Chapter 49
Mygdonia Basin (N. Greece) in the View of Isotope Geochemistry

P. Chantzi and E. Dotsika

Introduction

Mygdonia basin located 10 km N-E to Thessaloniki in northern Greece and it is consisted by two sub-basins: Koroneia and Volvi lakes. Both lakes constitute an important wetland which is being protected by International Ramsar Convention. Mygdonia basin constitutes an elongated EW tectonic depression which combined with adjusted minor basins (Zagliveri, Marathousa, Doubia) are the remains of an initial basin called Promygdonia (Koufos et al. 1993). The initial basin was formed by tectonic activity probably in the late Paleogene to early Neogene. In late Neogene and early Pleistocene a set of river and lake surface sediments deposited in this basin. A new tectonic activity at the end of the period "early-Pleistocene" resulted to many faults of Promygdonia basin were several smaller basins formed (Mygdonia, Zagliveri, Marathousa, Doubia). Among them the largest was Mygdonia basin forming the Mygdonia Lake which gradually drained during the medium-Pleistocene. Sedimentation continued in this basin mainly by lacustrine deposits (Psilovikos 1977**;** Sotiriadis et al. 1983). Koronia and Volvi lakes are the remnants of the initial Mygdonia Lake.

P. Chantzi (✉)
Laboratories of Stable Isotopes and Radiocarbon, Institute of Nanoscience and Nanotechnology, National Centre for Scientific Research "Demokritos", 15310 Agia Paraskevi, Attica, Greece
e-mail: p.chantzi@inn.demokritos.gr

E. Dotsika
Laboratories of Stable Isotopes and Radiocarbon, Institute of Nanoscience and Nanotechnology, National Centre for Scientific Research "Demokritos", 15310 Agia Paraskevi, Attica, Greece

Institute of Geosciences and Earth Resources, Via G. Moruzzi 1, 56124 Pisa, Italy
e-mail: e.dotsika@inn.demokritos.gr

P. Grammelis (ed.), *Energy, Transportation and Global Warming*, Green Energy and Technology, DOI 10.1007/978-3-319-30127-3_49

Mygdonia basin is bended in metamorphic layers from Serbomacedonian massif (paleozoic gneisses, amphibolites, schists, marbles and granitic intrusions) with groundwater circulating in metamorphic rocks and discharging in loose formations in basin. Moreover it covers a basin about 2026 km^2 where the terrestrial part covers about 656 km^2 and particularly extends west of Koronia Lake. The basin is defined by the mountains of Volvi (627 m) and the lower vertices of Vertiskos mountain (1103 m) in the north, in the east by the mountains of Psili Rachi (341 m) and Soulgianodiou (746 m) which are interposed between the mountains Kerdylion and Stratoniko and through the Strait of Rendina communicates with Strymoniko Bay and in the south side by Chortiatis mountain (1206 m) the lower vertices of Cholomontas (1165 m) and Stratoniko (918 m) with S-E direction. West boundaries of basin are not well defined as there are a set of low hills and depressions except Camila Mountain (569 m). The annual precipitation in the basin ranges 283–721 mm in the last 30 years. The climate varies from Mediterranean and continental. For the entire basin the average annual temperature is estimated about 13.55 °C and an average annual precipitation about 584.9 mm (Vatseris 1992).

Both Koroneia and Volvi subcatchments have been undergone sever environmental and human impacts resulting their ecological death (Nimfopulos, M. K. et al., 2002). An attempt was made in order to fingerprint the isotopic signature of groundwater in order to strengthen the knowledge on the hydrology regime of Mygdonia basin. Cold water samples from boreholes were collected from Mygdonia basin for stable isotope analyses of $\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$ which was performed in Laboratories of Stable Isotopes and Radiocarbon at NCSR "Demokritos". The network of boreholes that were sampled corresponded to shallow (30–60 m) and moderate deep water circulation (60–100 m). The sampling took place in June 2014 where the boreholes were operated for at least one month resulting in the water sample to correspond to the actual groundwater body. Moreover two water samples from lakes Koroneia and Volvi were taken however that wasn't possible for fresh spring water as no such springs were detected (Fig. 49.1).

Results and Discussion

Oxygen $\delta^{18}O$ and $\delta^{2}H$ Isotopes

The values of stable isotopes ranging from −10.3‰ to −7.3‰ and −70.4‰ to −45.7‰ for $\delta^{18}O$ and δD. In more detail on the sub-basin of Lake Koronia the isotope values of water molecules vary from −9.0‰ to −7.5‰ (range 1.5‰) and from −59.2‰ to −45.7‰ (range 13.5‰) for $\delta^{18}O$ and δD respectively, while on the sub-basin of Lake Volvi values vary from −10.3‰ to −7.3‰ (range 3‰) and from −70.4‰ to −47.2‰ (range 23.2‰) for $\delta^{18}O$ and δD respectively. These

Fig. 49.1 Study area of Mygdonia basin with Koronia and Volvi sub-basins (Google earth modified picture)

values are shown in diagram δ^2H‰ V-SMOW versus δ^{18}O‰ V-SMOW (Fig. 49.2) where global meteoric water line (GMWL, Craig 1961) and local meteoric water line (LMWL) for Greece as proposed by Dotsika et al. (2010) are pictured as well.

The correlation equation of groundwater for Mygdonia basin is:

$$\delta D = 7.8 * \delta^{18}O + 10.30 \tag{49.1}$$

Groundwater in Mygdonia basin presents an excellent correlation. Moreover Koronia is grouped with groundwater in the south part of Volvi sub-basin, sites where the network of boreholes is strong, supporting the hydraulic communication (Fig. 49.3).

The correlation equation of groundwater for Koronia and Volvi sub-basins are:

$$\delta D = 7.1 * \delta^{18}O + 4.11 \tag{49.2}$$

$$\delta D = 7.8 * \delta^{18}O + 10.95 \tag{49.3}$$

The correlation equations of Mygdonia, Koronia and Volvi basins present slopes «7.8», «7.8» and «7.1» respectively. For Central Macedonia a slope inferior to 7 is reported (Christodoulou et al., 1993) while for East Macedonia is reported slightly greater «7.5» (Leontiadis et al., 1984). Generally fresh precipitation of all types and surface water that have not undergone evaporation exhibit slopes between 7–8 (Craig 1961), while waters that have undergone secondary evaporation exhibit

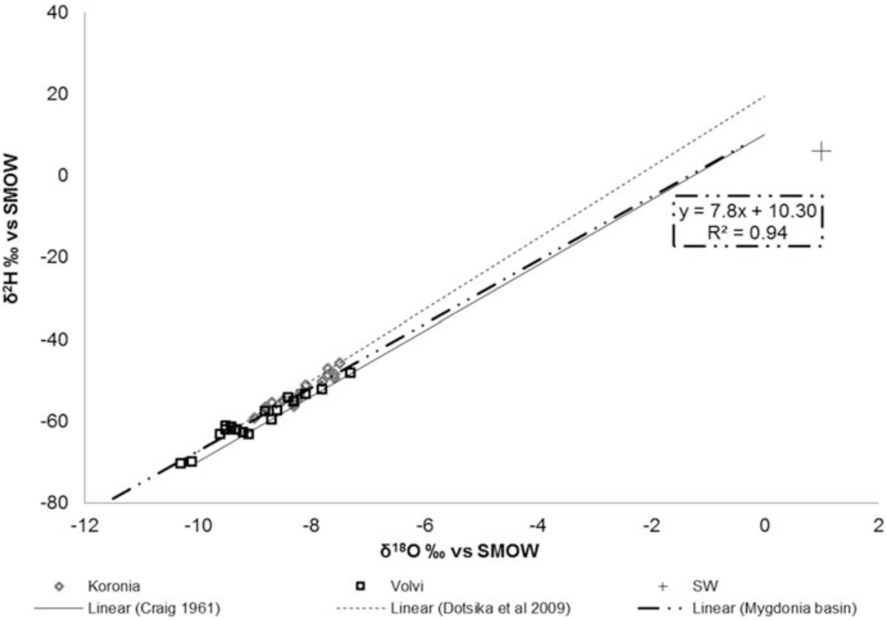

Fig. 49.2 δ^2H‰ V-SMOW versus δ^{18}O‰ V-SMOW of cold groundwater in Mygdonia basin

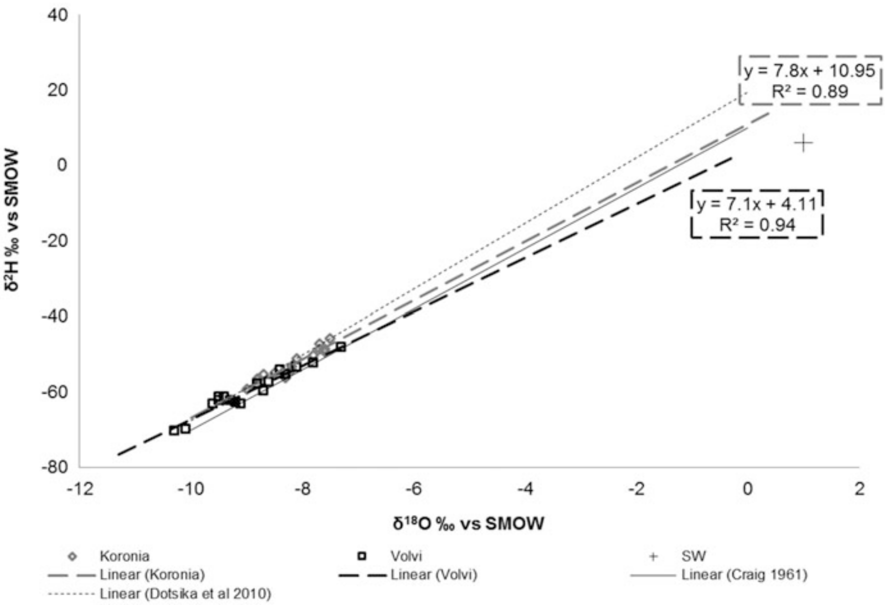

Fig. 49.3 δ^2H‰ V-SMOW versus δ^{18}O‰ V-SMOW of cold groundwater in Koronia and Volvi sub-basins

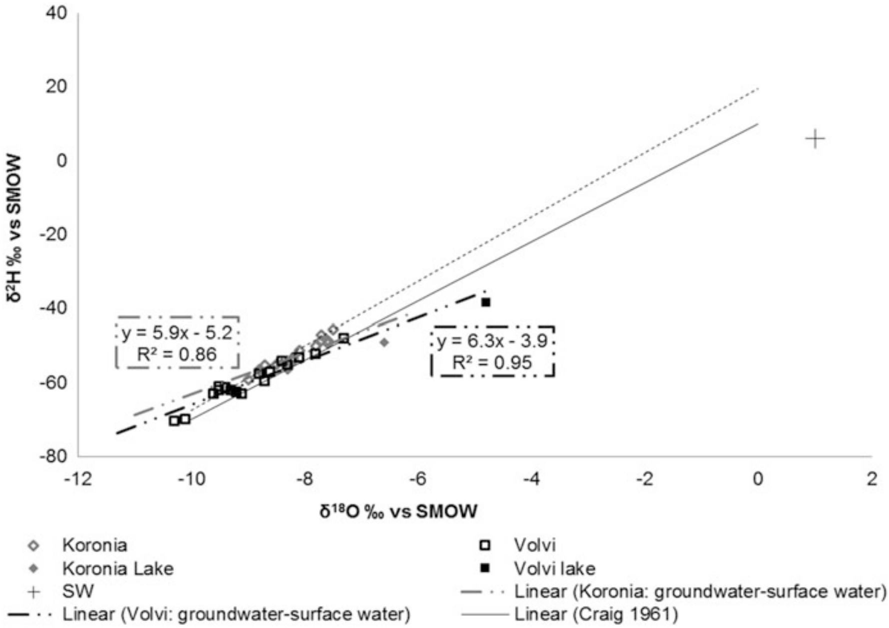

Fig. 49.4 δ^2H‰ V-SMOW versus δ^{18}O‰ V-SMOW of cold groundwater and surface water in Koronia and Volvi sub-basins

lower slopes about «6» (Gat 1980). Therefore it is concluded that groundwater of Mygdonia basin doesn't present any evaporation or mixing episodes with different isotopic water.

Both oxygen and deuterium isotopic values are characterized by homogeneity without significant fluctuations implying that no isotopic exchange with the geological environment takes place. This conclusion is in agreement with geological regime of the basin where groundwaters circulate in metamorphic rocks and discharge in loose formations in basin without presenting long retention time in groundwater aquifers.

The correlation between sub-basins and surface water of the corresponding lake is pictured in Fig. 49.4 with the following equations:

$$\delta \mathrm{D} = 5.9 * \delta^{18} O - 5.2 \tag{49.4}$$

$$\delta \mathrm{D} = 6.3 * \delta^{18} O - 3.9 \tag{49.5}$$

The slopes of lines (49.4) and (49.5) with values «5.9» and «6.3» for the Koronia and Volvi respectively reflect evaporation processes occurring in surface reservoirs with Koronia exhibiting a higher rate. In both sub-basins groundwater and surface lake water correlates excellent however the linking trend is evident in Volvi catchment implying their direct hydraulic communication but in Koronia catchment surface lake water placed slightly away from the corresponding trend-line. Isotopic values are strongly influenced by temperature and the evaporation processes but also by the humidity (Fritz and Fontes 1980). Therefore this slightly deviation could be attributed to the humidity above lake water layers. These observations possible imply the communication of surface water with groundwater in Koronia basin through lateral shallow formations as the lacustrine bottom is covered by a clay layer that makes it impermeable

Carbon Isotopes $\delta^{13}C$

The values of carbon isotopes $\delta^{13}C$ can detect the different origins of organic or inorganic carbon. The value of carbon in marine carbonate rocks is around 0‰, the soil CO_2 around −25‰ (similar to that of plants) and about −7‰ for atmospheric CO_2. However, carbonates evaporation may exhibits higher values about +10‰. The carbon isotopic ratio of fresh water is strongly affected by carbonate mineral dissolution in the case of carbonate bicarbonate aquifers: $CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$ (Dotsika 2015). In temperate climate the contribution of dissolved carbonates ($\delta^{13}C = -2$‰ to +1‰, Clark and Fritz, 1997) resulting groundwater $\delta^{13}C$ values about −11‰ (Jin et al. 2009) however in shallow aquifers soil CO_2 and atmospheric CO_2 (water-rock interaction product) contribute to the values formation resulting aquifers with $\delta^{13}C$ values between −11‰ and −22‰ (Jin et al. 2009). Carbon isotope values $\delta^{13}C$ range between −13.6‰ and −10.2‰ for Mygdonia basin. In greater detail range from −13.6‰ to −10.2‰ and from −13.2‰ to −10.4‰ for Koronia and Volvi groundwater respectively, reflecting both the dissolution of carbonate rocks and the participation of organic carbon from soils.

Conclusions

Stable isotope values of cold water samples ranged from −10.3‰ to −7.3‰, from −70.4‰ to −45.7‰ and from −13.6‰ to −10.2‰ for $\delta^{18}O$, δD and $\delta^{13}C$ respectively reflecting the isotopic signature of local precipitation water. In the entirely basin subsurface water circulation exhibits short retention time influenced by the strong network of irrigation wells without taking place any isotopic exchange with the geological environment. Mechanism of neither evaporation nor mixing with waters of different isotopic origin was detected. Dissolution of carbonate rocks and the participation of CO_2 from soils taking place through the circulation of groundwater to the shallow and middle shallow aquifers.

References

Christodoulou, Th., Leontiadis, I.L., Morfis, A., Payne, B.R., Tzimourtas, S., 1993: Isotope hydrology study of Axios River plain in northern Greece. J. Hydrol. 146, 391–404.

Clark, I. D., & Fritz, P. (1997). *Environmental isotopes in hydrogeology*. Boca Raton, FL: Lewis Publishers.

Craig, H. (1961). Isotopic variations in meteoric waters. *Science, 133*, 1702–1703.

Dotsika, E., Lykoudis, S., & Poutoukis, D. (2010). Spatial distribution of the isotopic composition of precipitation and spring water in Greece. *Global and Planetary Change, 71*, 141–149.

Dotsika, E. (2015, March). H–O–C–S isotope and geochemical assessment of the geothermal area of Central Greece. *Journal of Geochemical Exploration, 150*, 1–15.

Fritz, P., & Fontes, J. (1980). *Handbook of environmentai lsotope geochemistry*. New York: Elsevier.

Gat, J. R. (1980). Isotope hydrology of very saline lakes. In A. Nissenbaum (Ed.), *Developments in sedimentology* (Vol. 28, pp. 1–7). New York: Elsevier. Chapter 1.

Jin, L., Ogrinc, N., Hamilton, S., Szramek, K., Kanduc, T., & Walter, L. (2009, June). Inorganic carbon isotope systematics in soil profiles undergoing silicate and carbonate weathering (Southern Michigan, USA). *Chemical Geology, 264*(1–4), 139–153. ISSN: 0009-2541.

Koufos, G., Syridis, G., Kostopoulos, D., & Koliadimou, K. (1993). Preliminary results about the stratigraphy and the palaeoenvironment of Mygdonia Basin, Macedonia, Greece. In *Proceedings of the 1st congress of paleontological association*, Geobios.

Leontiadis, I., Payne, B.R., Letsios, A., Papagianni, N., Kakarelis, D., Chadjiagonakis, D., 1984: Isotope Hydrology study of Kato Nevrokopi of Drama. Proc. Of the Symposium on Isotope Hydrology 1983. International Atomic Energy Agency, Vienna, pp. 193–206.

Nimfopulos, M. K., Mylopoulos, N., & Katirtzoglou, K. G. (2002). A qualitative-quantitative study of water and environmental pollution at the broader area of the Mygdonia Basin, Thessaloniki, Northern Greece. In *Proceedings of the 6th Pan-Hellenical geographical conference of the Hellenic geographical society*, Thessaloniki, 3–6 October 2002 (Vol. II, pp. 436–444).

Psilovikos, A. (1977). Paleogeographic development of the basin and lake of Mygdonia (Lagada—Volvi area, Greece). Ph.D. thesis, Department of Geology, Aristotle University of Thessaloniki (in Greek).

Sotiriadis, L., Psilovikos, A., Vavliakis, E., & Syrides, G. (1983). Some tertiary and quaternary basins of Macedonia/Greece. Formation and evolution, *Clausthaler Geologische Abhandlungen* (p. 21).

Vatseris, C. (1992). Hydrogeologie des Mygdonias-Beckens (Nord-Griechenland) under Berucksichtigung der hydrochemischen und isotopen physikalischen komposition der thermalwasse. Ph.D. thesis, University of Munster, 171p.