KARSTIC FORMS IN CENTRAL GREECE (AREA OF MOUNTAINS PARNASSE, GIONA, ELIKONAS) AND THEIR IMPLICATION IN THE FIELD OF GROUNDWATER VULNERABILITY[1]

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ABSTRACT

The region of Parnassos is characterised by the continuous carbonic sedimentation of thickness over 1800 m which is interrupted by characteristic bauxitic horizons. The numerous karstic forms observed in all altitudes as well as excavation sites of bauxitic layers constitute frail points of pollution and contamination of underground water tables. In this work, a first recording of the most usual karstic surface landforms is made as well as on effort to determine their liability.

ΠΕΡΙΛΗΨΗ

Η περιοχή του Παρνασσού χαρακτηρίζεται από τη συνεχή ανθρακική ιζηματογένεση πάχους άνω των 1800 μ. η οποία διακόπτεται από χαρακτηριστικούς βωξιτικούς ορίζοντες. Οι πολυάριθμες καρστικές γεωμορφές που παρατηρούνται σε όλα τα υψόμετρα καθώς και οι θέσεις εξόρυξης βωξιτικών κοιτασμάτων αποτελούν ευπαθή σημεία ρύπανσης και μόλυνσης των υπόγειων υδροφόρων καρστικών συστημάτων. Στην εργασία αυτή γίνεται μια πρώτη καταγραφή και προσπάθεια καθορισμού της ευπάθειας των πιο συνηθισμένων καρστικών επιφανειακών γεωμορφών.

KEY WORDS: Karst. Karstic features. Epikarst. Karst groundwater. Vulnerability. Parnassos. Giona. Helikonas. Bauxite. Abandoned quarry.

1. PREFACE

It is known that more than 33% of Greek space is covered by carbonate rocks. Consequently resulting these regions presents a special interest in the field of karstic forms and configurations. One of the most interest as well as well known area is the eastern part of the central Greece. The mountains of Parnassos, Giona and Helikonas mainly compose the relief of this area.

From geological point of view, this area belongs to the geotectonic zone of Parnassos-Giona. This zone is represented by continuous carbonate sedimentation from Upper Triassic to the Cretaceous, characterised by neritic phases of a thickness over 1,800 m. Over the carbonate sequences, the flysch has an age of Paleocene – M. Eocene and the stratigraphic column ends with the neogene and quaternary sediments. The bedrock of this zone is completely unknown. It is supposed that metamorphic formations of Precarboniferous age or slightly metamorphic formations of M. Carboniferous – Permian should consist this bedrock.

Special character of Parnassos-Giona zone is the presence of three bauxite horizons between K_{7-8} and J_{13-K6} (upper or 3rd horizon), J_{13-K6} and J_{12} (middle or 2nd horizon) and J_{12} and J_{i-m} (low or 1st horizon).

The karstification of the carbonate sequences is rather intensive and most of the so-formed karstic aquifers present an hydrodynamic base near the sea level. The discharge of the karstic water is achieved by a row of coastal or submarine springs along the northern coast of the Corinthian gulf. The extended number of such springs and their considerable discharge rate has led to the opinion that the three above-mentioned mountains are completely karstified.

1:ΚΑΡΣΤΙΚΕΣ ΓΕΩΜΟΡΦΕΣ ΣΤΗΝ ΚΕΝΤΡΙΚΗ ΕΛΛΑΔΑ (ΠΑΡΝΑΣΣΟΣ, ΓΚΙΩΝΑ, ΕΛΙΚΩΝΑΣ) ΚΑΙ ΕΠΙΠΤΩΣΕΙΣ ΣΤΗΝ ΤΡΩΤΟΤΗΤΑ ΤΩΝ ΥΠΟΓΕΙΩΝ ΥΔΑΤΩΝ

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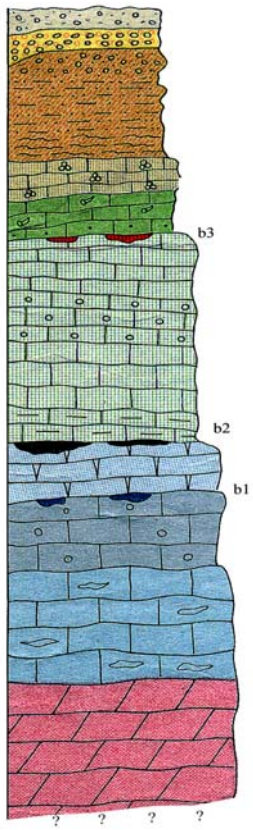

Recent alluvial deposits (Q)
Conglomerates (P_{3-c})
Undivided Flysch (F_p). Paleocene - Eocene. Thickness 300-400 m
Thin-bedded limestone (K_{8-e}). Senonian - Paleocene. Thickness 50-70 m
Compact or microcrystalline limestone (K_{7-8}). Touronian - Senonian.
- Bauxite of the upper horizon (b_3) -
"Intermediate" limestone (J_{13}-K_6). Tithonian - Kenomanian. Thickness 350-400 m
- Bauxite of the middle horizon (b_2) -
Thick-bedded compact limestone (J_{12}). Upper Jurassic - Kimmeridgian. Thickness 200-300 m
- Lower bauxitic horizon (b_1) -
Bituminous limestones (J_{i-m}). Middle and lower Jurassic, undivided. Thickness about 200 m
Limestones of J_{12} and J_{i-m} (J_{i-s}). Undivided Jurassic. Thickness about 500m
Dolomites crystalline (T_s). Upper Triassic. Thickness exceeds 600 m

Fig. 1. Columnar section of the zone Parnassos-Giona (Institut of Geological and Mining Researches)

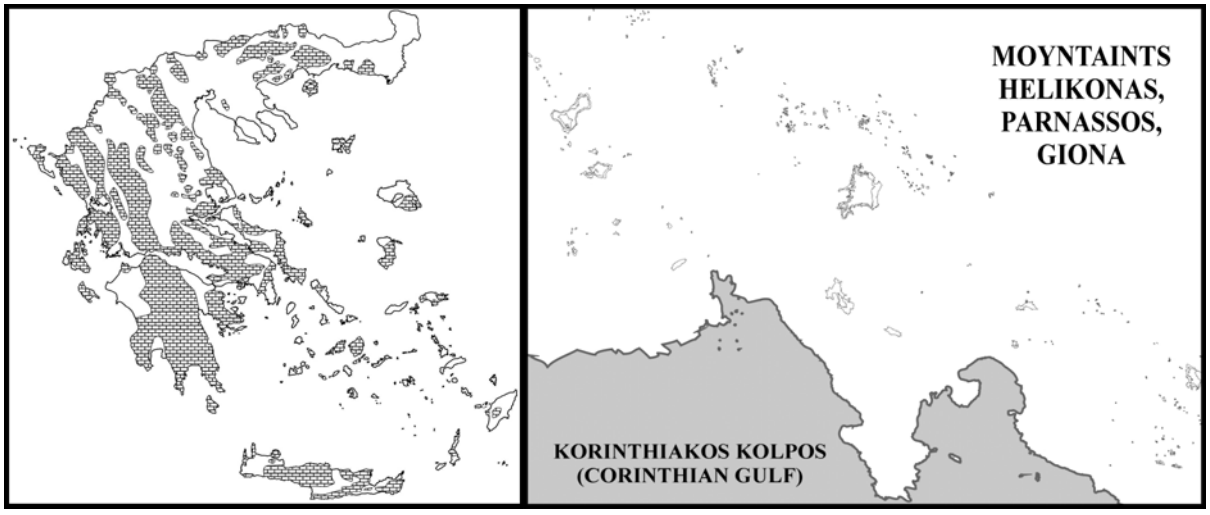

Fig. 2. Map of carbonates in Greece (left) and the study area of mountains Parnassos, Helikonas, Giona (right) with the location of the main karstic landscapes.

For Giona mountain at least, the excavation of the homonymous tunnel (14.5 Km), in the frame of the construction of the Mornos aqueduct, proved that Giona is karstified up to a certain depth from the surface. The interior of the mountain is without any karstification events, except of some solitary inactivated caves, filled by terra rosa. A certain quantity of the karst groundwater form intermediate aquifers in the level of the paleokarst, which is connected to the bauxite horizons. Because of the high discharge rates of the given aquifers, many mines used to operate with simultaneous continuous pumping,

which has affected other springs or aquifers, deforming the flow lines, since the bauxite mining operates as a drainage system for the surrounding karst groundwater.
The karstic forms encountered within the given area are numerous and represent all the different features noted in the bibliography. Referring to the general classification of the karstic features, the mentioned area presents the following characters.

2. TABLE OF TERMINOLOGY IN KARSTIC FORMS

Table 1. Superficial karstic forms (Exokarst)

DISPLAY	CATEGORY A	CATEGORY B	No	TERMINOLOGY	SYNONYM	GREEK DESIGNATION
Surface Weathering Forms Επιφ. Απο-σάθρωση	Karrenfeld Karren field Πεδίο karren Πεδίο Δακτυλογλυφών Αμαξοτροχιών	Karrenfree Ελεύθερα karren Bare karst Γυμνό καρστ	1	Rillenkarren (firstkarren)	Solution flutes	Ίχνη γλυφών
			2	Rinnenkarren	Solution runnels	Μικρές γλυφές
			3	Kluftkarren	Grike	Αυλακώσεις
			4	Spitzkarren	Lapies	Δακτυλογλυφές
			5	Flachkarren	Clint	Αμαξοτροχιές
			6	Trummerkarren		Ρωγμογενείς γλυφές
			7	Limestone pavement	Kalk plattform	Καρστικό λιθόστρωτο
			8	Maaderkarren	Meandering karren	Μαιανδρικές γλυφές
			9	Rundkarren	Round karren	Κυκλικές γλυφές
		partly covered karst Μερικώς καλυμμένο Καρστ	10	Solution pan	Kamenitza	Υδρόλακκος, λακούβα
			11	Solution notch		Τρύπα διάλυσης
			12	Undercut solution runnels		Υπεδάφια αυλάκια διάλυσης
		Covered karst Καλυμμένο καρστ Σύνθετο καρστ	13	Cryptokarst		Ασβεστ. θύλακοι με terra rossa
			14	Cavernous subsoil weathering		Κοιλότητες υπεδάφ. αποσάθρωσης
			15	Solution pipes	Geological organ	Αμμώδης αγωγός διάλυσης
Surface Landforms	Small Closed Depressions	Dolines	16	Solution dolines		Δολίνες διάλυσης
			17	Collapse dolines		Δολίνες κατάρρευσης
			18	Cover subsidence dolines	Suffosion dolines	Δολίνες καθίζησης του καλύμματος
			19	Alluvial streamsink dolines		Αλλουβιακές δολίνες
		Uvalas	20	Compound sinks		Σύνθετες δολίνες - ουβάλες
		Cockpits	21	Cockpit karst		Δολινοβριθές καρστ
			22	Kegelkarst	Turmkarst	Τοπίο δολινών
			23	Cone karst	Tower karst	Κωνικό καρστ, πυργοειδές καρστ
	Other Closed Depressions	Poljes Interior valleys	24	Border polje		Συνοριακή πόλγη
			25	Marginal polje		Περιθωρειακή πόλγη
			26	Piedmont polje		Πόλγη υπωρειών (προπόδων)
			27	Overflow polje		Πόλγη υπερχείλισης
			28	Base level polje		Πόλγη επιπέδου βάσης
			29	Polymorphous polje	Polygenetic polje	Πολυγενετική (πολύμορφη) πόλγη
		Corrosion plains	30	Closed basin	Closed depression	Κλειστή λεκάνη
			31	Karst plain	Peneplain	Καρστικό πεδίο
			32	Hum	Karst inselberg	Καρστικοί λόφοι μάρτυρες

Table 1. Superficial karstic forms (Exokarst)
(suit)

DISPLAY	CATEGORY A	CATEGORY B	No	TERMINOLOGY	SYNONYM	GREEK DESIGNATION
Επιφ. Γεω-			33	Karst windows		Καρστικό παράθυρο
Μορφές			34	Gulf (large karst window)	Steep-walled dep.	Καρστικός κόλπος (χάσμα;)
			35	Half-blind valley		τυφλή και ξηρή κοιλάδα
			36	Blind valley		Τυφλή κοιλάδα
			37	Dry valley		Ξηρή ("πεθαμένη") κοιλάδα
			38	Gorge	Canyon	Χαράδρα, φαράγγι
	Other		39	Meander cave		Μαιανδρικό σπήλαιο ποταμού
	Karst		40	Natural bridge		Φυσική γέφυρα
	Features		41	Natural arch		Φυσική αψίδα
			42	Constructional action rives		Δομική δράση ποταμών
			43	Solution chimneys-karst shafts		Καρστικά φρεάτια - κάρκαρα
			44	Shallow hole - shallet	Ponor	Καταβόθρα
			45	Estavelle		Εσταβέλλα (πηγή και καταβόθρα)
			46	Karst spring		Καρστική πηγή
			47	Karst lake		Καρστική λίμνη
			48	Glaciokarst	Alpine karst	Παγετοκάρστ
			49	Caves		
			50	Detritic deposits within the karsic environment		
			51	Abandoned quarries		
			52	Sterile materials		

3. KARSTIC FORMS IN CENTRAL GREECE

Karstic forms in central Greece (area of mountains Parnassos, Giona, Helikonas)
and their implication in the field of groundwater vulnerability
BELLOS, TH. & G. STOURNARAS (2001)
Table 2

no photo	Description	No of table 1	Assessed vulnerability consequences	Remarks
1	Terrace at the stream's exit	50	Allochthon soil cover susceptible of further sediments deposit or erosion. Limited lateral infiltrability	Rather erosible outcrop
2	Deep erosion, high infiltrability	38	Dispersed form within a linear arrangement of the infiltration and eventual contamination's concentration	Infiltrability strongly depended on the flow level.
3	Deep erosion, low infiltrability	38	Strictly linear form of infiltration and eventual contamination's concentration	Infiltrability moderately depended on the flow level
4	Deep erosion, medium infiltrability	38	Linear to dispersed form within a linear arrangement	Infiltrability moderately depended on the flow level
5	Deep erosion, low infiltrability	38	Linear form of infiltration	Infiltrability weakly depended on the flow level
6	Erosion form in the river bed	38	Concentrated infiltration/contamination	Infiltrability strongly depended on the flow level
7	Erosion form in the river bed	38	Concentrated infiltration/contamination	Infiltrability strongly depended on the flow level
8	Erosion form in the river bed	38	Concentrated infiltration/contamination	Infiltrability strongly depended on the flow level
9	Fault/extended rupture in the river bed	38	Point infiltration/concentration	Infiltrability related to the active extension of the rupture depthwards
10	Erosion form in the river bed	38	Dispersed infiltration/contamination	Infiltrability strongly depended on the flow level. Possible epikarstic sequence
11	Erosion form in the river bed	38	Concentrated infiltration/contamination	Infiltrability strongly depended on the flow level
12	Terrace at the stream's exit	50	Allochthon soil cover susceptible of further sediments erosion. Limited lateral infiltrability additional soil cover	Rather erosible outcrop
13	Terrace at the stream's entry	50	Allochthon soil cover susceptible of further sediments erosion. Limited lateral infiltrability additional soil cover	Rather erosible outcrop
14	Erosion form in the river bed	38	Concentrated infiltration/contamination	Infiltrability strongly depended on the flow level
15	Deep erosion	38	Extended lateral infiltration/contamination	Infiltrability strongly depended on the flow. Presence of epikarstic sequence

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Table 2 (suit)

no photo	Description	No of table 1	Assessed vulnerability consequences	Remarks
16	Karstic erosion forms (karren)	2	No significant effect in vulnerability without the action of discontinuities	Indication of strong karstification
17	Karstic erosion forms	4	Additional strong presence of discontinuities	Possible additional tectonic action
18	Karstic erosion forms	11	No significant effect in vulnerability without the action of discontinuities	Indication of strong karstification
19	Karstic erosion forms	16	Very vulnerable media presenting strong infiltrability	Usual epikarstic sequence
20	Karstic erosion forms	6	Very vulnerable media presenting strong infiltrability	Usual epikarstic sequence
21	Karstic erosion forms	9	No significant effect in vulnerability without the action of discontinuities	Indication of strong karstification
22	Karstic erosion forms	38	Significant infiltrability mainly of discontinuities	Dispersed linear forms of infiltration/contamination
23	Karstic erosion forms	2	No significant effect in vulnerability without the action of discontinuities	Indication of strong karstification
24	Karstic erosion forms	4	Significant infiltrability mainly of discontinuities	Dispersed linear forms of infiltration/contamination
25	Deep erosion probably in tectonic event	38	Very high dispersed and linear infiltrability	Usual epikarstic sequence
26	Karstic erosion forms	38	Very high dispersed infiltrability	Possible epikarstic sequence
27	Deep erosion probably in tectonic event	43	Very high dispersed and point infiltrability	Usual epikarstic sequence
28	Karstic erosion forms	3	Very high dispersed infiltrability	Possible epikarstic sequence
29	Karstic erosion forms	38	Very high dispersed infiltrability	Usual epikarstic sequence
30	Karstic erosion forms	5	High dispersed infiltrability	Possible epikarstic sequence
31	Karstic erosion forms	11	No significant effect in vulnerability without the action of discontinuities	Indication of strong karstification
32	Cave in Elikonas	49	High dispersed (rockmass) and high concentrated (cave) groundwater flow	High degree of discontinuities interconnection around the cave. Intense infiltrability

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Table 2 (suit)

no photo	Description	No of table 1	Assessed vulnerability consequences	Remarks
33	Cave in Elikonas	49	Low dispersed (rockmass) and high concentrated (cave) groundwater flow	Low degree of discontinuities interconnection around the cave. Variable infiltrability
34	Cave "Eptastomo" in Parnassus	49	Mediocre dispersed (rockmass) and high concentrated (cave) groundwater flow	Mediocre degree of discontinuities interconnection around the cave. Variable infiltrability
35	Levelling surface	31	Soil covering a permeable formation (conglomerates) lying over karst	High infiltrability
36	Karst form adjacent to cave "Eptastomo" in Parnassus	6	Mediocre dispersed (rockmass) and high concentrated (cave) groundwater flow	Mediocre degree of discontinuities interconnection around the cave. Variable infiltrability
37	Karst form adjacent to cave "Eptastomo" in Parnassus	6	Mediocre dispersed (rockmass) and high concentrated (cave) groundwater flow	Mediocre degree of discontinuities interconnection around the cave. Variable infiltrability
38	"Faedriades Petres" (Delphi). Deep erosion	38	Mediocre dispersed and high linear infiltration/contamination	Additional tectonic action
39	Trizinikos spring	44, 45	Concentrated infiltration (sinkhole function)	Estavella
40	Cave "Korykion Andron"	49	Dispersed (rockmass) and linear (cave) groundwater flow	Mediocre infiltrability around the cave. Variable infiltrability
41	Polje "Kalivia Arahova)	27	Polje flooded by Trizinikos spring	Estavella
42	Dry valley	37	High potential dispensed infiltrability	Dry valley (alt.: 2300 m)
43	Cave-conduit "Drakokarkaro" in Parnassus	43	Dispersed (rockmass) and linear (cave) groundwater flow	Mediocre infiltrability around the cave. Variable infiltrability
44	Doline in Giona	17	High infiltrability around	Doline's characteristics
45	Doline in Elikonas	17	High infiltrability around	Doline's characteristics
46	Doline in Giona	17	High infiltrability around. Hydraulic communication with the sea water	Doline's characteristics
47	Doline in Elikonas	20	Variable thickness of soil cover	Doline's characteristics
48	Doline in Parnassus	21	High infiltrability around	Doline's characteristics
49	Doline in Parnassus	16	High infiltrability around	Doline's characteristics
50	Doline in Parnassus	21	High infiltrability around	Doline's characteristics
51	Doline in Parnassus	16	High infiltrability around	Doline's characteristics

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no photo	Description	No of table 1	Assessed vulnerability consequences	Remarks
52	Doline in Elikonas	17	High infiltrability around	Doline's characteristics
53	Doline in Parnassus	16	High infiltrability around	Doline's characteristics
54	Doline in Parnassus	16	High infiltrability around	Doline's characteristics
55	Waste disposal in karst environment (abandoned quarry)	51	Modification of the infiltrability of the karstic sequence	Abandoned quarry
56	Solution chimney	43	Limited infiltration capacity	Inactive sinkhole
57	Solution chimney	43	Limited infiltration capacity	Inactive sinkhole
58	Sterile material in gorge bed	52	Linear reduction of initial karstic infiltrability	Extremely local and restricted event
59	Subsurface mining in Elikonas	51	Local increase of groundwater flow	Case similar to cave with increasing length and changeable shape
60	Subsurface mining in Elikonas	51	Increase of groundwater flow	Case similar to cave with increasing length and changeable shape
61	Surface mining in Elikonas	51	Modification of the infiltrability of the karstic sequence	Changeable length and shape
62	Ponor in Stiri area	44	Concentrated infiltrability	Ponor
63	Surface mining in Elikonas	51	Modification of the infiltrability of the karstic sequence	Changeable length and shape
64	Panoramic view of Arachova-Delphi valley	31,38	Different forms of karstic landscapes	Different conditions of infiltrability

4. CONCLUSION

As it becomes clear, by the high degree of karstification, the groundwater in such regions is exceptionally vulnerable to contamination. These vulnerability phenomena depend on the nature of the contaminants (specific vulnerability), on the character of the karst network and form (intrinsic vulnerability) and on the attenuation factors during the water infiltration and the contaminant transportation. These contaminants result from the different land uses, such as agriculture, excavations, industries, urban wastes, transports, storage reservoirs etc. The thickness of the protective cover (overburden) can considerably improve the quality of infiltrated and transported water. Hence, the analytical description of the protective cover – factor C (as it is named recently by the COST 620 action) seems to be of great importance for the assessment and the risk mapping of the karst aquifers vulnerability.

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PHOTOGRAPHIC IMAGES WHICH CORRESPOND ON THE TABLE 2:

Photos No: 1-15

Photos No: 16-31

Photos No: 32-43

Photos No: 44-54

Photos No: 55-64