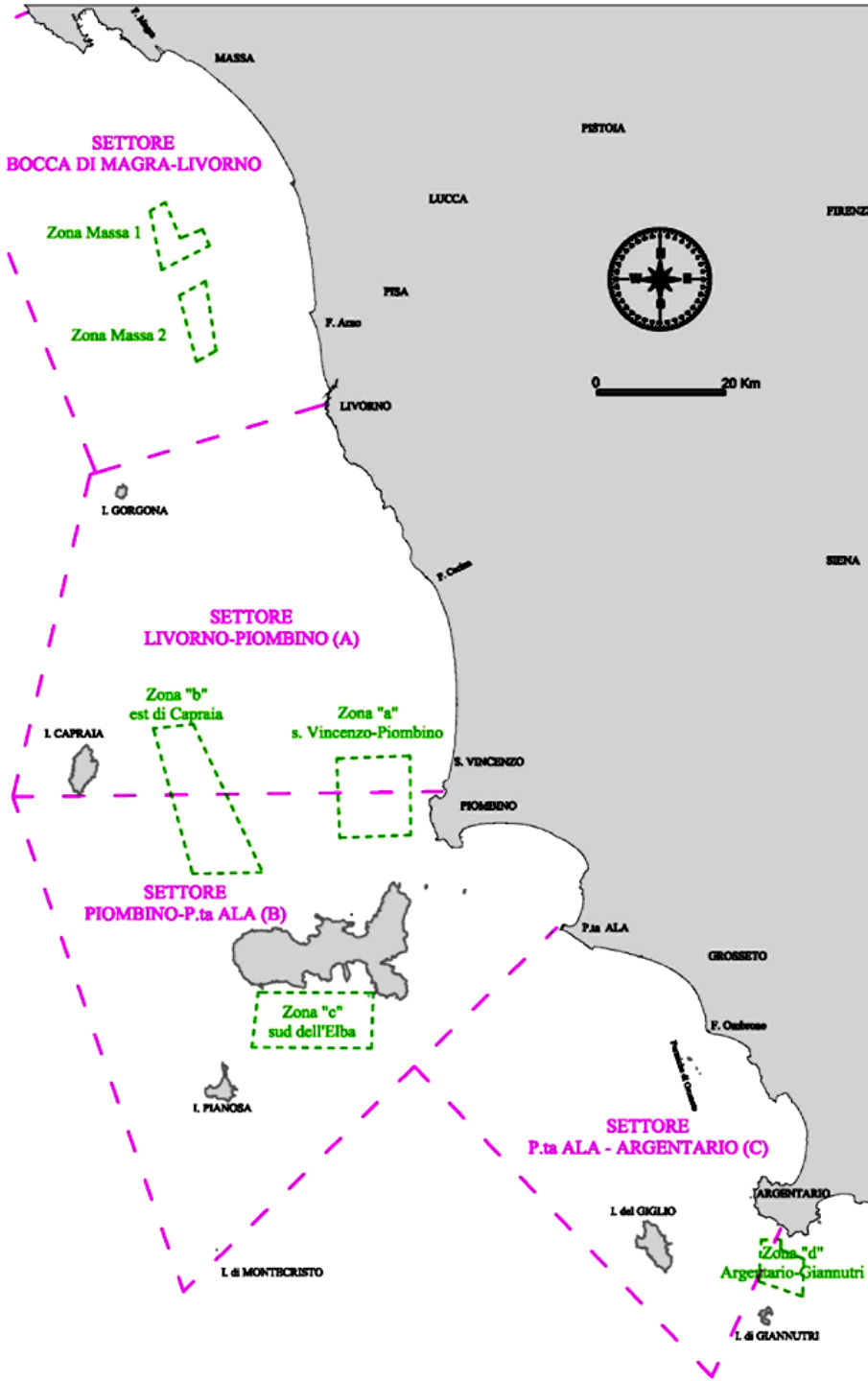


# STARTIGRAPHIC SKETCH OF TUSCANY CONTINENTAL SHELVES



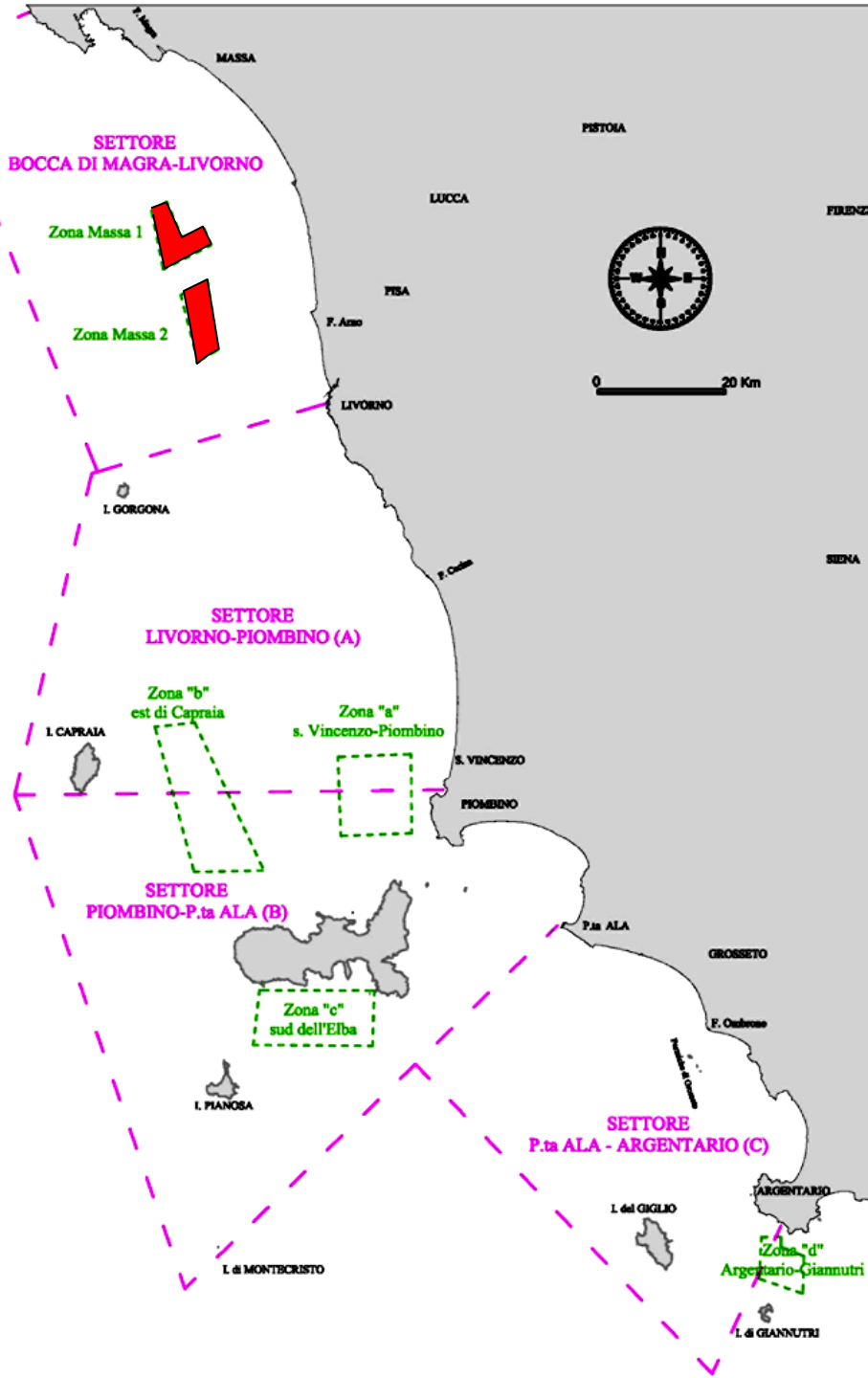
Promising  
mining zones:

1. Massa
2. San Vincenzo Piombino
3. Est di Capraia
4. Sud dell'Elba
5. Argentario - Giannutri



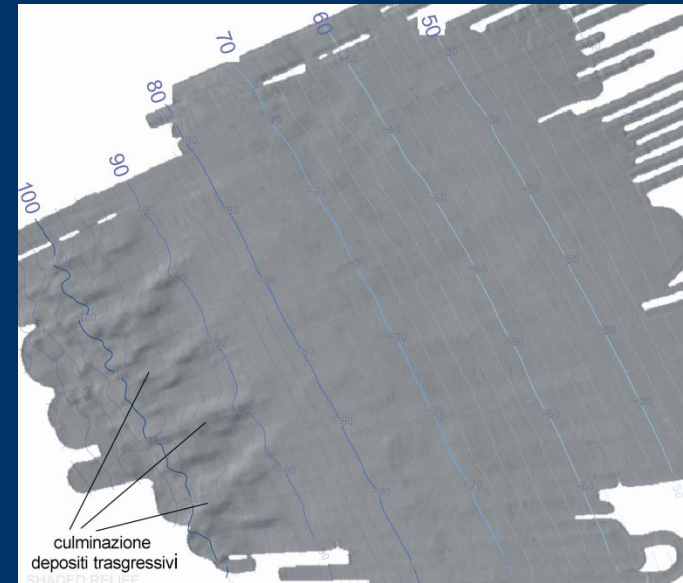
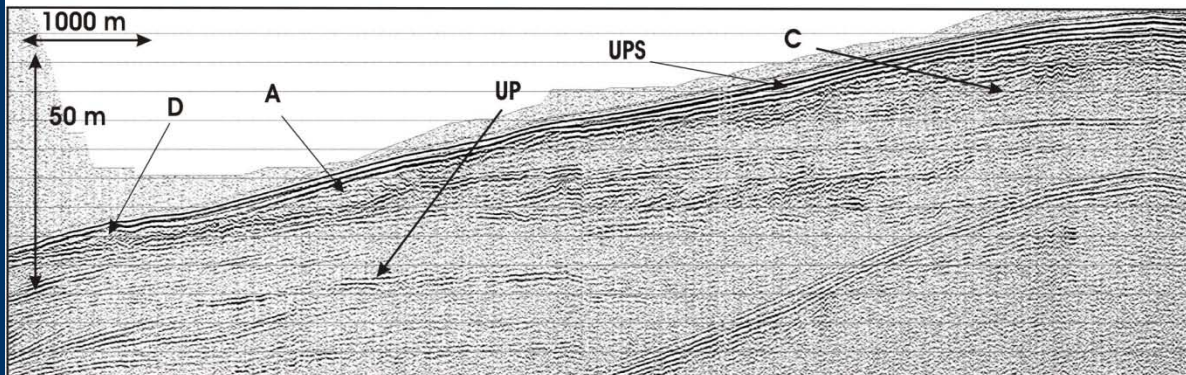
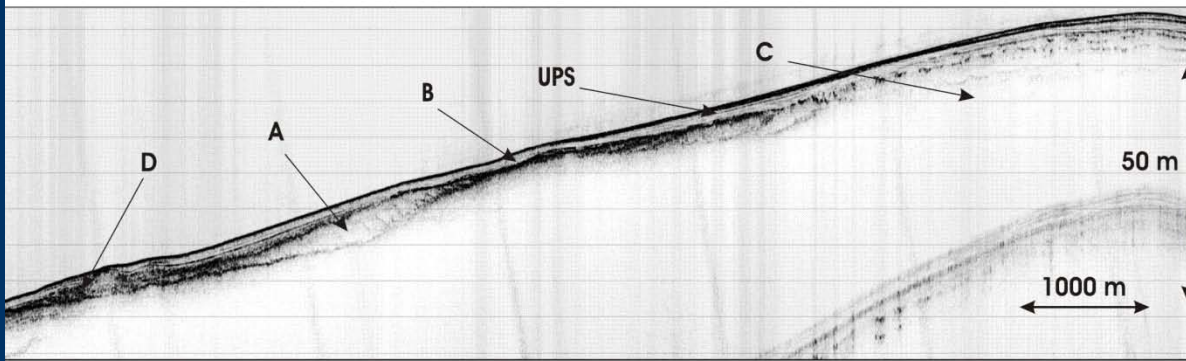
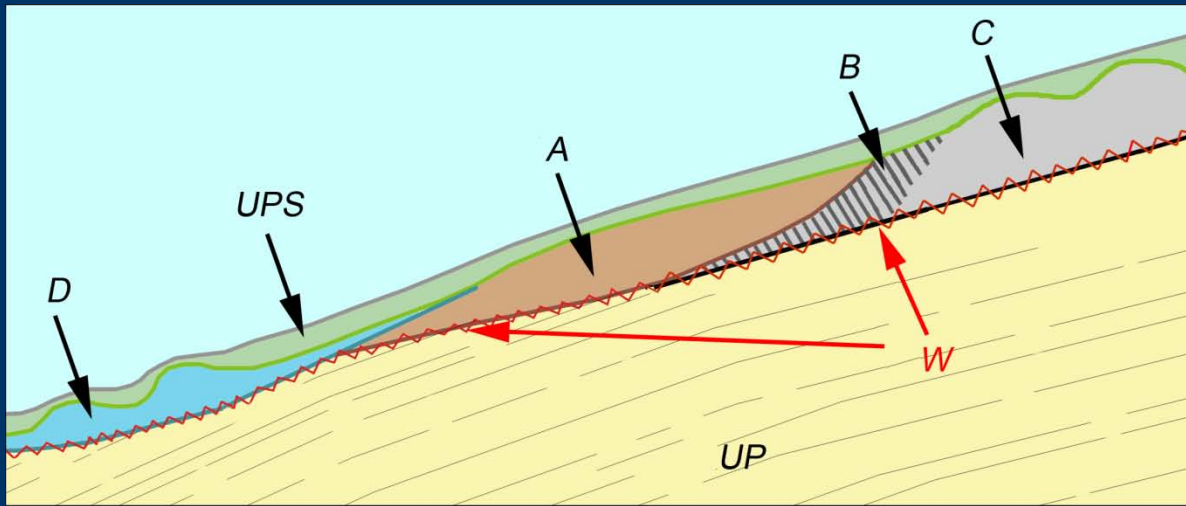
## Promising mining zones:

1. **Massa**
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4. Sud dell'Elba
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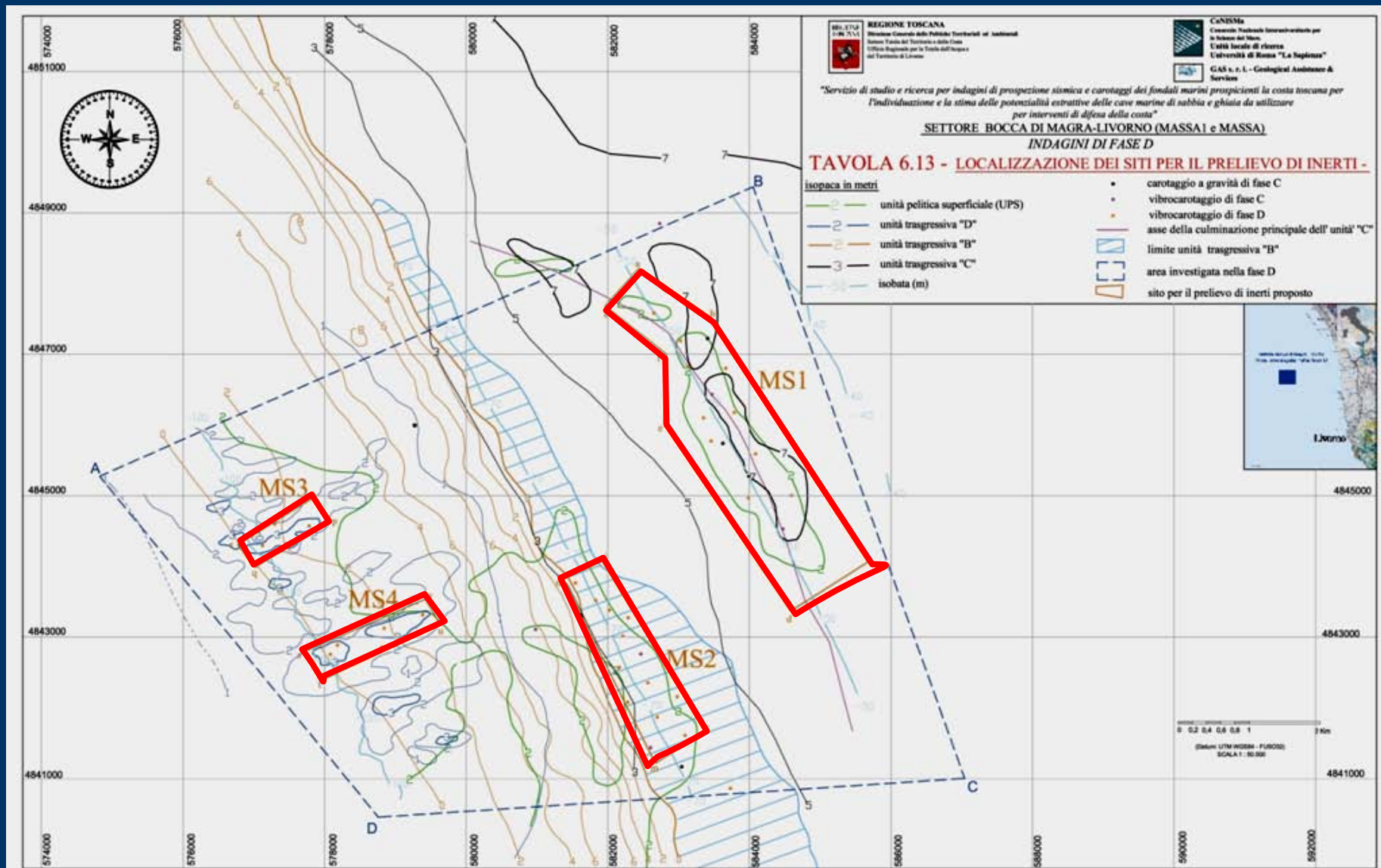




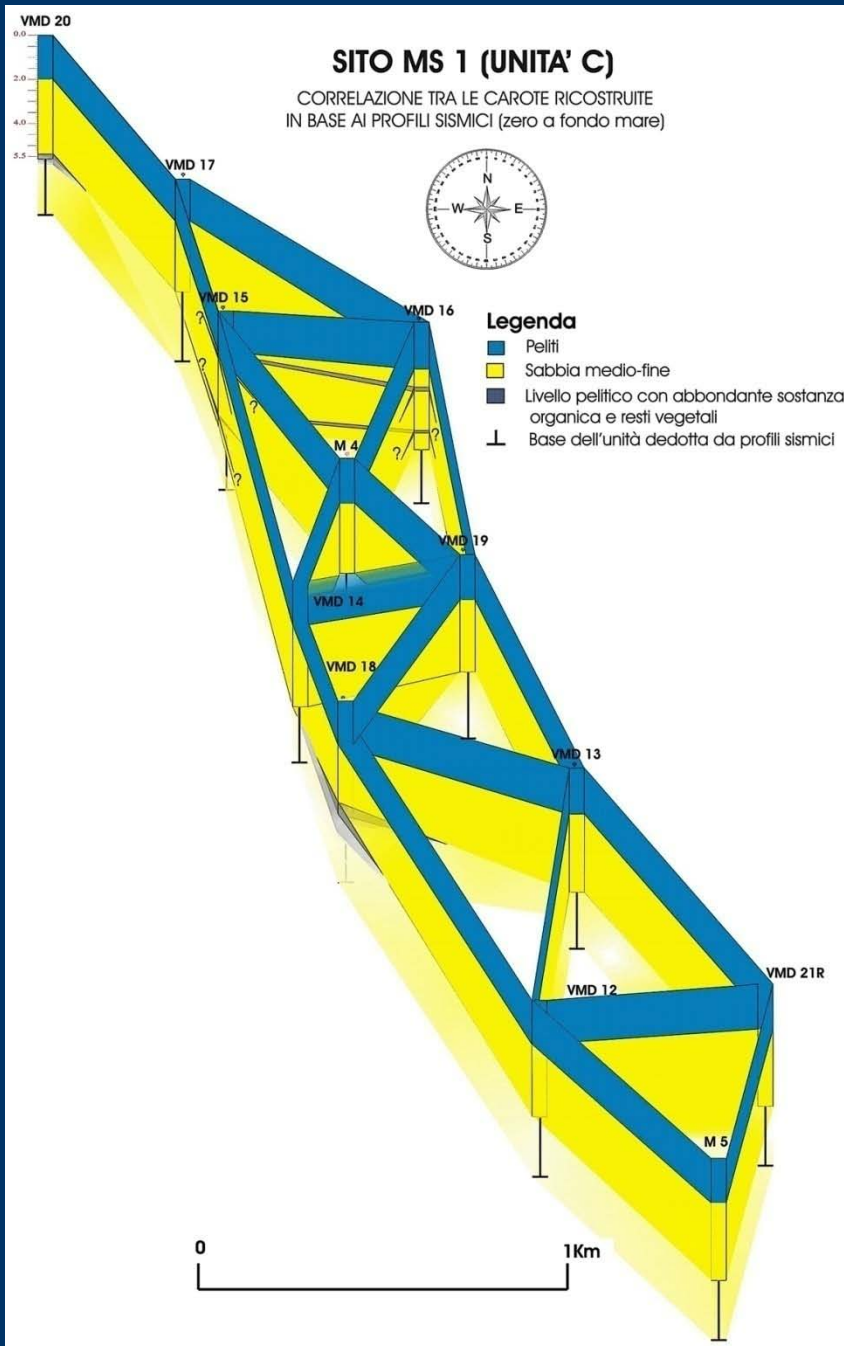
# Massa mining zone



# 4 Dredging corridors for sediment having different characteristics



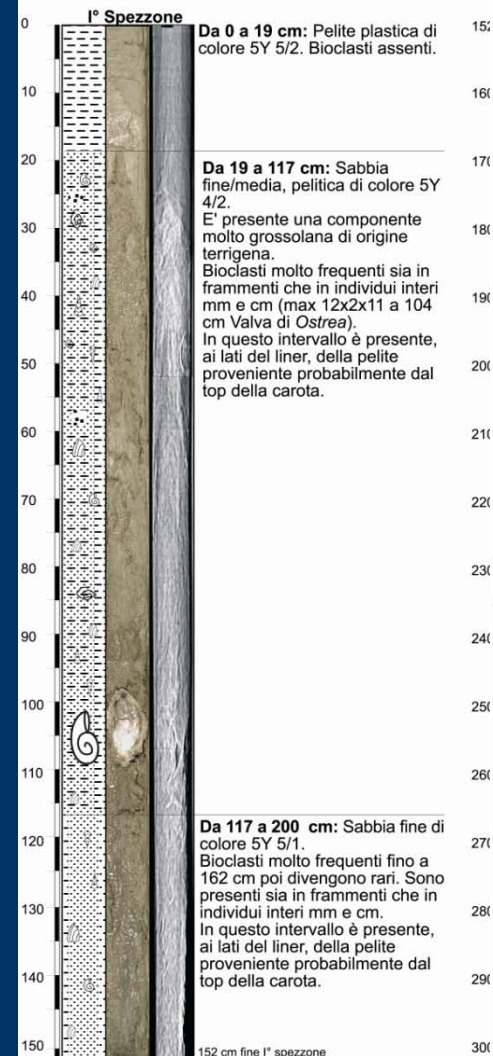
## Corridor MS1 - "C" unit



- Distance to coast: 18 km
- Water depth: 44 – 54 m
- Area: 6.050.000 m<sup>2</sup>
- Overlying mud thickness: 2-3 m
- Sand thickness: 6-7 m
- Sand volume:  
38.400.000 m<sup>3</sup> seismically defined;  
18.000.000 m<sup>3</sup> groundtruthed
- Mud volume : 13.700.000 m<sup>3</sup>
- D<sub>50</sub> and M<sub>Z</sub>: 0.2 mm

### VMD15 (ZONA MASSA - CAROTA RAPI)

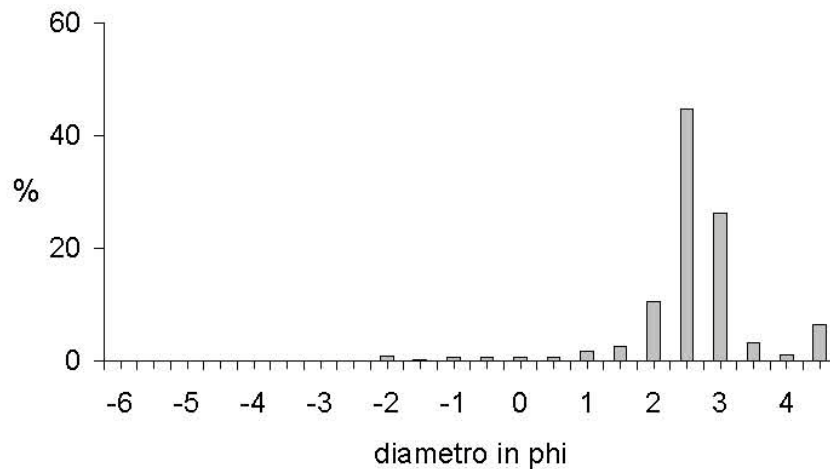
(Lunghezza: 576 cm; Profondità: 50 m; Lat: 43° 46')



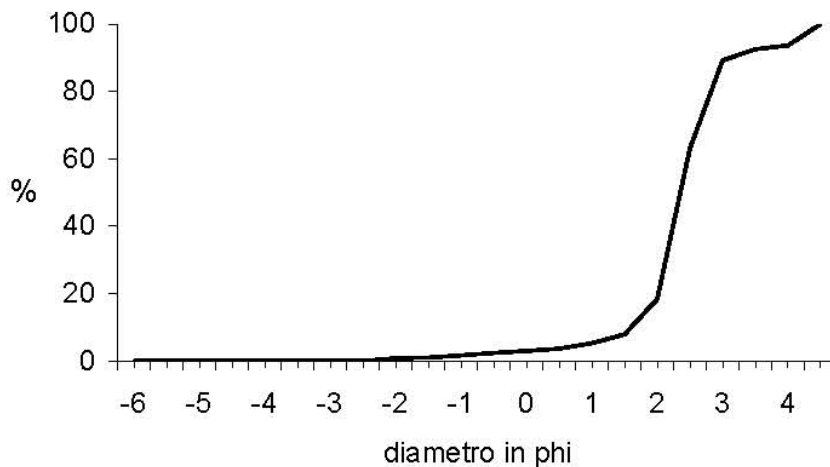
intervallo	% ghiaia	% sabbia	% pelite	D50 mm	Mz mm
19-117	4,34	73,01	22,65	0,203	0,099
117-200	4,68	89,35	5,96	0,210	0,221
200-216	0,15	60,86	38,99	0,129	0,031
216-477	0	91,58	8,42	0,191	0,183
477-487	0,95	56,49	42,56	0,118	0,027
487-576	0,23	87,62	12,15	0,177	0,165
117-576	1,65	92	6,35	0,196	0,192

Interv:  
per le  
216; 2  
per le

### distribuzione di frequenza



### curva cumulativa



### ESENTATIVA DEL SITO MS1)

#### IV° Spezzone

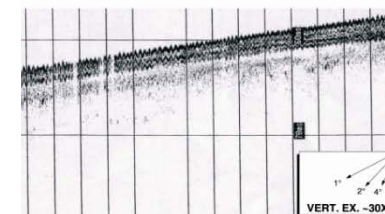


5 cm fine IV° spezzone

**Da 446 a 477 cm:** Prosegue la sabbia fine ampiamente bioturbata di colore 5Y 5/1.

**Da 477 a 486 cm:** Livello organico costituito da un unico resto vegetale di colore 10YR 2/2.

**Da 486 a 576 cm:** Sabbia fine, bioturbata di colore 5Y 5/1. Bioclasti rari. Da 494 a 503 cm: E' presente una componente pelitica di colore 10YR 2/2.



## Geological remarks

11 possible corridors to quarry relict sand

128.970.000 m<sup>3</sup> of relict sand (+ Capraia East) potentially available for Tuscany beaches nourishment

Relict sand and gravel are a not-renewable resource. To manage it, a census of deposits is necessary with a medium-long term plan for coastal restoration with beach nourishment.



2009 - 2011

**Environmental Impact Study for the exploitation of potential relict sand and gravel reservoirs located along the Tuscan continental shelf to be used for artificial beach nourishment interventions.**

**Approximate cost: 1.000.000 €**

**Study Area: Massa and San Vincenzo - Piombino**

**Project Structure:**

**Phase A: Reference Framework**

**Phase B: Detailed Characterization**

**Phase C: Monitoring Program**

- Phase A Reference Framework :

- *A1 Search of available information and literature about:*

- meteo-marine conditions
    - chemical - physical and biological properties of sea water;
    - marine ecosystems (fish population, *Posidonia oceanica* etc. ..);
    - morphology, bathymetry and seabed characteristics;
    - Presence of marine archaeological sites, protection of marine areas, parks and nature reserves, *Pelagos Cetacean Sanctuary*.

- *A2 Implementation of available information about:*

- provide a more detailed description of the study area;
    - Identify the characteristics of the area that can be altered or disturbed by dredging activities;
    - The information gathered in Phase A1 were held in ESRI ArcGIS platform.

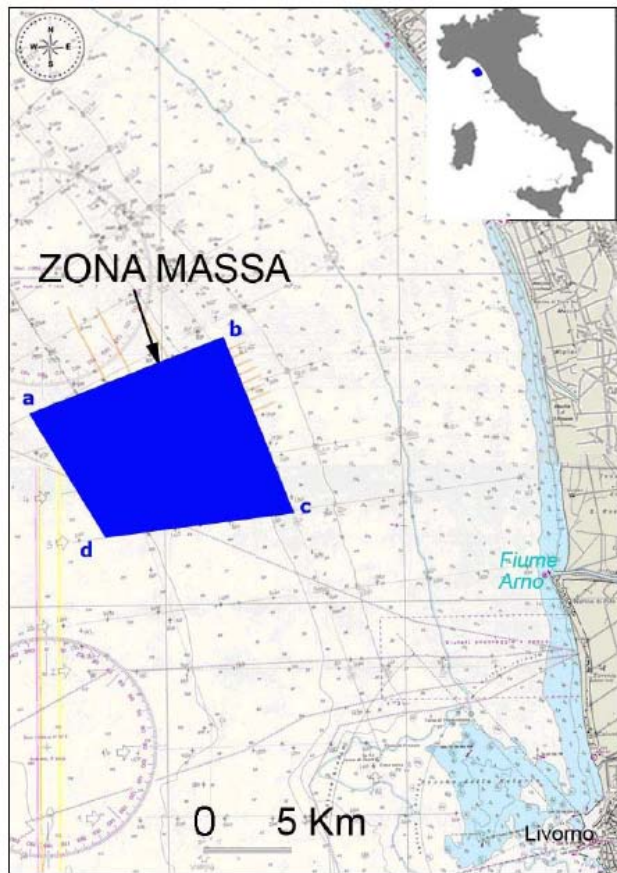


- Phase B Detailed Characterization:

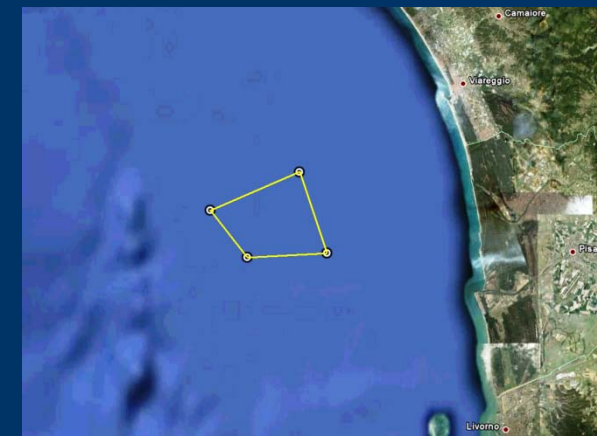
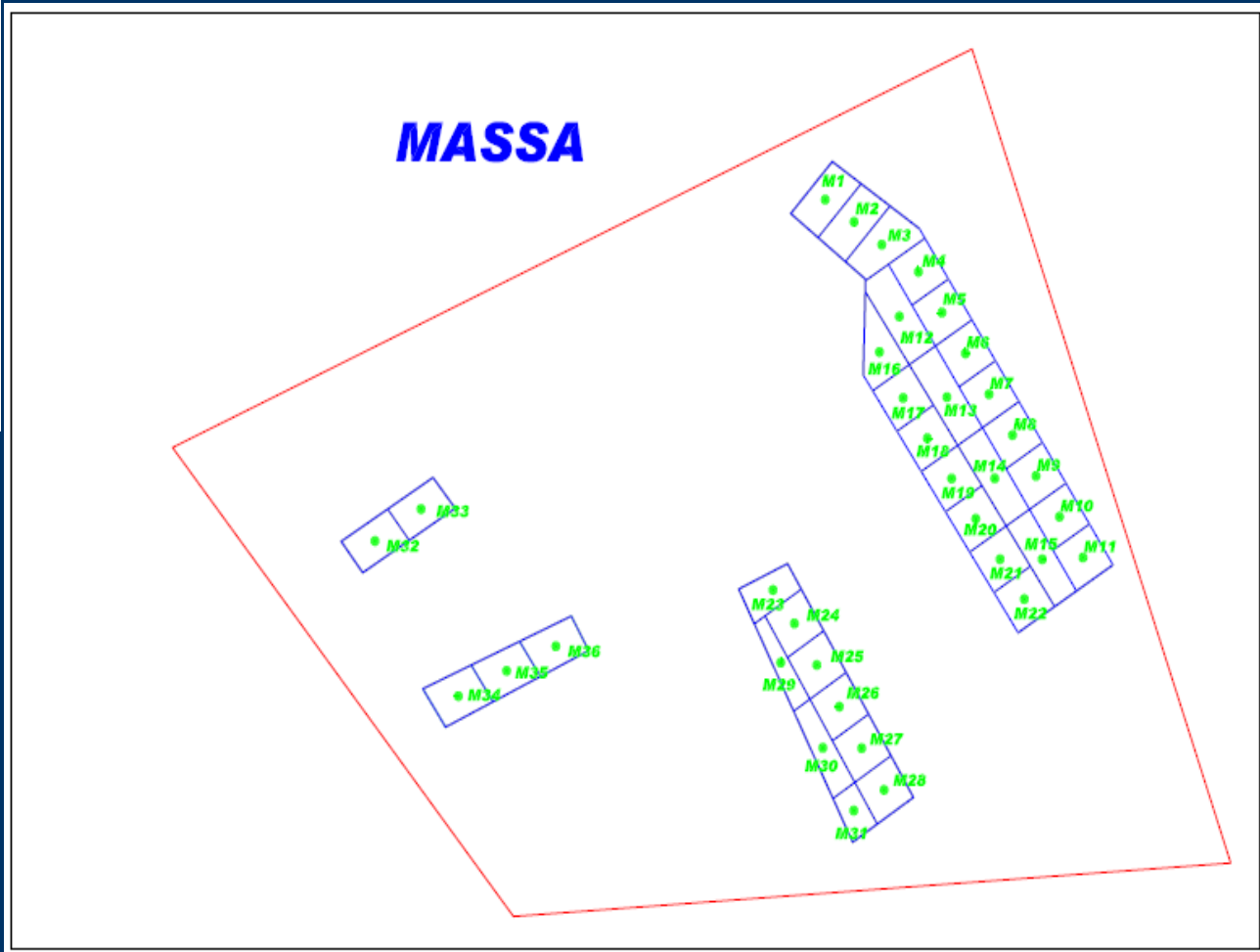
- B1 *Dredging sites*:

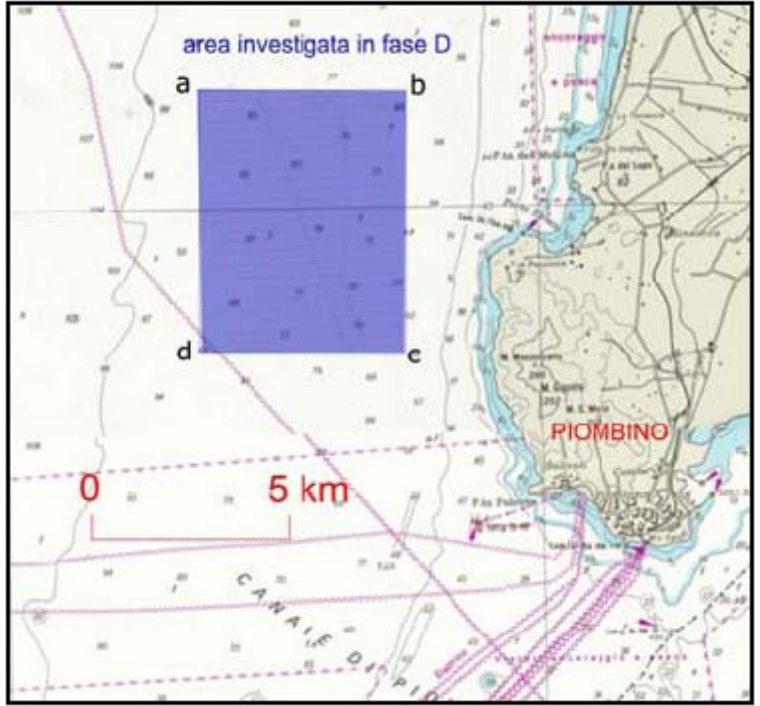
- realization of 58 vibrocores of 6 m length;
    - physical, chemical, microbiological and ecotoxicological properties of the sediments to be taken at different levels;
    - assessment of the compatibility of the marine aggregates, to be used for beach nourishment, with the native sediments;
    - chemical - physical characteristics of the water column;
    - benthic and fish population.



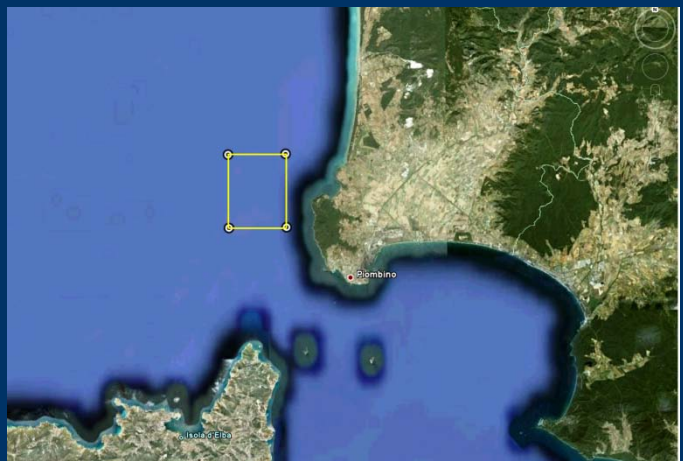
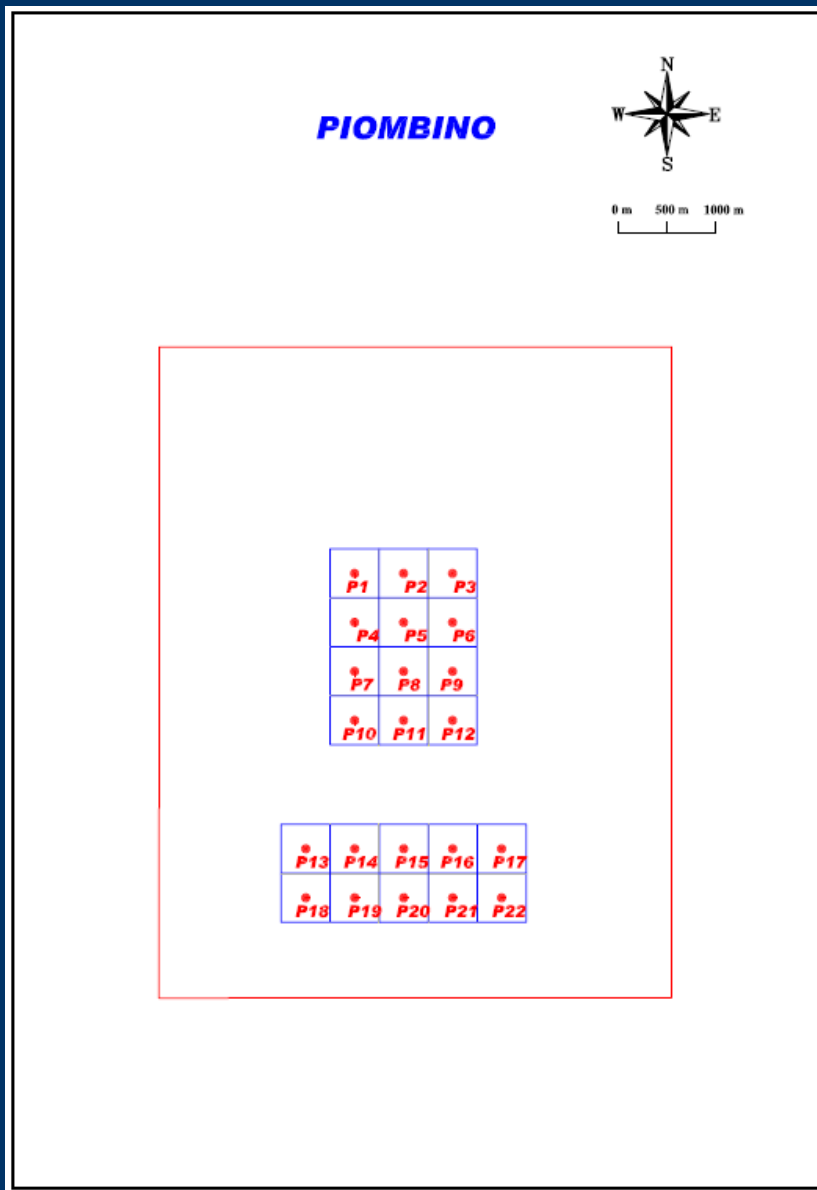


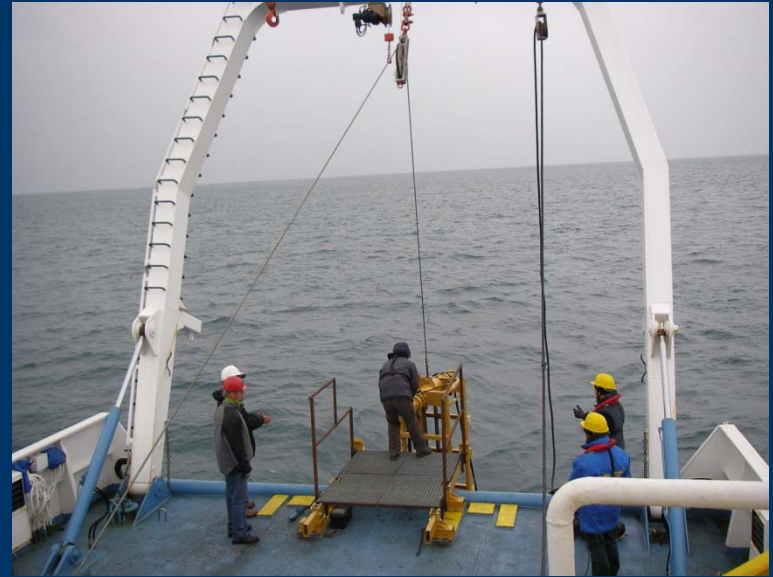
## 36 Vibrocores positioning





## 22 Vibrocores positioning

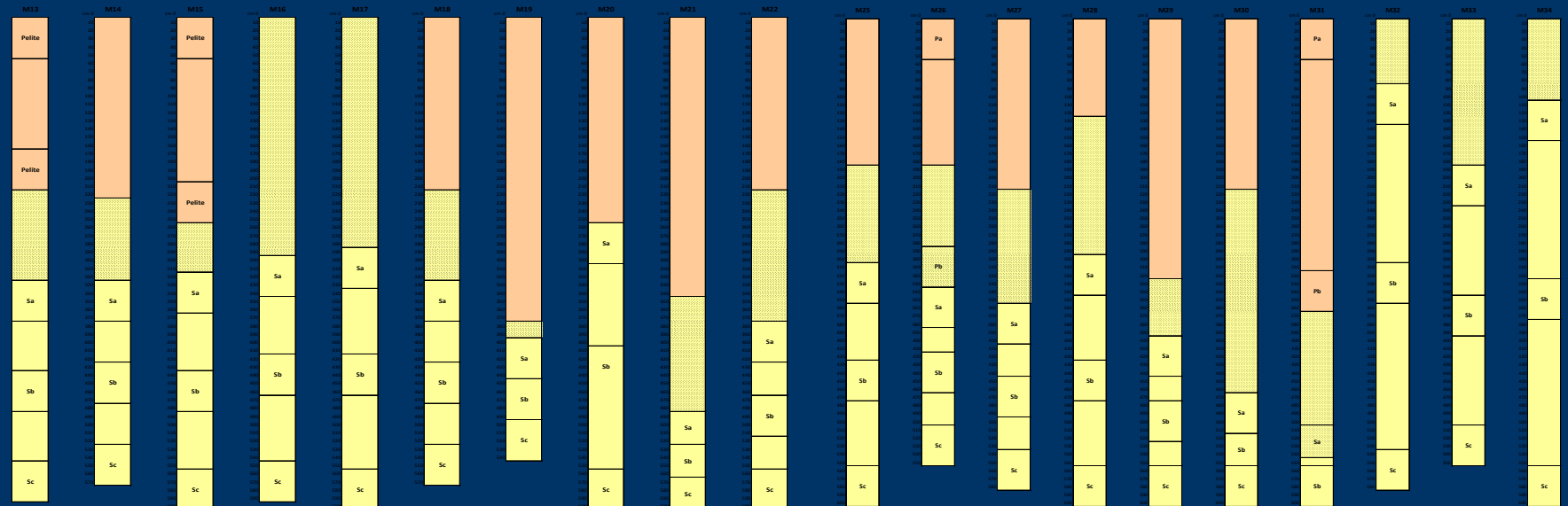
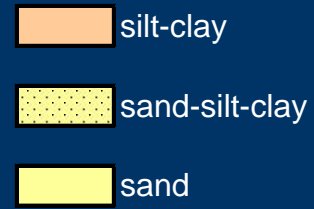
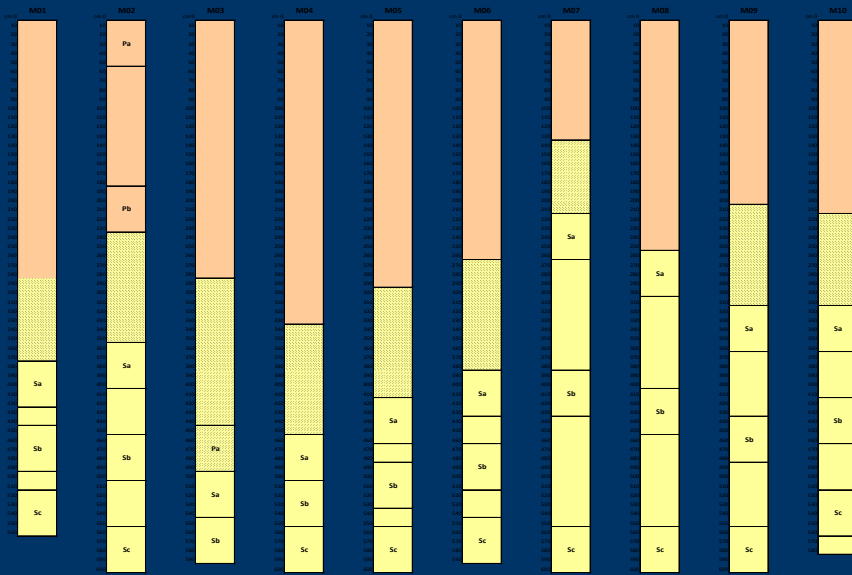




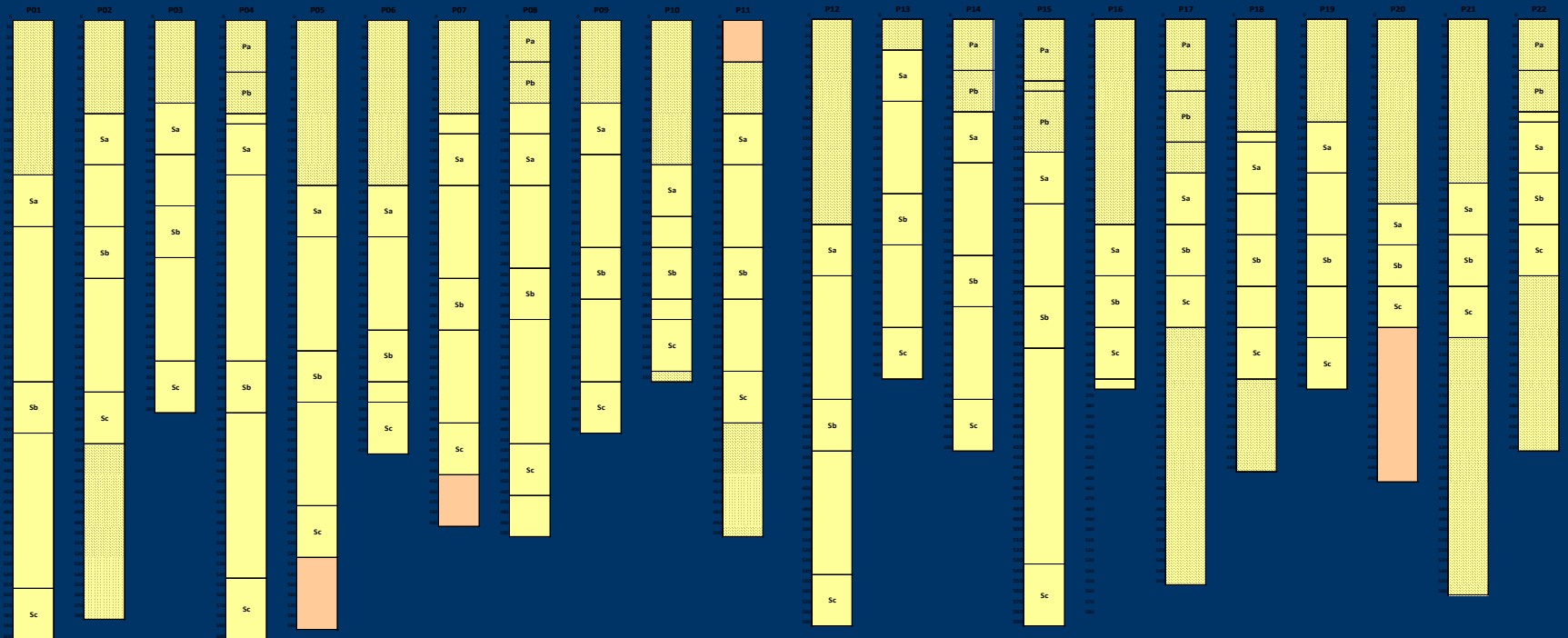
## On board operations



# Massa vibrocores



# Piombino vibrocores



## Main parameters analyzed

- Grain size (gravel, sand, silt-clay)
- Metals: Al, Fe, As, Cd, Cr tot, Ni, Pb, Hg, Cu, V, Zn
- Total hydrocarbons (C<12 e C>12)
- PAH
- Organochlorine pesticides
- Polychlorinated biphenyls
- Tributyltin (TBT)
- Microbiology
- **Ecotoxicology**

### Bioassay battery

*Paracentrotus lividus* applied on elutriate



*Vibrio fischeri* (bacteria) applied on elutriate



*Corophium orientale* applied to the whole sediment



	Metalli	mg/kg s.s
7440-43-9	Cadmio	0,3
7439-97-6	Mercurio	0,3
7440-02-0	Nichel	30
7439-92-1	Piombo	30
	Organo metalli	µg/kg
	Tributilstagno	5
	Policiclici Aromatici	µg/kg
50-32-8	Benzo(a)pirene	30
205-99-2	Benzo(b)fluorantene	40
207-08-9	Benzo(k)fluorantene	20
191-24-2	Benzo(g,h,i)perilene	55
193-39-5	Indenopirene	70
120-12-7	Antracene	45

NUMERO CAS	PARAMETRI	SQA-MA <sup>(1) (2)</sup>
206-44-0	Fluorantene	110
91-20-3	Naftalene	35
	Pesticidi	
309-00-2	Aldrin	0,2
319-84-6	Alfa esaclorocicloesano	0,2
319-85-7	Beta esaclorocicloesano	0,2
58-89-9	Gamma esaclorocicloesano lindano	0,2
	DDT <sup>(3)</sup>	1
	DDD <sup>(3)</sup>	0,8
	DDE <sup>(3)</sup>	1,8
60-57-1	Dieldrin	0,2
118-74-1	Esaclorobenzene	0,4

## LCB value by ISPRA

In: "Manuale per la movimentazione di sedimenti marini"

Parameter	LCB (sand > 25%)	LCB (sand < 25%)
Trace elements	[mg kg <sup>-1</sup> ] d.w.	[mg kg <sup>-1</sup> ] d.w.
As	17	23
Cd	0,20	0,35
Cr	50	100
Cu	15	35
Hg	0,20	0,40
Ni	32	60
Pb	25	37
Zn	50	100

LCB (Level Chemical Base) = value of the chemical concentration of close to natural background relatively free of contamination for which revealed no toxic effects





# Piombino Chemical results

*Percentage of samples resulting above the values reported in DM 56/09 (total number of samples: 99)*

PIOMBINO	Parameter	% Contaminated samples
SILT-CLAY	Trace elements	100
	Pesticides	75
SAND	Trace elements	100
	Pesticides	50

Metals that exceed the quality standards are composed primarily of arsenic, chromium and nickel

The organochlorine pesticides are Lindane, DDE, and to a lesser extent, by Hexachlorobenzen

# Massa Chemical results

Percentage of samples resulting above the values reported in DM 56/09 (total number of samples: 145)

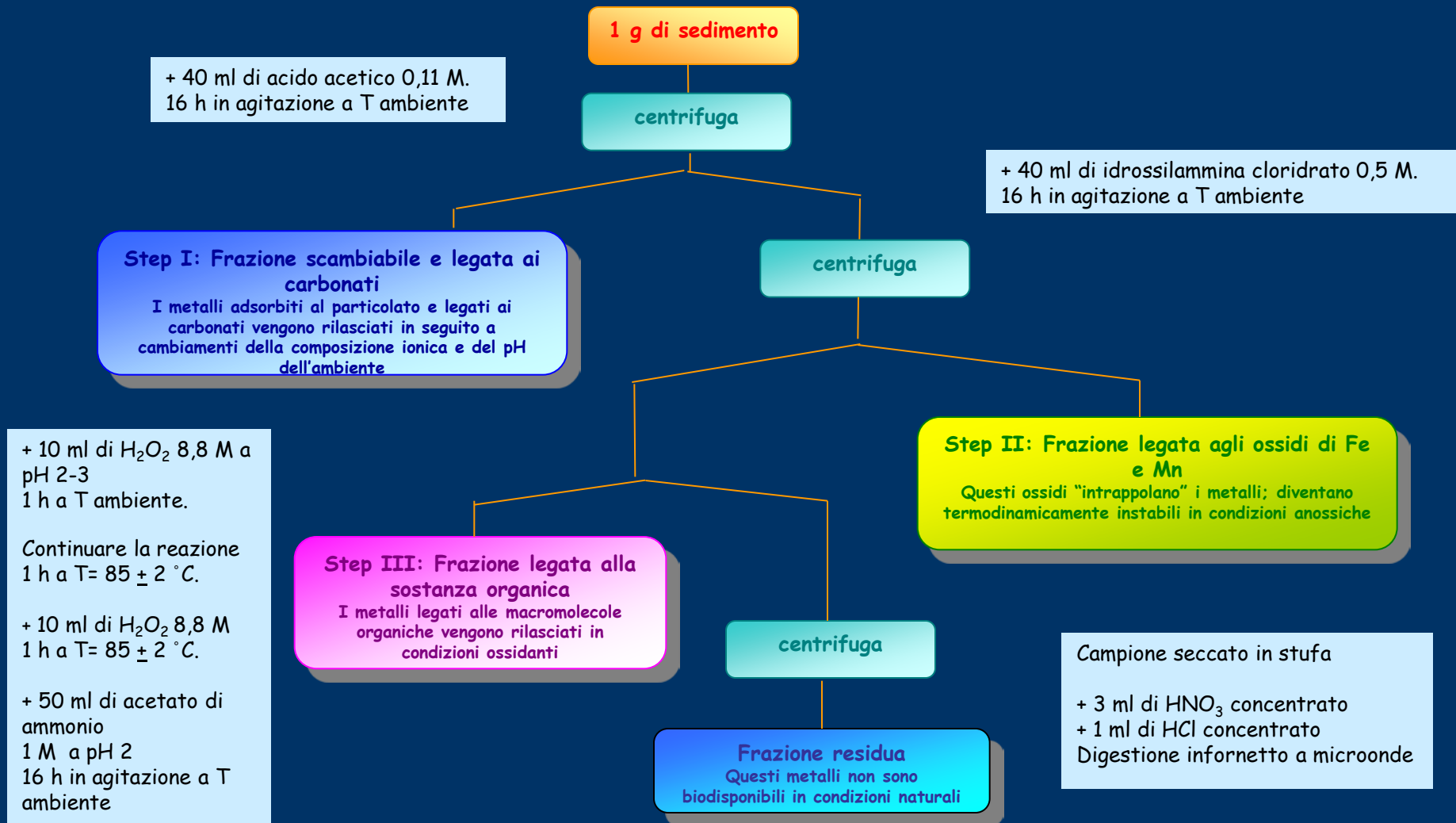
MASSA	Parameter	% Contaminated samples
SILT-CLAY	Trace elements	92
	Pesticides	15
SAND	Trace elements	26
	Pesticides	8

Metals that exceed the quality standards are composed primarily of arsenic, chromium and nickel

Low percentage of samples contaminated with pesticides,  $\alpha,\beta,\gamma$  HCH, DDT and DDE

# Sequential extraction

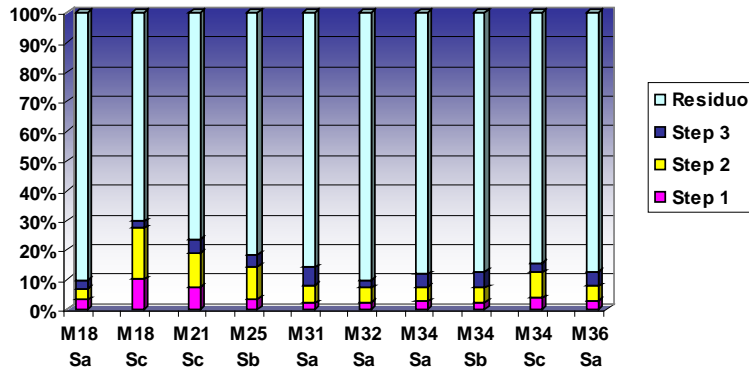
Three stage sequential extraction procedure for metal speciation in the relict sands. The European Community Bureau of Reference (BCR), was used. As was determined by Graphite furnace atomic absorption spectrometry (GFAAS), Cr and Ni by Inductively Coupled Plasma (ICP)



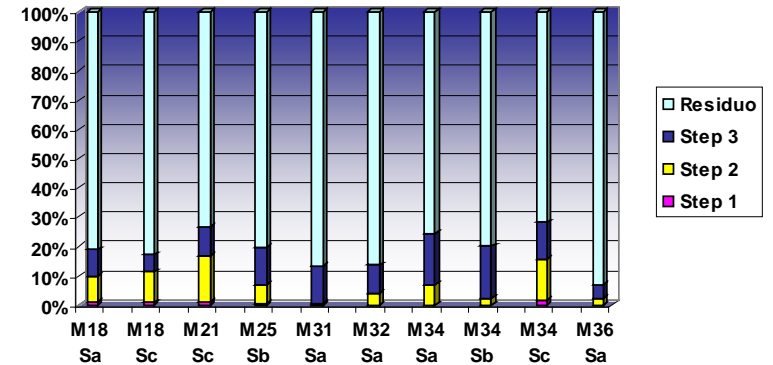
# Results of sequential extraction

## As, Cr, Ni distribution in the different fractions in the Massa relict sands

Percentuali di As nelle singole frazioni rispetto al totale

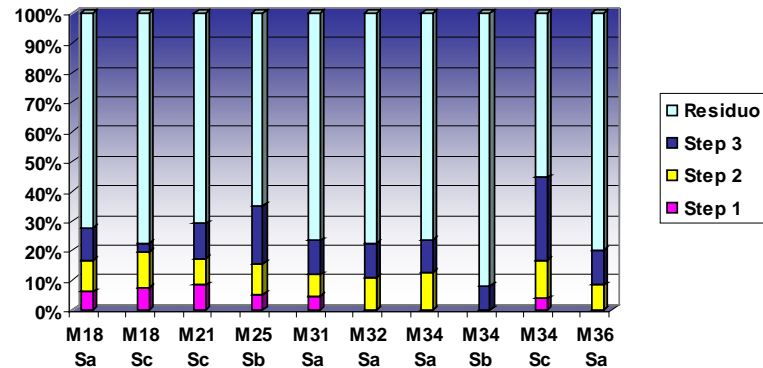


Percentuali di Cr nelle singole frazioni rispetto al totale



Trace elements in the fractions 1, 2 and 3 are bioavailable.

Percentuali di Ni nelle singole frazioni rispetto al totale

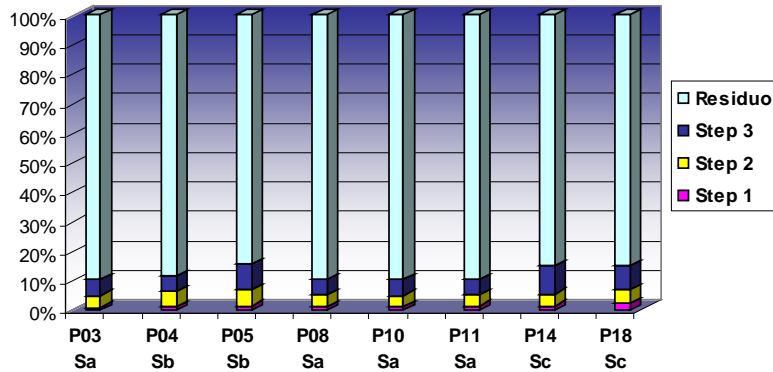


The residual fraction (light blue) is not bioavailable and it is generally of geological origin

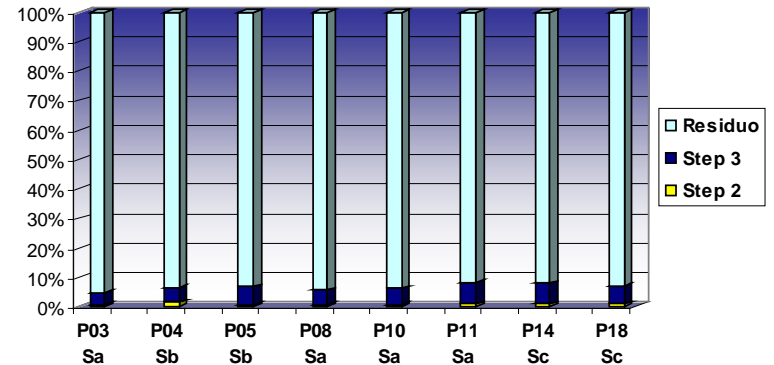
# Results of sequential extraction

## As, Cr, Ni distribution in the different fractions in the Piombino relict sands

Percentuali di As nelle singole frazioni rispetto al totale

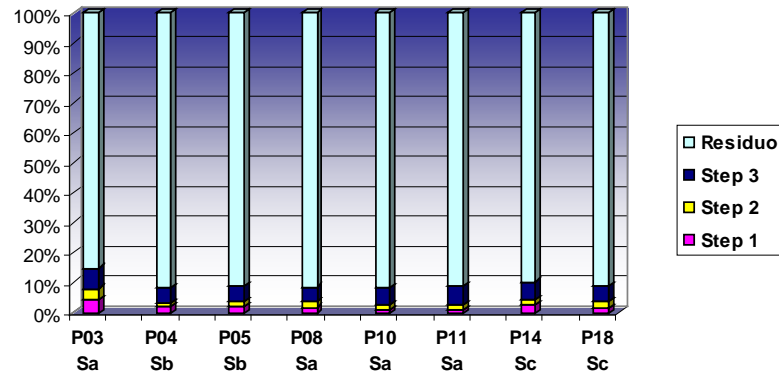


Percentuali di Cr nelle singole frazioni rispetto al totale



Trace elements in the fractions 1, 2 and 3 are bioavailable.

Percentuali di Ni nelle singole frazioni rispetto al totale



The residual fraction (azure) is not bioavailable and it is generally of geological origin

## Chemical and ecotoxicological remarks

There is a generalized heavy metal contamination mainly due to Arsenic, Chromium and Nickel, however, the study of speciation shows that these elements are almost exclusively of geological origin, and therefore present in physical and chemical forms which is not bioavailable;

There is a light pesticide contamination in the Piombino reservoir. It is assumed that originates from pelitic sediments that cover the sand body; additional analysis are in progress;

Comparative analysis of the bioassay data shows that out of the 3 species-test system, only 1 (*Paracentrotus lividus*) has (in 30% of cases) a moderate toxicity.

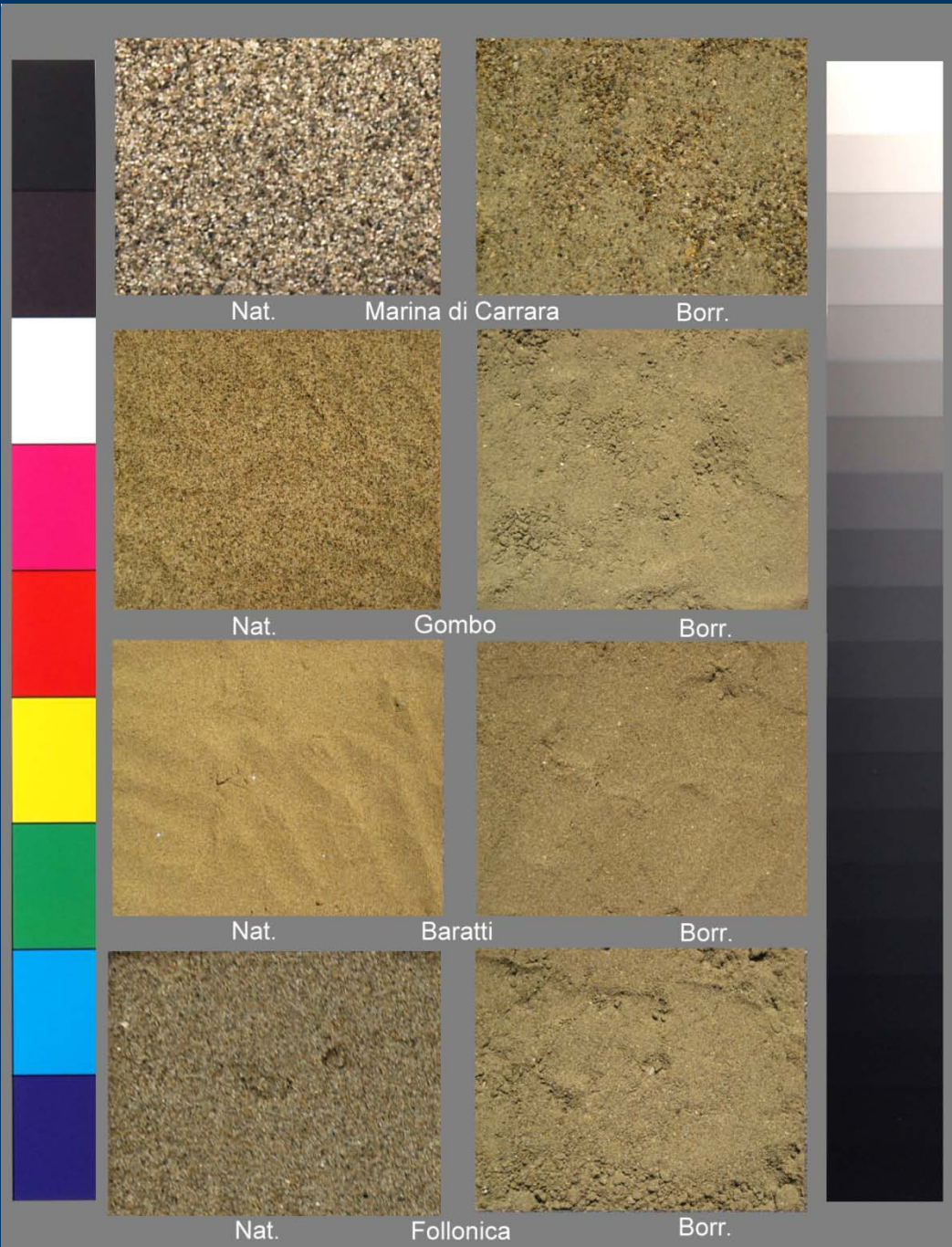


- Phase B Detailed Characterization:
  - B4 *Deposition sites:*

For each deposition site representative samples must be taken in order to perform analysis necessary to assess any environmental impact on the basis of the following:

- macroscopic (**color**, odor, etc.)
- physical (grain size)
- chemical properties (organometallic, metals, etc.)
- microbiological (coliform Enterococci, etc.)





# Sand colour rating and chromatic compatibility of borrow sediments

From Pranzini E., Simonetti D., Vitale G. (2010) *Journal of Coastal Research*, 26: 798-808.



“Chromatic compatibility using CIEL\*a\*b\* colour space”



## CONCLUSIONS



1. Considering the continental shelf sand and gravel reservoirs;
2. Considering the environmental impact study for the exploitation of Massa and Piombino reservoirs;
3. Considering the volume of sand presently available along the updrift side of coastal infrastructures:

**Region of Tuscany is presently implementing its Coastal Sediment Management Plan (CSMP)**





Regione Toscana  
Diritti Valori Innovazione Sostenibilità



CoNISMa



Grazie per l'attenzione!

Thank you!



RESEAU POUR L'ENVIRONNEMENT DANS L'ESPACE MARITIME  
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