«Climate Change Risk Assessment»

ΙΩΑΝΝΗΣ ΠΑΠΑΝΙΚΟΛΑΟΥ

ΕΠΙΚΟΥΡΟΣ ΚΑΘΗΓΗΤΗΣ
ΤΟΜΕΑΣ ΓΕΩΛΟΓΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
ΤΜΗΜΑ ΑΞΙΟΠΟΙΗΣΗΣ ΦΥΣΙΚΩΝ ΠΟΡΩΝ ΚΑΙ ΓΕΩΡΓΙΚΗΣ ΜΗΧΑΝΙΚΗΣ
ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ΥΠΟΥΡΓΕΙΟ ΓΕΩΡΓΙΑΣ, ΑΓΡΟΤΙΚΗΣ ΑΝΑΠΤΥΞΗΣ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

ΤΜΗΜΑ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

ADVANCED ENVIRONMENTAL STUDIES S.A.

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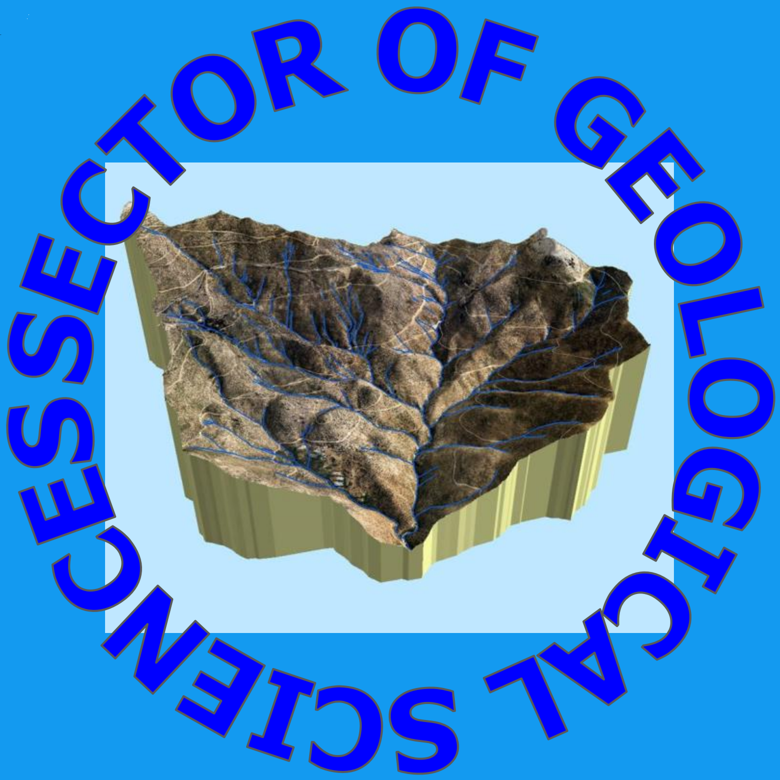
AGRICULTURAL UNIVERSITY OF ATHENS

6 Οκτωβρίου 2016



Γεωλογικοί Κίνδυνοι και Κλιματική Αλλαγή Σεισμοί - Κατολισθήσεις- Καθιζήσεις

ΙΩΑΝΝΗΣ ΠΑΠΑΝΙΚΟΛΑΟΥ

Ass. Professor,

Natural Hazards

365 bn US$

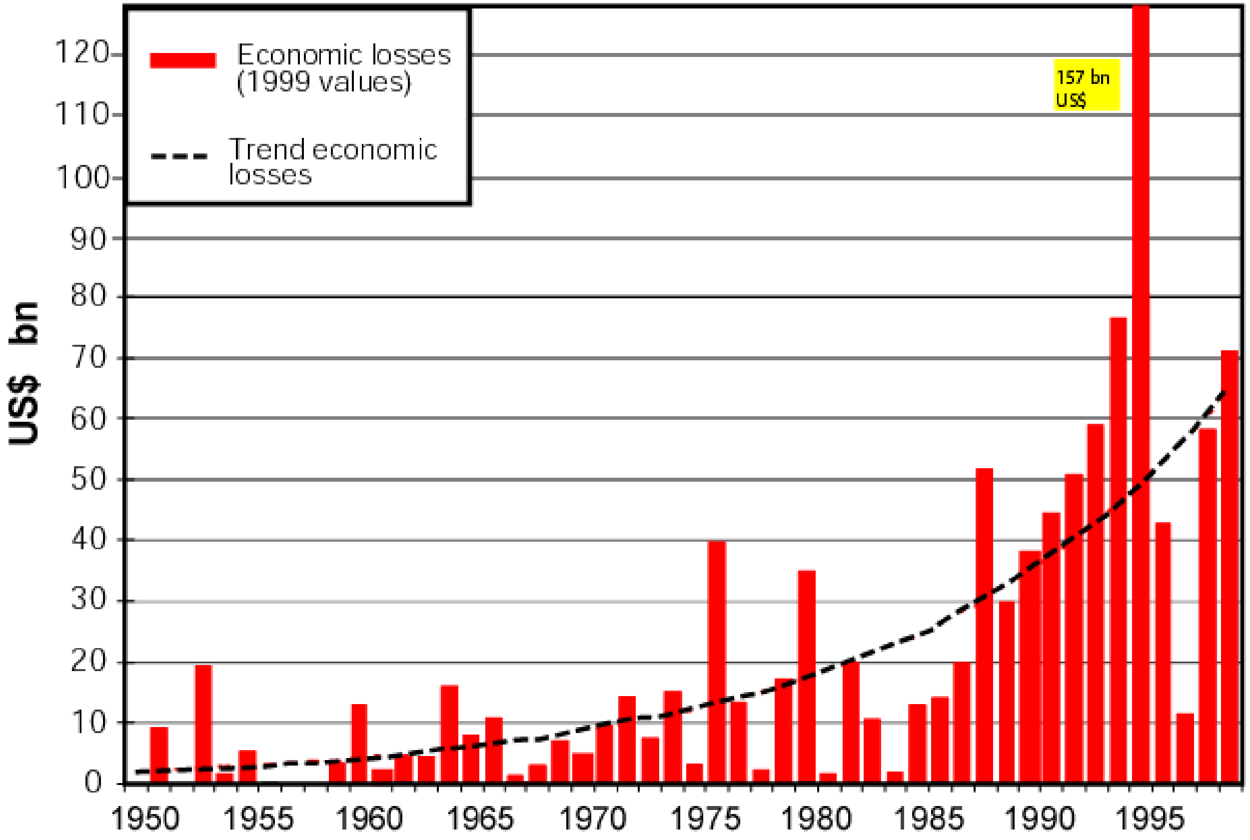


Figure 1.1 Chart showing the development of economic losses (in US dollars projected to 1999 values) due to great natural catastrophes since 1950 (After Munich Re Group, 1999).

…. 2011

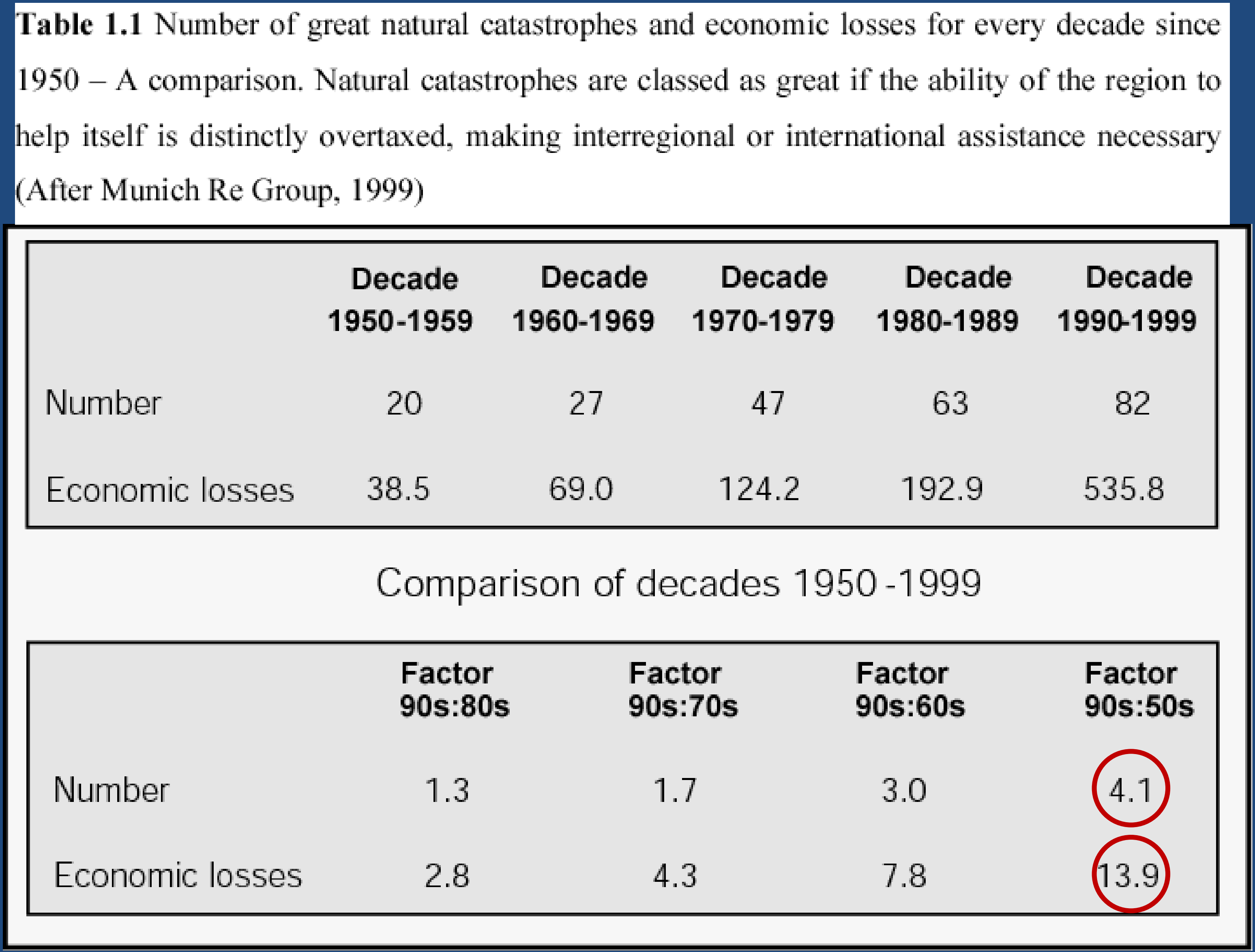


Table 1.1 Number of great natural catastrophes and economic losses for every decade since 1950 – A comparison. Natural catastrophes are classed as great if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary (After Munich Re Group, 1999)

	Decade 1950-1959	Decade 1960-1969	Decade 1970-1979	Decade 1980-1989	Decade 1990-1999
Number	20	27	47	63	82
Economic losses	38.5	69.0	124.2	192.9	535.8

Comparison of decades 1950 -1999

	Factor 90s:80s	Factor 90s:70s	Factor 90s:60s	Factor 90s:50s
Number	1.3	1.7	3.0	4.1
Economic losses	2.8	4.3	7.8	13.9

The number of “great” natural catastrophes have increased by a factor of 4 since the 1950s

Economic losses have been increased by a factor of 14

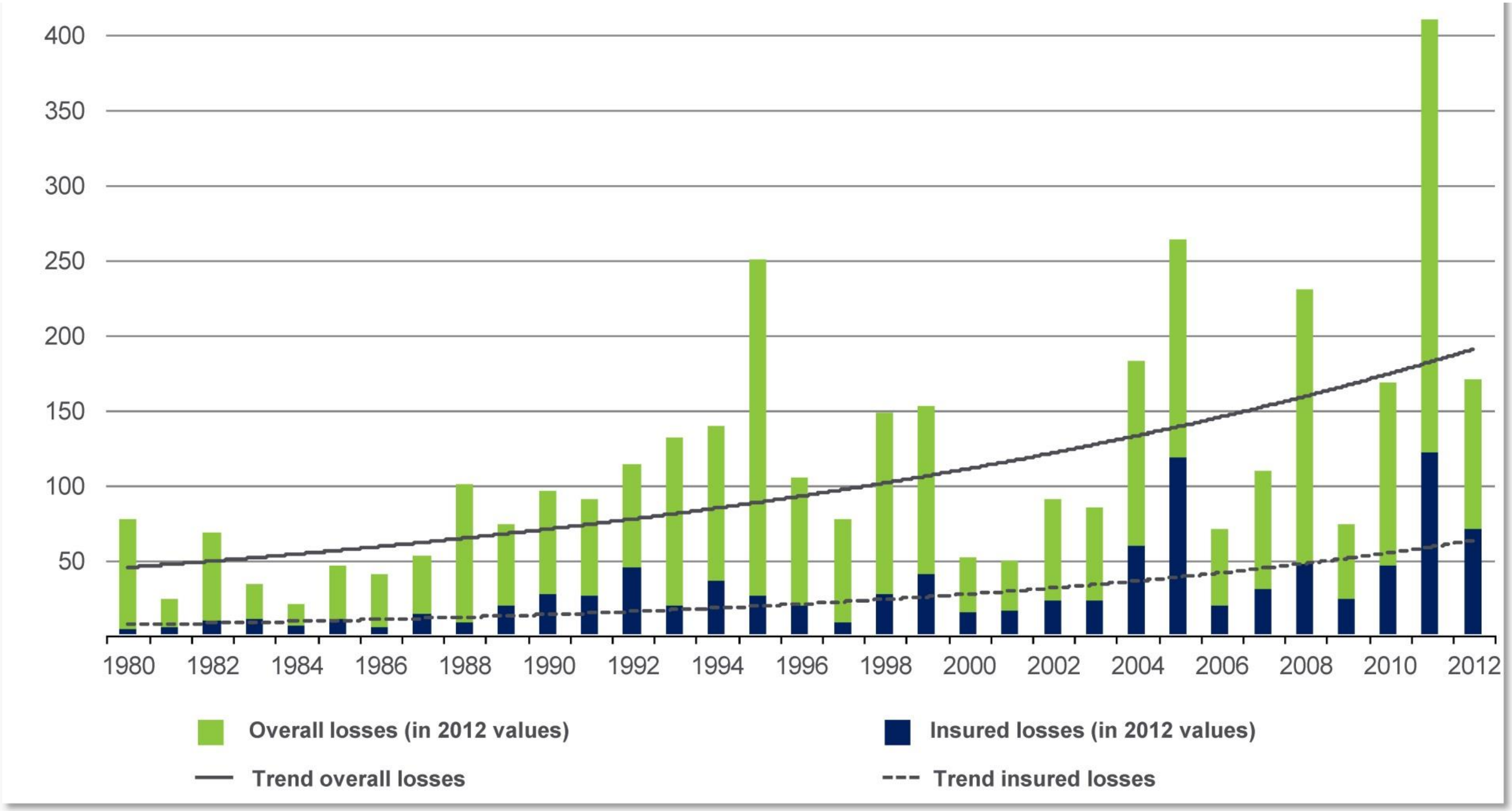
NatCatSERVICE

Natural catastrophes worldwide 1980 – 2012

Overall and insured losses with trend

Munich RE

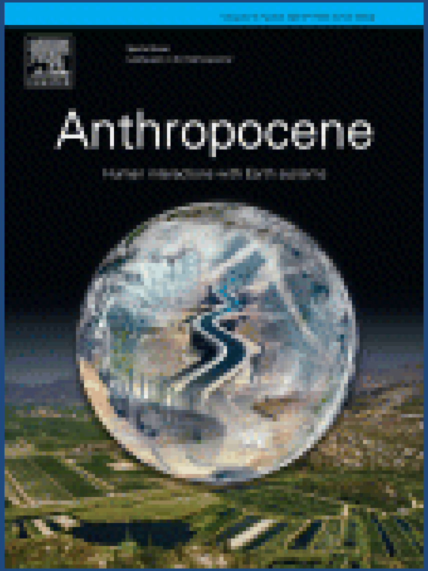
Following the year 2000 there is a two fold increase in the cost of catastrophic events since the 90ies and 3 fold increase since the 80ies



Anthropocene a new geological epoch?

Geologists today debate on whether to officially declare the existence of a new geological epoch, the “***Anthropocene***” to acknowledge that humans are radically reshaping the earth’s surface processes leading to <u>higher vulnerability</u>

More catastrophes



The Anthropocene

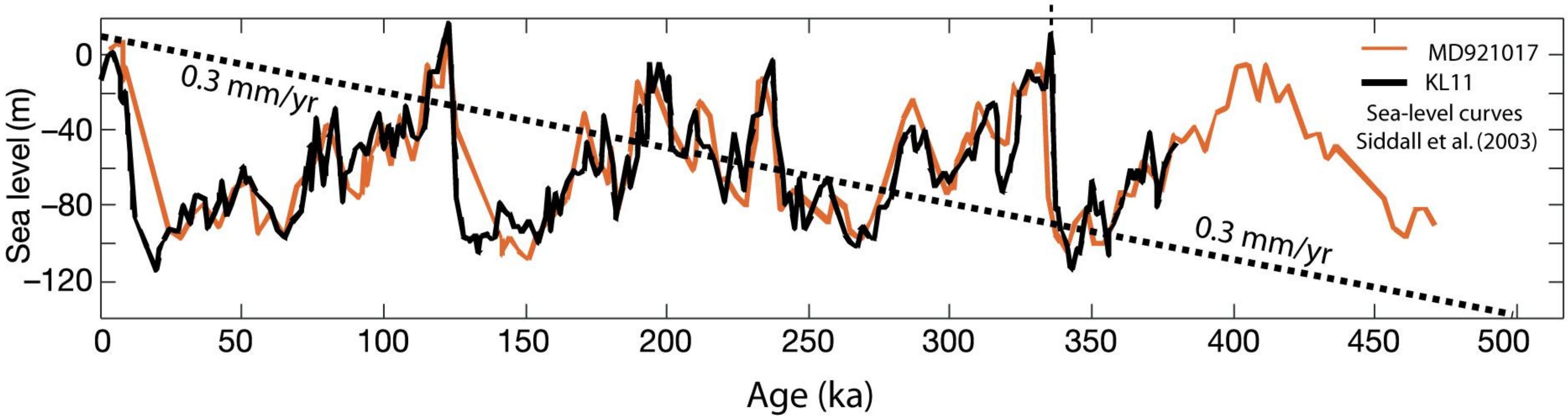
A man-made world

Science is recognising humans as a geological force to be rec

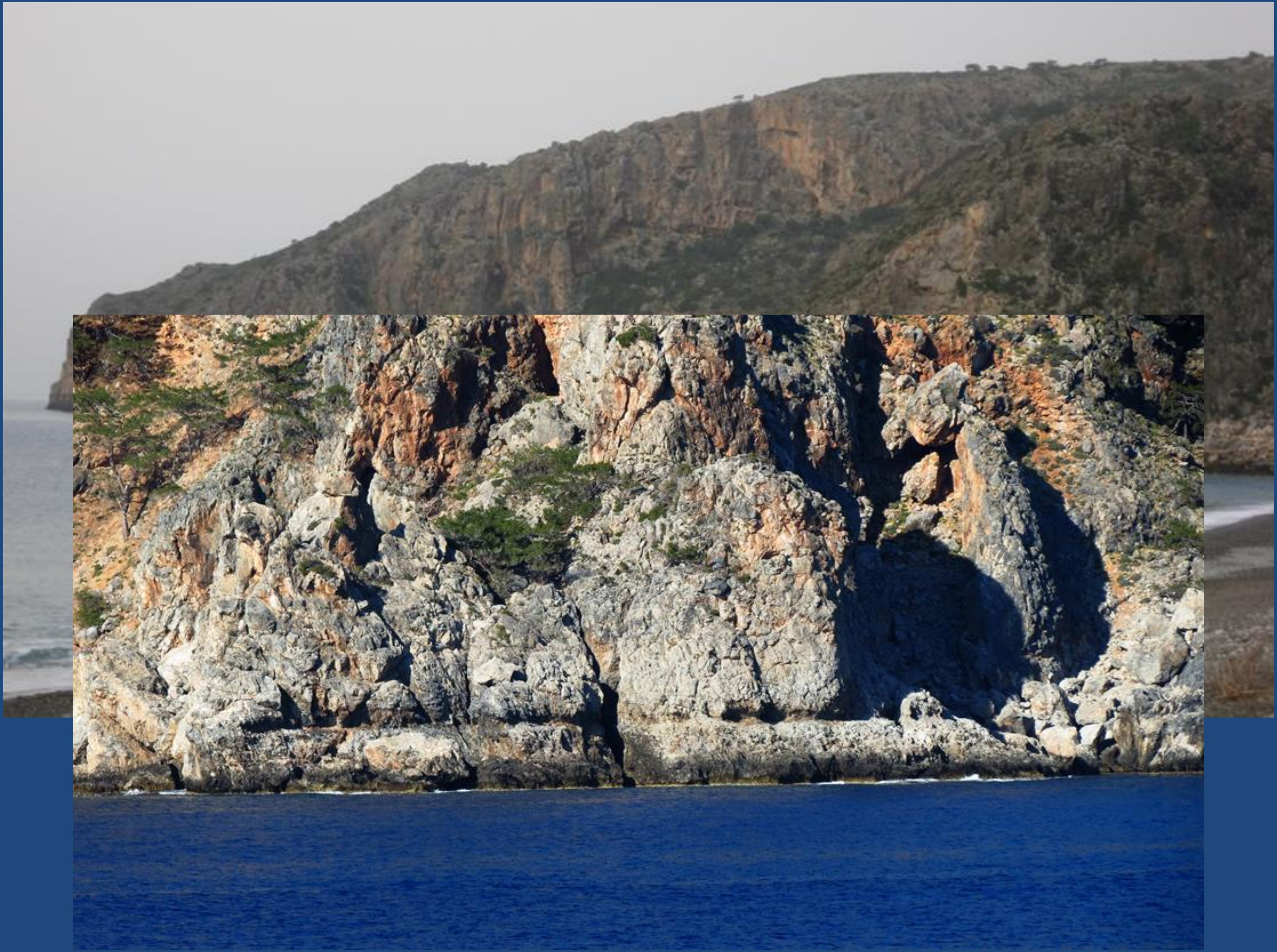
May 26th 2011 | from the print edition

THE here and now are defined by astronom
Astronomy takes care of the here: a planet
star embedded in one of the spiral arms of
galaxy that is itself part of the Virgo superc
millions of similarly vast entities dotted thro
Geology deals with the now: the 10,000-ye

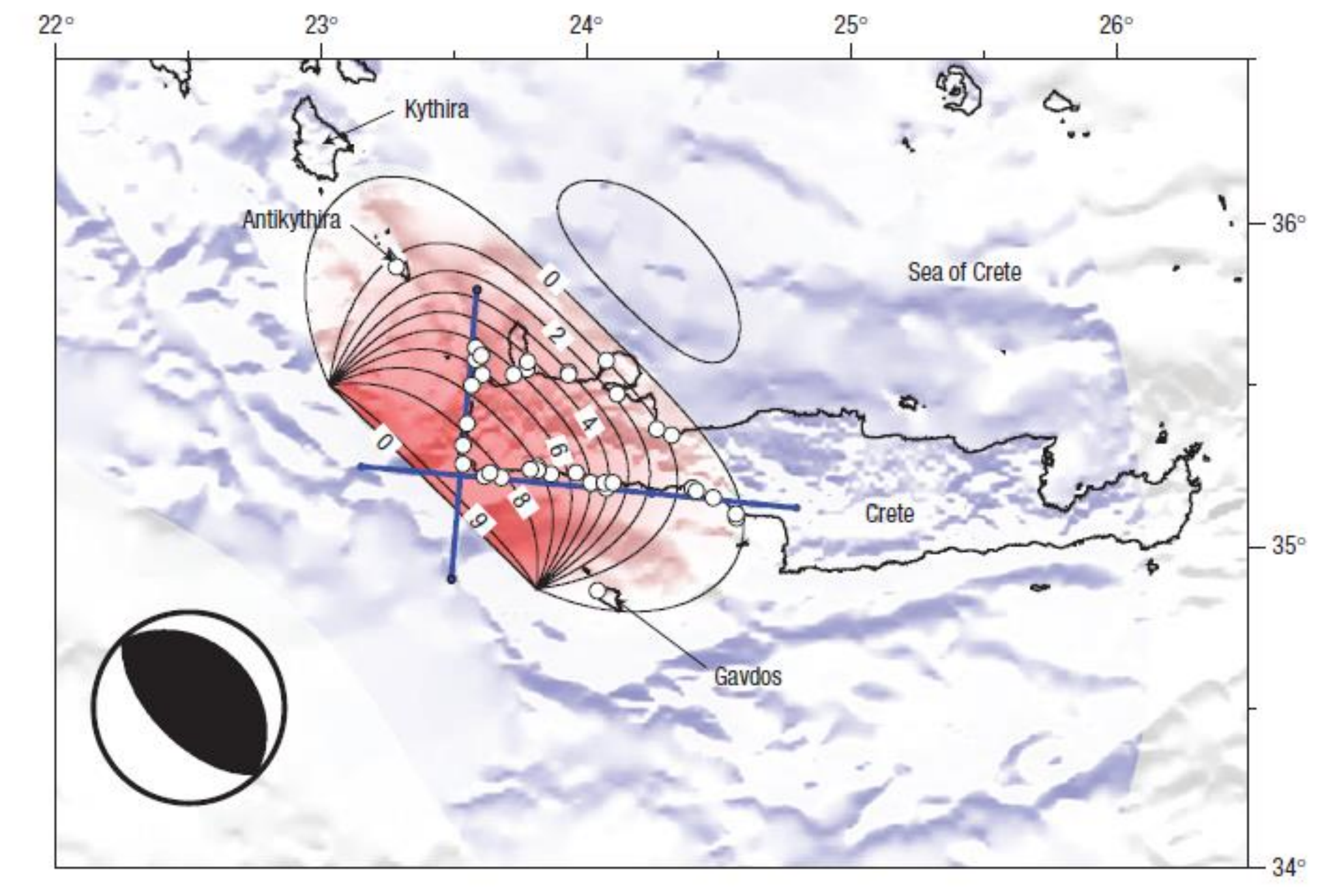
Sea level change over the last 500.000 years



Sidall et al.(2003) Nature

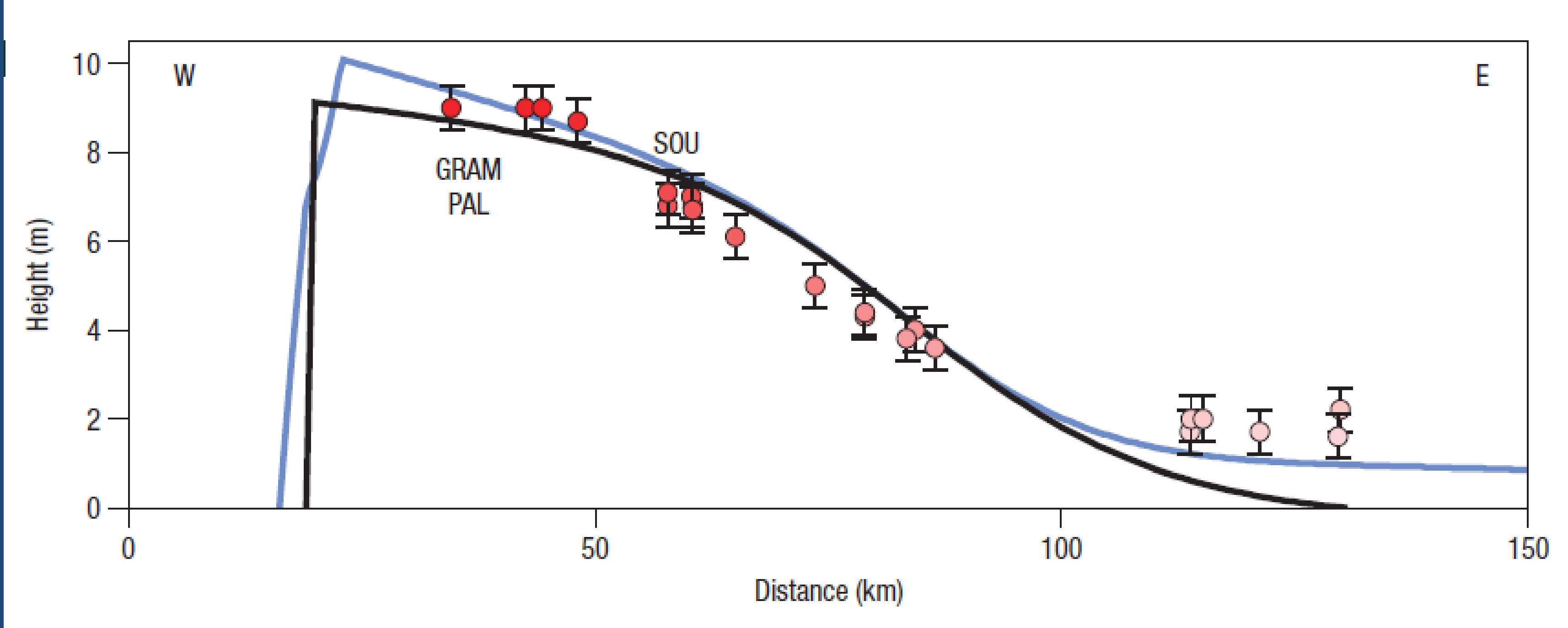


365 A.D. Earthquake in Crete M~8.2
(Hellenic Arc– Subduction zone)



Shaw et al. 2008 (Nature)

Uplift vs Distance



Shaw et al. 2008 (Nature)

Tectonic Uplift of Cyprus

- Pleistocene marine terraces

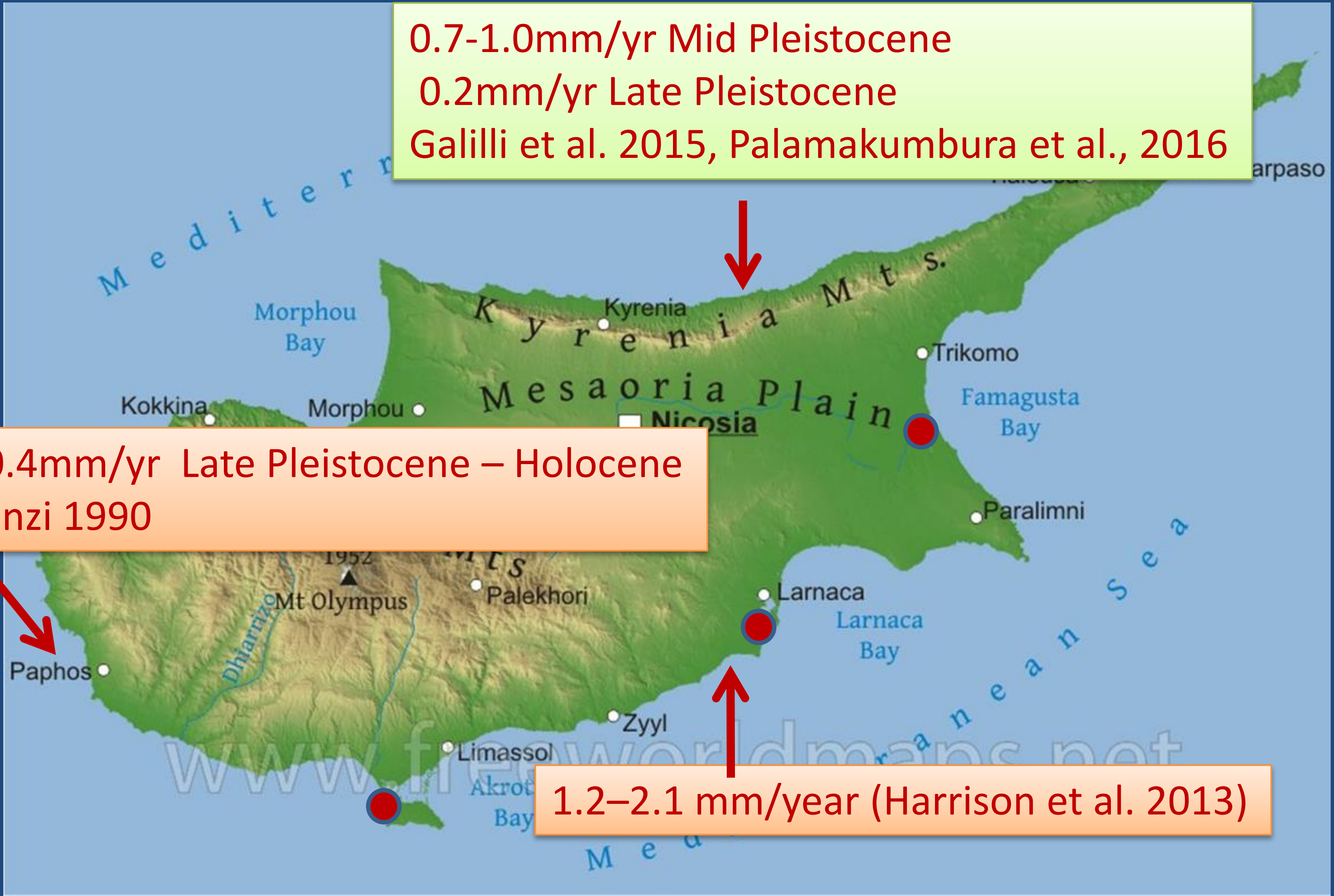
  (from 1.2-2mm/yr in Early Pleistocene with a decreasing trend in Mid and Late Pleistocene)

  (Southern Cyprus higher uplift than the Northern part)

- Holocene notches
- Archeaological sites

  (Hala Sultan Tekke, Bamboula and Enkomi

  1.1-2.7mm/yr (Gifford 1978, Harrison et al. 2013)



0.7-1.0mm/yr Mid Pleistocene
0.2mm/yr Late Pleistocene
Galilli et al. 2015, Palamakumbura et al., 2016

0.35-0.4mm/yr Late Pleistocene – Holocene
Vita Finzi 1990

1.2–2.1 mm/year (Harrison et al. 2013)

● Uplifted Archeaological sites Hala Sultan Tekke, Bamboula and Enkomi 1.1 - 2.7mm/yr (Gifford 1978, Harrison et al. 2013)

Plate Tectonics

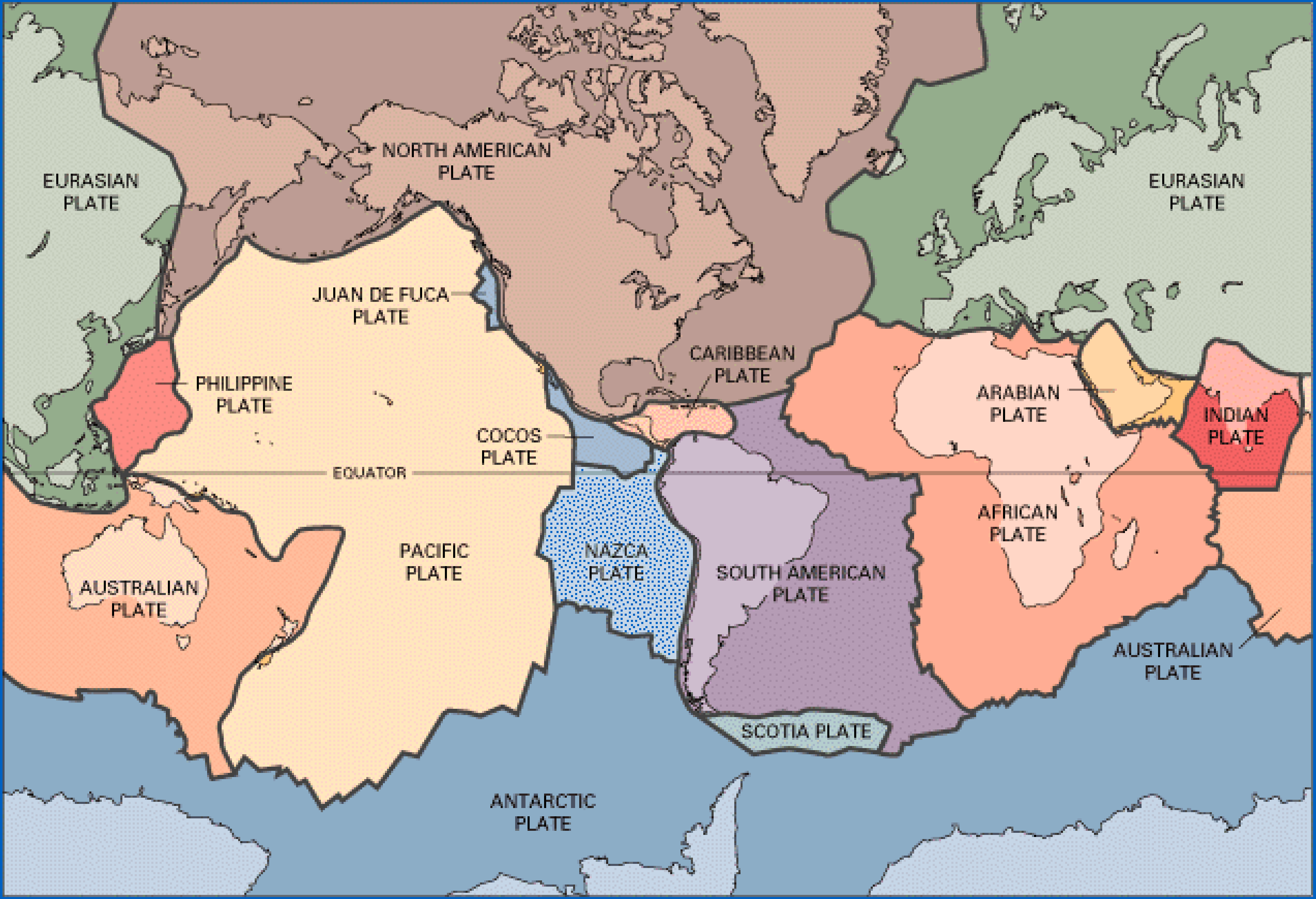
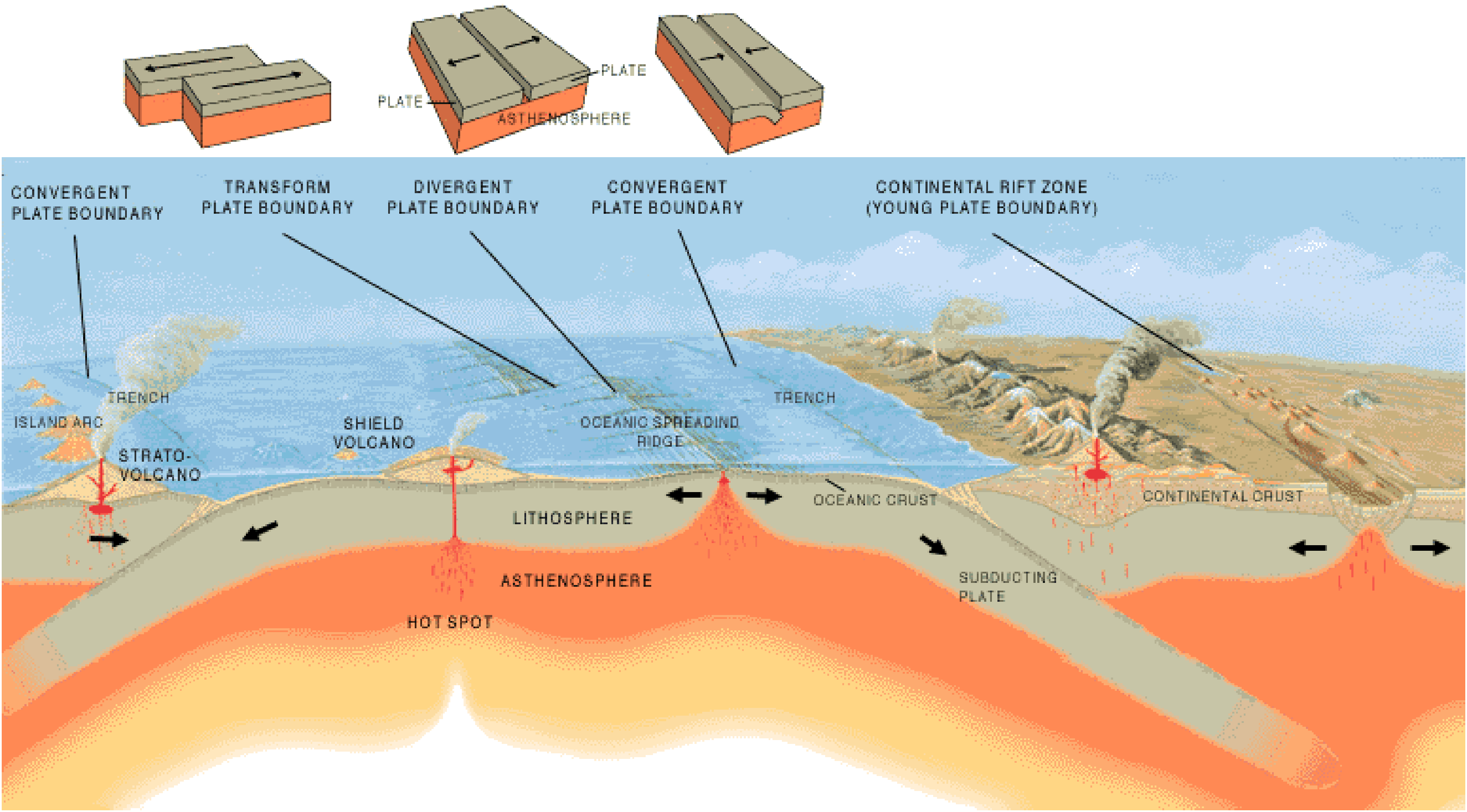


Plate Boundaries



GEODYNAMIC – TECTONIC SETTING

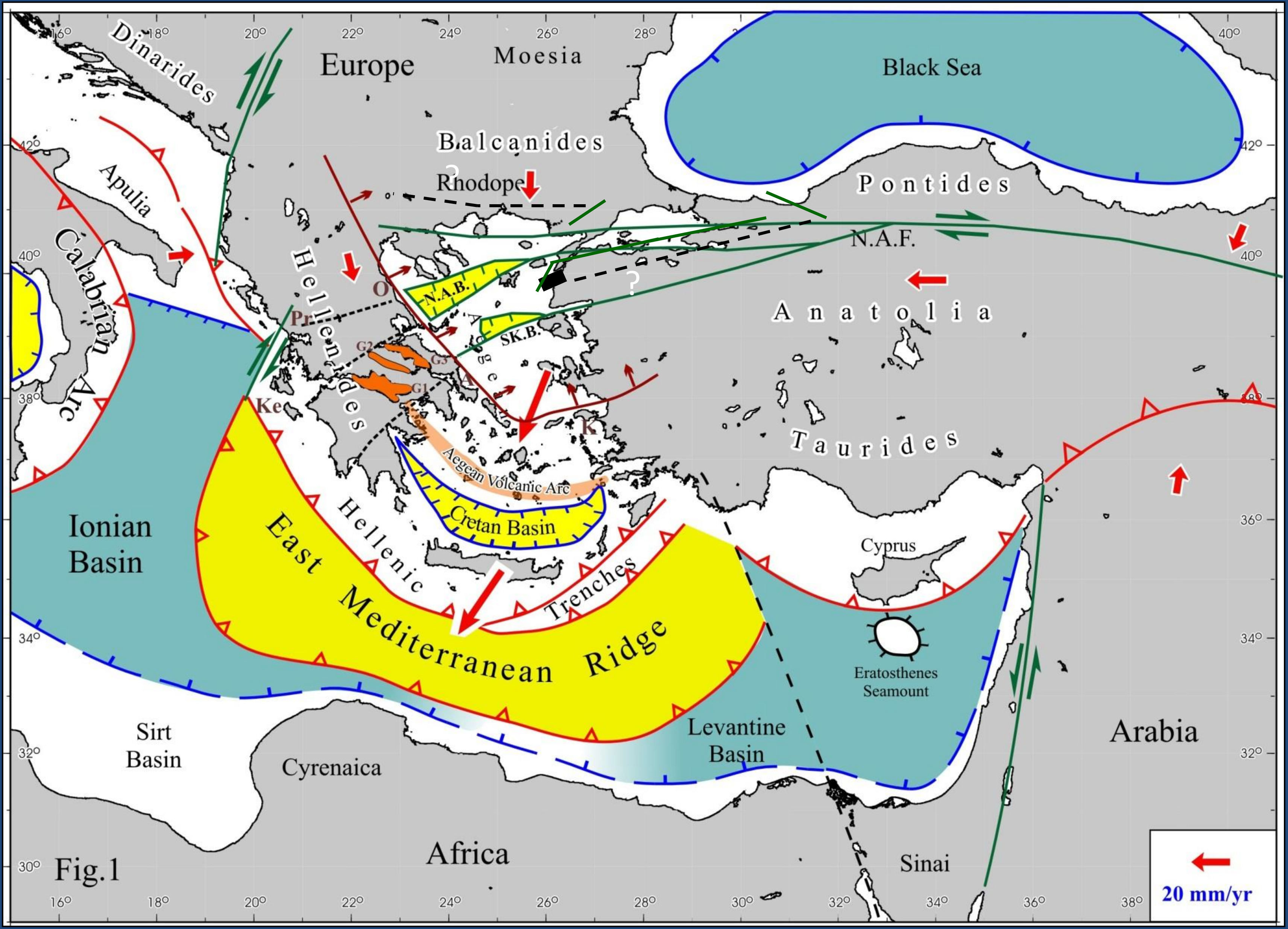
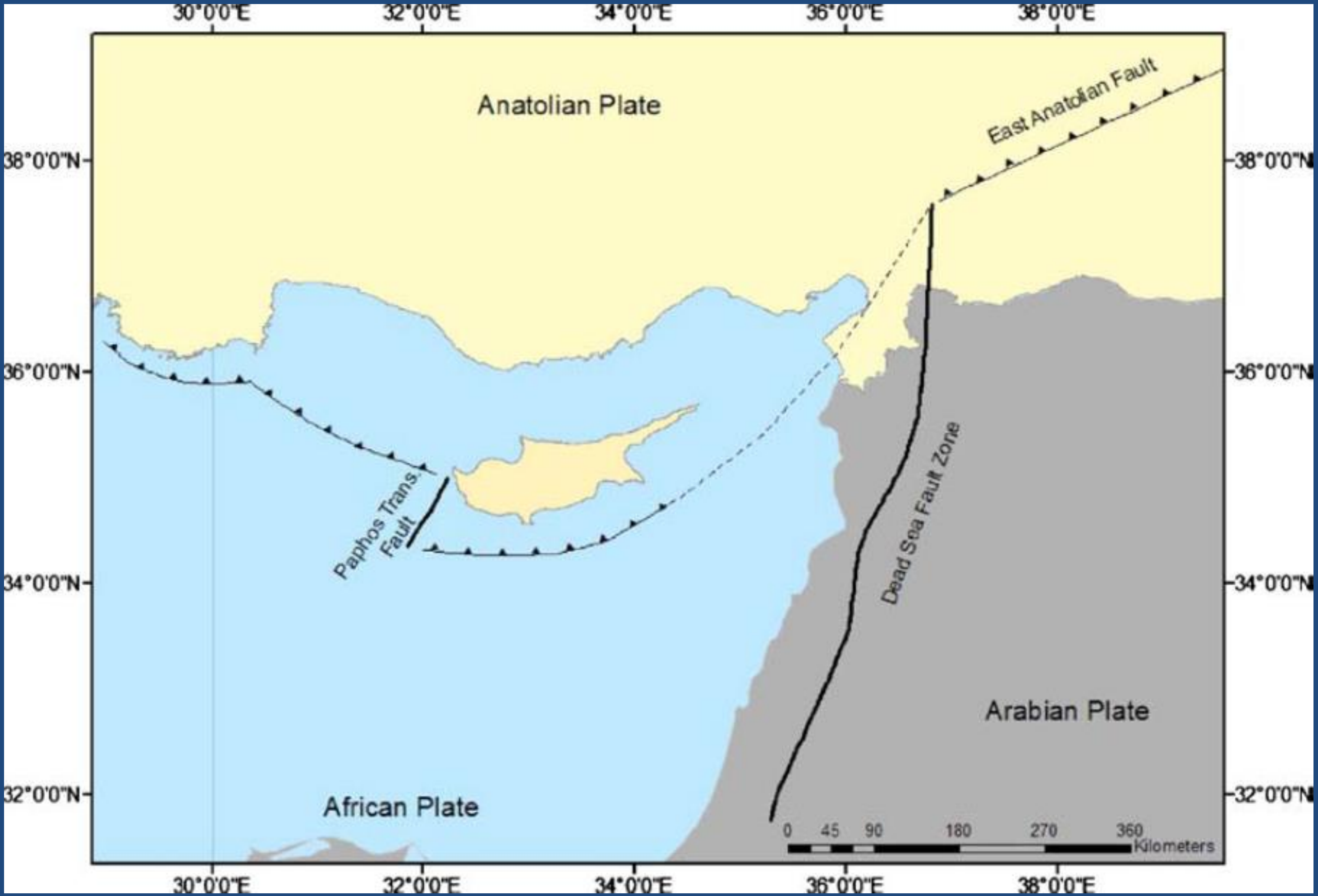
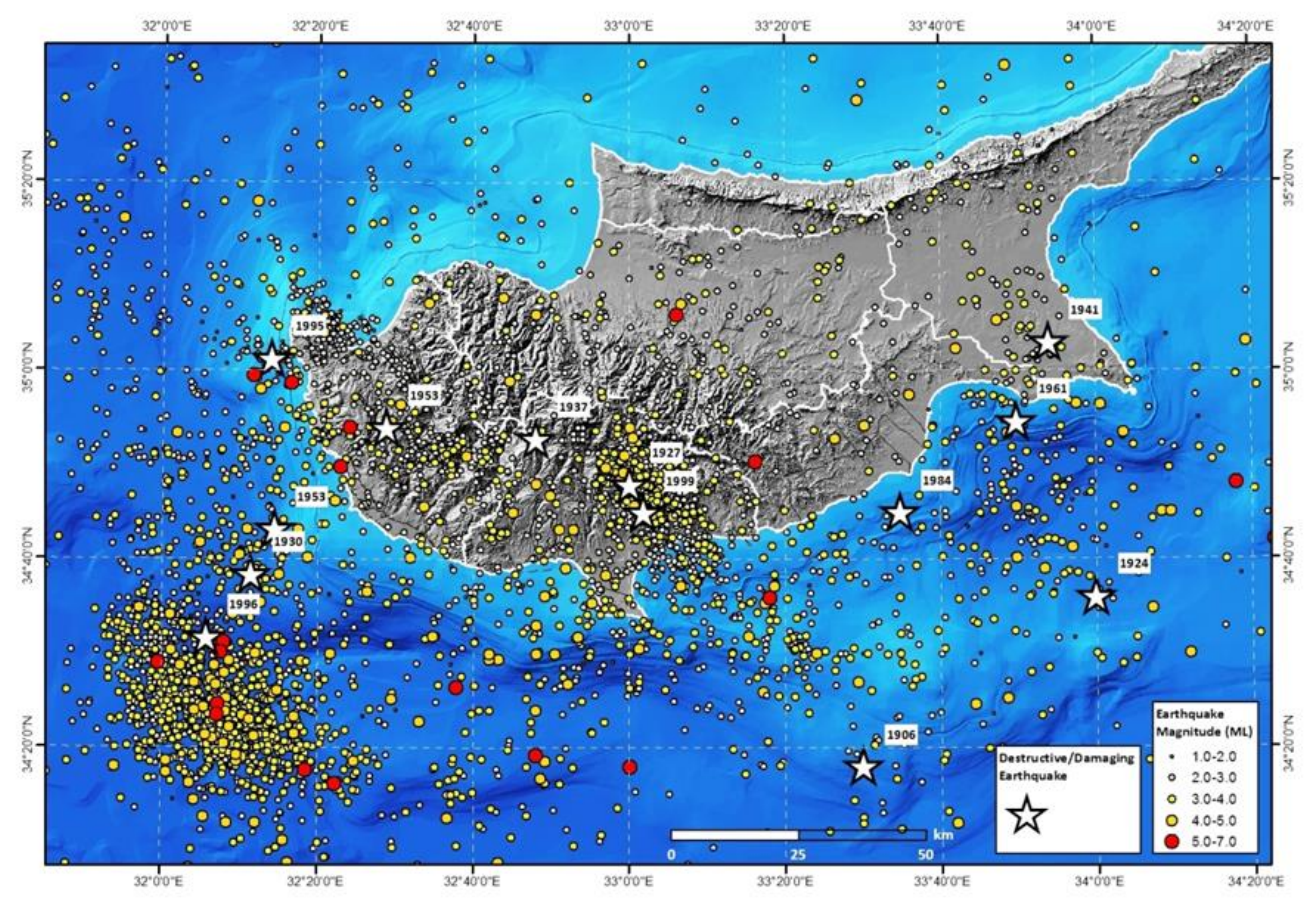


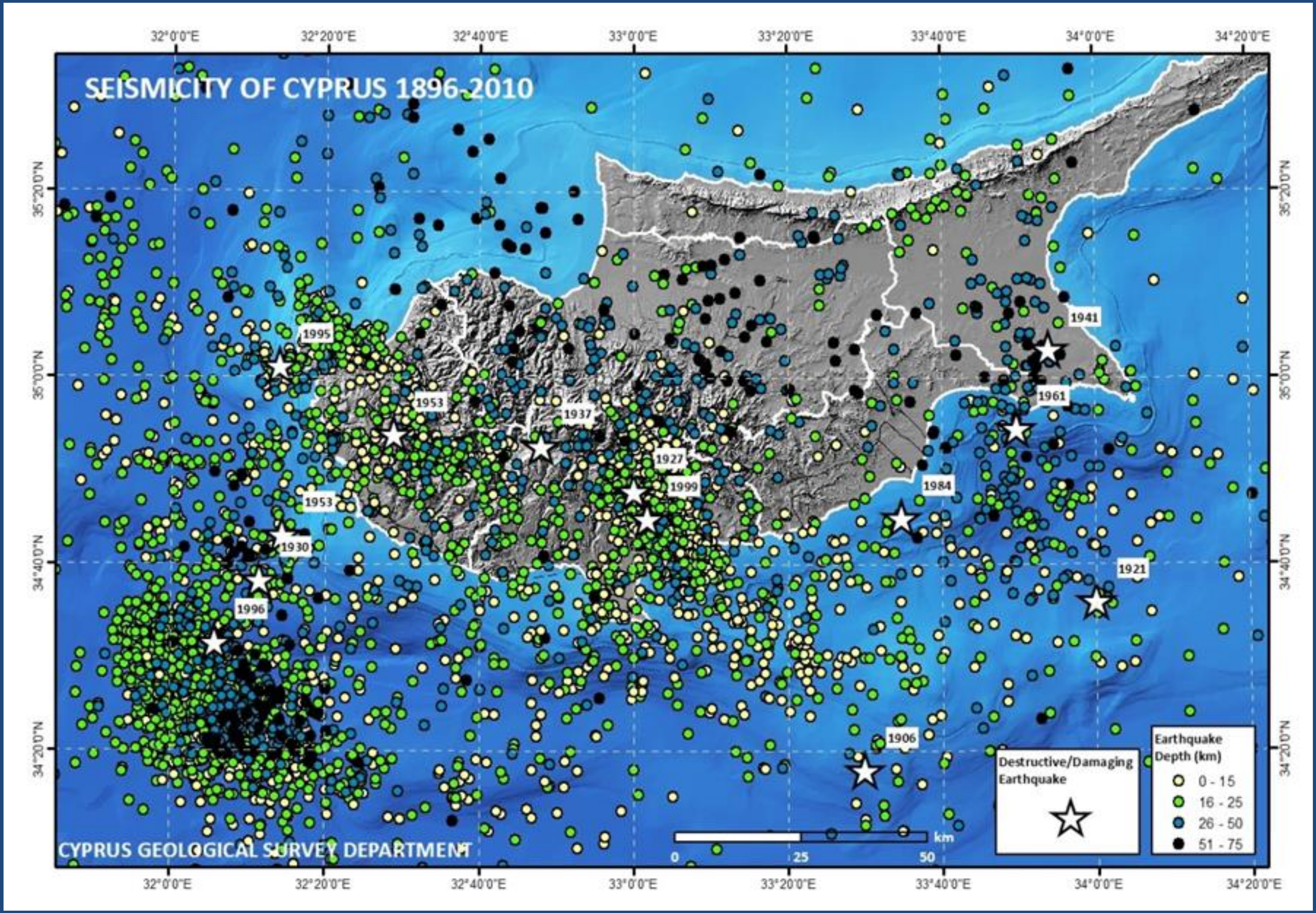
Fig.1



Simplified map showing the proposed plate boundary in the Eastern Mediterranean area
Papazachos and Papaioannou (1999)



Map showing the distribution of earthquake epicentres (colour scale denotes the magnitude scale) recorded by seismological networks during 1896-2010 (source Geological Survey Department of Cyprus).

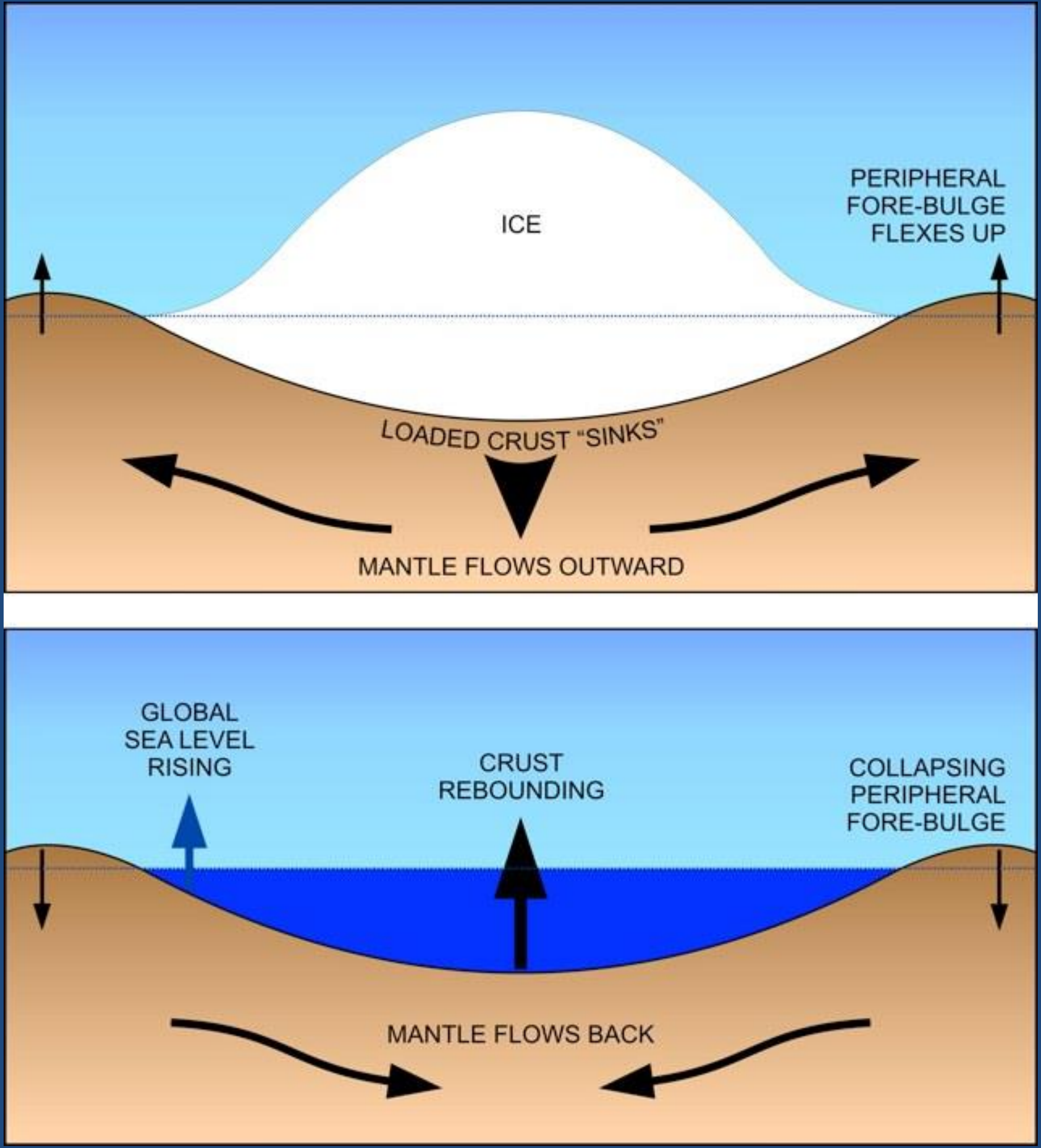


Map showing the depth distribution of earthquake epicentres recorded by seismological networks during 1896-2010 (source Geological Survey Department of Cyprus).

Magnitude (Ms)	Return period (years)	No. of earthquakes in 100 years
4.6-5.0	8	12.5
5.1-5.5	26	3.8
5.6-6.0	36	2.8
6.1-6.5	75	1.3
6.6-7.0	166	0.6

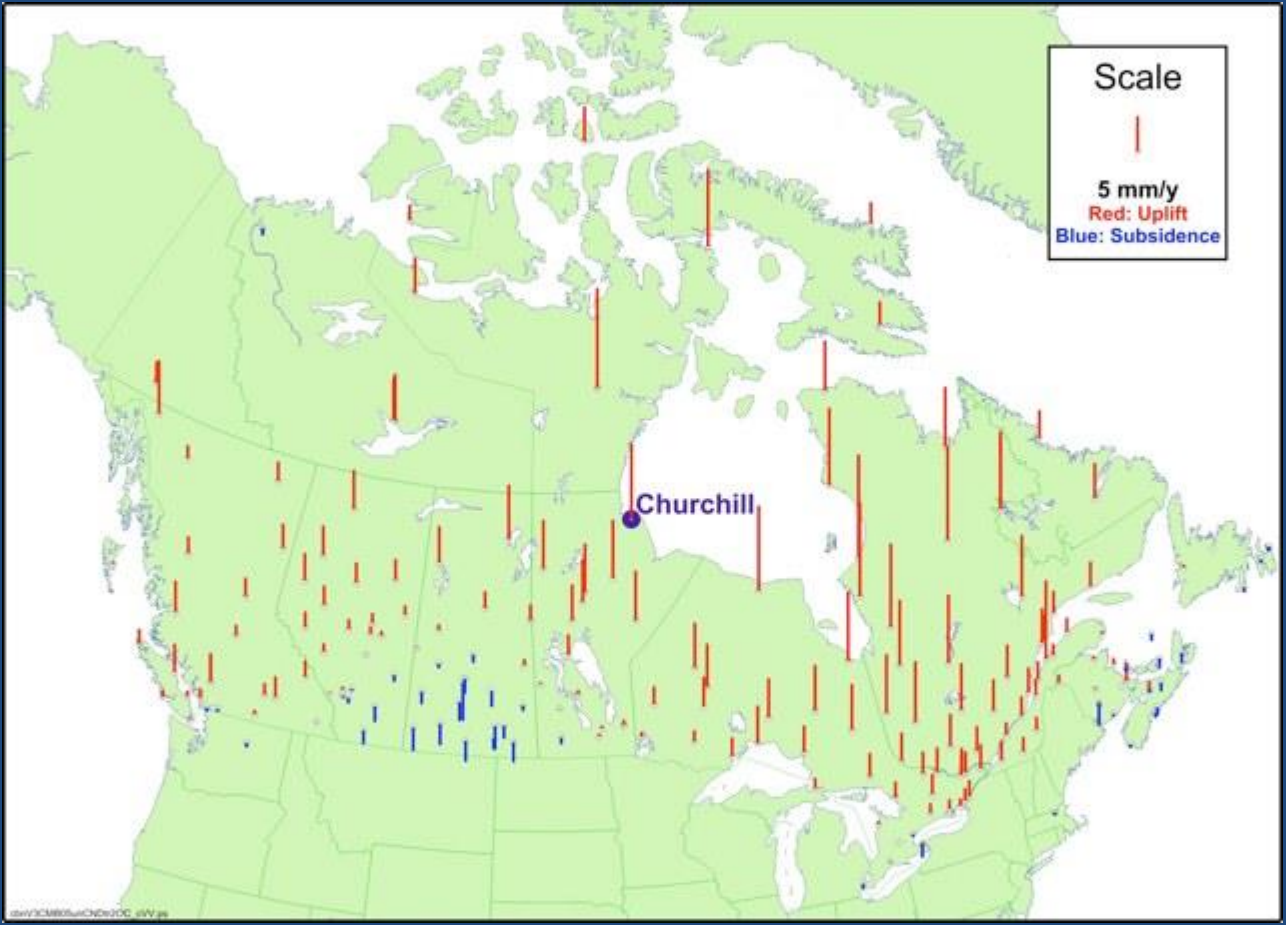
Table : Statistical elaboration of instrumentally seismicity data (source Research and Development Center Intercollege Unit of Environmental Studies 2004)

Earthquakes and Climatic Change



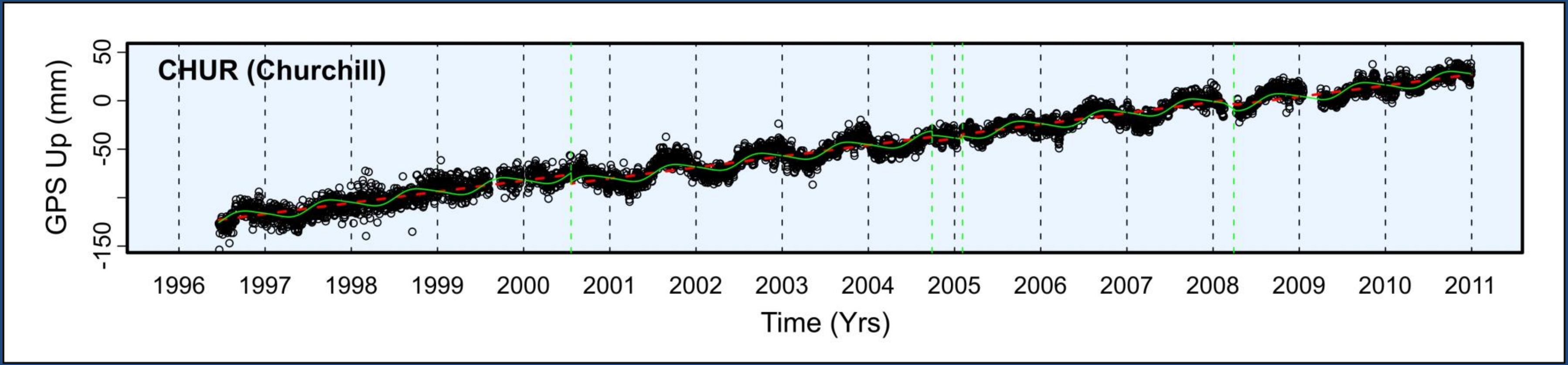
Glacial isostatic adjustment

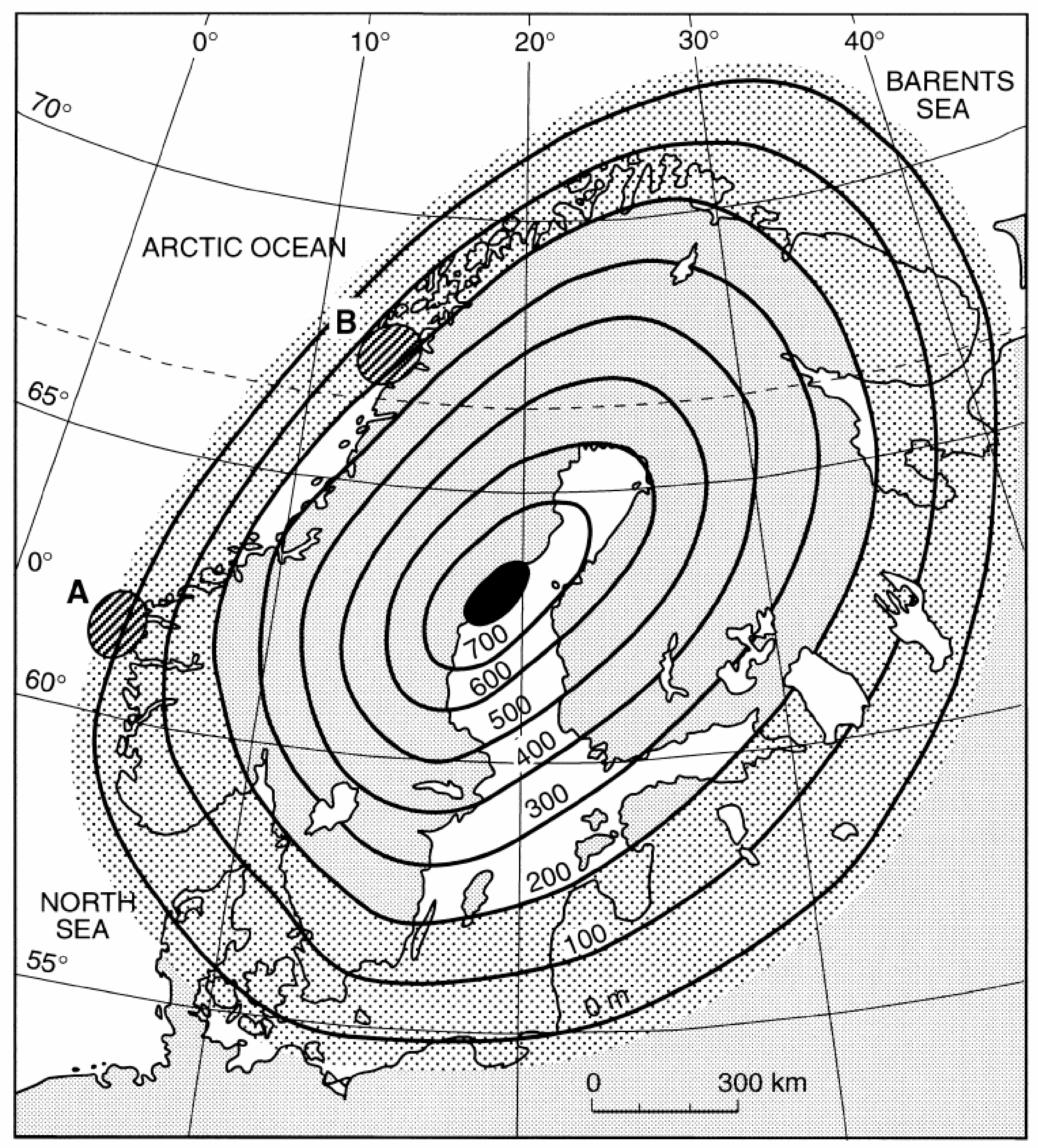
Source
Canadian Geodetic Survey



GPS values in Canada

Source
Canadian Geodetic Survey





Estimated total postglacial uplift in Fennoscandia (Morner, 1980, Gudmundsson 1999)

No such processes (e.g. Glacial isostatic adjustment) that are climatically driven in Cyprus at present day

Have not occured even during or immediately after the last glaciation

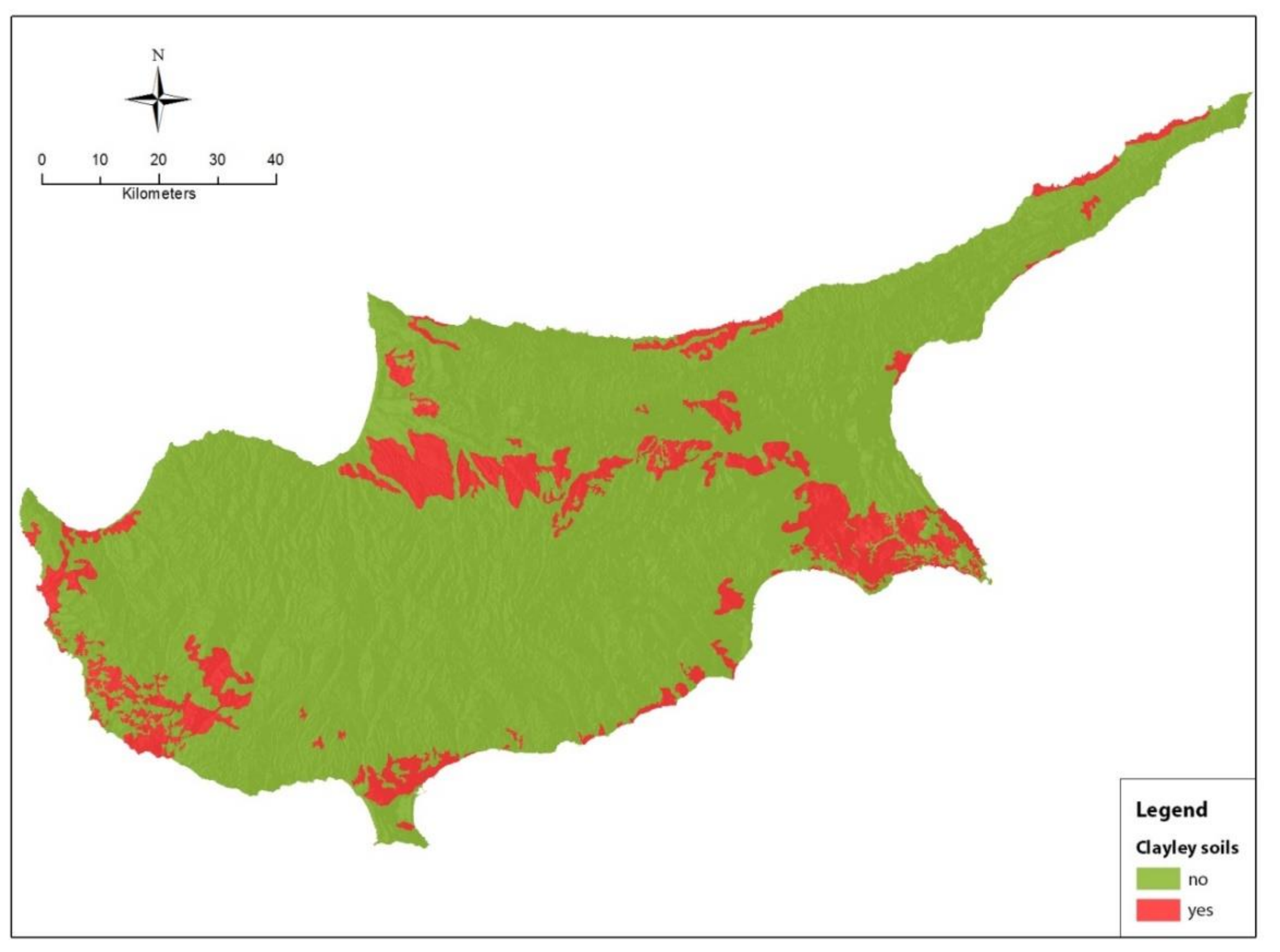
No glacial remains traced in Cyprus during the last glaciation

Some glaciation remains have been reported for Crete and Peloponnese only at altitudes > 2000m (e.g. higher elevations than the Troodos Mt).

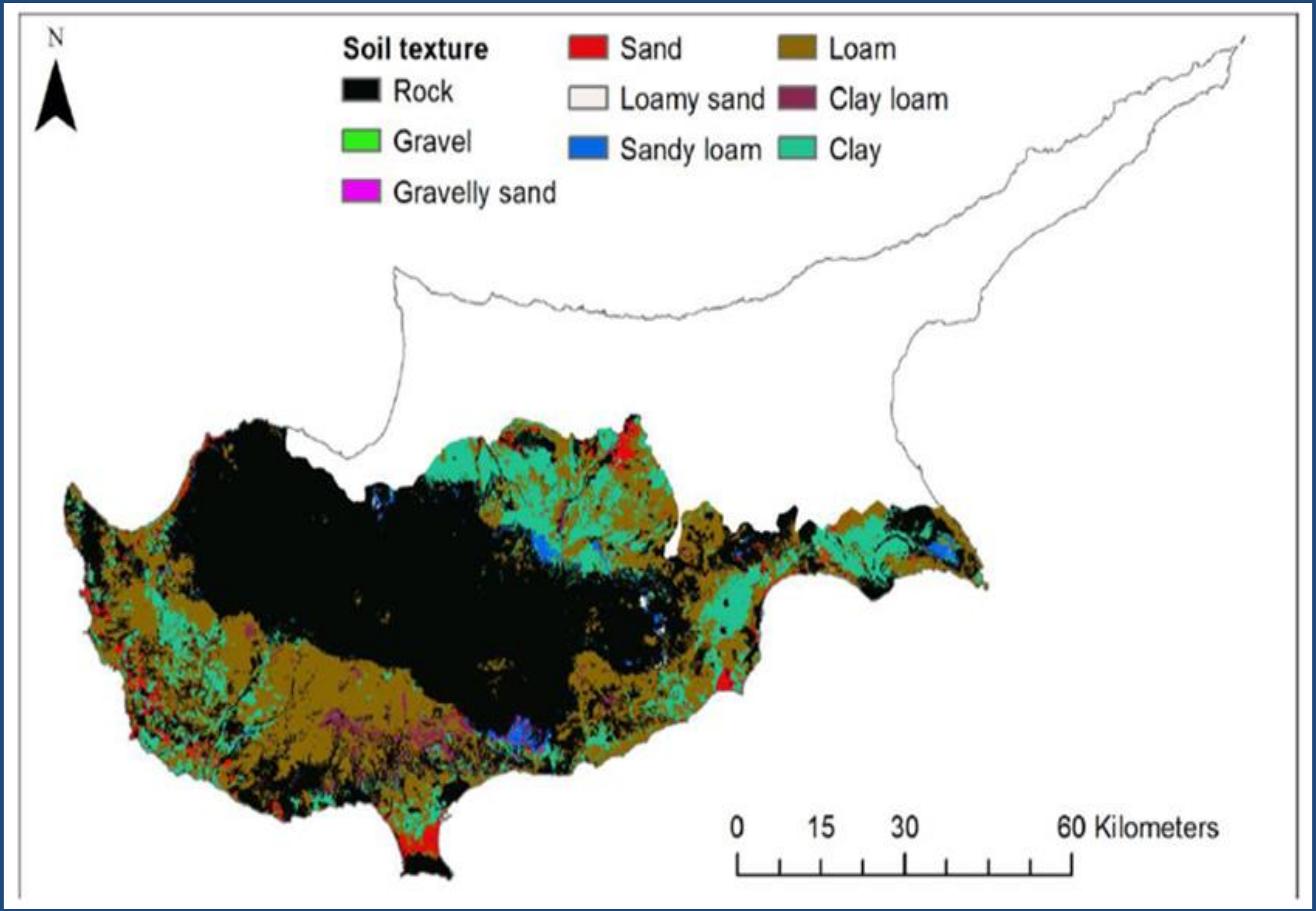
Climate can not directly affect current seismicity levels in Cyprus.

The only mechanism where climate can indirectly affect seismicity is the construction of new dams leading to reservoir induced seismicity for several years, temporarily increasing seismicity and promoting failure to mature neighbouring faults acting as a “clock advance” mechanism.

Subsidence



Distribution of clayley soils (1:250.000 scale soil map of Cyprus)



1:25000 soil texture map of Cyprus through digital and soil mapping techniques. The distribution of Clay and Clay loam soil groups are displayed, comprising 15,7% of the total area (Zomeni et al. 2014).

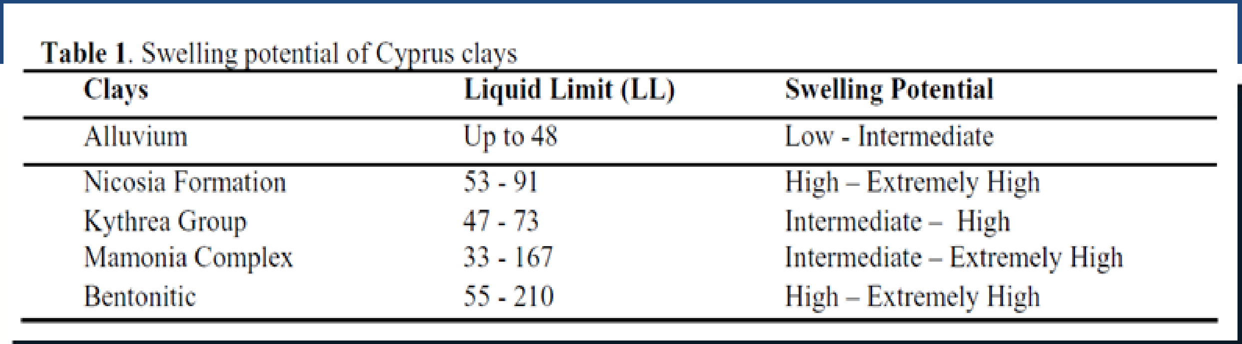
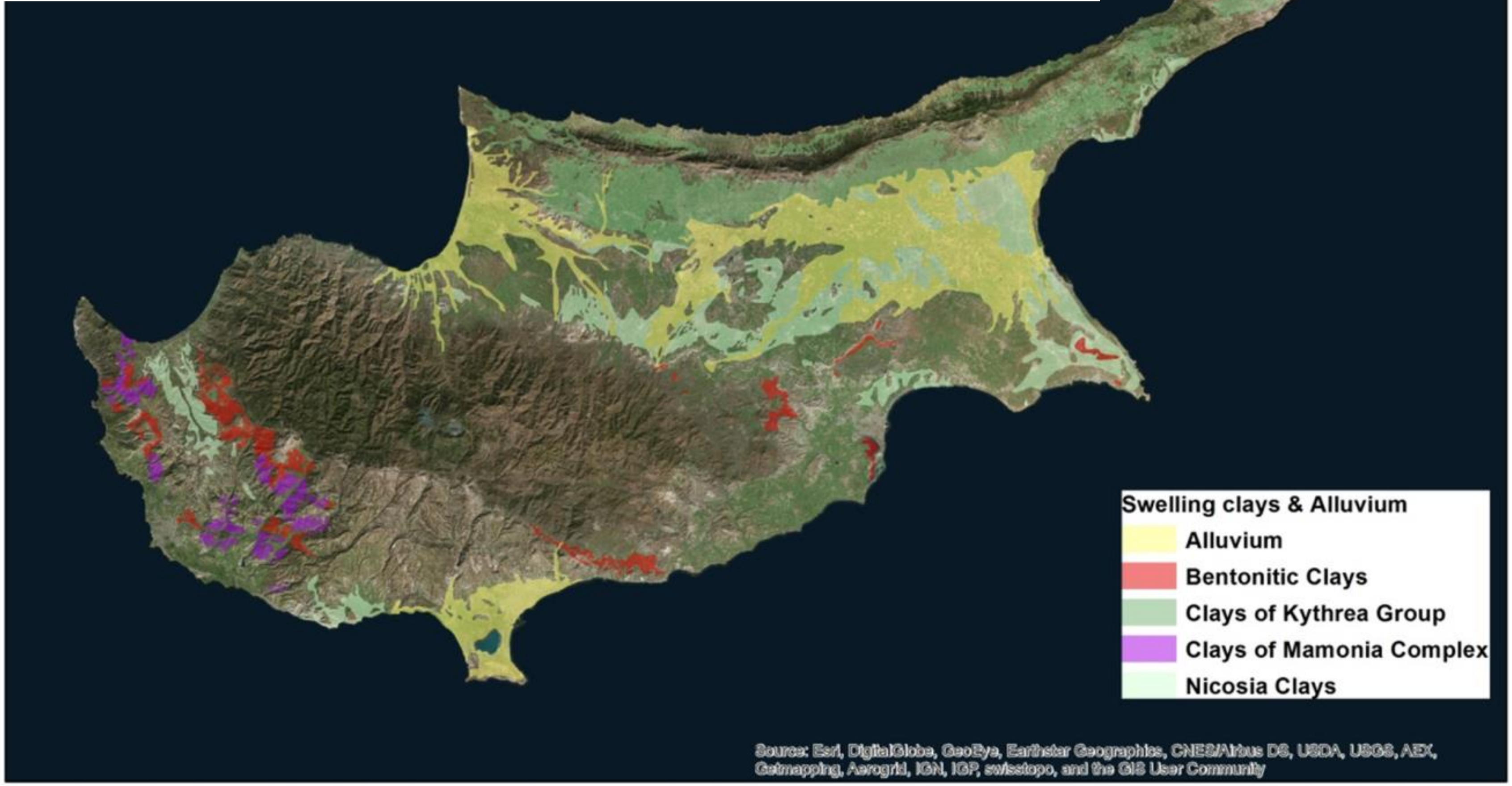


Table 1. Swelling potential of Cyprus clays

Clays	Liquid Limit (LL)	Swelling Potential
Alluvium	Up to 48	Low - Intermediate
Nicosia Formation	53 - 91	High – Extremely High
Kythrea Group	47 - 73	Intermediate – High
Mamonia Complex	33 - 167	Intermediate – Extremely High
Bentonitic	55 - 210	High – Extremely High



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Swelling clays of Cyprus are divided into five groups with diverge swelling potential (GSD 1995, Atalan and Kilic 2006)

Subsidence from clay swelling and shrinkage phenomena

No significant damages reported in the literature and the insurance industry

Considering the precipitation, temperature and relative humidity estimates for Cyprus (Hadjinicolaou et al. 2011, Cyprus Climate Change Risk Assessment this study), that indicate:

i) a precipitation decrease of 2–8 % in the next four decades;

ii) temperature increase by 1,5-2.5 °C;

iii) that future relative humidity will be decreased by 5% over the worst case scenario;

then the impact of climate regarding the swelling clay occurrences is expected to be negligible.

Groundwater over-abstraction

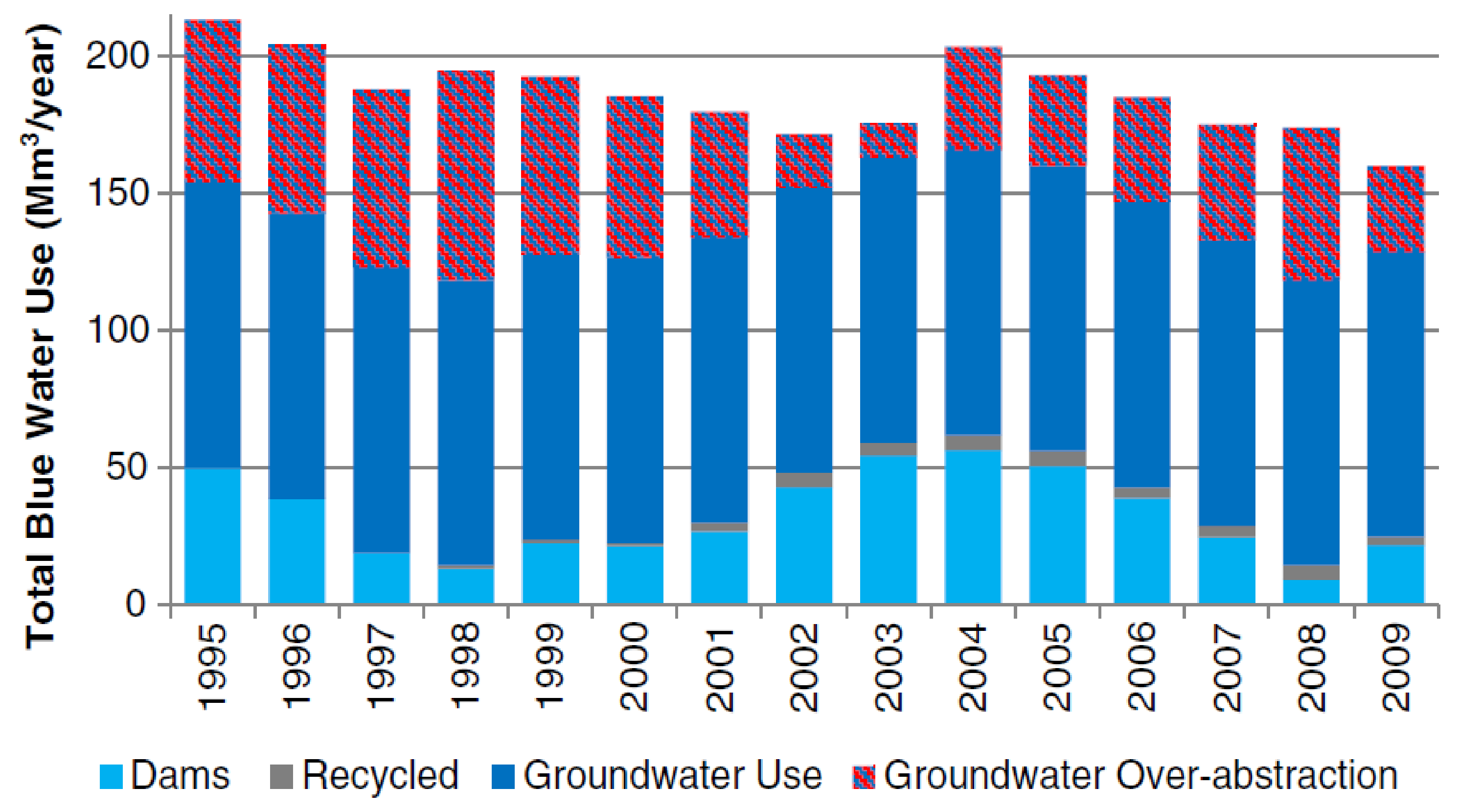
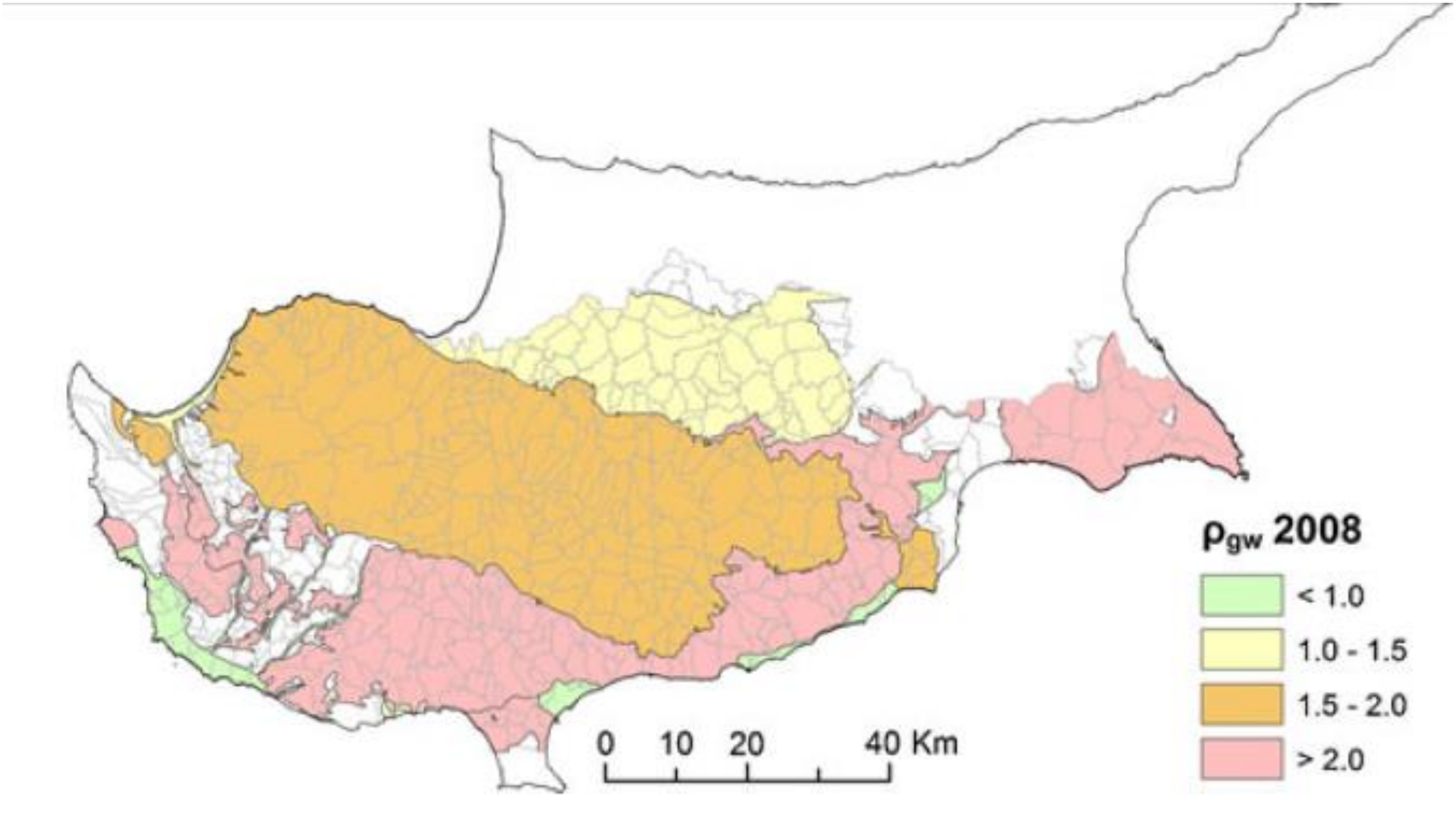


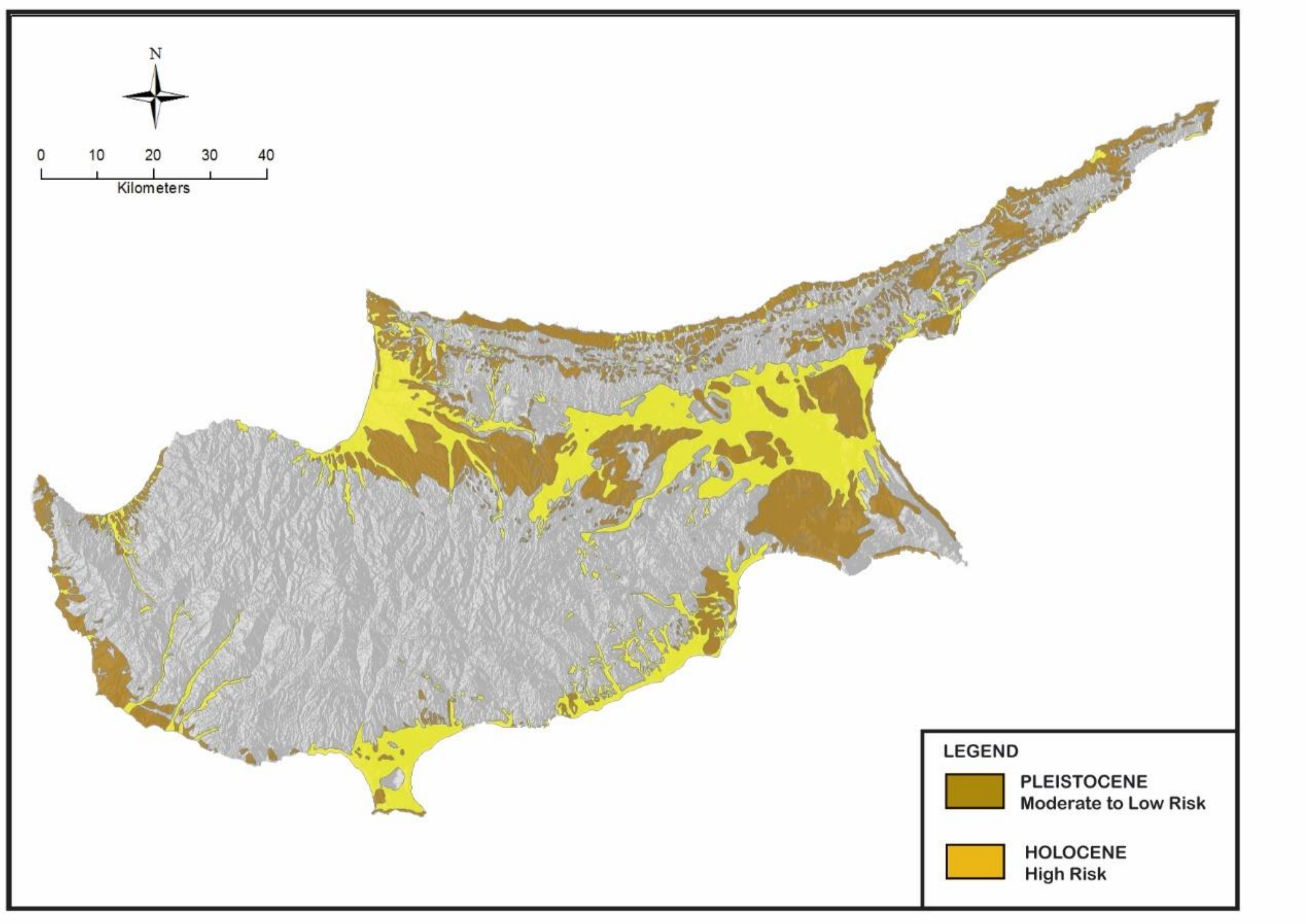
Diagram showing the share of groundwater and the level of groundwater over-abstraction for the period 1995–2009 (Zoumides et al. 2013).

Exploitation rate per groundwater body

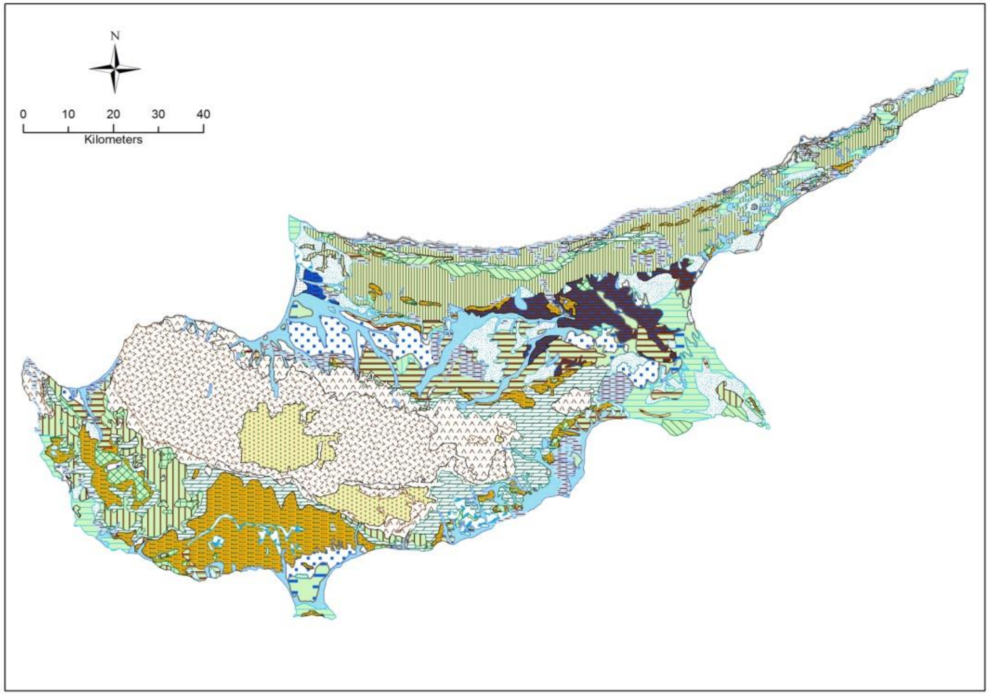


Map showing the exploitation rate per groundwater body (groundwater use over recommended volume), for the dry year of 2008 (Zoumides et al. 2013).

The vast majority of the area is overexploited.



Map showing the spatial distribution of Pleistocene and Holocene geological formations, based on the official 1:250.000 scale geological map. Pleistocene is regarded as moderate to low risk, whereas Holocene are considered of higher risk.



Hydrogeology250k

A. EXTENSIVE GROUNDWATER BODIES IN ALLUVIAL SAND AND GRAVEL, CONGLOMERATE, SANDSTONE AND CALCARENITE. A1.Alluvial deposits

- ■ Unconfined water generally at shallow depth in connection with riverbeds, deltaic gravel-sand deposits and including estuarine deposits.
- ▭ Water in alluvial deposits with impermeable to semi-permeable surface
- ▦ Clay and silt of undefined thickness containing water-bearing lenses of sand, underlain by generally impervious marl or siltstone, water commonly mineralized
- ░ Dune sand, forming part of aquifer systems
- ▤ Dune sand, normally shallow on Kythrea beds

A2. Pleistocene sand, gravel and siltl

- ░ Unconfined water in marine and terrestrial fanglomerate and terrace formations, locally including calcarenite.
- ▤ Very shallow ground water controlled by the configuration of underlying silt, clay or marl, in some formations as above

A3. Pliocene and Upper Miocene Sandstone, Calcarenite, and connected fragmental Limestone

- ▤ Unconfined ground water in sandstone, sandy marls and calcarenite (i.e. Nicosia formation), mineralized at depths and along coast by sea water intrusion
- ▥ Confined ground water in sandstone, sandy marls and calcarenite (i.e. Nicosia formation), mineralized at depths and along coast by sea water intrusion
- ░ Shallow unconfined ground water controlled by the configuration of impervious or semi-pervious strata, in same formations as above

A4. Middle Miocene sandstone

- ▨ Unconfined ground water in sandy parts of Middle Miocene (Pakhna formation)

B. EXTENSIVE GROUNDWATER BODIES IN FRACTURED AND KARSTIC LIMESTONE, DOLOMITE, GYPSUM, CHALK, AND MARLY CHALK

- ▧ Unconfined ground water in reef limestone and detrital limestone (Koronia limestone, Terra limestone), saline in coastal areas
- ▩ Unconfined ground water in gypsum aquifers, saline in deep confined aquifers
- ▤ Unconfined ground water in aquifers of secondary importance of mainly massive, highly retentive chalk, occasionally mineralized
- ▦ Unconfined ground water in aquifers of secondary importance consisting of cherty, locally marly chalk, sometimes including strata of massive chalk.
- ▦ Ground water in highly retentive rocks such as chalk interbedded with marls (Pakhna formation and Lapatza formation)
- ▨ Ground water in crystalline, brecciated and somewhat karstic limestone and dolomite aquifers of the Kyrenia Range

C. LOCAL AND SMALL DISONTINUOUS GROUNDWATER BODIES IN COMPLEX SEDIMENTARY AND IGNIOUS UNITS. C1. Units with alternating semi-permiable or impermeable beds and permeable beds including Chalk or Limestone of minor importance

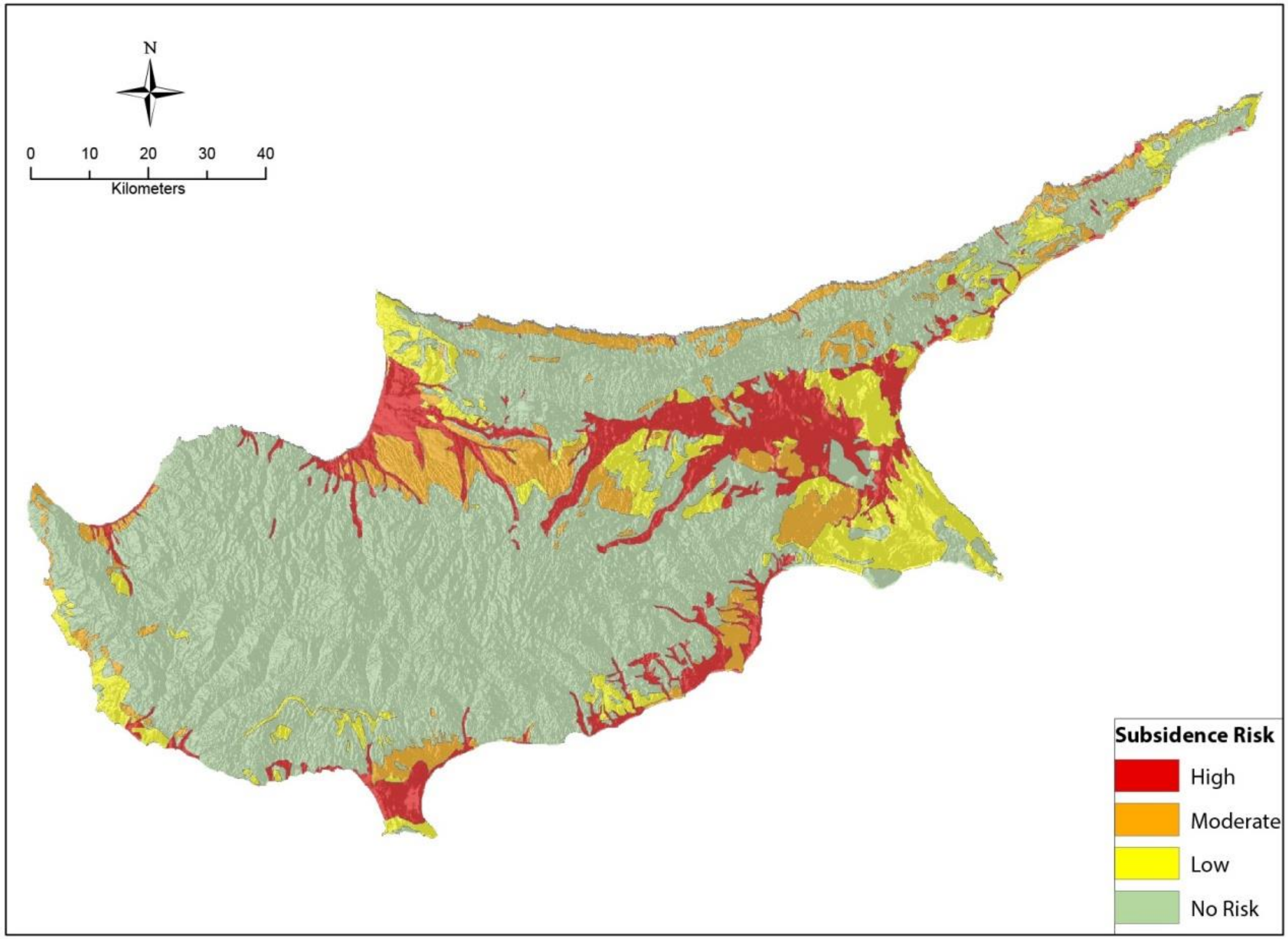
- ▤ Clay, marl and siltstone (Mainly rocks of the Mesaoria Group locally including marl, silt and clay of the Alluvium)
- ▥ Alternating marl, siltstone, greywacke, clay and shale (Kythrea formation), well water normally highly mineralized
- ▥ Mamonia Complex, including serpentine

C2. Igneous rock units

- ░ Volcanics with dominantly submarine pillow lavas, occasional pockets of highly saline water
- ░ Heavily fractured intrusive rocks
- ░ Plutonic rocks, springs common

1:250.000 scale
Hydrogeological map
by the Geological Survey of Cyprus showing the different types of groundwater bodies along the island.

Subsidence risk



Map showing the potential subsidence risk due to the decrease of the groundwater level (due to lower discharge rates or excessive pumping or both)

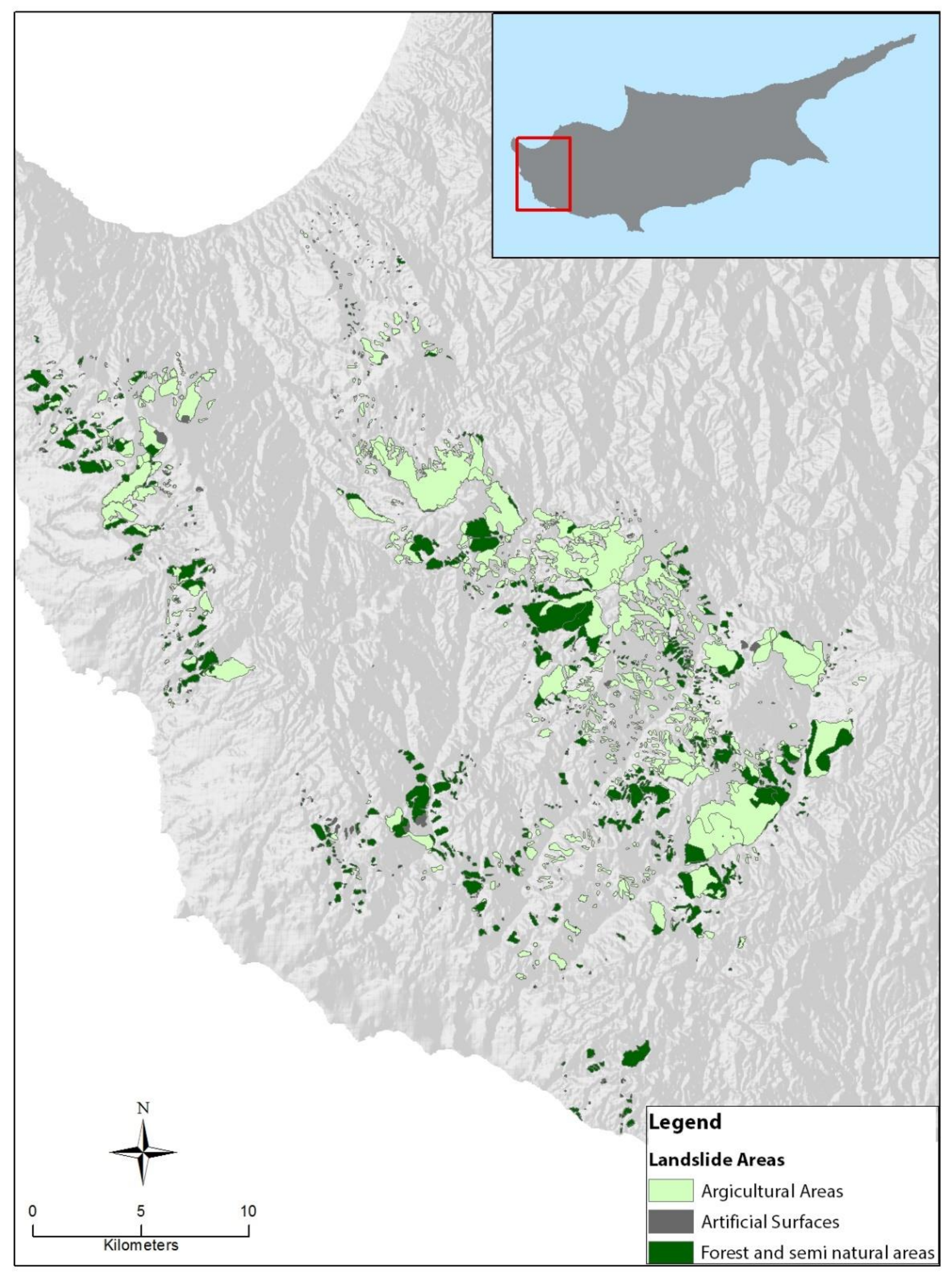
Significant stresses
Higher Water demand and lower groundwater recharge

- Following the expected increase of temperature, then the estimated increase in water demand for 2050 and 2080 is expected to range between 1.2% and 3.4% for the 2050 and between 1.8% and 5.5% depending on the season and location
- A precipitation decrease of 2–8 % is expected in the next four decades, while temperature will increase at least by 1 °C in winter to 2 °C in the summer (Hadjinicolaou et al. 2011).
- A 5% decrease in average rainfall will result in 25% decrease in average surface runoff and groundwater recharge (In Chapter 3.1 and 3.2 of the Water Sector report this study).

Landslide and Climate change

- Lower rainfall due to climate change can slightly decrease the occurrence of landslides in highly susceptible sites. However, the predicted decrease of rainfall is too minor to exert any influence on the landslide occurrence.
- On the other hand, increased evapotraspiration, lower humidity and higher temperatures will lead to drought and the generation of more wildfires. There is a well-documented expected increase of wildfires over the next decades (see Chapter 5.2 of Forestry report). An increase in temperature will increase the number of days with fire risk (1–4 weeks) (Giannakopoulos et al. 2009).
- Loss of vegetation due to wildfires will increase slope instability phenomena, particularly for shallow slides and will accelerate creeping effects. Climate effects can indirectly impact on landslides by the loss of vegetation

Landslide risk



High spatial resolution map, showing the landslides (provided by the Geological Survey), land use and vegetation cover.

Dark green areas are landslide areas covered by forest and semi natural areas, which imply a higher wildfire risk. These areas are regarded of higher risk for reactivating landslides, due to the higher number of forest fires expected due to climate change.

Conclusions

Geohazards and climate change

- Earthquakes (no direct effect in Cyprus), indirectly a temporary increase could be expected only if large new dams will be constructed
- Landslides (indirectly due to increase of forest fires) Development of actions plans for forest fire prevention
- Subsidence in recent sedimentary basins hosting shallow aquifers due to Intensive groundwater pumping Prevention measures for avoiding overexploitation