GEOCHEMICAL STUDY ON THE HYDROTHERMAL SYSTEMS IN THE NORTHERN PART OF ALGERIA

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論 文 名　：　GEOCHEMICAL STUDY ON THE HYDROTHERMAL SYSTEMS IN THE NORTHERN PART OF ALGERIA
（アルジェリア北部の熱水系の地化学的研究）

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論 文 内 容 の 要 旨

Algeria as a part of North Africa is located in a complex geological setting that gives rise to an important geothermal potential causing more than 120 hot springs locating in northern part of the country and generating a heat discharge of 240 MW_t. This thesis focuses on the hydrochemistry and estimation of geothermal reservoir temperatures of three main zones of northern Algeria: (1) the northwestern geothermal system, (2) the Hammam Righa geothermal field in the north-central geothermal system, and (3) the northeastern geothermal system in order to construct a geothermal conceptual model for each area of interest. Fractured carbonates formations constitute the main geothermal reservoirs. The Tlemcenian dolomites are the main geothermal reservoir in northwestern area, the dolomite-limestone of the Tellian zones compose the north-central geothermal reservoir, whilst the Neritic Canstantinois formations of the Tellian thrust-sheet (North Algeria) form the geothermal reservoir in the northeastern part of the country.

Chapter 1 introduces the general background of the northern Algerian geothermal waters, sampling points, geological and hydrogeological outline of northern Algeria. Additionally, the relationships between hot spring water and the magmatic emplacement were explained. The purposes and objectives were described in this chapter.

Chapter 2 describes the chemistry of the northwestern Algerian thermal waters. The discharge temperature of collected hot waters ranges between 42.9°C to 66.1°C with a high total dissolved solids (TDS) value up to 4002 mg/L. The chemistry of waters show four water types: Na-Ca-Cl, Na-Ca-Cl-HCO_3, Na-Ca-Cl-SO_4 and Na-HCO_3-Cl type. The estimated reservoir temperatures using silica geothermometers and fluid mineral equilibria overlaps the range of 66°C to 125°C. According to stable isotopes composition, the collected water samples are of meteoric origin, which infiltrated at depth between 1.1 km to 2.2 km and heated by a high conductive heat of 80-140 mW/m^2 and mixed at a shallower part with a high Mg content cold groundwater giving the immature water feature in the Na-K-Mg diagram. These results were summarized by a geothermal conceptual model.

Chapter 3 deals with the hydrogeochemical characteristics of the thermal waters of the Hammam Righa geothermal field (North-Central part of Algeria). The discharge temperatures of cold waters are of 25°C and hot waters are ranging from 32.1°C to 69°C, with a near neutral pH (6 to 7.6). Thermal water shows a high TDS ranges between 492 mg/L and 2527 mg/L, while for cold water is between 659 mg/L to 852 mg/L. The chemical analysis shows two main types: Ca-Na-SO_4 type for hot waters in the upflow area (Hammam Righa) and Ca-Na-HCO_3 water type for the cold water representing the recharge zone area (Zaccar Mount). The estimated reservoir temperatures using silica geothermometers and fluid/mineral equilibria infers a temperatures of 78°C, 92°C and 95°C for HR4 and HR2 and HR1, respectively. According to stable isotopic data of ($\delta^{18}O$, δ D), the thermal waters of Hammam Righa are of meteoric origin. The meteoric recharge infiltrated at depth through the fractured dolomite limestones of the Zaccar Mount and conductively heated at a depth between 2.1 km to 2.2 km. The raised hot waters interacted at depth with Triassic evaporites which gives Ca-Na-SO_4 type. During their ascension, the thermal waters are mixed with shallower rich Mg groundwater giving the immature water field in the Na-K-Mg diagram. Those results are well illustrated in the geothermal conceptual model of the Hammam Righa geothermal field.

Chapter 4 focuses on the water and gas chemistry of the northeastern Algerian thermal waters. The radiogenic isotopes of helium gas were used to detect the origin of the geothermal fluid. In the Guelma basin, the heat flow map shows an anomaly of 120 ± 20 mW/m^2 linked to the highly conductive Triassic extrusion. Chemical data-base reveals the existence of three water types: Ca-SO_4 and Na-Cl which are likely related the evaporitic "diapir" rich in halite and gypum minerals. The third type of water is of Ca (Na)-HCO_3 which mostly characterizes the carbonated Tellian sector. The origin of thermal waters using gas mixing model gives a meteoric origin of the most of thermal waters except for El-Biban hot springs (W10) giving He/Ar ratio of 0.213 and suggesting the presence of batholith. The helium distribution map indicates a lower $^{3}He/^{4}He$ ratio between 0 and 0.04 Ra in W10 and W15 samples, compatible with the crustal ratio. Reservoir temperatures estimated by silica geothermometers give temperatures less than 133°C. The hydrothermal-geothermal conceptual model of the northeastern Algerian geothermal system is developed by the deep penetration of infiltrated cold waters to the depth up to 2.5 km and then heated from below by a conductive heat source (batholith for El-Biban case). The hot waters flow up to the surface through the deep-seated fractures. During their ascension, they are mixed with shallow cold ground water, which increase the Mg content and give the immature classification of the hot waters samples.

Chapter 5 consists of the summary and conclusion of this research topic by using a correlative table that recapitulates the major results of this study.

〔作成要領〕

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