Introduction to the Almopia Speleopark

Scientific Annals, School of Geology Aristotle University of Thessaloniki (AUTH)	Special volume 98	27-31	Thessaloniki, 2006

THE GEOLOGY OF ALMOPIA SPELEOPARK

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Abstract: The Almopia Speleopark is located on the boundary of two geological zones: the Almopia (Axios) zone eastwards and the Pelagonian zone westwards. The Almopia zone in the area of study is comprised of metamorphic rocks (schists, marbles and cipolines), ophiolites, limestones and clastic formations whereas the Pelagonian zone consist of carbonate rocks of Triassic-Jurassic age, sediments of Upper Cretaceous age and flysch of Upper Maastrictian-Lower Paleocene. In the area there are also travertine deposits of significant quantity and excellent quality. The seismicity in the area can be considered as not significant.

Key words: Almopia, Speleopark, geology, volcanology, seismicity.

INTRODUCTION

The Almopia area geotectonicaly belongs to the Almopia zone, which together with the Peonia and Paikon zones constitute the old Axios (Vardar) zone (Mercier, 1968). The Axios zone (Kossmat, 1924) is situated between the Pelagonian massif to the west and the Serbo-Macedonian massif to the east. The Almopia and Peonia zones, constituting the westernmost and easternmost parts of the Axios zone, respectively, were deep-water oceans separated by the shallow ocean of the Paikon zone, consisting of thick carbonate rocks of mainly Triassic to Cretaceous age.The Almopia zone is characterized by huge masses of ophiolites (Bebien *et al.,* 1994).

The Almopia zone was deformed during two orogenic periods: the Upper Jurassic-Lower Cretaceous and the Upper Cretaceous-Middle Eocene. During the first period the Almopia ocean closed, the Almopia zone emerged temporary until the Middle-Upper Cretaceous transgression and the ophiolitic rocks overthrusted on the Pelagonian platform westwards (Mercier, 1968). Between the Upper Cretaceous and the Middle Eocene (second orogenic period) the final emersion of Almopia zone took part. Because of the orogenic movements the Almopia rocks (older metamorphic rocks, ophiolites and upper Cretaceous transgression sediments) formed small to big dislocated slices in the form of units named usually according to the villages names. They are distinguished in different groups (Mountrakis, 1985; Mercier, 1968; fig. 1) such as:

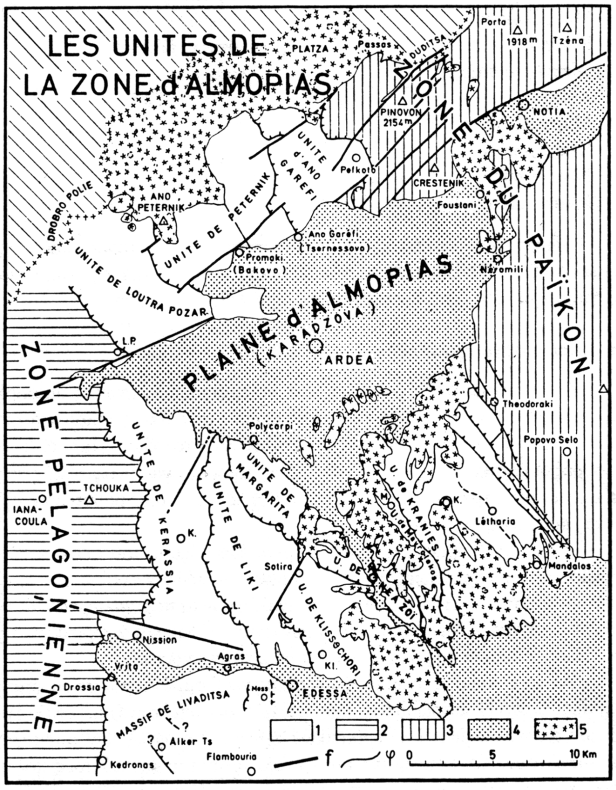

Figure 1. Sketch of Almopia zone units: 1. Almopia units; 2. Pelagonian zone; 3. Paikon zone; 4. Quarternary; 5. Post-alpine volcanic formations, f. Faults, Φ. Anomalous contacts (after Mountrakis, 1985 & Mercier, 1968).

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East Units	West Units	Middle Units	North Units
Ano Garefi	Kerassia	Liki	Peternik
Mavrolakkos	Kedronas	Margarita	Loutra
Kranies		Klissochori	
		Nea zoi	
		Messimeri	

In general, the Almopia zone formations show some differences from place to place reflecting maybe paleogeographic differences. The main formations from the lower to upper parts are (Mountrakis, 1985, fig. 2).

Al 1. Augen gneisses and amphibolites alternating in the upper parts with pre-alpine quartzites and amphibolitic-, mica- and chloritic-shists (Peternic unit).

Al 2. Metamorphic rocks consisting of continuous alternations calcic-, chloritic-, sericitic-schists, phyllites and marbles of Triassic to maybe Jurassic age.

Al 3. Metamorphic rocks of the same sedimentation (Triassic to Jurassic age) such as marbles, crystalline limestones and dolomites with intercalations of schists

Al 4. Tectonically emplaced on the previous formations there are mélanges ophiolitics. They consist of big or small marble and metamorphic blocks set in an ophiolitic mass. The age of the tectonic emplacement is considered to be Upper Jurassic. This formation appears in various places of the Almopias zone, especially in the area of Klissochori.

Al 5. Huge masses of ophiolites consisting of serpentines, basic laves, dolerites etc of Jurassic age.

Al 6,7,8. On the ophiolites or synfold with them there are sedimentary (6) volcanosedimentary (7) and clastic (8) formations.

Al 9. Basal conglomerate of Middle-Upper Cretaceous age.

Al 10. Gray to black limestones of Upper Cretaceous age.

Al 11. Flysch of Upper Maastrichtian-Lower Paleocene age.

GEOLOGICAL STRUCTURE OF SPELEOPARK

The Speleopark area is located at the boundary of two geotectonic zones that are: the Almopia zone, at the East and the Pelagonian one, at the West (Mountrakis, 1976, fig. 3).

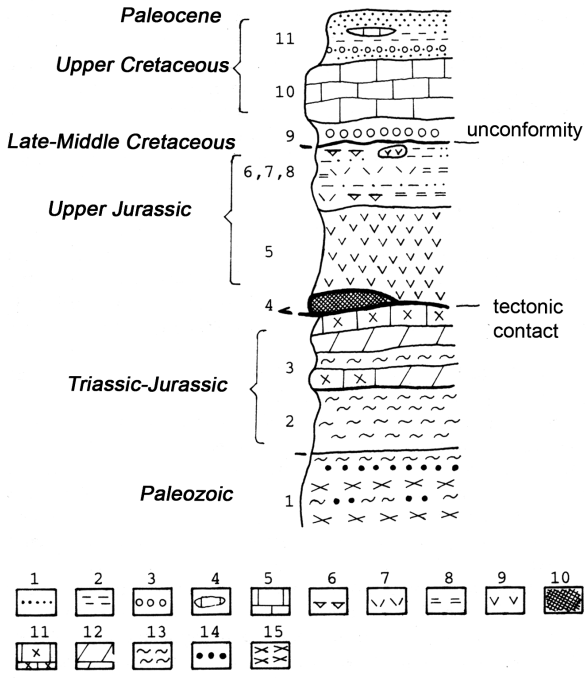

Figure 2. Modified generalized lithostratigraphic column of Almopia zone: 1. Sandstone; 2. Clay and slates; 3. Conglomerates and others clastic sediments; 4. Calcareous lenses; 5. Limestones; 6. Cherts; 7. Volcanic materials; 8. Tuffs and volcanoclastics; 9. Ophiolites; 10. Melanges ophiolitics; 11. Marbles and crystalline limestones; 12. Dolomites; 13. Slates; 14. Amphibolites; 15. Gneisses (after Mountrakis, 1985).

ALMOPIA ZONE

The Almopia rocks in the Loutra area are of the following rock types starting from the lower to upper formations:

Metamorphic system

It consists of alternating metamorphic rocks, such as phyllites, sericite schists, greenschists, amphibolitic schists, marbles and cipolines. The general direction of the metamorphic system is NW-SE with NE dip. The thickness of each member of this system varies from about 50 to 200 m. The metamorphic system is characterized by an ibricate structure that results in the repetition of the rock members. This system was formed during the Mesozoic time.

Ophiolites

There is a large mass of ophiolitic rocks and some smaller bodies in the area of Loutra. They generally consist of basic to ultra basic rocks that suffered intense serpenti-

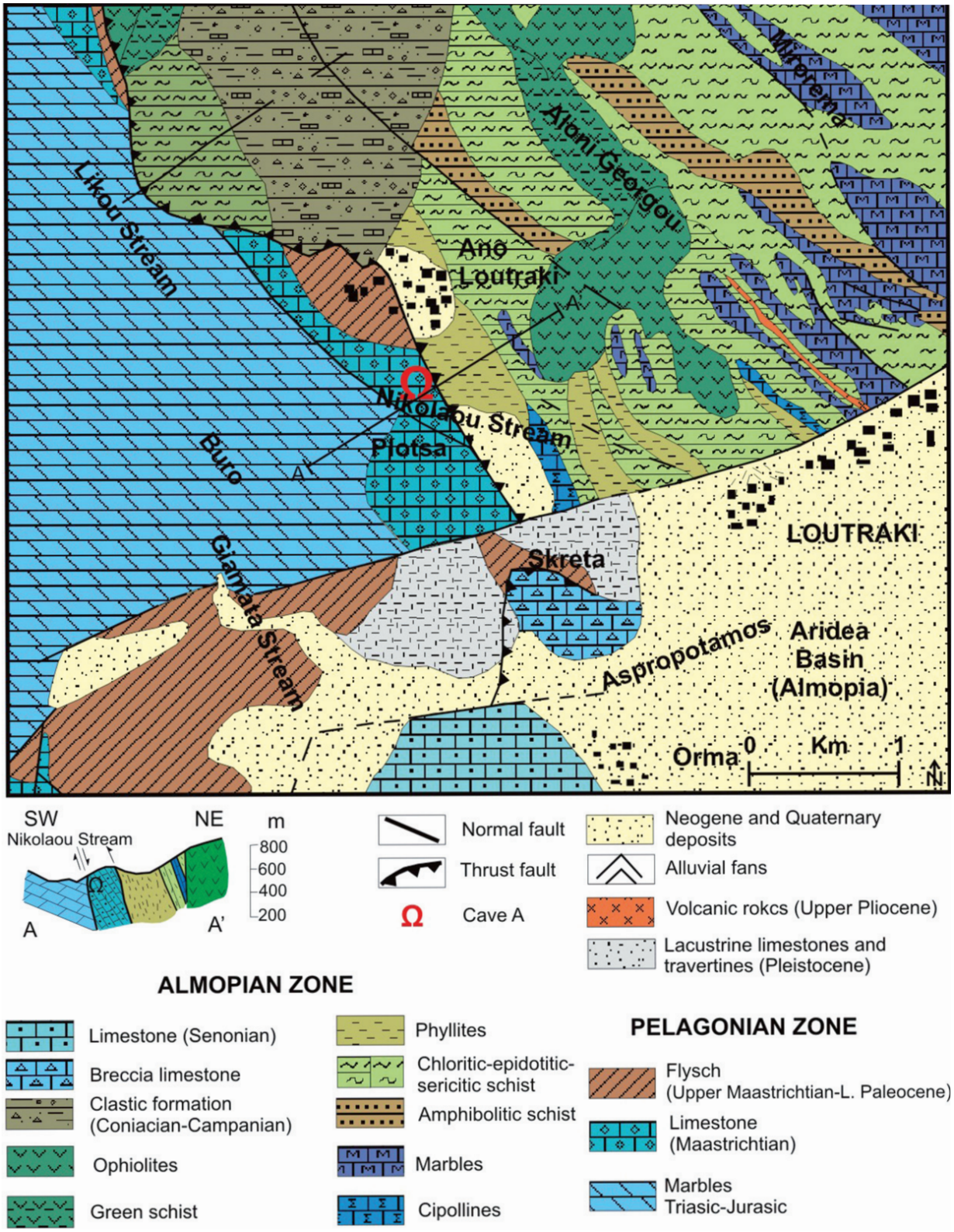

Figure 3. Geological map of the Loutra area (based on the map in Mountrakis, 1976, modified by K. Chatzopoulou and Ath. Vassiliadou).

nization. As is known the name "ophiolites" comes from their green color looking like the skin of a snake. The existence of these rocks and their age imply that the area was a large ocean during Upper Jurassic, about 150 million years ago.

The Diasselo Limestone

The Diasselo limestone is slightly green in color. As it is slightly recrystallized, the fossils that it contains have not been destroyed. It covers the ophiolites and its contact with the metamorphic system does not clearly have conformity. In general it is a very small outcrop, but very important because it proves the transgression of the sea during Middle Cretaceous, about 130 to 90 million years ago.

Clastic formation of Mariam

It is a sedimentary formation with intense tectonic deformation and slight metamorphism. It consists of alternations of fine- to coarse-grained sediments containing gneissic or ophiolitic pebbles. The coarse-grained character, as well as the foraminifera found in this formation reveal the coastal or neritic facies of sedimentation during Upper Cretaceous, probably Coniacian - Campanian, about 80 million years ago.

PELAGONIAN ZONE

The following rock outcrops are observed in the broader study area:

Carbonate cover of Triassic- Jurassic age

The carbonate cover consists of recrystallized carbonate sediments such as marbles, dolomitic marbles and dolomites of white and light grey color. This formation appears to be homogenous due to the effect of tectonic movements and the metamorphism which have distracted the boundaries between the different rock members and the pre-existing fossils.

Very close to the caves site, the rocks of the carbonate cover are intensely mylonitized.

Transgressional sediments of Upper Cretaceous

These sediments overlay the carbonate cover of Triassic-Jurassic age and are immediately in contact with rocks of the Almopia zone. They comprise the following formations from the lower to the upper parts:

i. The sediments of Upper Santonian-Campanian are slightly to darker gray in color and slightly recrystallized with fossils of the genus *Distefenella*.
ii. The Maastrichtian sediments are dark gray limestones, of a thickness more than 100 m, bearing foraminifera (*Orbitoides media)*.

In the area of Loutra the distinction between these limestones is not possible because the Pelagonian formations suffered intense tectonism by the overthrust of the Almopian rocks.

Flysch of Upper Maastrichtian - Lower Paleocene

The Pelagonian flysch is immediately below the thrust of the Almopia zone. In the broader area of study, the flysch consists of alternating dark clay-pelitic sediments with intercalation of calcitic and quartzitic sandstone. Near the Loutra area, the formation is more calcarinate and more tectonically disturbed.

VOLCANOLOGY

During Pliocene - Quaternary time tensile forces acted in the Almopia area and resulted in new faults and reactivated old ones that formed the Almopia basin and accommodated upwelling of magmas from the deeper parts of the earth giving rise to volcanism.

The Almopia volcanic rocks (AVRs) are located on the Voras Mt., and have been emplaced above the alpine metamorphic basement of the Almopia series, consisting mainly of greenschists, phyllites, limestones, gneisses, amphibolites, marbles and ophiolitic rocks.

The AVRs extend beyond the Greek - F.Y.R.O.M. boundaries covering an area of approximately 200 km^2. They belong to the widespread volcanic activity, which has affected the Aegean and the surrounding areas since Tertiary (Fytikas *et al.,* 1984). This volcanism is generally related to the subduction of the African plate underneath the southern margins of the Eurasian plate (Boccaletti *et al.,* 1974).

Based on pollen spores found in cineritic tuffs Mercier & Sauvage (1965) suggested an Upper Pliocene age for Almopia volcanism. This suggestion was supported by K/Ar dating on whole rock and mineral separates (biotite, hornblende) which have provided ages from 1.8 to 5.0 Ma (Bellon *et al.,* 1979; Kolios *et al.,* 1980). Ages up to 6.5 Ma have been published for the volcanic rocks in the F.Y.R.O.M. sector (Vougioukalakis, 2002).

On the basis of petrographical and petrochemical criteria the AVRs can be distinguished on six groups that are: high-K andesites-dacites, trachydacites, trachytes, latites, rhyolites and shoshonites (Vougioukalakis, 2002). The last group is found only as enclaves in the rest groups. All the rocks have a porphyritic texture mostly

characterized by the presence of prismatic or tabular phenocrysts of sanidine, often of relatively large size (up to 2-3 cm). Moreover there are phenocrysts of plagioclase, biotite, hornblende and pyroxene. The AVRs have an intermediate chemical character and are enriched in potassium. They belong to the high-K calc-alkaline to shoshonite rock series.

The AVRs are connected with transversal faults of SW-NE and SE-NW directions. An extensional tectonic regime has being active in this area since the Neogene. The AVRs form several distinct centers, consisting of lava domes and subordinate lava flows and dikes. The eruptive centers are surrounded by large amounts of volcanoclastic materials. A characteristic feature of Almopia volcanism is the intense explosive activity and the huge amounts of volcanoclastic materials (Vougioukalakis, 2002).

According to the last author, the volcanic activity was manifested in three distinct chrononogically and magmatologically periods:

The first period was manifested between 6.5/5.6 and 5 Ma to the east and central sector of the volcanic field. It was fed by andesitic and dacitic magmas. The second period was manifested between 4.9 and 4.2 Ma in the central and west sector of the Voras Mt. fed by latitic and trachytic magmas and the third and last eruptive period occurred between 4 and 1.8 Ma. It was restricted to the SW sector of the volcanic field and was fed at the beginning by trachytic magmas (up to 3 Ma) and later by latitic magmas.

TRAVERTINE

One of the most important geological formations of the Almopia region is the travertine deposits found either in the caves of the Speleopark or in the broader area of Aridea, the significance of which comes as a result of their quantity and quality. The Almopia's travertine deposits hold the first place in the travertine deposits of Greece. These rocks have been unearthed, processed and exported all over the world. The major characteristics of the Almopia's travertines are their clearance and fine crystallization, as well as the absence of xenoliths.

SEISMICITY

Based on geologic observations, the Almopia region is regarded as an area with tectonic activity. However, there is absence of significant earthquakes and only in the broader area, during the last century, have been registered few of them varying from M= 4.0 to M= 5.3.

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