ORIGIN AND FORMATION OF SOME CHARACTERISTIC GEOMORPHOLOGICAL OCCURRENCES IN THE TECTONIC VALLEY OF LANGADA-VOLVI. «NYMPHOPETRES»

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S u m m a r y : Within the tectonic Basin of Langada - Volvi and particularly on the left side of the road between the villages Prophetes and Nymphopetra are situated some characteristic rocks called «Nymphopetres».

From the geomorphological and petrological point of view they are very different from the surrounding area.

After a brief survey of the geological and tectonic structure as well as of the development of the Langada - Volvi Basin, the formation, the morphology and the chemical composition of the Nymphopetres rocks are studied carefully. It has been proved that the formation of these rocks have a continental origin and are due to the chemical deposits which result from the activity of hot - mineral springs along the marginal faults of the basin. These hot - mineral springs after having left their traces, dried up and disappeared because of the tectonic instability of the respective area, and the creation of new faults and depressions. The present characteristic morphology of these formations (steep, huge rocks) can be mainly ascribed to the continued activity of the tectonic factors on one hand (faults and joints) and to the weathering and erosion factors on the other. The rainwater entering into the joints of the rocks caused the mechanical loosening and chemical transformation of the sediments.

The result of the foregoing factors is the present peculiar form of the distinct steep rocks.

GEOLOGICAL SETTING OF THE STUDY AREA

Situation - Boundaries:

The geomorphological occurrences «Nymphopetres», reported here, are situated about 3,5 kilometres northwest of Lake Volvi. The Langada and Volvi Lakes together are part of a greater tectonic Basin of Mygdonia (J. Cvijic, 1901) which is stretched northeast of Thessaloniki from the Gallicos River valley up to the Gulf of Orphanos (Aegean Sea) in a west-east orientation.

Regarding its orientation, the Mygdonia Basin is generally an exception to most Basins of Macedonia which have a northwest-southeast orientation.

The tectonic Basin of Mygdonia is bound by Mountain chains: Vertiskos - Kerdillion in the north and Chortiatis - Cholomon in the south. The hills of Dervenion - Megali Tsouka - Devekoran are on its

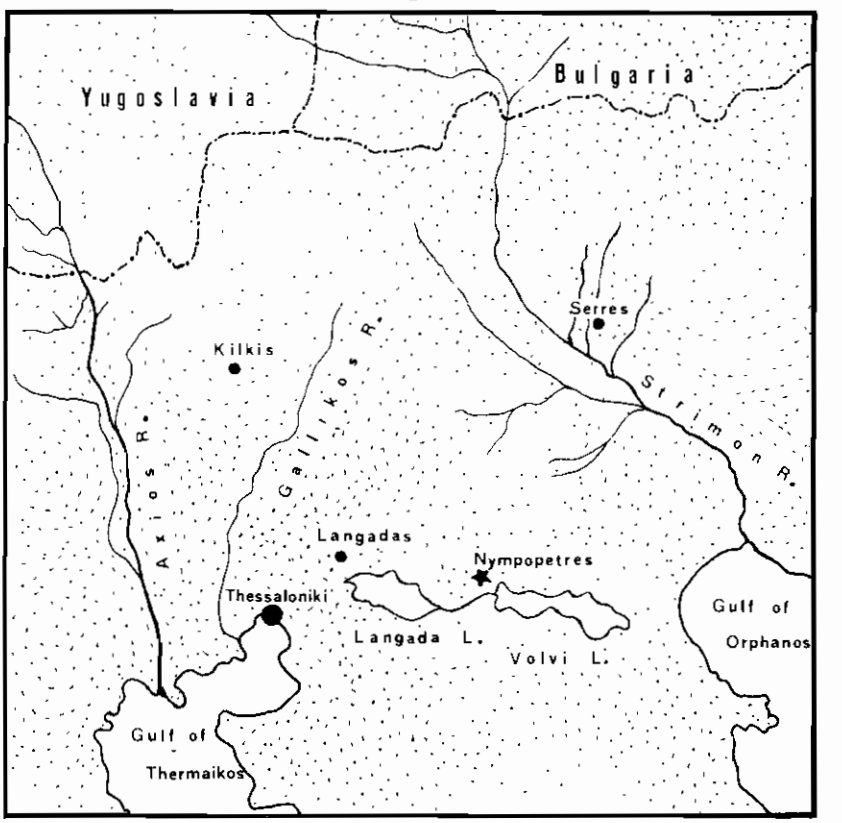

Figure 1.
«Area map. Nymphopetres»

western end, and by means of the Rentina's defile is connected with the Gulf of Orphanos in the east.

Geological Structure:

Geologically, the base and sides of the Mygdonia Basin are composed of metamorphic rocks as well as of post-tertiary sediments which occupy the lower parts of it and were deposited after its formation.

The main metamorphic rocks are gneiss and granite - gneiss, amphibolite, marble, micaschist and phyllite. They are found on the south side of the Vertiskos - Kerdillion Mountain chain, and on the north side of Chortiatis - Cholomon.

In many places they are interrupted by insertion of acid and basic igneous rocks. Acid igneous rocks, especially granites, are found on the north side of the basin at the Prophetes area, as well as on the south side of it at the area between the villages of Zangliverion - Nea Apollonia.

Basic igneous rocks occur in the Amphibolites group and are composed of metadiabase, with ophitic fabric, which is transformed into uralite - gabbro.

Oswald (1938) and Neubauer (1957) found that the age of metamorphic rocks is probably Devonian because of the lack of fossils within them. Borsi, Ferrara and Mercier (1965) found that the age of metamorphic rocks is the Carboniferous one. Their conclusions were based on the results of radiochronology experiments they had carried out on pegmatite dikes passing through the rocks of the Mountain of Vertiskos.

We can distinguish two main systems of Post-tertiary sediments deposited on the Langada - Volvi Basin:

a. The system of Neogene - Pleistocene sediments: and

b. The system of Alluvial deposits.

The first system of sediments extends around the margins of the basin, mainly in the northwest parts of it, in the Melissochorion - Ntevekoran area, where they occupy some low hills, as well as on the south side of the Volvi Lake in the Zangliverion - Nea Apollonia area. There some rivers have cut the ground deeply so that the thickness of visible sediments amounts to some decades of meters. Maravelakis (1936), who drilled in the Langada area, found that the thickness of Neogene - Pleistocene sediments ranged from 150 to 300 meters. These sediments are composed of red - clay, including quartz - sand and conglomerates, as well as of sand beds alternating with clay and conglomerates.

Neumayr (1879) considered these sediments as «genuine tertiary».

Regarding the younger beds of the first system, especially the red-clay which were deposited mainly in the southwest part of the basin, he concluded that these beds were derived from the weathering of epigneisses on the north side of the Mountain chain of Chortiatis - Cholomon during the Pleistocene.

This opinion was shared by BURGESTEIN (1879), who studied analogous sediments on the southwest side of the same mountains in the Chalkidiki area.

GARDIKAS (1939), considered the upper red-clay beds probably of the Pleistocene period in spite of the lack of fossils in them. Within the red-clay beds of Nea-Apollonia area were found fossilized bones of mammals in a bad natural state. At the present time some of these are to be found in the collection of the Palaeontological and Geological Musuem of the University of Thessaloniki and are recognized as bones of Proboscidea of the Pleistocene.

It is clear, therefore, that the red-clay beds of the first system of sediments are of the Pleistocene. Within similar red-clay beds in other places of Macedonia were also found fossilized bones of mammals (MARINOS, 1965) characteristic of the Pleistocene.

The second system of alluvial deposits occupy the low surface of the Basin, especially the shores of Langada and Volvi Lakes, as well as the area between them. These are river and terrestrial deposits having a maximum thickness of about 110 meters and include sand, clay, conglomerates and peat material in some places.

Tectonic Structure:

Many Greek and foreign geologists engaged in the past with the tectonic structure of the Mygdonia Basin, namely: KOSSMAT (1924), MARAVELAKIS (1936), JARANOFF (1937), OSSWALD (1938), GEORGALAS - GALANOPOULOS (1953), KOCKEL and WALTER (1968), (1971), and others.

Tectonically, the great Basin of the Mygdonia is divided into two smaller Basins:

a. In the Langada Basin extending from Langada to Zangliverion valley, and

b. In the Volvi Basin.

KOSSMAT (1924) and OSSWALD (1938) examined geotectonically the Langada Basin with the Zangliverion Valley and considered this area as a part of the Axios Zone which is characterized by a northwest to southeast orientation. In this area many faults are observed in the same direction.

According to KOCKEL and WALTER (1968) the northeast parts of the Langada Basin with the Zangliverion Valley are regarded as belonging to the Serbomacedonian massif.

In the year 1971, KOCKEL, MOLLAT and WALTER described this area as belonging mainly to the east boundaries of the Axios Zone on the characteristic line of Melissochorion - Cholomon.

The Basin of Volvi is bound by the Mountains of Lachana - Vertiskos - Cholomon.

According to ARSOVSKI (1961), DIMITRIJEVIC (1963), KOCKEL and WALTER (1968), the area of the Volvi Basin belongs to the Serbomacedonian massif which is regarded as a particular geotectonical zone. The west to east orientation of the Volvi Basin follows the direction of the faults and depressions of this area.

GEORGALAS and GALANOPOULOS (1953), concluded that the west to east orientation of the eastern parts of the Mygdonia Basin was the result of the same orientation of the faults system which is very typical of the Aegean Province and is regarded as characteristic of East Mediterranean Sea. In spite of the west to east orientation of the eastern parts of the Mygdonia, the western parts of it have a northwest to southeast orientation, which is characteristic of the Dinaric tectonic Province.

It is obvious, therefore, that the eastern parts of the Langada - Volvi Basin were created by the Aegean tectonic movements while the western parts of it were created by the Dinaric tectonic movements.

Many hot-mineral springs emerged along the faults of such a tectonic unstable area in the past. Some of them continue to exist and are active to date, i.e., the hot-mineral springs of Langada, of Nea Apollonia, of Therma Nera, and others.

The occurrence of chemical sediments in many places within the basin and especially along the faults of it, are regarded as strong evidence of the hot-mineral springs' activity in the past. These pre-existing springs dried up probably by very strong earthquakes during the Pleistocene.

This view is shared first by GEORGALAS and GALANOPOULOS and also by many geologist as MARAVELAKIS (1936) OSSWALD and others.

The Langada - Volvi Basin continues to be unstable and in a state of equilibrium thereby still causing earthquakes.

MARAVELAKIS (1936) supposed that there were three (3) seismic foci in the Gulf of Akanthos, in the Lake Volvi, and in the Asprovalta area. GEORGALAS and GALANOPOULOS thought that the latest earthquakes in

the year 1932 had the same seismic focus in the Gulf of Ierissos.

The development of the Langada - Volvi Basin:

The Langada - Volvi Basin constitutes a tectonic depression created by the restoration of the balance of the orogenic beds during the Palaeogene, while fault-blocks continued moving until the Diluvian.

The rainwater falling in the surrounding area of the basin, released debris which did not remain at the place of their origin but moved down by the erosion factors and accumulated on the base and at the lower parts of the basin.

The accumulation of the water in the basin had as a result the formation of the great Lake of Mygdonia during the Pleistocene.

The absolute depth of this lake was about 176 meters.

The existing Lakes of Langada and Volvi take up two small parts of the base of the old Mygdonia and are regarded as two small remnants of it.

During the later Pleistocene, when in Greece faults and depressions were taken place, a furrow was created in the west side of the Mygdonia Lake (in the Rentina area) through which the water flew to the Gulf of Orphanos into the Aegean Sea.

The furrow deepened while the water continued flowing out of the lake, and the surface of it continued to descend. At the end of this process, the water of the Mygdonia Lake created the defile of Rentina through which flowed to the Aegean Sea. In the deepest parts of the base of the Mygdonia were formed the two smaller Lakes of Langada and Volvi by the remaining water.

NYMPHOPETRES

General remarks:

On the left side of the road between the villages Prophetes and Nymphopetra, in the County of Langada, are found some characteristic rocks giving the impression of old castles.

They are impressively huge rocks and geomorphologically very different from the surrounding area. As mentioned previously, they are located within the tectonic Basin of Langada - Volvi about 3500 meters northwest of the Volvi Lake at an altitude of 150 meters.

The main group of Nymphopetres rocks take up an elongated area of about 200 meters in length and 70 meters in width with a general N 25° W. orientation.

There are also some other similar rocks in the same area: Three rocks, one after the other about 800 meters west of the main group with the same orientation; another rock about 200 meters in the north; and, four other rocks about 2000 meters southwest of them with a S 40° W orientation.

Geomorphologically they appear as very steep rocks, they have a height of 8 meters and a thickness of 3 - 4 meters with four vertical sides which are cut in two main directions, i. e., one northwest to southeast and another northeast to southwest.

They have a spongy outward appearance and are composed mainly of grains of $CaCO_3$ very strongly joined together and covered by a grey-black deposit of $CaCO_3$. In some places inside of the mass of these rocks, some irregular surfaces of erosion are observed. These can be ascribed probably to the temporary interruption of the process of chemical sedimentation.

This interruption was caused by the interference of natural obstacles which have changed the local direction of the flow of the hot-mineral springs. This can be concluded from the fact that the masses of $CaCO_3$ separated by erosive surfaces present slightly different directions of the current flow.

The weathered sides of the rocks are light-grey with impressive small cavities which were created by the rainwater and the attack of wind.

A large number of joints are observed on the rocks, starting from the top of them and ending at the base which follows the direction of the rock sides.

Because of the characteristic contrast between these rocks and their surrounding area, their peculiar form and grouping, as well as the impression they create, had been the object of the mythology.

According to one myth, this group of rocks with their special form and orientation represents a wedding procession coming from the bride's (Nymphi) village and going to the bridegroom's neighboring village, but due to a curse of the bride's mother they subsequently became stonified (Petres).

Structure:

Although the rocks of the Nymphopetres group seem to be separated and independent, a more careful observation is needed to prove that they are connected at their base with a bed of the same material. The thickness of this bed varies from place to place but generally it

is about 50 cm. In the northern end of the Nymphopetres group, the basic bed has been swept away by a stream which has cut the ground. The bed reappears on the opposite bank of the stream where it becomes thinner and gradually disappears a few meters from the bank.

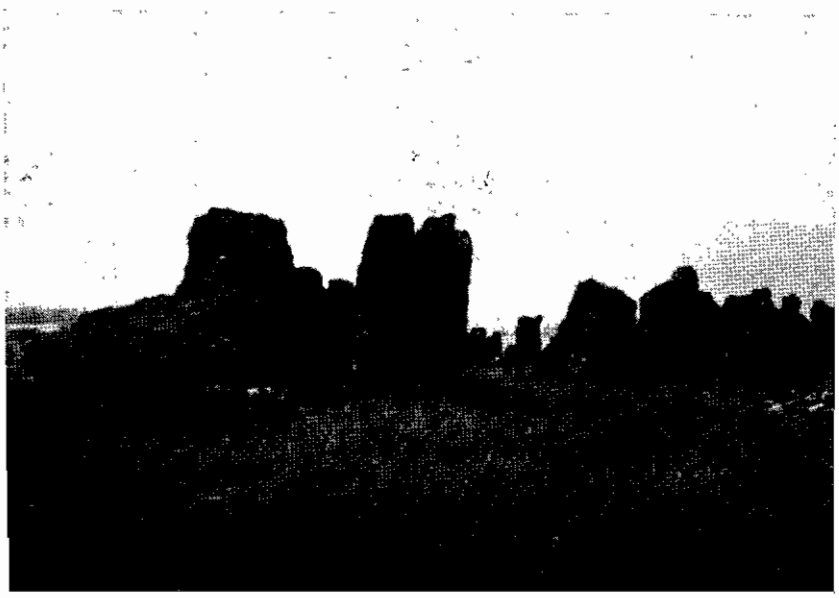

Plate I. General view of the Nymphopetres rocks.

This basic bed occupies a larger area than the one occupied by the Nymphopetres group stretching about 400 meters to the north of them. It is important to remark that this bed does not extend in a western or southwestern direction from the Nymphopetres group in order to connect the similar smaller rocks. It is clear, therefore, that the main occurrences of the Nymphopetres are independent and have no connection with their neighbouring ones in the same area. Under the basic bed there is a thinner one including conglomerates, coarse grains of sand and clastic materials about 40 cm. thick. A third bed underlying the second one includes very thin layers of fine sand and clay, which are regarded to be derived from the sedimentation of the lake.

The system of the three beds described above, with the Neogene sediments of the basin under them have been subjected to earthquakes and other forces which caused faults, joints and depressions. All of these tectonic processes can be ascribed to the instability of the basin.

Under the Neogene sediments of the basin are found some crystal-

line rocks as gneiss, micashists, phyllites and others which constitute the base of this basin.

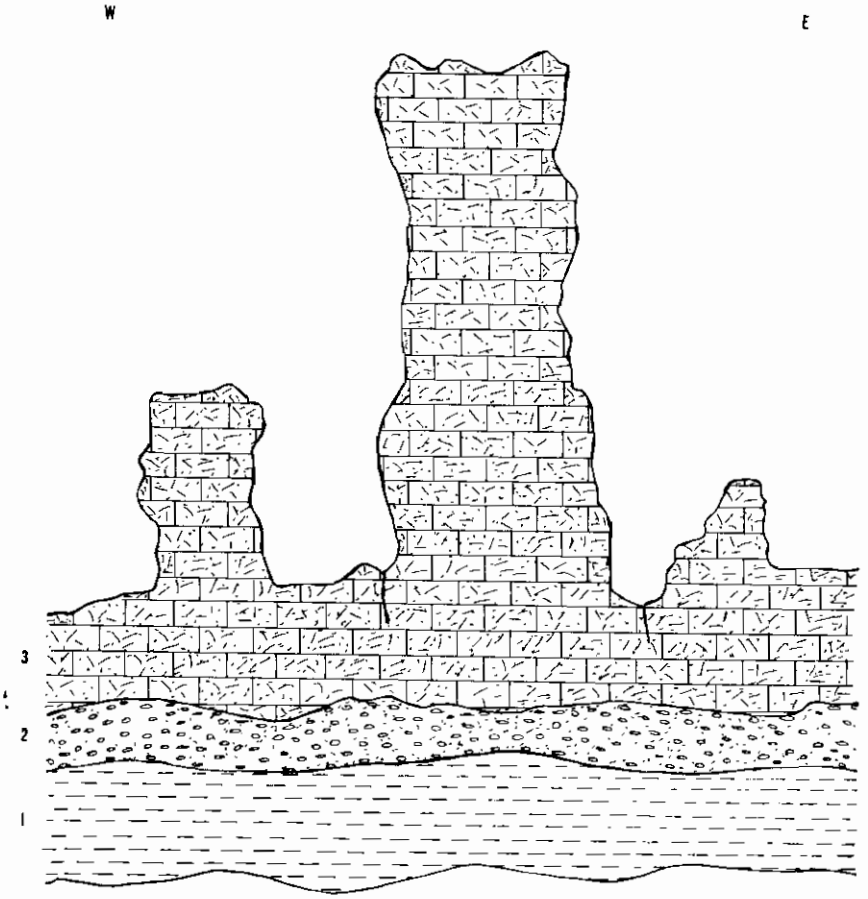

Figure II.

Cross - Section along a stream flowing through the northern side of the Nymphopetres rocks.

1. *Very thin layers of fine sand and clay deposits;*
2. *Clastic materials including conglomerates, coarse grains of sand and pebbles;*
3. *Chemical deposits.*

Origin and Formation:

As mentioned above, during the Pleistocene and Quaternary,the Langada - Volvi Basin had undergone tectonic movements which caused faults and depressions. Many hot - mineral springs emerged along these

faults in the basin, but most of them disappeared because of the continuous tectonic movements leaving behind them superficial chemical deposits in many places.

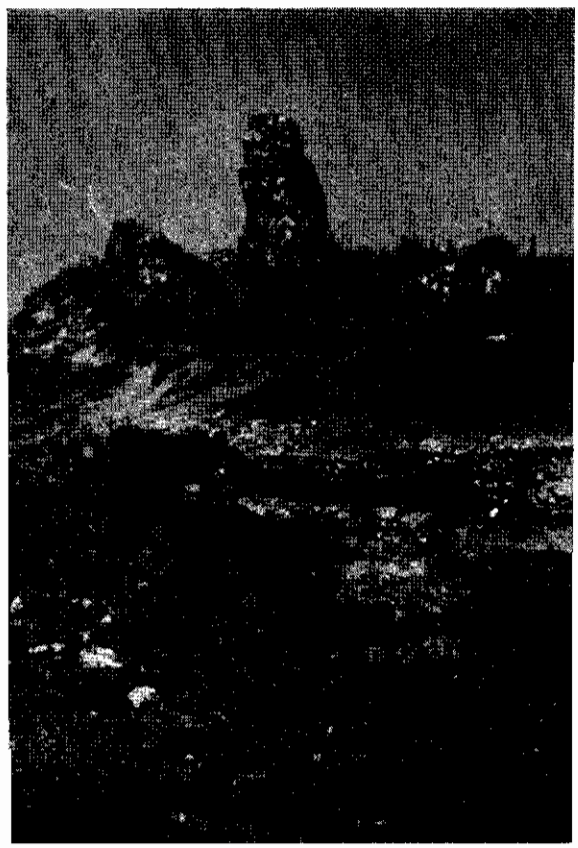

Plate II. Outward morphology of the Nymphopetres rocks.

There are concrete chemical deposits in a few locations in the basin proving the existence of hot - mineral springs in the past. There are also a few active hot - mineral springs in the Langada, Nea Apollonia and Therma Nera area which are therapeutically active to date.

Although the Nymphopetres rocks are independent from the smaller ones in the west and in the north, they are derived from the activity of hot - mineral springs in the past.

Similar rocks occur in many locations in the Nea Apollonia area — in the south of the Lake Volvi—but they are very different from the pecu-

liar geomorphological features of the Numphopetres.

The hot - mineral spring materials were deposited and accumulated on the margins of the Mygdonia Lake and especially on the shore materials. As shown in Figure II, the upper bed of chemical deposits of the hot - mineral springs lies on a bed of such shore materials which are regarded as a proof of the recession of the water of the Mygdonia.

Plate III. A natural cross - seetion of the Nymphopetres rocks.

Fossilized bones of mammals which were found in the Numphopetres, as well as the lack of a distinct internal tecture are regarded as a further evidence of continental origin. The activity of such springs possibly started in the shallow waters of the Mygdonia. In such an enviroment, deposition and accumulation of spring materials were impossible, because many water currents swept them away. It is clear, therefore, that the hot - mineral spring materials were deposited after the recession of the water of the Mygdonia Lake. As soon as the surface of the lake water lowered, the hot - mineral springs from the bottom of the shallow waters came out on the shore and began to deposit chemical sediments mixed up with shore materials, mainly sand, forming a superficial solid mass of about 10 meters thickness.

Because of continuous tectonic movements, the hot - mineral springs dried up the process of deposition was interrupted and a lot of joints

were created on the solid mass. At the same time there was intense weathering and erosion. If the weathering and erosion factors had only acted on this superficial solid mass, it would had been lowered uniformily leaving behind a thin bed lying on the shore materials. The creation, therefore, of such peculiar rocks with steep sides was the result of some more factors especially of joints and small faults. These joints are distinguished on the basis of their direction into two main

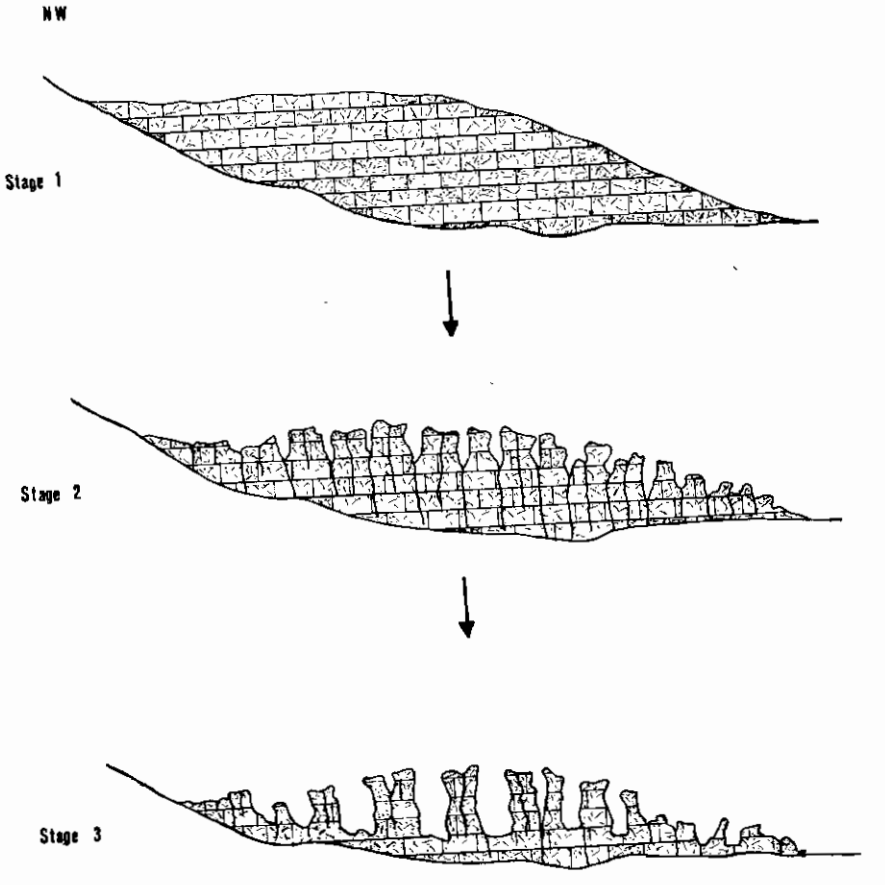

Figure III.

Representation of the Nymphopetres profile development.

Stage 1. *Superficial solid mass formed by deposition of hot - mineral springs.*

Stage 2. *Joints on the mass and the beginning of weathering and erosion along them.*

Stage 3. *Nymphopetres roeks at present day appearance.*

groups crossing each other. The first group has a northwest to southeast direction and the second group a northeast to southwest direction.

At the beginning of the weathering and erosion processes, the rainwater entered into the joints causing loosening of the solid mass and chemical changes of its ingredients. The narrow joints became deeper and wider offering a larger surface to the corrosion processes. In addition, the wind armed with sand grains blew against the rocks and created abrasion especially along the joints and cracks opening a large number of cavities and gaps.

All of the above factors contributed to the separatiou of the solid mass into the smaller rocks of Nymphopetres. The results of the weathering, erosion and corrosion in and out of the Nymphopetres rocks showed the destructive factors and the manner of their action.

The explanation of the origin and formation of the Nymphopetres rocks given above is based on two main facts:

1) The connection of the Nymphopetres rocks with a basic bed of the same material is regarded as strong evidence of their common origin from the same solid mass.

2) The orientation of the steep sides of the rocks in two main directions — one northwest to southeast and the other northeast to southwest — is regarded as strong evidence of the existence of joints along which intense weathering and erosion took place.

Analogous chemical deposits are found at the hot - mineral springs of the Agia Paraskevi area in the Anthemous Valley but in the usual form of spring deposition.

The Nymphopetres rocks were made of chemical deposits from the hot - mineral springs. These accumulated on the shore materials after the recession of the water of the Mygdonia Lake during the late Pleistocene. It is, therefore, obvious that it is a newly established formation of the Quaternary.

Chemical Composition:

As concluded from the chemical analysis of the Nymphopetres rocks, they are primary of calcite origin. Hence, the contents of both CaO and CO_2 are extremely high, forming more than 90 % of the whole. There are also other constituents of no special importance. The representative sample of the rocks dried up in the laboratory before the chemical analysis took place. In Table 1, the chemical composition of the Nymphopetres rocks is given in comparison with another chemical co-

mposition of Travertine from Mammouth Hot Springs of the Yellowstone National Park in the United States of America.

TABLE I

CHEMICAL COMPOSITION (Percent)

Constituent	A	B
SiO_2	0.97	0.09
Al_2O_3	1.64	{ 0.11
Fe_2O_3	0.21	
MnO	—	—
MgO	4.74	0.35
CaO	48.34	55.37
Na_2O	0.18	—
K_2O	0.03	0.04
CO_2	43.86	43.11
SO_3	—	0.44
H_2O+	—	{ 0.32
H_2O-	—	
Organic	—	0.17
Total	99.97	100.00

A - Nymphopetres Rocks.

B - Traventine, Mamouth Hot Springs, Yellowstone Pett. John, F. J. Sedimentary Rocks, p 384).

ΠΕΡΙΛΗΨΙΣ

'Εντὸς τῆς τεκτονικῆς λεκάνης Λαγκαδᾶ - Βόλβης καὶ συγκεκριμένως ἐπὶ τῆς δημοσίας ὁδοῦ μεταξὺ τῶν χωρίων Προφήτου - Νυμφόπετρας εὑρίσκονται ὡρισμένοι ἐντυπωσιακοὶ σχηματισμοὶ ὑπὸ τὴν ὀνομασίαν «Νυμφόπετρες», οἵτινες διαφέρουν τελείως ὡς πρὸς τὴν πετρογραφικὴν σύστασιν καὶ τὴν μορφολογικὴν κατασκευὴν τῆς πέριξ περιοχῆς.

Κατόπιν μελέτης τῆς γεωλογικῆς καὶ τεκτονικῆς κατασκευῆς ὡς καὶ τῆς μορφογενετικῆς ἐξελίξεως τῆς λεκάνης Λαγκαδᾶ - Βόλβης, ἐξετάζονται ἐπισταμένως αἱ ἰδιόμορφοι ἐμφανίσεις τῶν «Νυμφοπετρῶν» ὡς πρὸς τὸν τρόπον σχηματισμοῦ, τὴν μορφολογίαν καὶ τὴν ἐξέλιξίν των. 'Αποδεικνύεται ὅτι ὁ σχηματισμὸς τῶν «Νυμφοπετρῶν» εἶναι χερσαίας προελεύσεως καὶ ὀφείλεται εἰς ἀποθέσεις χημικῶν ἱζημάτων. Τὰ χημικὰ ταῦτα ἱζήματα εἶναι ἀποτέλεσμα τῆς κατὰ τὸ παρελθὸν δράσεως θερμομεταλλικῶν πηγῶν κατὰ μῆκος ρηγμάτων εἰς τὰ περιθώρια τῆς λεκάνης. Αἱ πηγαὶ αὗται ἄφησαν τὰ ἴχνη των καὶ τελικῶς ἐξηφανίσθησαν συνεπείᾳ τῆς τεκτονικῆς ἀσταθείας τῆς περιοχῆς καὶ τῆς δημιουργίας νέων ρηγμάτων καὶ μεταπτώσεων. 'Η σημερινὴ χαρακτηριστικὴ μορφολογία τῶν σχηματισμῶν τούτων (κατακόρυφοι ὀγκώδεις βράχοι) ὀφείλεται κυρίως εἰς τὴν ἐπίδρασιν ἀφ' ἑνὸς μὲν τεκτονικῶν παραγόντων (διακλάσεις - μικρορήγματα), ἀφ' ἑτέρου δὲ διαβρωτικῶν τοιούτων (ὕδωρ - ἀήρ). Τὸ ὕδωρ τῆς βροχῆς εἰσήρχετο ἐντὸς τῶν διακλάσεων τῆς κυρίας μάζης καὶ προεκάλη κατὰ μῆκος αὐτῶν ἀφ' ἑνὸς μὲν μηχανικὴν χαλάρωσιν τῶν ἱζημάτων, ἀφ' ἑτέρου δὲ χημικὴν ἀλλοίωσιν αὐτῶν, μὲ ἀποτέλεσμα οἱ σχηματισμοὶ οὗτοι νὰ λάβουν σήμερον τὴν χαρακτηριστικὴν μορφὴν κατακορύφων μεμονωμένων βράχων.

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