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Fissured Rocks and Water Reservoirs in Eastern Thessaly Mountain Range, Greece (Olympus, Ossa, Maurovouni and Pelion): The Role of Tectonic Deformation

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The storage capacity of fractured hard rocks is lower than porous media and karst formations, though they can yield groundwater of sufficiently good quality for drinking purposes and may host important water resources, even if they are often of low permeability. In particular, for countries like Greece, where water needs for the local population and the tourist industry are excessive and waterfall limited, these reservoirs are of strategic importance. The mountain Range in Eastern Thessaly comprises an extensive nappe of metamorphic rocks, consisting of schists, gneisses, involving partly some ophiolithic rocks and marble intercalations. The thickness of the nappe exceeds 600 m in Ossa, whereas in the area of Pelion is estimated up to 3.000 m. This nappe rests on top of the Autochthonous Olympus- Ossa unit, which forms a massive Mesozoic carbonate sequence.

Extensive fieldwork data supported by the analysis of the physical and chemical properties of a large number of springs and combined by the study of the geological structure both local and regional, resulted in important outcomes regarding the fissured rocks permeability, water flow and springs distribution.

Schists are characterized by heterogeneity regarding their permeability features. They are divided into hard-rocks where quartz, epidote and amphiboles prevail, displaying higher permeability and soft-rocks where clay minerals prevail, exhibiting low permeability features, because the presence of clay blocks the fissures and prevent any infiltration process. The marbles are of high permeability, but are of limited extent. A few springs are located in marbles, but the vast majority of the springs are associated to the hard-rock schists, are scattered and characterized by high seasonal discharges. In the area of Ossa in particular, the most important reservoirs exist at the bordering zones of the metamorphic and the post-alpine formations due to the enrichment of the sedimentary post-alpine formations.

In the area of NE Pelion, 93 springs were recorded and 47 have been analyzed regarding their hydrochemical properties, whereas in the area of Ossa 126 springs have been recorded and 49 have been sampled. The large number of springs implies that water recharge and percolation occurs mainly via the fracture network, forming preferential flow paths. Tectonic deformation has proved to have a fundamental role in the hydrogeological pattern in both localities, because water flow either follows or is severely influenced by the major tectonic structures, such as mega-anticlines and faults.

It is interesting to note that this fracturing pattern does vary spatially and in all scales, involving the microscopic (foliation, lineation), the mesoscopic (fractures) and the macroscopic scale (faults). In the microscopic scale the clay/platy minerals in the schists recrystalized perpendicular to the applied stresses, forming foliation features towards the NE, promoting flow parallel to foliation. In the mesoscopic scale, two main set of fractures were observed. The intrabedded longintudinal NE-SW fractures and the transverse NW-SE trending fractures, which are highly penetrative. In the macroscopic scale, faults are several km in length and dominate the

groundwater flow, forming preferential pathways. Springs are aligned to the faults and in the area of Pelion, three dominant sets of faults are observed. Two of them are NE-SW trending (N 030o ± 10o and N 050o ± 10o), forming a 20o angle of tectonic wedge, whereas the third set is NW-SE trending (N 320o ± 5o). The geometry of faults in the area of Ossa (striking at N 035o ± 25o and N 325o ± 5o) is similar to the area of Pelion and exerts a similar influence to the distribution of springs. This should be the case in other domains of the Hellenic region with similar lithology that experienced the same deformation phase and features.

In the area of Pelion the low conductivity values (90% of the springs display less than 300 μS/cm) and the substantial variability in the discharge rates throughout the year are attributed to a decrease in fracture connectivity with depth, indicating that the aquifers are surficial, of limited capacity and have short residence times. Water physical properties also show that as elevation decreases, conductivity and water temperature values gradually increase. Water in lower altitudes is getting warmer as it flows from higher elevations so that is enriched by the constant input of warmer surficial waters. Moreover, it follows a longer path within the metamorphic rocks, obtaining also higher number of dissolved solids, increasing its conductivity values. Moreover, springs in higher elevations experience a significantly higher drop in the discharge rates during summer, compared to springs in lower elevations, suggesting that there is a time delay mechanism, so that springs in higher elevations recharge the ones in lower elevations. PH values range from slightly acid 6.7 up to alkaline 8.8. The relatively high values of Na+ (0.01 up to 3.94 meq) and Cl- (0.3 to 1.00meq) indicate the influence from sea aerosols. Hydrochemical analysis has also revealed the host rocks. Two hydrochemical types are extracted in Pelion, the Mg–Ca–HCO3 (indicating schists and gneisses influence) and Ca–HCO3 (Marbles influence), and three types in Ossa, Mg-Ca-HCO3 (Schists), Ca-Mg-HCO3 (Marbles) and Mg-HCO3 (mainly peridotites).

In conclusion, the thickness, the hydraulic gradient, the physical and chemical properties and the overall pattern of these heterogeneous aquifers change spatially over short distances not only due to lithology, but also due to the tectonic deformation.