CHINESE GEOGRAPHICAL SCIENCE
Volume 11, Number 2, pp. 150 - 154, 2001
Science Press, Beijing, China

CENOZOIC VOLCANISM AND GEOTHERMAL RESOURCES IN NORTHEAST CHINA

WANG Xi-kui[1], QIU Shan-wen[2], SONG Chang-chun[2], KULAKOV Aleksey[3], TASHCHI Stepan[3], MYASNIKOV Evgeny[3]

(1. College of Earth Sciences, Jilin University, Changchun 130012, P. R. China; 2. Changchun Institute of Geography, the Chinese Academy of Sciences, Changchun 130021, P. R. China; 3. Pacific Institute of Geography, Far East Science Center of the Russian Academy of Sciences, Vladivostok 690041, Russia)

ABSTRACT: This paper is concentrated on Cenozoic volcanism and geothermal resources in Northeast China. There are a lot of Cenozoic volcanoes, a large area of volcanic rocks, a large number of active faults and rich geothermal resources in Northeast China. The time and space characteristics of Cenozoic volcanism and the space distribution characters of hot springs and high geothermal flux regions in Northeast China are described and discussed on the basis of geological, geothermal, drilling and volcanological data. It is revealed that the hot springs and high geothermal flux regions are related to the Cenozoic volcanism, rifting and faulting in Northeast China. It is especially emphasized that the hot springs and high geothermal anomaly areas are controlled by active deep faults. It is proposed that the Cenozoic volcanism regions, rift basins, active fault belts, activated plate suture zones and large earthquake occurrence points are the best areas for prospecting geothermal resources. The geothermal resources in younger volcanic zones are richer than those in older volcanic belts. The hot springs and active or activated faults might be a very good clue for looking for geothermal resources.

KEY WORDS: volcanism; active faults; geothermal resources; Northeast China

CLC number: P317. 1 Document code: A Article ID: 1002-0063(2001)02-0150-05

1 INTRODUCTION

Northeast China is located in the eastern marginal part of Eurasian plate. There are about 700 Cenozoic volcanoes and about 50 000km^2 volcanic rocks in Northeast China. The Cenozoic volcanism is related to the Pacific plate subducting, back-arc spreading and corresponding marginal continental rifting. About 700 Cenozoic volcanoes in Northeast China are concentrated at some places, so Shuangliao, Keluo, Wudalianchi, Yitong, Shulan, Shangzhi, Longgang, Jingbo Lake, Shuangyashan, Kuandian, Changbai Mountains, Dalainuor, Halaha and Nuomin River volcanic groups are formed. The Cenozoic volcanoes in Northeast China are roughly symmetrically distributed about Songliao basin, forming Liaohe-Shuangliao, Jiamusi-Yitong, Fushun-Mishan, Changbai Mountains and Da Hinggan Mountains volcanic belts (Fig. 1). With the Cenozoic crust extending, magma intruding and volcano erupting, rich hot groundwater resources and hot dry rocks are formed in Northeast China.

Received date: 2000-05-25
Foundation item: Financed by the National Natural Science Foundation of China(No. 49471013).
Biography: WANG Xi-kui(1955 -), male, a native of Changchun City of Jilin Province, professor. His research interests include Quaternary Geology and Environmental Geology.

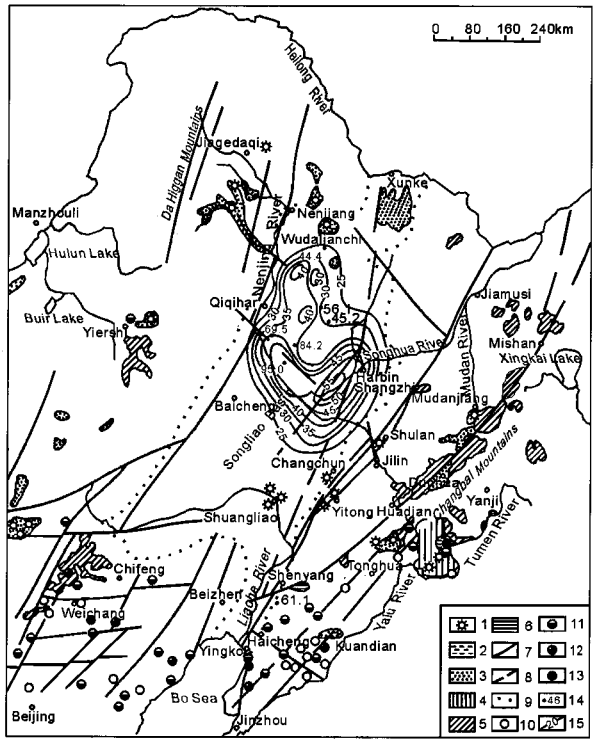

Fig. 1 A sketch of Cenozoic volcanoes and hot springs in Northheast China

1. crater; 2. middle Pleistocene-Holocene trachyte, pantellerite and pumice; 3. Pleistocene basalt; 4. Pliocene basalt; 5. Miocene basalt; 6. Palaeogene basalt; 7. active fault; 8. buried active fault; 9. boundary of Songliao basin; 10. hot spring of 25 – 40℃; 11. hot spring of 40 – 60℃, 12. hot spring of 60 – 80℃; 13. hot spring of 80 – 100℃; 14. geothermal flux(mW/m²); 15. geothermal gradient(℃/km)

2 THE CHARACTERISTICS OF CENOZOIC VOLCANISM AND GEOTHERM

2.1 Liaohe-Shuangliao Volcanic Belt

The Liaohe-Shuangliao volcanic belt is located in the middle part of Songliao basin and is composed of the volcanic interbeds in Liaohe basin and the volcanic rocks of Shuangliao volcanic group. The volcanic eruption of this belt began at about 63Ma B. P. and ended at about 25Ma B. P. The volcanic rocks of this belt are mainly basanites, olivine basanites, olivine basalts and alkaline olivine basalts. The volcanism of this volcanic belt is accompanied by the crust spreading. On the basis of K_2O and Na_2O contents, as well as the degree of silicon saturation, it can be inferred that the spreading rates of Liaohe basin are separately 5 – 6mm/a in Palaeocene and 2 – 3mm/a in Oligocene (CHEN *et al.*, 1992).

Liaohe basin is a part of Songliao basin. The average efflux of heat in Liaohe basin is 63mW/m² and the geotherm gradient is 2.3 – 3.5℃/100m. The temperature of rocks at 1000m depth is 30 – 45℃ with an average temperature of 34℃.

Songnen basin to the north of Liaohe basin is the main part of Songliao basin. The heat efflux in the middle Songnen basin is 70.76 – 95.04mW/m² with an average heat efflux of 82.06mW/m². The heat efflux in the eastern and western marginal Songnen basin is 44.38 – 69.50mW/m² with an average heat efflux of 54.01mW/m² . The average heat efflux for the whole Songnen basin is 68.24mW/m². The geotherm and geothermal gradient in the middle Songnen basin are higher than that in the eastern and western marginal parts. The geothermal gradient at the marginal Songnen basin is less than 3℃/100m. But the geotherm gradient at the middle Songnen basin is 3 – 5℃/100m with an average geothermal gradient of 3.8℃/100m. The temperature of rocks at 1000m depth is 30 – 50℃ (Fig. 2). The geotherm gradient isotimic of larger than 40℃/km forms two high temperature belts which are obviously controlled by active faults (Fig. 1).

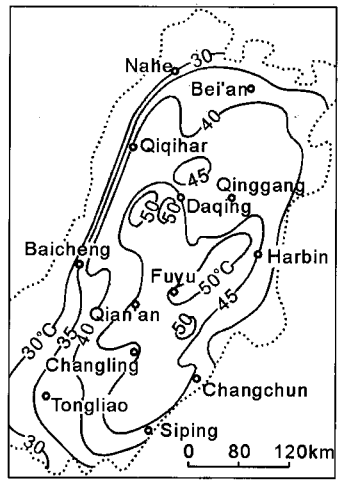

Fig. 2 Isothermal map at 1000m depth of Songliao basin (after CHEN *et al.*, 1994)

2. 2 Jiamusi-Yitong Volcanic Belt

Jiamusi-Yitong volcanic belt is located to the east of Liaohe-Shuangliao volcanic belt and extended along Jiamusi-Yitong graben. This volcanic belt is composed of Yitong, Shulan and Shangzhi volcanic groups. Yitong volcanic group is composed of 16 volcanic cones which are mainly composed of olivine basalts and basanites. The volcanic eruptions of Yitong volcanic group happened from 21Ma B. P. to 7. 78Ma B. P. Shulan volcanic group is composed of 27 volcanic cones which are mainly composed of alkaline olivine basalts and basanites. The volcanic eruptions of Shulan volcanic group happened from 13. 5Ma B. P. to 3. 90Ma B. P. Shangzhi volcanic group is composed of volcanic cones and basanites which have the age of 13. 1Ma B. P. The volcanism of Jiamusi-Yitong volcanic belt is the most intense in Miocene. The spreading rate of Jiamusi-Yitong graben is 1. 80 – 3. 64mm/a, which is inferred by the K_2O and Na_2O contents as well as the degree of silicon saturation. On the basis of olefiant depth, it can be inferred that the geotherm and geothermal gradient under Jiamusi-Yitong graben are higher than that in the areas of outside Jiamusi-Yitong graben.

2. 3 Fushun-Mishan Volcanic Belt

Fushun City is located to the northeast of Shenyang City and about 42km from it. Fushun-Mishan volcanic belt is extended along Fushun-Mishan graben called also Dunhua-Mishan graben. Fushun-Mishan volcanic belt is composed of the volcanoes and volcanic rocks at Fushun, Qingyuan, Dunhua, Muling, Mishan and so on. The volcanic eruptions in the northern Fushun-Mishan graben are more intense than that in the southern segment. The volcanic rocks in the Fushun-Mishan graben are mainly tholeiites, alkaline olivine basalts and basanites. The volcanic eruptions of Fushun-Mishan graben began at about 44. 9Ma B. P. and ended at about 5140a B. P. The volcanic eruptions in Miocene are the most intense. The last eruption of this belt occurred at a place west to the Jingbo Lake forming the famous "Crater Forest Volcano". The spreading rate of Fushun-Mishan graben is 1 – 2mm/a, which is inferred by the K_2O and Na_2O contents as well as the degree of silicon saturation.

2. 4 Changbai Mountains Volcanic Belt

Changbai Mountains volcanic belt is composed of Kuandian volcanic group, Longgang volcanic group, Changbai Mountains volcanic group and the basalts at Wangqing, Dongning and so on. The middle part of this belt is composed of Longgang Mountains and Changbai Mountains where the Cenozoic volcanism is the most intense.

Kuandian volcanic group is located in Kuandian basin and is composed of 20 volcanic cones. The volcanic rocks of this volcanic group are mainly basanites and alkaline basalts which have the age of 0. 274 – 0. 124Ma B. P. On the basis of K_2O and Na_2O contents as well as the degree of silicon saturation, it can be inferred that the spreading rate of Kuandian basin is 1. 5 – 3. 0mm/a. There are a lot of hot springs in and around Kuandian basin . The temperature of the hot spring waters in the area is generally 30 – 70℃ and the highest temperature of the hot spring waters is 85℃. There are a lot of active faults in this area. The neotectonic movement of this area is very intense. An earthquake of magnitude 7. 3 occurred at Haicheng town in 1975. The hot springs and volcanoes of this area are controlled by active faults (Fig. 1).

Longgang volcanic group is located in the middle Longgang Mountains and has 164 volcanic cones. The volcanic eruptions of Longgang volcanic group began at about 27. 3Ma B. P. and ended at about 785a B. P. Most of the basalts in this area have the ages of 1. 49 – 1. 05Ma B. P. The eruptions from 1580a B. P. to 785a B. P. are very intense forming a lot of cinder cones. The volcanic rocks of Longgang volcanic group are mainly olivine basalts, basanites, tholeiitic basalts and cinders. On the basis of K_2O and Na_2O contents as well as the degree of silicon saturation, it can be inferred that the spreading rate of Longgang Mountains is 1. 0 – 2. 2 mm/a in early Pleistocene. There are some hot springs in the Longgang volcanic district and the adjacent areas (Fig. 1).

Changbai Mountains volcanic group is located to the east of Longgang volcanic group and has more than 200 volcanoes and 12 000km^2 of basalts(SONG, 1990). This volcanic group erupted a lot of times from Miocene to early Pleistocene forming Zhenfengshan basalts (20. 19 – 19. 8Ma B. P.), Naitoushan basanites (16. 7 – 15. 0Ma B. P.), Changbai town tholeiites (16. 40 ± 1. 19Ma B. P.), Wangtian'e trachyandesites (5. 56 ± 0. 22Ma B. P.), Hongtoushan pantellerites (3. 11 ± 0. 053Ma B. P.), Wangchi basalts(2. 79 ± 0. 27Ma B. P.), Junjianshan basalts (2. 77 ± 0. 03Ma B. P.), upper Jin River basalts (2. 59 ± 0. 25Ma B. P.), Baijinhoushan and Shibadaogou alkaline olivine basalts (2. 41 – 2. 05Ma B. P.) and Guangping olivine basalts (1. 48 ± 0. 10Ma B. P.). The later eruptions of Changbai Mountains volcanic group are mainly concentrated at Heaven Lake and its adjacent areas forming alkaline trachytes and pantellerites (0. 551 – 0. 0876Ma B. P.) as well as pumices (1489 – 704a B. P.) . The last eruptions of Heaven Lake volcano occurred separately in 1668 and 1702. The volcanic ash erupted from Heaven Lake volcano in 1215 A. D. was transported to North Japan(MACHIDA, 1983) . On the basis of K_2O and Na_2O contents as well as the degree of silicon saturation, it can be inferred that the spreading rate of Changbai Mountains is 0 – 2. 9mm/a from Pliocene to early Pleistocene. There are a lot of hot springs around Heaven Lake volcano forming Changbai hot spring group, Heaven Lake hot spring group and upper Jin River hot spring group. The Changbai hot spring group is located to the north of Heaven Lake volcano and is composed of about 100 hot springs. The hot springs having a water temperature of more than 60℃ are 47 and th highest temperature of the spring water is 86℃. Every day about 6500t of hot water is flowed out of the springs. Heaven Lake hot spring group is located at the northern marginal part of Heaven Lake forming a belt of 20m wide. The temperature of the hot waters is only 20 – 40℃ because of mixing with the Heaven Lake water. The upper Jin River spring group with an area of 110m^2 is located to the south of the Heaven Lake volcano. The water temperature of this hot spring group is about 58℃. Every day about 580t of hot water is flowed out of the springs in the upper Jin River valley.

2. 5 Da Hinggan Mountains Volcanic Belt

Da Hinggan Mountains volcanic belt is located to the west of Songliao basin and composed of Dalainuor volcanic group, Halaha volcanic group and Nuomin River volcanic group as well as the basalts at Wuchagou. The Wuchagou basalts have the age of 9. 94 – 8. 93Ma B. P. (LIU, 1987) and the Tianchi Forestry Center basalts in the middle segment of Da Hinggan Mountains have the age of 0. 340 ± 0. 203Ma. On the basis of K_2O and Na_2O contents as well as the degree of silicon saturation, it can be inferred that the spreading rate of Da Hinggan Mountains is 2. 0 – 3. 0mm/a(E, 1987). Only two hot springs are discovered in Da Hinggan Mountains volcanic belt because most of the volcanic belt is covered by forests. The temperature of the hot spring water in this area is more than 40℃.

2. 6 Other Volcanism and Geotherm Characteristics

At the northern marginal part of Songliao basin, there is a potassic basalt belt striking in north-west-north. The potassic basalt belt is mainly composed of Keluo, Wudalianchi and Erkeshan volcanic groups. The eruption of this volcanic belt began at about 0. 563Ma B. P. and continued intermittently till recent. The Laoheishan volcano and Huoshaoshan volcano of Wudalianchi volcanic group erupted during 1719 – 1721A. D. There are no hot springs but cold ones in Wudalianchi volcanic area since there are island permafrost layers under this area.

There are also a lot of hot springs in the mountainous area of western Liaoning and Yanshan Mountains which are roughly coincident with the suture zones between North China plate and Songnen plate. In general, the hot spring waters in this area have the temperature of 30 – 70℃. The hot springs in this area are distributed along active faults(Fig. 1) . A arge earthquake of Ms7. 8 occurred at the northern marginal district of North China Plain on July 28 in 1976, which shows that the neotectonic movement in this area is very intense.

3 CONCLUSIONS

(1) Hot springs and geothermal resources are very developed in Cenozoic volcanic eruption areas since there might be shallow magma bodies under Cenozoic volcanoes. The younger the volcanoes are, the richer the geothermal resources are. There might be hot dry rocks under some Cenozoic volcanic eruption areas if there is hardly groundwater there.

(2) Cenozoic rifting basins are the best places for looking for geothermal resources since there might be shallow magma bodies and covering layers under the Cenozoic deposits.

(3) Geothermal fields might be found at some intense neotectonic movement belts and large earthquake occurrence districts.

(4) Large geothermal fields might be found at some activated suture zones and faulted belts. The hot springs and activated faults might be a clue for looking for geothermal resources.

REFERENCES

CHEN Mo-xiang, WANG Ji-yang, DENG Xiao, 1994. *Geothermal Resources in China*[M]. Beijing: Science Press, 139 – 159. (in Chinese)

CHEN Wen-ji, LI Da-ming, LI Qi *et al.*, 1992. Chronology and geochemistry of basalts in Lower Liaohe Basin[A]. In: LIU Ruo-xin. *Chronology and Geochemistry of Cenozoic Volcanic Rocks in China*[C]. Beijing: Seismological Press, 44 – 80. (in Chinese)

E Mo-lan, ZHAO Da-sheng, 1987. *Cenozoic Basalts and Deep Source Rock Inclusions*[M]. Beijing: Science Press, 86 – 132. (in Chinese)

LIU Jia-qi, 1987. Research on chronology of Cenozoic volcanic rocks in Northeast China[J]. *Acta Petrologica Sinica*, 3(4): 21 – 31. (in Chinese)

MACHIDA H, ARAI F, 1983. Extensive ash falls in and around the Sea of Japan from large late Quaternary eruptions[J]. *Journal of Volcanology and Geothermal Research*, 18(4): 151 – 164.

SONG Hai-yuan, 1990. *Research on Changbai Mountains Volcanoes*[M]. Yanji: Yanbian University Press, 77 – 103. (in Chinese)