



ΠΑΝΕΠΙΣΤΗΜΙΟ
ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS



ΠΑΝΕΠΙΣΤΗΜΙΟ
ΔΥΤΙΚΗΣ ΕΛΛΑΔΑΣ

Titan Patras Cement Plant: Biodiversity Study for Artimes Limestone Quarry

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SDIMI2013
30 June - 3 July



SUSTAINABLE DEVELOPMENT IN THE MINERALS INDUSTRY
6th International Conference
Milos Island, Greece

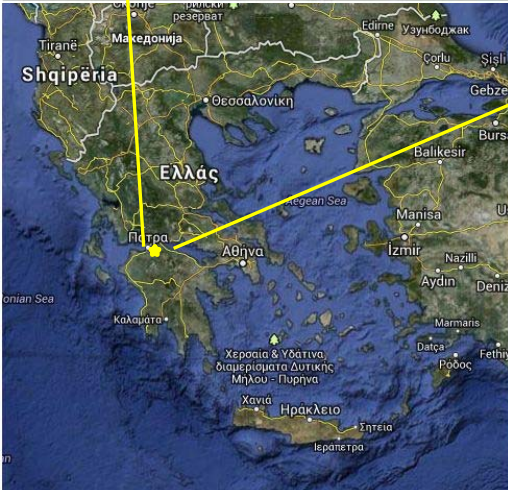


The main target
was to study
the flora & the vegetation
inside the quarry limits and the surrounding area
Also, an important goal was to compare the floras of
the two areas using biodiversity indices



The study area

- Limestone quarry & surrounding area at 235-395m above sea level
- It is situated at ‘Artimes’ location above the villages Drepano & Arachovitica of Achaia, Greece
- It is consisted of slopes (10m high) & benches (5m wide)
- It is being used since 1967 and being restored since 1971



Stages of quarry restoration

- Formation of the surfaces that will be restored
- Selection of plant species
- Planting shrubs and trees
- Hydro-seeding
- Protection from over-grazing and drought
- Monitoring of natural succession



Restoration through
planting &
hydro-seeding



Methodology-The study of flora

600 samples collected by the authors

• Inside the quarry:

← slopes and benches

• Outside the quarry (surrounding area):

← Nearby and distant region

Identification

- Flora Europaea I-IV
- Flora Hellenica I & II
- Flora d' Italia
- Flora of Turkey & the Aegean Islands
- Flore de France
- Samples of the Herbarium of University of Patras (UPA)

Nomenclature

- Med-Checklist 1-4
- Flora Hellenica I & II
- Flora Europaea I-IV
- Mountain Flora I & II

Angiosperm Classification

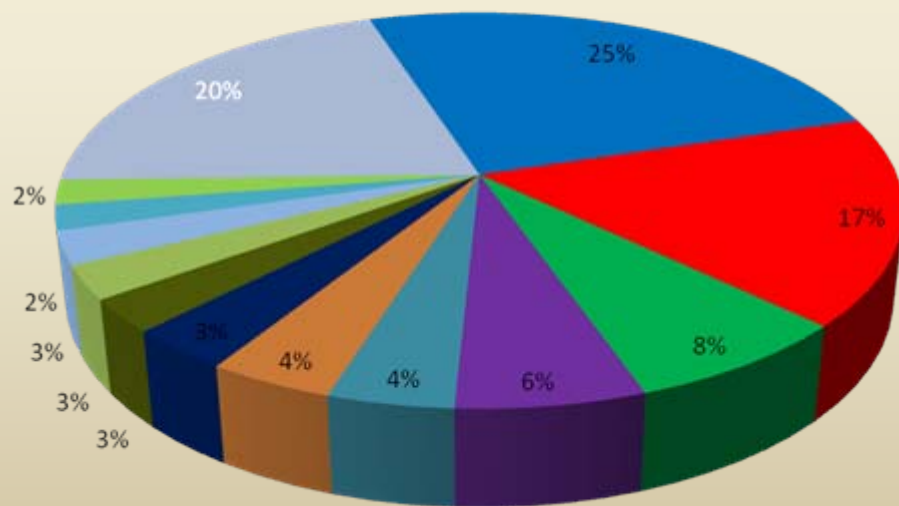
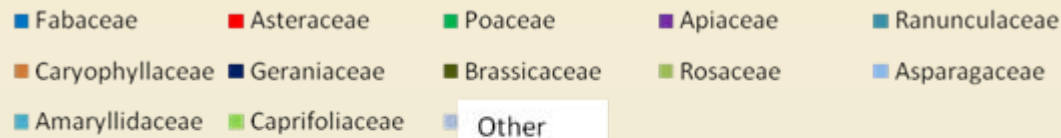
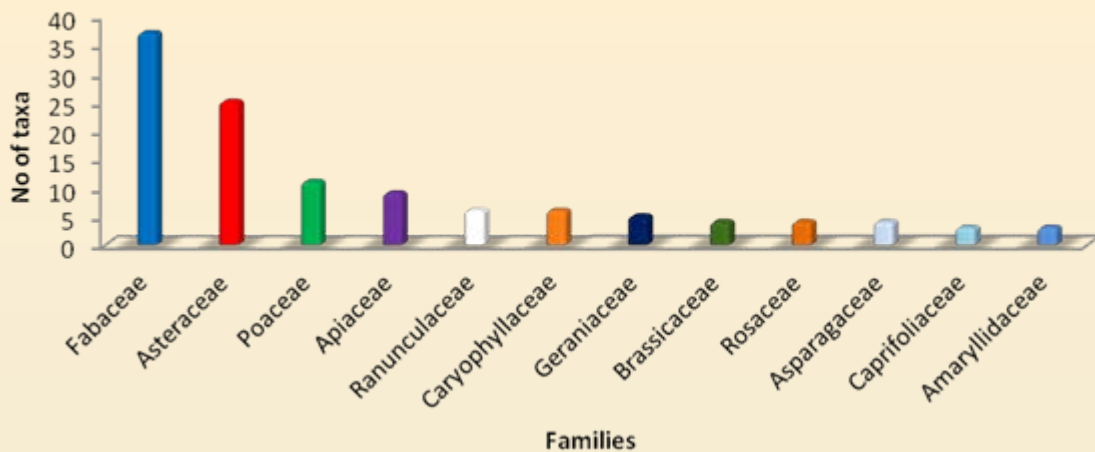
- APG III-Angiosperm Phylogeny Group III system (2009)

Floral study

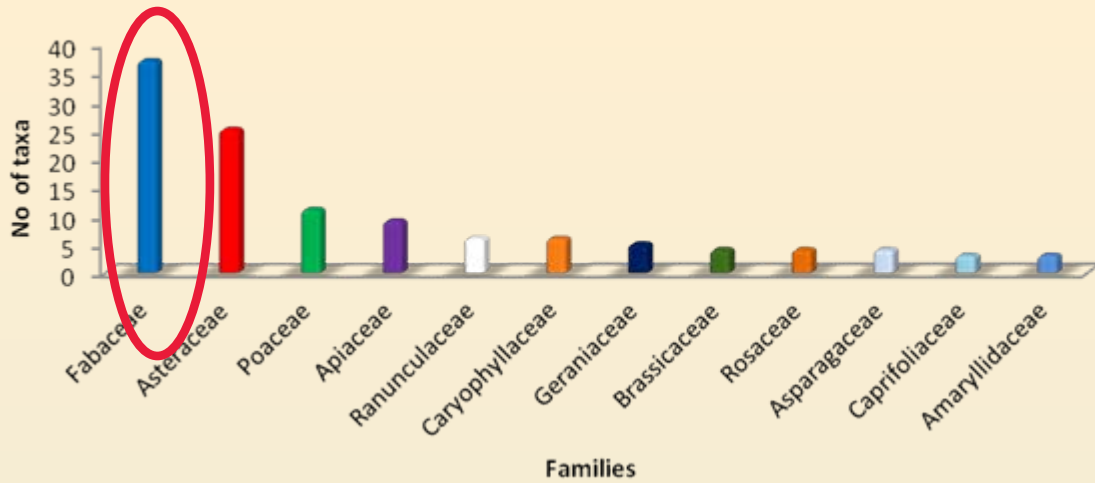
	Families	Genera	Taxa	% of the total taxa
Gymnospermae	2	2	4	2,72
Angiospermae Dicotylidones	28	89	122	82,09
Angiospermae Monocotylidones	6	18	21	14,29
Total	36	109	147	100

Floral study

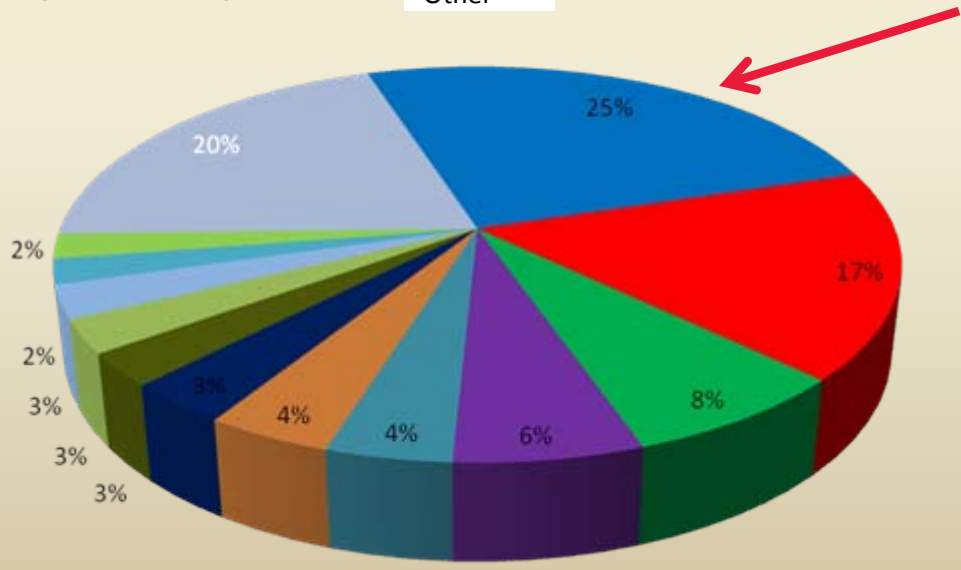
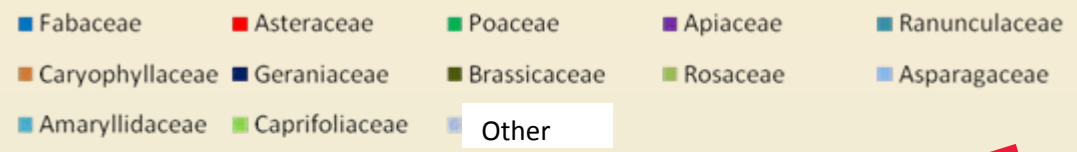
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Families	No of taxa
Fabaceae	37
Asteraceae	25
Poaceae	11
Apiaceae	9
Ranunculaceae	6
Caryophyllaceae	6
Geraniaceae	5
Brassicaceae	4
Rosaceae	4
Asparagaceae	4
Caprifoliaceae	3
Amaryllidaceae	3
Other	32



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Amaryllidaceae	3
Other	32





Trifolium angustifolium



Trifolium stellatum



Trifolium campestre

Genera	No of taxa
Trifolium	6
Medicago	5
Lathyrus	3
Ranunculus	3
Vicia	3
Geranium	3
Allium	3

Chorological analysis of the Quarry Flora

147 taxa: 3 greek endemics

4

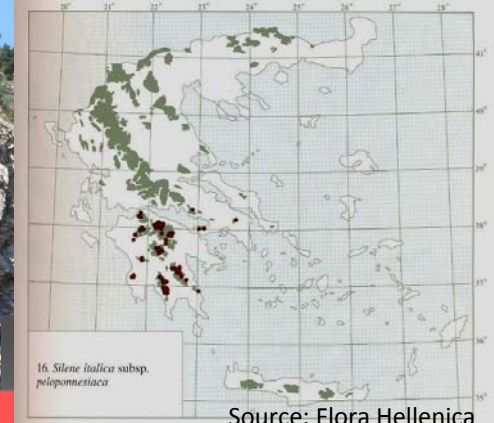
balkan

endemics

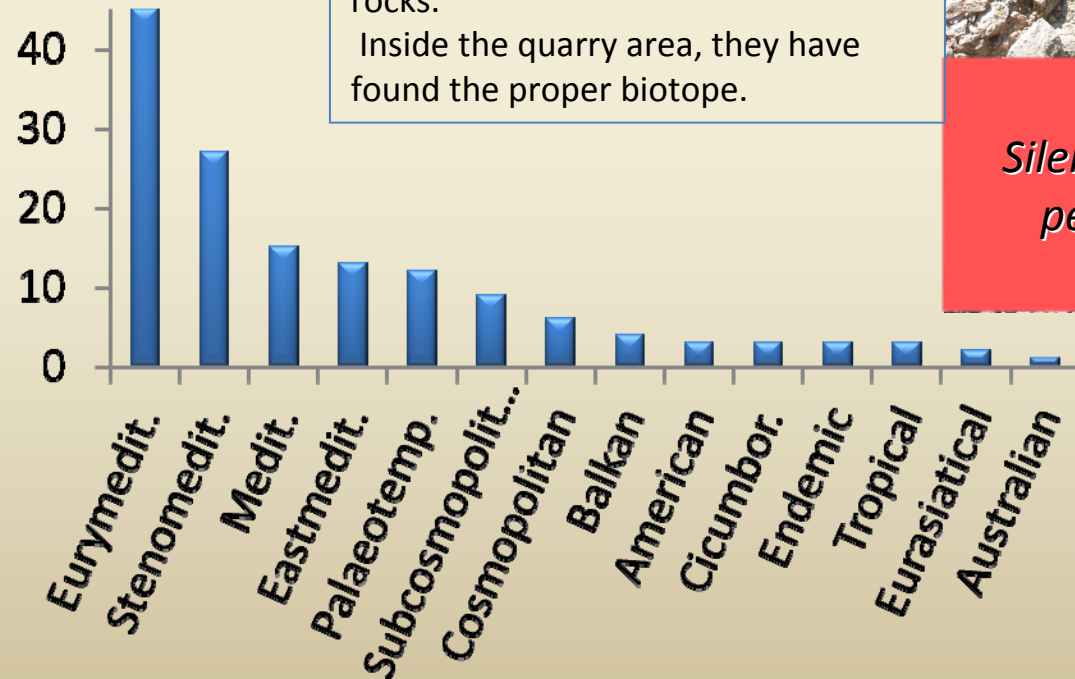
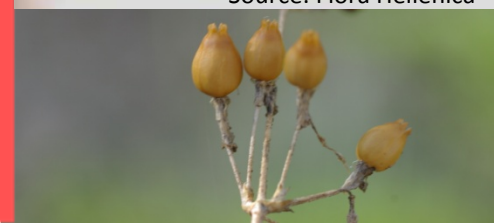
4 alien species

It's a greek endemic plant species, which is mainly located in North Peloponnese at vertical limestone rocks.

Inside the quarry area, they have found the proper biotope.



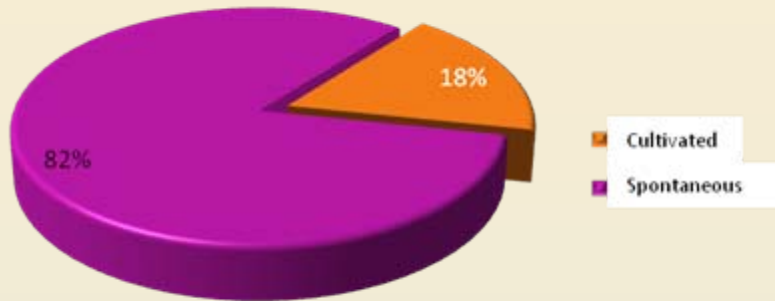
Silene italica subsp. *peloponnesiaca*



* According to Flora d' Italia (Pignatti, 1982)

Cultivated Flora

Cultivated/Spontaneous Taxa

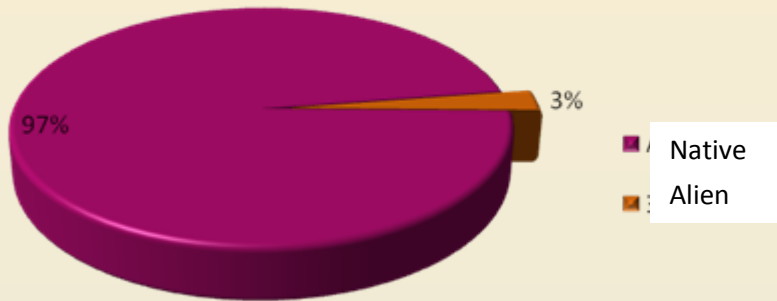


26 of the total taxa have been used for the restoration of the quarry area

<i>Pinus halepensis</i> subsp. <i>halepensis</i>	<i>Cercis siliquastrum</i>
<i>Pinus halepensis</i> subsp. <i>brutia</i>	<i>Medicago arborea</i>
<i>Cupressus sempervirens</i>	<i>Medicago lupulina</i>
<i>Cupressus arizonica</i>	<i>Robinia pseudoacacia</i>
<i>Pistacia lentiscus</i>	<i>Spartium junceum</i>
<i>Pistacia terebinthus</i>	<i>Quercus ilex</i>
<i>Dittrichia viscosa</i>	<i>Laurus nobilis</i>
<i>Cistus</i> spp.	<i>Eucalyptus globulus</i>
<i>Arbutus andrachne</i>	<i>Myrtus communis</i>
<i>Arbutus unedo</i>	<i>Olea europaea</i>
<i>Acacia saligna</i>	<i>Rhamnus alaternus</i>
<i>Calicotome villosa</i>	<i>Pyrus amygdaliformis</i>
<i>Ceratonia siliqua</i>	<i>Sanguisorba minor</i>

Cultivated Flora

Native/Alien taxa



4 alien species were planted in order the quarry area to be restored.

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Flora of the surrounding undisturbed area

	Families	Genera	Taxa	% of the total taxa
Gymnospermae	1	1	1	0,59
Angiospermae Dicotylidones	30	104	144	85,21
Angiospermae Monocotylidones	8	21	24	14,20
Total	39	126	169	100

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Total	39	126	169	100

Summary: The flora of the two areas

	Quarry (disturbed area)		Surrounding area (undisturbed area)	
	No of taxa	%	No of taxa	%
Gymnospermae	4	2,74	1	0,59
Angiospermae Dicotylidones	122	82,99	144	85,21
Angiospermae Monocotylidones	21	14,29	24	14,20
Total	147		169	

124 taxa are common in both sites, 84,35% of the quarry flora

Life-form spectra of the two areas flora

Life-form spectra	Quarry		Surrounding area	
	No of taxa	%	No of taxa	%
T (Therophytes)	70	47,62 ←	82	48,52 ←
H (Hemicryptophytes)	29	19,73	27	15,98
P (Phanerophytes)	27	18,37	33	19,53
G (Geophytes)	14	9,52	17	10,06
Ch (Chamaephytes)	10	6,80	10	5,92

Life-form spectra characterises the environmental conditions. The life-form spectra of the quarry corresponds to the xerothermic climatic conditions of the area.

*According to the Flora d'Italia (Pignatti, 1982)

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=~67%

Life-form spectra characterises the environmental conditions. The life-form spectra of the quarry corresponds to the xerothermic climatic conditions of the area.

The large percentage of both therophytes and hemicryptophytes (~67%) indicates prolonged drought and human interference.

*According to the Flora d'Italia (Pignatti, 1982)

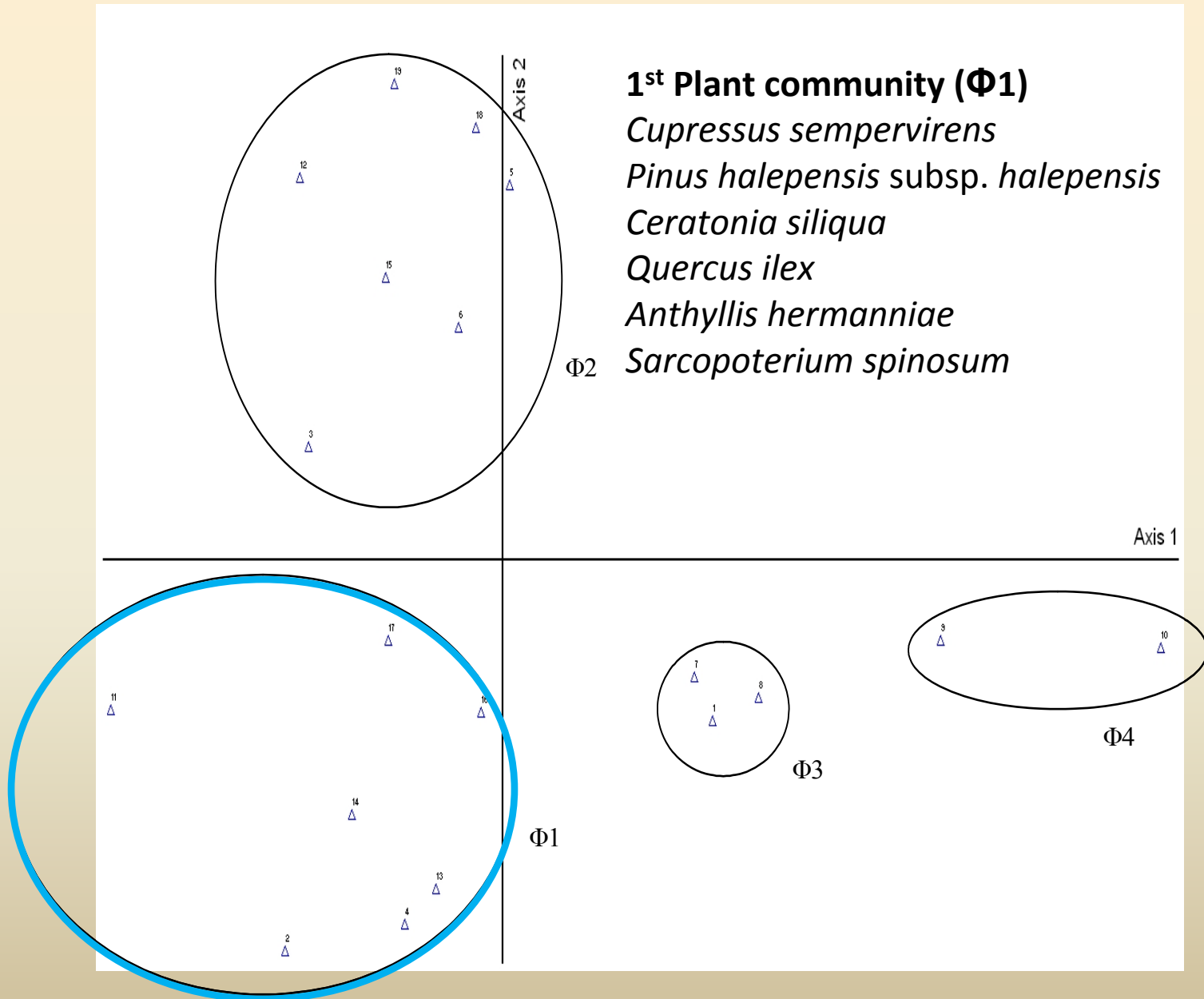
Methodology-Vegetation study

- Establishment of 19 sampling plots (5x5 m) on the slopes & depleted benches of the quarry & 9 sampling plots (10x10 m) in the surrounding area
- Plant cover of every taxon was calculated according to the phytosociological method of Braun-Blanquet
- Registered into the TurboVeg Database (Hennekens, 1995 & 1999)
- Twinspan & DECORANA (DCA) of the PC-Ord 5 Software

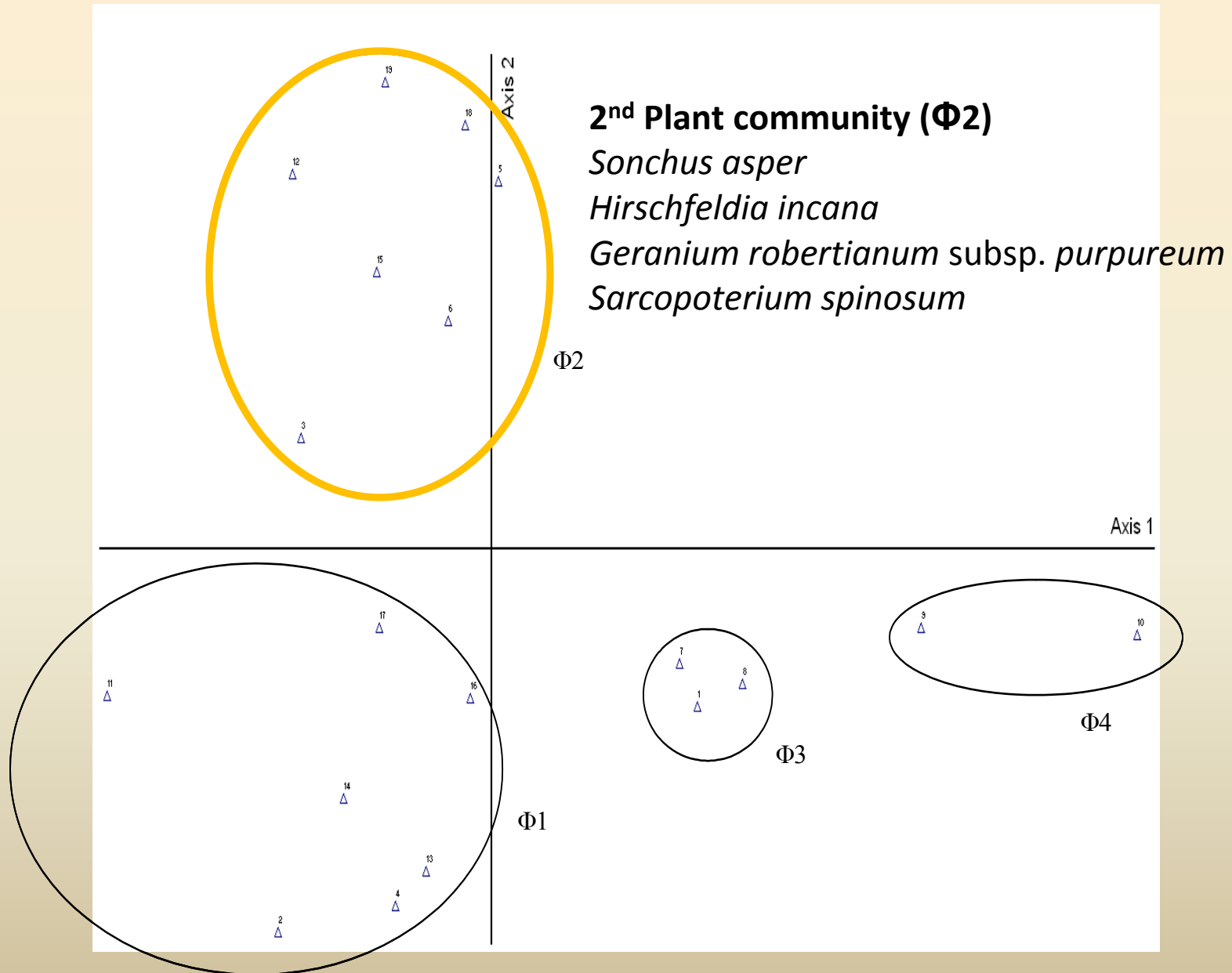
Quarry vegetation



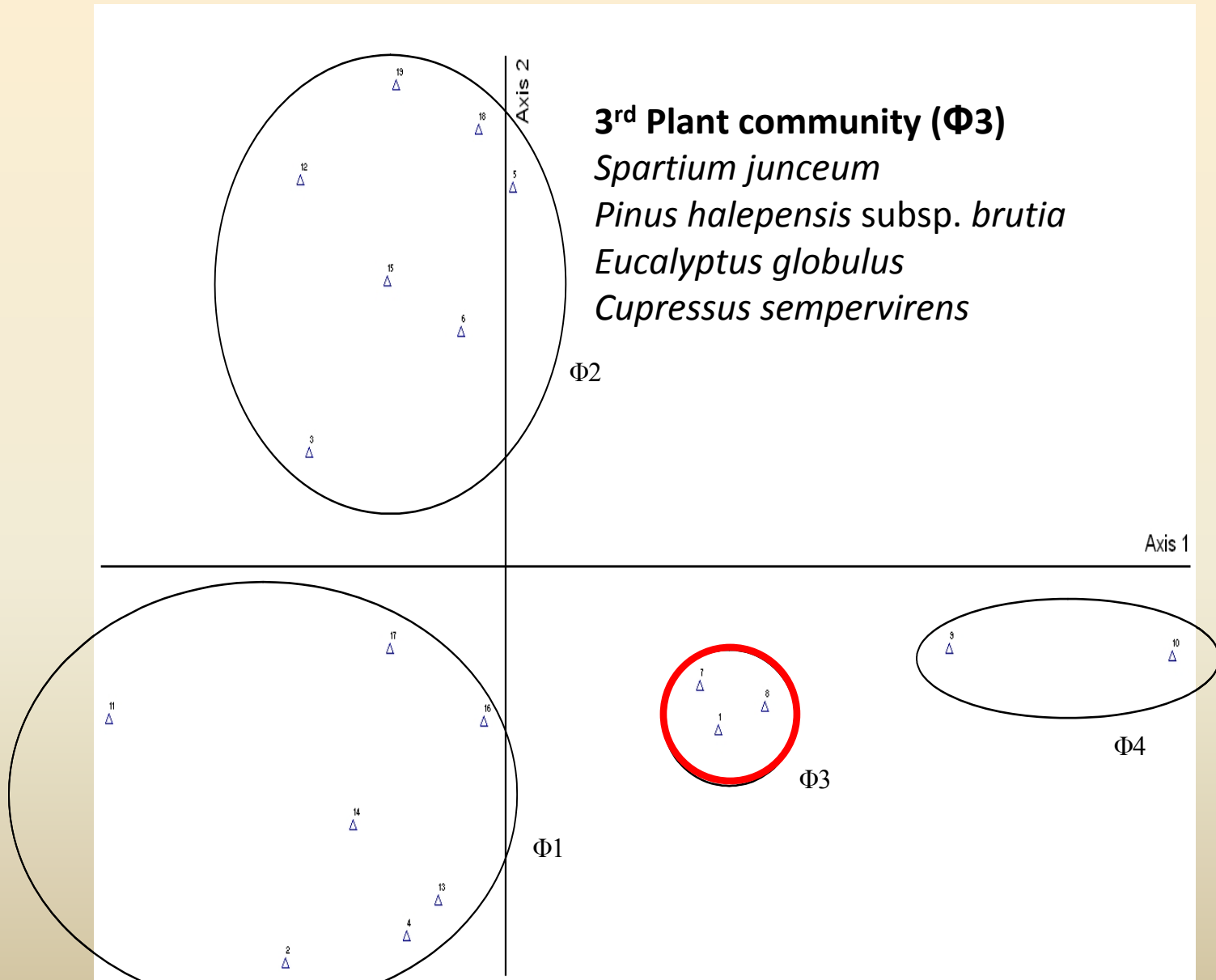
Plant communities inside the quarry



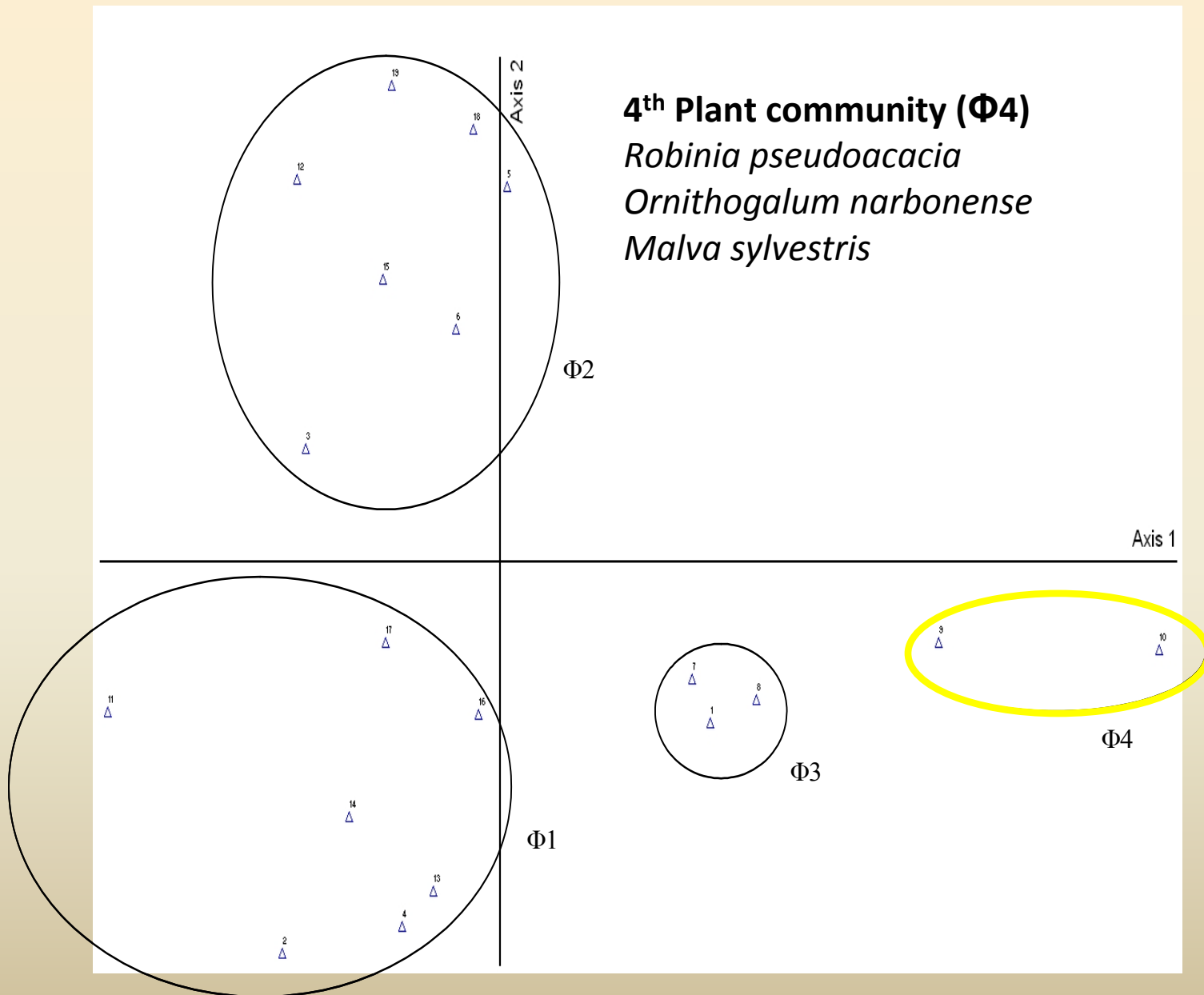
Plant communities inside the quarry



Plant communities inside the quarry



Plant communities inside the quarry



Species

of the class *Quercetea ilicis* Br.-Bl. 47, order *Quercetalia ilicis* Br.-Bl. 36, alliance *Quercion ilicis* Br. Bl. 36, such as *Quercus ilex*, *Quercus coccifera* & *Crataegus monogyna*.



Quercus coccifera



Quercus ilex

Species

of the class *Cisto-Micromerietea* Oberdorfer 1954, order *Cisto-Micromerietalia* Oberdorfer 1954, such as *Anthyllis hermanniae*, *Sarcopoterium spinosum*, *Satureja juliana*, *Cistus creticus*, *Hypericum empetrifolium* & *Dorycnium hirsutum*.



Hypericum empetrifolium



Anthyllis hermanniae



Satureja juliana

Species

of the order *Brachypodio-Chrysopogonetea*
Horvatić 58, such as *Bituminaria bituminosa*,
Hymenocarpos circinnatus & *Trifolium stellatum*.



Species

of the order *Cymbogo-Brachypodietalia* Horvatić 58, such as *Reichardia picroides* και *Brachypodium distachyon*.



Reichardia picroides

Vegetation of the surrounding area



East region

Species

of the class *Quercetea ilicis* Br.-Bl. 47, order *Quercetalia ilicis* Br.-Bl. 36 & alliance *Quercion ilicis* Br.-Bl. 36, such as *Quercus ilex* and *Quercus coccifera*.

East region

Species

of the class *Quercetea ilicis* Br.-Bl. 47, order *Quercetalia ilicis* Br.-Bl. 36 & alliance *Oleo-Ceratonion* Br.-Bl. 47, such as *Pistacia lentiscus* and *Olea europaea*.

East region



Pistacia lentiscus



Olea europaea subsp. *europaea*



Quercus coccifera

West region

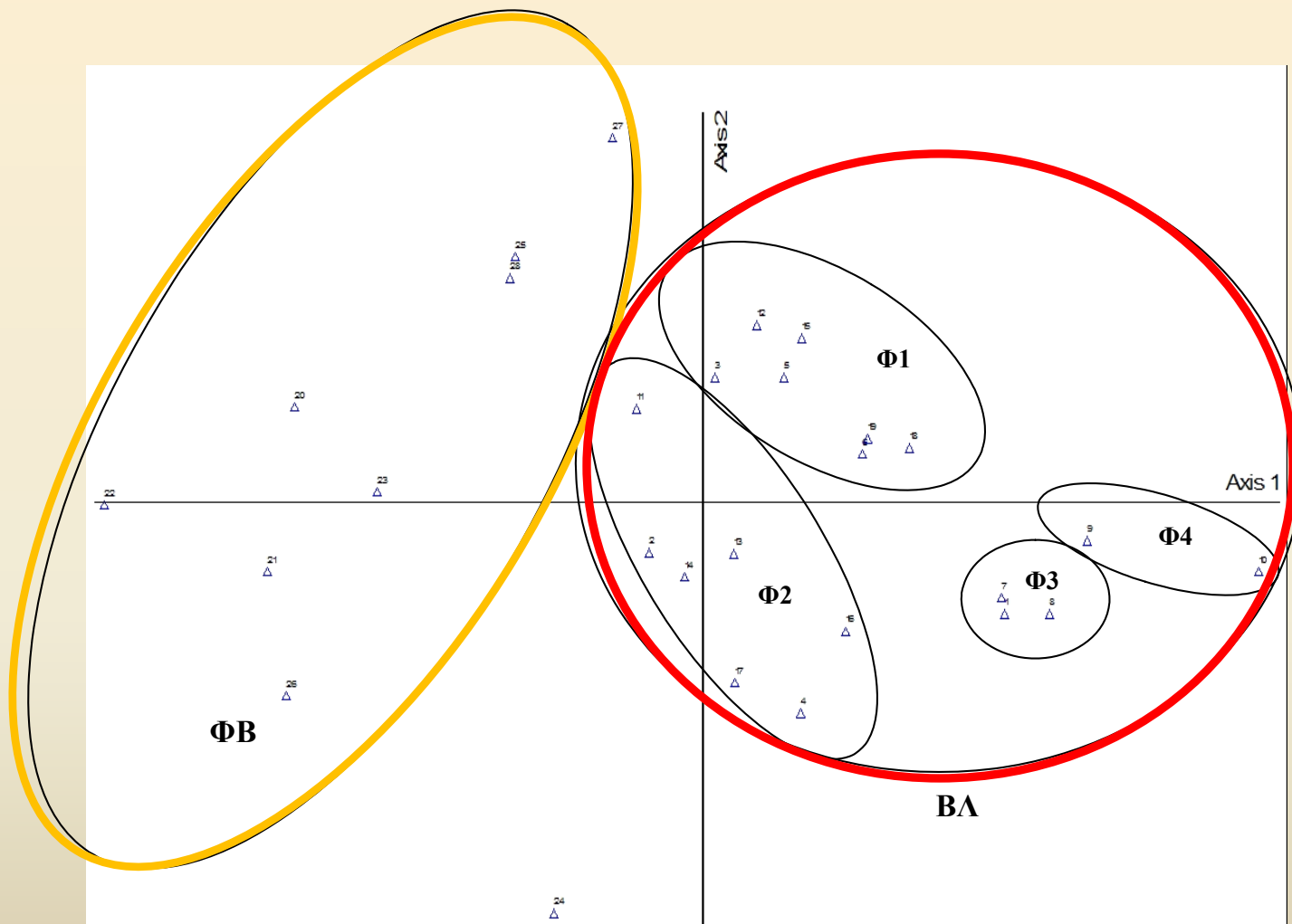
Species

of the class *Cisto-Micromerietea* Oberdorfer 1954, order *Cisto-Micromerietalia* Oberdorfer 1954, such as *Anthyllis hermanniae*, *Sarcopoterium spinosum* and *Cistus creticus*.

West region



Cistus creticus



Plant diversity study

Biodiversity indices:

Shannon-Wiener

$$H = - \sum_{i=1}^s p_i \ln p_i$$

$$1,5 \leq H \leq 3,5$$

Evenness

$$E = \frac{H}{H_{\max}} = \frac{- \sum_{i=1}^s p_i \ln p_i}{\ln s}$$

$$0 \leq E \leq 1$$

Simpson

$$D = 1 - \sum_{i=1}^s p_i^2$$

$$0 \leq D \leq 1$$

*using the PC-Ord 5 Software

Biodiversity indices

	Average number of taxa	Average number of taxa per plot	H	E	D
Quarry	15,5	0,82	2,170	0,821	0,7987
Surrounding area	10,7	1,19	1,627	0,710	0,6637

Biodiversity indices

	Average number of taxa	Average number of taxa per plot	H	E	D
Quarry	15,5	0,82	2,170	0,821	0,7987
Surrounding area	10,7	1,19	1,627	0,710	0,6637

The three diversity indices showed greater diversity inside the quarry area. This sounds incompatible. But the area is influenced by important factors like:

- 1) Human interference
- 2) Restoration practices and selection of plant species &
- 3) Natural restoration through natural succession

Conclusions

Restoration

Initially (until 1993), the company chose to use both native and alien species.

- *Eucalyptus globulus* → Australia
- *Robinia pseudoacacia* } North America
- *Acacia saligna* }
- *Cupressus arizonica* }

Today, only native species are being used.

- *Cistus creticus*
- *Dittrichia viscosa*
- *Pistacia lentiscus* etc.

Conclusions

Native taxa

The native flora is the 97,28% of the total plant taxa .

Most of them are “pioneer” plant species like *Dittrichia viscosa* and *Centranthus ruber*.



Dittrichia viscosa



Centranthus ruber

Conclusions

10,20% of the total plant taxa can be found at the quarry area exclusively.

These are:

<i>Cupressus arizonica</i>	<i>Ceratonia siliqua</i>
<i>Cupressus sempervirens</i>	<i>Medicago arborea</i>
<i>Silene italica</i> subsp. <i>peloponnesiaca</i>	<i>Robinia</i> <i>pseudoacacia</i>
<i>Convolvulus althaeoides</i> subsp. <i>tennuissimus</i>	<i>Spartium junceum</i>
<i>Cuscuta approximata</i>	<i>Laurus nobilis</i>
<i>Euphorbia characias</i>	<i>Eucalyptus globulus</i>
<i>Acacia saligna</i>	<i>Sanguisorba minor</i>
<i>Pinus halepensis</i> subsp. <i>brutia</i>	

- Most of them have been used for the restoration of the quarry benches and slopes.
- Their seeds were saved in the top-soil seed bank.
- Their seeds were transferred via air or birds.

Conclusions

25,17% of the total quarry flora belong to the family Fabaceae.

The great percentage of them indicates human interference in the area and especially fire.



The first plants which are established in the post-fire

ecosystems

They improve the soil quality:

- Their roots develop symbiotic relationships with nitrogen-fixing bacteria & contribute to the enrichment of the soil with nitrogen (natural fertilizer) &
- While decomposing, they can help create the top-soil in order for other plants to establish



Scorpiurus muricatus



Lathyrus setifolius



Anthyllis vulneraria
subsp. *rubriflora*



Dorycnium hirsutum

Conclusions

Is the restoration (technical & natural) of the quarry successful?

The evaluation is based on the similarity of the two floras.

The Sørensen index has been used:

$$S = \frac{2c}{a+b} = 0,785 \quad 0 \leq S \leq 1$$

Conclusions

Is the restoration (technical & natural) of the quarry successful?

The evaluation is based on the similarity of the two floras.

The Sørensen index has been used:

$$S = \frac{2c}{a+b} = 0,785 \quad 0 \leq S \leq 1$$

Suggestions

- The restoration should take place using only native plant species, which can be found in the surrounding area, such as *Anthyllis hermanniae*, *Hypericum empetrifolium*, *Phillyrea latifolia* etc.
- The use of alien species should be avoided.

Suggestions

- The seeds and seedlings should have originated from the surrounding area.
- The monitoring of the flora & the vegetation should be continued.

Thanks to:

D. Tzanoudakis, Professor of University of Patras
O. Georgiou, As. Professor of University of Patras
G. Vasileiou, biologist
D. Kontakos, forester (Msc.)
D. Doganos, forester (Msc.)
V. Laskari, biologist
G. Verroios, biologist (PhD)
S. Spanou, biologist (PhD)



Thank you very much!

