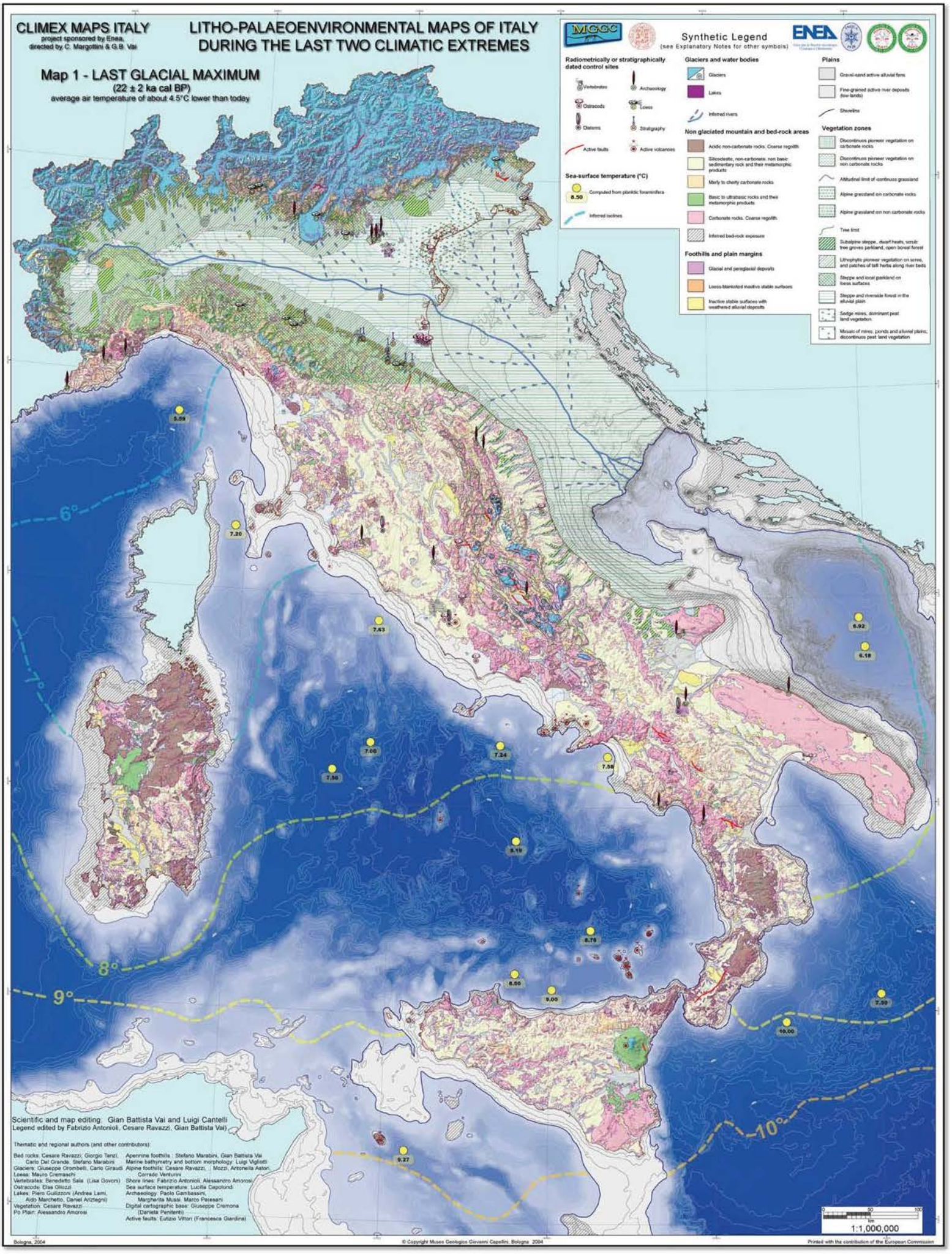
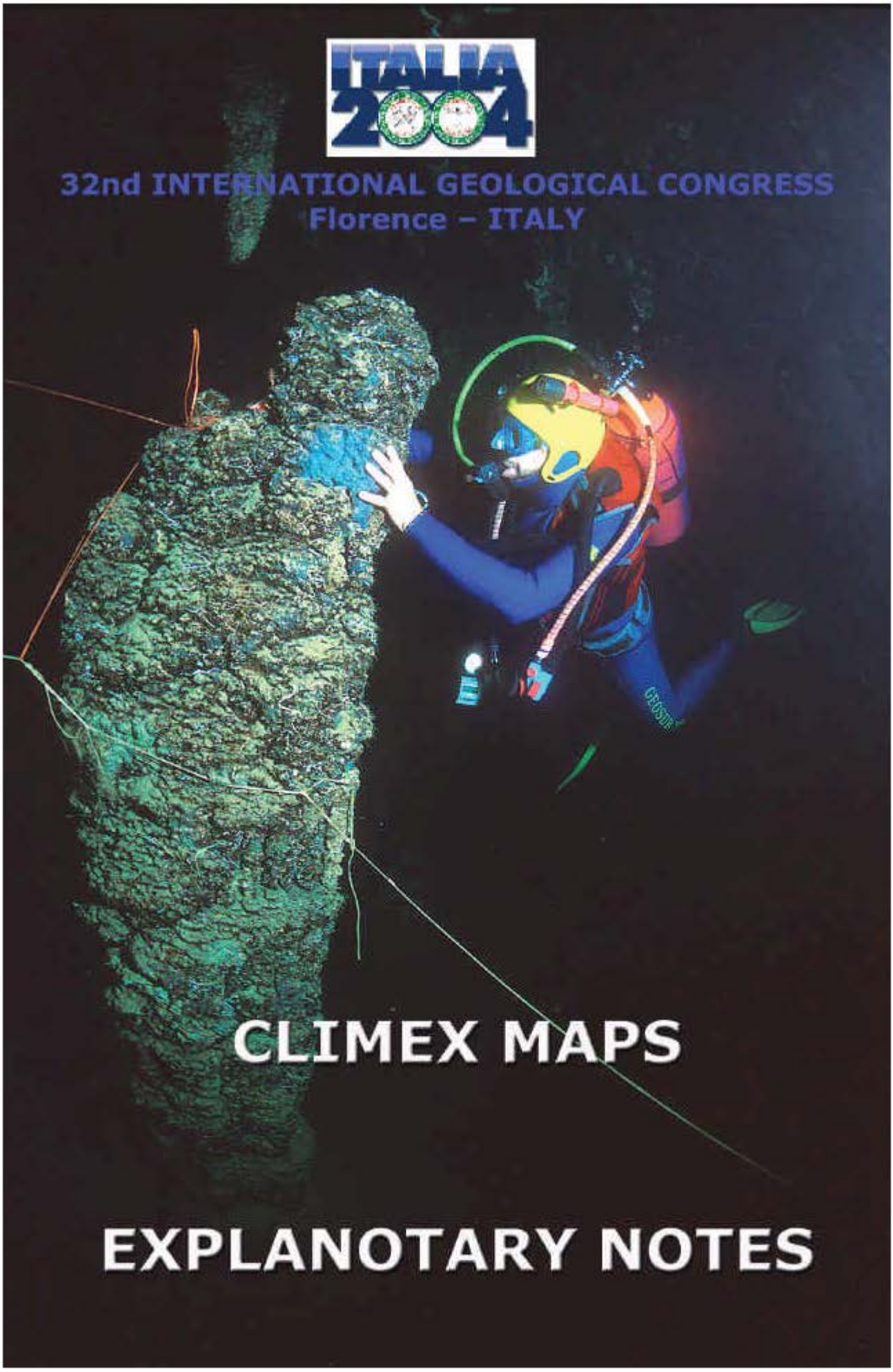

CLIMEX MAPS ITALY
project sponsored by Enea,
directed by C. Margottini & G.B. Vai
LITHO-PALAEOENVIRONMENTAL MAPS OF ITALY
DURING THE LAST TWO CLIMATIC EXTREMES
Map 1 - LAST GLACIAL MAXIMUM
(22 ± 2 ka cal BP)
average air temperature of about 4.5°C lower than today
Synthetic Legend
(see Explanatory Notes for other symbols)
Radiometrically or stratigraphically dated control sites
Vertebrates
Archaeology
Ostracods
Loess
Diatoms
Stratigraphy
Active faults
Active volcanoes
Sea-surface temperature (°C)
8.50
Computed from planktic foraminifera
Inferred isolines
Glaciers and water bodies
Glaciers
Lakes
Inferred rivers
Non glaciated mountain and bed-rock areas
Acidic non-carbonate rocks. Coarse regolith
Siliciclastic, non-carbonate, non basic sedimentary rock and their metamorphic products
Marly to cherty carbonate rocks
Basic to ultrabasic rocks and their metamorphic products
Carbonate rocks. Coarse regolith
Inferred bed-rock exposure
Foothills and plain margins
Glacial and periglacial deposits
Loess-blanketed inactive stable surfaces
Inactive stable surfaces with weathered alluvial deposits
Plains
Gravel-sand active alluvial fans
Fine-grained active river deposits (low-lands)
Shoreline
Vegetation zones
Discontinuous pioneer vegetation on carbonate rocks
Discontinuous pioneer vegetation on non carbonate rocks
Altitudinal limit of continuous grassland
Alpine grassland on carbonate rocks
Alpine grassland on non carbonate rocks
Tree limit
Subalpine steppe, dwarf heath, scrub; tree groves parkland, open boreal forest
Lithophytic pioneer vegetation on scree, and patches of tall herbs along river beds
Steppe and local parkland on loess surfaces
Steppe and riverside forest in the alluvial plain
Sedge mires, dominant peat land vegetation
Mosaic of mires, ponds and alluvial plains; discontinuous peat land vegetation
6°
7°
8°
9°
10°
5.20
7.20
7.63
7.00
7.50
7.24
7.58
8.10
8.70
8.50
9.00
9.27
10.00
7.50
6.92
6.18
Scientific and map editing: Gian Battista Vai and Luigi Cantelli
Legend edited by Fabrizio Antonioli, Cesare Ravazzi, Gian Battista Vai)
Thematic and regional authors (and other contributors):
Bed rocks: Cesare Ravazzi, Giorgio Tanzi, Carlo Del Grande, Stefano Marabini
Glaciers: Giuseppe Orombelli, Carlo Giraudi
Loess: Mauro Cremaschi
Vertebrates: Benedetto Sala (Lisa Govoni)
Ostracods: Elsa Gliozzi
Lakes: Piero Guilizzoni (Andrea Lami, Aldo Marchetto, Daniel Ariztegni)
Vegetation: Cesare Ravazzi
Po Plain: Alessandro Amorosi
Apennine foothills : Stefano Marabini, Gian Battista Vai
Marine bathymetry and bottom morphology: Luigi Vigliotti
Alpine foothills: Cesare Ravazzi, Mozzi, Antonella Astori, Corrado Venturini
Shore lines: Fabrizio Antonioli, Alessandro Amorosi
Sea surface temperature: Lucilla Capotondi
Archaeology: Paolo Gambassini, Margherita Mussi, Marco Peresani
Digital cartographic base: Giuseppe Cremona (Daniela Peritenti)
Active faults: Eutizio Vittori (Francesca Giardina)
0 50 100 km
1:1,000,000
Bologna, 2004
© Copyright Museo Geologico Giovanni Capellini, Bologna 2004
Printed with the contribution of the European Commission


CLIMEX MAPS ITALY
project sponsored by Enea,
directed by C. Margottini & G.B. Vai
LITHO-PALAEOENVIRONMENTAL MAPS OF ITALY
DURING THE LAST TWO CLIMATIC EXTREMES
Map 2 - HOLOCENE CLIMATIC OPTIMUM
(8 ± 1 ka cal BP)
average surface air temperature of about 2°C higher than today
Synthetic Legend
(see Explanatory Notes for other symbols)
Radiometrically or stratigraphically dated control sites
Archaeology
12 Beaches
Ostracods
Stratigraphy
Diatoms
Active volcanoes
Active faults
Shoreline
Foothills and plains
Moreno arcs of Pleistocene age
Inactive stable surfaces
Undifferentiated inactive surfaces and active plains
Active alluvial plain of the Alpine-Venetian margin (partly calcareous sediments)
Active alluvial plain of the Apennine margin (mainly siliciclastic fine sediments)
Active alluvial plain of the Po river and its Alpine tributaries
Sea-head deltas
Lagoon/estuary
Glaciers and water bodies
Glaciers
Lakes
Vegetational zones
Discontinuous vegetation and grassland
Timberline
Forests, mires and salt marshes
Sea-surface temperature (°C)
Computed from spelean serpulids
12.82
Computed from planktic foraminifera
Inferred isolines
12.09
12.15
12.82
12.62
14.00
13.20
13.90
13.04
13.62
13.03
13.75
15.00
13.91
13.83
14.16
13.70
13.92
14.50
15.00
17.00
17.74
17.04
16.01
16.09
17.11
11°
13°
15°
17°
Scientific and map editing: Gian Battista Vai and Luigi Cantelli
Legend edited by
Fabrizio Antonioli, Stefano Marabini, Cesare Ravazzi, Gian Battista Vai
Thematic and regional authors (and other contributors):
Glaciers: Giuseppe Orombelli, Carlo Giraudi
Vertebrates: Benedetto Sala (Lisa Govoni)
Ostracods: Elsa Gliozzi, Costanza Faranda
Serpulids: Sergio Silenzi
Lakes: Piero Guilizzoni (Andrea Lami, Aldo Marchetto, Daniel Ariztegui)
Vegetation: Cesare Ravazzi
Po Plain and other alluvial plains: Alessandro Amorosi, Stefano Marabini, Carlo Dal Grande
Apennine foothills: Stefano Marabini, Gian Battista Vai
Marine bathymetry and bottom morphology: Luigi Vigliotti
Shoreline: Fabrizio Antonioli, Alessandro Amorosi
Alpine foothills: Cesare Ravazzi, Paolo Mozzi, Antonella Astori, Katiuscia Discenza, Corrado Venturini
Sea surface temperature: Lucilla Capotondi
Archaeology: Paolo Gambassini, Margherita Mussi, Marco Peresani
Active faults: Eutizio Vittori, Francesca Giardina
UTM Projection, Zone 33
1:1,000,000


ITALIA 2004
32nd INTERNATIONAL GEOLOGICAL CONGRESS
Florence – ITALY
CLIMEX MAPS
EXPLANOTARY NOTES

CLIMEX MAPS ITALY
project sponsored by Enea and directed by C. Margottini & G.B. Vai

LITHO-PALAEOENVIRONMENTAL MAPS OF ITALY DURING THE LAST TWO CLIMATIC EXTREMES

Map 1 - LAST GLACIAL MAXIMUM (22 ± 2 ka cal BP) average air temperature of about 4.5°C lower than today
Map 2 - HOLOCENE CLIMATIC OPTIMUM (8 ±1 ka cal BP) average surface air temperature of about 2°C higher than today
1:1,000,000 scale

EXPLANATORY NOTES

By

Amelia Aceti (Milan), Alessandro Amorosi (Bologna), Fabrizio Antonioli (Rome), Daniel Ariztegui (Geneva), Giorgio Belluomini (Rome), Luigi Cantelli (Bologna), Lucilla Capotondi (Bologna), Mauro Cremaschi (Milan), Anna Correggiati (Bologna), Saverio Devoti (Rome), Sandro Demuro (Cagliari), Paolo Gambassini (Siena), Carlo Giraudi (Rome), Elsa Ghiozzi (Rome), Lisa Govoni (Ferrara), Giuseppe Groppelli (Milan), Piero Guilizzoni (Verbania), Kurt Lambeck (Canberra), Andrea Lami (Verbania), Stefano Marabini (Faenza), Mauro Marchetti (Modena), Aldo Marchetto (Verbania), Claudio Margottino (Rome), Ruggero Marocco (Trieste), Carmelo Monaco (Catania), Adriana Moroni (Siena), Paolo Mozzi (Padua), Margherita Mussi (Rome), Giuseppe Orombelli (Milano), Paolo Orrù (Cagliari), Rossella Pagliarulo (Bari), Marco Peresani (Ferrara), Cesare Ravazzi (Milan), Benedetto Sala (Ferrara), Sergio Silenzi (Rome), Giorgio Tanzi (Milan), Gian Battista Vai (Bologna), Luigi Vigliotti (Bologna), Eutizio Vittori (Rome)

Edited by

Fabrizio Antonioli and Gian Battista Vai

Bologna 2004

Sea Level at 8 and 22 ka cal BP on Italian coastline

Antonioli F.[1], Lambeck K.[2], Amorosi A.[3], Belluomini G.[4], Correggiari A.[5], Devoti S.[6], Demuro S.[7], Monaco C.[8], Marocco R.[9], Pagliarulo R.[10], Orrù P.[7], Silenzi S.[6]

[1]ENEA, Via Anguillarese 301, 00060 Roma, fabrizio.antonioli@casaccia.enea.it
[2] Research School of Earth Sciences, National Australian University, Canberra, ACT 0200, Australia
[3] Bologna University, Dip. di Scienze della Terra, Via Zamboni 67 - 40127 Bologna
[4]CNR, Laboratorio di radiodatazioni e Geochimica, Montelibretti, 00100 Roma
[5]CNR ISMAR- C.N.R. Sezione di Geologia Marina di Bologna, Via Gobetti 10-40129 Bologna
[6]ICRAM Central Institute for Marine Research, via Casalotti 300, 00166, Roma
[7]Dipartimento di Scienze Geologiche, Università di Cagliari,
[8] Catania University,Dipartimento di Scienze Geologiche ,Corso Italia 55, Catania
[9]Trieste University,Dipartimento di Scienze Geologiche, Ambientali e Marine,
[10]CNR- Istituto di Ricerca per la Protezione Idrogeologica- Bari

1. Method

Sea level change along the Italian coast is the sum of eustatic, glacio-hydro-isostatic, and tectonic factors. The first is global and time-dependent while the latter two also vary with location. In order to drawn the palaeocostline at 8 and 22 ka cal BP we used data published from Lambeck et al., 2004. This paper contain exhaustive description of ice-volume-equivalent sea level (**esl**) values, models, observed data and error bars of the marker used for the Italian sea level change occurred during last 20 ka.

"The dominant pattern of the sea levels for all epochs is determined by the hydro-isostatic contribution, with the sea basin floor subsiding under the additional water load. Thus observed sea levels from the island sites such as Pantelleria, between Sicily and Tunisia, Marettimo and Sardinia, should exhibit lower levels than sites on the Italian Peninsula for the same epoch. Along the central Tyrrhenian coast, between about Argentario and Palinuro, the isobases are nearly parallel to the shore and data from different locations can be combined into a composite regional sea-level curve if desired.

But this is not the case for the Adriatic coast where the glacio and hydro isostatic contributions combine to produce a well-defined north–south gradient such that levels in the northern Adriatic lie persistently above those further south. At 10 ka BP the isobases range from about 55 to 35 m below present level but the shallowest values occur where the sea has not yet encroached. Only by about 8 ka does the Adriatic take its present form. At 6 ka BP the sea levels begin to approach present-day values but the spatial variability remains significant, coastal levels ranging from -2 m at Gabes to -9 m in Sicily and Calabria. At the Roman period, 2 ka BP, levels fluctuated from about 0.5 in the north of the Adriatic to as low as 1.8 m in parts of Sardinia." from Lambeck et al., 2004. The esl values used for 8 and 20 ka shorelains are -13 and -149 m, see fig 12 of Lambeck et al., 2004, Fig. 1 and 2.

In this short note are described the sea level markers used in Italy to validate the Lambeck's

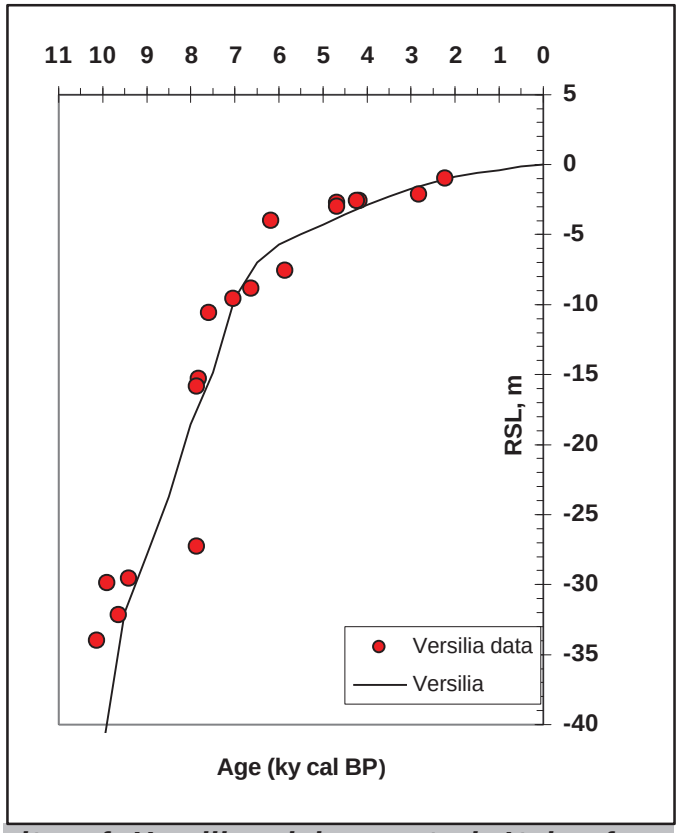


Fig. 1 Predicted sea level curve and observed data for the tectonically stable site of Versilia plain, central Italy, from Lambeck et al., 2004.

model., all calibrated with the same method (Bard, 1998) and studied on stable coastline (with the exception of Sybari and del Volturno sites). The 8 ka shorelines on the whole important delta coastal area was corrected on the basis of the presence of cores radiocarbon data (see numbers on the map). As regard the 20 ka shorelines it is important to underline that are not published observed data to confirm the predicted data by Lambeck that we used.
Such methodology is subject to error bars (model and ^{14}C ages) the positioning of the shorelines marked on the maps are intended as a first approximation.
The more complete the data set has been sampled on numerous cores in the northern Adriatic sea (Correggiari et al., 1997). Twenty-seven dates from 60 continuously-cored boreholes drilled in the subsurface of southeastern Po Plain provide the basis for detailed reconstruction of coastal paleogeography at 8 ka cal BP (Amorosi et al., 1999; 2003; in press). Data sampled on cores on Versilia, Cagliari and Sibari Plain was very useful for test and refine the Lambeck's model for Italy.

2. Data

The numbers in bold correspond to those marked into the HCO map.
1 Versilia ENEA core. It is an important data set: a core crossed 34 m of Holocene lagoonal sediments, sixsteen ^{14}C analyses allowed to built a precise Italian Holocene sea level curve. Two papers describe this stable site: Antonioli et al., 1999 and Nisi et al., 2004. On fig. 1 are compared the predicetd sea level curve of Lambeck et al., 2004, with the observed lagoonal radiocarbon data.
2 Argentarola speleothems. Sampling and aging serpulids overgrowths that coverd submerged speleothems allowed to reconscrutct a sea level rise data at the Argentario promontory during last semiglacial cycle. The samples were collected by scuba diving at depths from 3.5 to 21.7 m measured with a digital depth gauge Age control is provided by radiocarbon ages on marine and continental layers of the speleothems and range from 6.5 to 9.6 ka cal. BP (Alessio et al., 1992,1996; Bard et al., 2002; Antonioli et al., 2004.
3 Roma. "The data at this site comes from cores drilled 2 km apart, east from the present-day coastline of the prograding Tevere Plain near the silted-up ancient Roman harbour.Belluomini et al. (1986) used sea-level markers consisting of ^{14}C-dated peat, marsh and wood fragments found between –3 and –31 m. The corresponding calibrated ages are in the interval 5.9 - 11 ka cal. BP" from Lambeck et al., 2004.
4 Fondi. The Fondi Plain is a small coastal plain bordered by limestone relief, with outcroppings of Pleistocene and Holocene alluvial, aeolian, lagoon, and marine deposits.Samples containing *Cerastoderma* at -1.8 m previously gave an ^{14}C

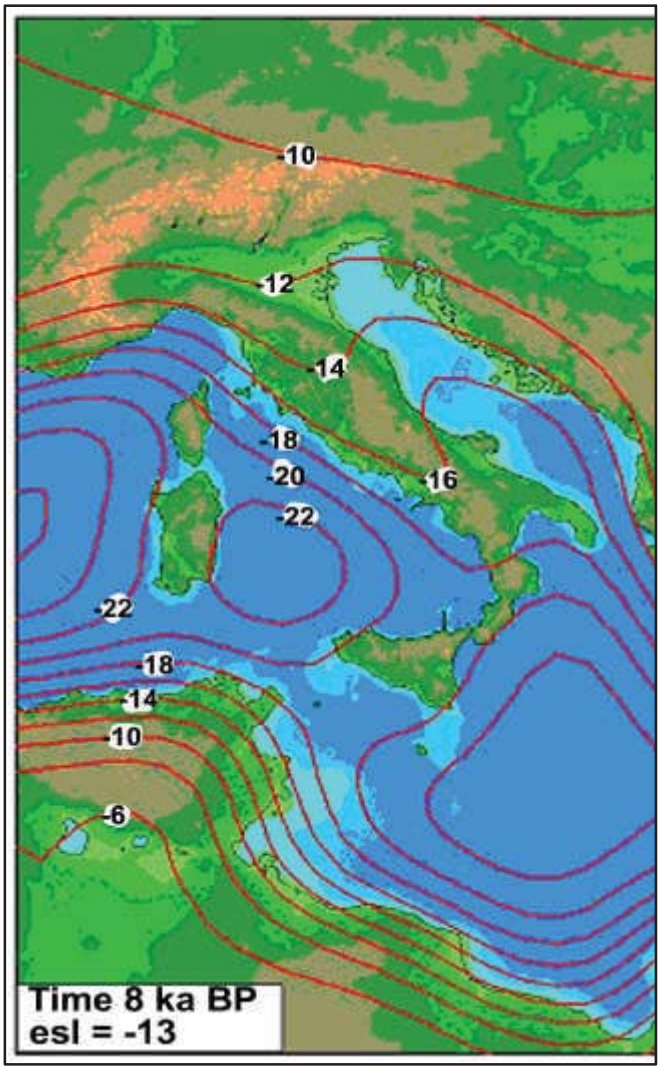


Fig.2a Palaeogeographic reconstructions at 8 and 20 ka cal BP for Italy. The red (negative) contours refer to the sea level change. Palaeo water depths are indicated by the change in shades of blue at depths of 25, 50, 100, 150 and 200 m. The ice-volume-equivalent sea level (esl) value are given in meters (from Lambeck et al., 2004).

age of about 7.5 ka cal. BP (Antonioli et al., 1988). More recently a continuously cored borehole was drilled (Devoti et al., 2004; Lambeck et al., 2004) near the outcrops that intersected marine sediments that filled a palaeo-valley carved during the LGM, at about 0.75 km inland from the present-day shoreline (N 41°18'12'' - EGw 13°17'24''). The core was detailed with sedimentological and micro-

palaeontological analysis; moreover, eleven biomarker samples (8 shell fragments, 1 peat sample, 1 *Cerastoderma glaucum* valve and 1 fragment of *C. caespitosa*) were collected for chronology with ^{14}C AMS dating. The dated samples were correlated with backshore deposits and shallow marine environment

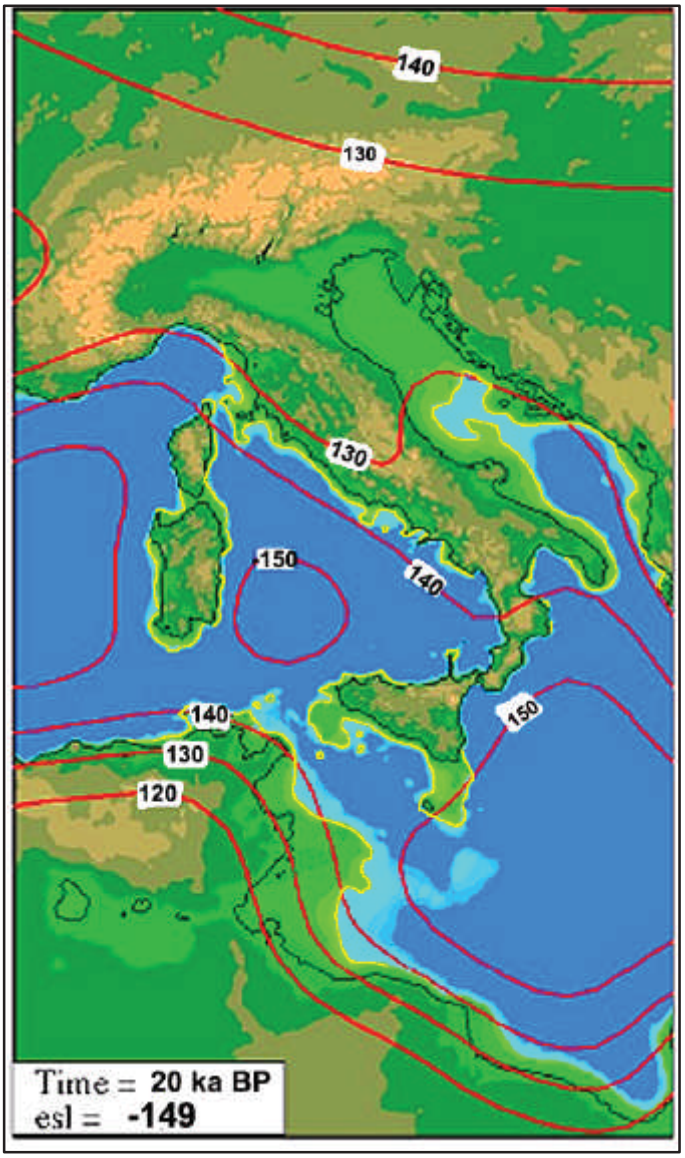


Fig.2b Palaeogeographic reconstructions at 20 ka cal BP for Italy (from Lambeck et al., 2004).

deposits; the palaeobathimetry of these samples may be estimated at about +2/-4 m. Marine shells between -3 and –33.7 m yielded calibrated ages in the interval 7.4 – 8.6 ka cal BP.

5 Volturno Plain. "The Volturno River coastal plain formed during the Holocene as a complex of beach-ridges and flat back-barrier depressions
with lagoonal sedimentation. Lagoonal facies have been found in a core located at 2.5 km from the present beach over a depth range of 10 m. Radiocarbon ages of peats found in this core are given by Barra et al. (1996) and the calibrated ages span the interval from 4.8 ka at –3 m to 7.4 ka BP at -8 m " from Lambeck et al., 2004.

6 Palinuro Promontory.The analyses on serpulids overgrowths that coverd submerged speleothems in sea caves at Palinuro promontory allowed to reconscruct the sea level rise data at Palinuro promontory during Holocene. The samples were collected by scuba diving at depths from -18 to -49 m measured with a digital depth gauge Speleothems from the Scaletta cave were sampled at depths between 27 and 48 m and yielded ages from 8.4 to 10.2 ka cal. BP (Alessio et al., 1992,1996, Antonioli & Oliverio 1996).

7 Catania Plain. A stratigraphic and sedimento-logical study, accompanied by ^{14}C AMS dating, has been carried out by means of three boreholes in the most depressed coastal sector of the Catania Plain, the Pantano di Lentini. The boreholes showed that clear lagoon deposits, constituted by dark organic silts, are present only in the upper 2-3 m. Moreover, ^{14}C AMS dating on pulmonate gastropod indicated an age not older than 2.5 ka for these deposits. The remaining sediments, down to the Lower-Middle Pleistocene marly clayey substratum reached at depths variable between -20 and -39 m, are represented by infralitoral beach deposits containing rare lagoon levels. The ^{14}C AMS dating on shell fragments collected at various depths suggested an Holocene age, between 6.4 and 9.3 ka, for these deposits (Monaco et al., 2004).

8 Sybari Plain. "Archaeological excavations on the Sybari alluvial plain have led to the identification of three superimposed levels of occupancy from the 6th to the 1st century BC: the ancient Greek town of Sybaris, the Hellenistic town of Thurium, and the Roman Copia. This plain forms a graben that runs in an ENE-WSW direction, bordered by regional fault systems. The upper part of this depression is filled with ~ 400 m of deposits consisting of sands including fine clay-sands, coarse gravels and peat levels at various depth. A core from the plain yielded ^{14}C-based ages in the interval 5.3 to 11.1 ka cal. BP for peats and marsh deposits from depths of 3 to 55 meters below sea level (Cherubini et al., 2000)", from Lambeck et al., 2004.

9 North Adriatic. "The northern part of the Adriatic Sea is characterised by a shallow sea-bottom morphology (at 30-50 m depth) with sediments deposited by the Po River in the immediate offshore area. The low shelf gradient and the lower sediment input near the central part of the basin results in significant landward shifts of depositional environments at times of sea-level rise. In consequence, successive backstepping sequences do not completely overlap. Furthermore, transgressive deposits are not always covered by younger highstand

sediments and they can, therefore, be selectively sampled using conventional gravity and piston coring (Correggiari et al., 1997). Sediment cores from a number of sites have yielded 23 depth-age data points within the depth interval from 26 to 52 m with radiocarbon-based ages of 9.3 to 12.9 ka cal. BP." from Lambeck et al., 2004.

10 Po Plain. A very high-resolution stratigraphic framework for the subsurface of the Po Plain has been constructed in the last decade on the basis of 27 ^{14}C dates from several tens of cores, at 40-200 m depth, which were made available by the Geological Survey of Regione Emilia-Romagna. This excellent data set provides a unique opportunity to depict the complex scenario of transgressive depositional environments during the Holocene in the subsurface of Ravenna (Amorosi et al., 1999), Ferrara (Amorosi et al., 2003) and Rimini (Amorosi et al., 2004) coastal areas, showing evolution from an early transgressive coastal plain/lagoonal environment (12-10 ka cal BP) to a backstepping barrier-lagoon system, with lateral transition to a wave-dominated estuary (up to approximately 7 ka cal BP); this was followed by extensive delta progradation during the ensuing highstand phase. Reconstruction of 3-D stratigraphic architecture beneath the modern coastal plain, combined with radiometric data from inland locations (Preti, 1999; Amorosi et al., in press) enables a precise identification of shoreline position at 8 ka cal BP, with a further distinction between the nearshore zone (boundary between marine and brackish-water environments) and the inner margin of the lagoon/estuary (boundary between brackish and continental environments).

11-12 Caorle an Marano Plains. "Several cores have been drilled in different lagoons between Venice and Trieste in which lagoonal shells and marsh deposits have been identified. Radiocarbon analyses indicate ages from 0.9 to 9 ka cal. BP at elevations of –0.90 to –8.30 meters (Marocco,1989; Galassi and Marocco, 1996)" from Lambeck et al., 2004.

13 Cagliari Plain. Tree cores have been drilled in lagoonal-marine sediments, in which lagoonal shells have been identified. Radiocarbon analyses indicate ages from 2 to 10.4 ka cal PB at elevations of -2 and -32m. The predicted sea level curve of this site is in particular agreement with observed data (Orrù et al., 2004).

14 Sardinian beachrock. "A great number of well-conserved palaeo-shorelines have been discovered in northern Sardinia on the continental shelf up to depths of -120 m. De Muro and Orrù (1998) observed beach deposits (sandstone and conglomerates) on an erosional platform of crystalline bedrock at depths ranging from 0 to 55 meters from two main localities; Orosei and northern Sardinia. The chronology has been established from ^{14}C dating of the carbonate matrix that was considered to correspond to early-stage magnesium-calcite cementation, with samples ranging in age from 0.2 up to 9.7 ka cal. BP at progressively deeper depths of 0 to 29 m below present sea level" from Lambeck et al., 2004.