Geothermics (1970) - SPECIAL ISSUE 2
U. N. Symposium on the Development and Utilization of Geothermal Resources, Pisa 1970. Vol. 2, Part 2

A Note on the Hot Springs of Ecuador

A. DE GRYS *, J. VERA ** AND P. GOOSSENS ***

ABSTRACT

Waters from several Ecuadorian hot springs were analyzed. On a preliminary basis the springs may be divided into three groups: *a)* coastal springs which have not been studied; *b)* a northern group of springs which are in the vicinity of volcanoes; and *c)* a southern group of springs associated with travertine deposits, situated in an area of Plio-Pleistocene volcanism. The last group has waters with high concentrations of Ca, HCO_3, Na, and Cl, besides abnormal amounts of Li, As and B; but the SO_4 content is low. There may be a relationship between these waters and the numerous epithermal deposits in the area.

Introduction

A survey of Ecuadorian hot springs was started recently and this note is a progress report on the work done to date. So far, only a few of the springs in some of the areas have been visited and the waters analyzed, but we hope to extend this study to cover the whole country in the future.

There are numerous hot springs in Ecuador and many were used for bathing even in Inca times as indicated by the Quechua names of some of the springs and from Indian myths and legends (MUÑOZ 1949). Examples of Quechua names are: Cununcyacu or hot water; Cachihuaico or salty creek; Cununcpugyo or hot spring; and Yanayacu or black water. For the Incas, the search and maintenance of the springs for bathing was a specialized task and entrusted to special water seekers. In colonial times some of the more accessible springs such as Baños of Tungurahua and Baños of Cuenca were used as spas but only in this century have the springs been commercialized for the tourist industry.

The first comprehensive study of the thermal springs was by DRESSEL in 1876 who published analyses of some of the waters. Other published works refer principally to the medicinal properties of the waters (GENTEY 1906; VIVAR 1889; WANDEMBERG 1924). MUÑOZ (1949, 1951, 1957 and 1959) wrote extensively on the hot springs and presented some new analyses, but he also stressed the curative properties of the waters.

* Proyecto Minero, Apartado A-371, Quito, Ecuador.
** Servicio Nacional de Geología y Minería, Apartado A - 23, Quito, Ecuador.
*** United Nations Project, B.P. 72, Ouagadougou, Upper Volta, Africa. Now at the Dept. of Geology and Geological Engineering, Michigan Technological Univ., Houghton, Nich. 49931, USA.

From historical record there is evidence that the hot springs have on occasions been affected by earthquakes. In 1938 an earthquake in the Valle de los Chillos, near Quito, caused one set of springs to disappear while for another the temperature rose and the discharge increased, and has apparently remained the same ever since. As a result of the Pelileo (near Tungurahua) earthquake in 1949, according to eye witness accounts, the springs of Baños (Tungurahua) dried up and only gas emanated. The springs reappeared about fifteen days later.

The present study

Figure 1 shows the distribution of the known springs in Ecuador as indicated by the literature, and includes some relevant geological features. Results of the spring waters analyzed in the present study are given in Tables 1 and 2. Major elements were analyzed by conventional methods and trace elements by colorimetry and atomic absorption. Table 3 gives some descriptive data of the hot springs.

Description of the springs

The distribution of the springs should be seen in the general context of the structure, geology and volcanology of the country. Ecuador can be divided into three geographical zones: the coastal plain; sierras; and the « oriente » or jungle lowlands. Both the coastal plain and jungle lowlands (Amazon basin) are covered by recent alluvial deposits. The sierras or Andean ranges are bounded on the east and west by pre-Cambrian metamorphic and sedimentary rocks. Rocks from the Jurassic to the present constitute the main body of the sierras and include both volcanics and sediments. Batholiths intrude the older rocks but their age is uncertain. The most recent rocks are the glacial and volcanic deposits (GOOSSENS 1970 a).

The separation of the sierras from the plains is probably structurally controlled. Grabens within the sierras are bound by north-south faults. There is evidence of a major deep east-west structure that extends across the continent, because approximately in one line are to be found the Galapagos Islands and Galapagos wrench fault, the Gulf of Guayaquil, the Cañar fault and the Amazon river (GOOSSENS 1970 b). This

TABLE 1. — *Major elements in Ecuadorian hot springs. All values in ppm.*

	T °C	pH	Na	K	Ca	Mg	HCO_3	Cl	SO_4	SiO_2	Total dissolved solids
Apuela	52	6.2	552	11	255	3	27	780	641	15	2940
Cununcyacu	26	7.0	165	17	38	2	243	16	39	35	660
El Tingo	34	7.3	340	32	29	2	506	221	5.0	65	1500
La Merced	34	6.6	147	18	46	2	247	16	17	65	735
Baños (Tungurahua)	42	6.7	248	46	320	14	1540	29	2892	50	6900
Los Elenes	20	7.6	327	8	254	57	468	123	995	10	2010
Cununcpugyo	22	7.8	112	4	66	24	403	94	42	14	470
Guapán	45	6.7	5600	160	363	65	3090	5160	35	42	13,000
Baños (Cuenca)	87	7.3	2500	80	140	50	846	3540	458	23	7200
Unnamed near Azogues	22	8.3	2360	177	850	40	3540 (1)	4870	17	nd	10,000
Unnamed near San Bartolomé	30 ?	6.3	1930	116	208	33	2850	3740	7.0	8	7400
Portovelo Mine	50	6.7	340	3	370	240	163	182	916	17	2100
Aguas Calientes	50	7.1	84	22	145	0.2	19	200	288	27	780
Río Bono	30 ?	9.1	95	nd	19	0.5	14 (2)	36	35	16	220

(1) 109 CO_3^{--}
(2) 6.8 CO_3^{--}

structural line also approximately marks the southern limit of the Plio-Pleistocene volcanoes although volcanic deposits are spread both north and south of this line. The volcanoes occur in roughly two belts running parallel to the coast. Four of these volcanoes are considered active; Reventador; Tungurahua, Cotopaxi and Sangay (SAUER 1965). South of this structural line volcanism was intense in the Pliocene.

The structural line is also convenient for the dividing of the hot springs into two groups. Although many hot springs are known in Ecuador the majority have temperatures between 22 and 30 °C, only about ten springs have temperatures above 50 °C and those with temperatures greater than 70 °C are probably less than five. Most of the springs are found in the sierras or foothills although some have been reported on the coast (Figure 1). The coastal springs may prove interesting as their waters, besides having a possible magmatic component, are no doubt contaminated by the ocean and by petroleum brines from the nearby oilfields. It is possible that submarine springs exist.

The hot springs of the northern belt (except those along the coast) are all within 30 km of the nearest volcano. Most of these springs are along river banks and possibly the river courses are fault controlled. Usually a group of springs are found several kilometres apart along the river. Near Quito, Cuncuncyacu, El Tingo, La Merced and Alangasi, together with several other unnamed springs, are found within a distance of 30 km of each other along the Río San Pedro, and encircle an extinct volcano Ilaló. They are also within 30 km of the volcano Pichincha.

Temperatures of the springs of the northern area are in the range 20-50 °C and rarely do they exceed 50 °C. The hot waters emerge along the river banks and algae grow in profusion on the stream sediments near the outflow. So far, only at Baños (Tungurahua) has an ochrous scum been observed, otherwise (as far as we are aware) the springs are not depositing salts, although there are some salt and travertine deposits from springs that have disappeared. Composition of the spring waters is variable and is probably greatly influenced by ground and river waters. Total dissolved solids of the waters is from 500-3000 ppm. As the lithium, boron, arsenic and silica concentrations are low, it is probable that these waters have only a very small magmatic component.

The springs of the southern belt are the end stages of an active hot spring cycle and volcanism during the Plio-Pleistocene. All the known springs except some outside the area of volcanic cover, are related to travertine deposits. However, the converse is not true and some of the springs have dried up and the travertine deposits have suffered erosion exposing the fissures and walls of the original plumbing of the hot springs system and in some cases erosion has proceeded so far that only blocks of travertine remain in the alluvial cover. The variations of the morphology of the travertine deposits suggest that there have been different cycles of hot spring activity. A United Nations report describes the travertine deposits in detail (United Nations Development Programme, 1969).

At the travertine deposits the position of the springs is continually changing, from year to year and even from month to month. A very little water bubbles through the travertine in different places of the deposit, often accompanied by clouds of smoke. Some of the springs are cold, but temperatures as high as 87 °C have been recorded.

Naturally these waters have high concentrations of Ca and HCO_3, but Na and Cl are also present in considerable quantities (Table 1). O'ROURKE (1967) suggested that the calcium carbonate of the travertine is derived from the San Marcos formation, the only limestone formation in the area. The San Marcos formation is Cretaceous in age and consists of sedimentary series

TABLE 2. — *Minor elements in Ecuadorian hot springs. All values in ppm; nd - not detected; na - not analyzed.*

	Li	B	As	Sb	Fe	Mn	Cu	Pb	Zn	Ag	I	F
Apuela	1.9	9	nd	nd	nd	nd	na	na	na	na	nd	nd
Cununcyacu	0.1	1.2	nd	na	0.4	nd	0.01	na	nd	na	nd	nd
El Tingo	0.5	5.1	0.04	na	0.4	nd	0.002	0.06	0.02	na	0.01	nd
La Merced	0.2	1.3	0.05	na	4	nd	0.007	na	0.008	na	0.02	nd
Baños (Tungurahua)	1.4	2.8	nd	nd	94	1.0	0.001	na	0.0004	na	nd	nd
Los Elenes	0.1	0.5	nd	na	1.0	nd	nd	nd	0.008	0.017	nd	nd
Cununcpugyo	0.06	0.9	nd	nd	nd	0.2	nd	0.017	.005	.023	0.03	nd
Guapán	13	105	nd	nd	0.4	0.8	nd	0.05	0.01	nd	nd	5.8
Baños (Cuenca)	3.0	13	0.12	nd	1.2	0.4	nd	0.08	0.01	nd	0.5	4.3
Unnamed near Azogues	12	131	nd	nd	nd	0.3	0.029	0.06	nd	nd	0.8	nd
Unnamed near San Bartolomé	2.6	52	0.08	nd	0.6	nd	0.022	0.036	nd	nd	nd	nd
Portovelo	1.2	4.8	0.02	nd	9.3	2.5	0.054	0.04	0.98	0.233	nd	7.2
Aguas Calientes	2.6	7.8	0.05	nd	nd	nd	0.035	0.024	0.034	nd	0.2	nd
Río Bono	nd	2.0	0.004	nd	0.1	0.3	nd	0.024	0.022	nd	nd	4.0

TABLE 3. — *Description of Ecuadorian springs.*

NAME	LOCATION	GEOLOGY	STRUCTURE	VOLCANOLOGY	MINERALIZATION
Apuela	80 km W of Ibarra, along Río Intag	Within recent volcanic cover. In vicinity of marble deposits	Possible fault	15 km W of Vn. Cotacachi	Near San José de Minas, Pb, Ba, Hg, Zn.
Cununcyacu	15 km E of Quito, along Río S. Pedro	Quaternary		15 km E of Vn. Pichincha. Also near extinct volcano Ilaló	
El Tingo	24 km SE of Quito, along Río S. Pedro	Quaternary		20 km SE of Vn. Pichincha. Also near extinct volcano Ilaló	
La Merced	30 km SE of Quito, along Río S. Pedro	Quaternary		25 km SE of Vn. Pichincha. Also near extinct volcano Ilaló	
Baños (Tungurahua)	60 km SE of Ambato	Within recent volcanic cover, near contact with metamorphics		10 km N of Vn. Tungurahua	
Los Elenes	14 km N of Ríobamba	Quaternary		30 km SE of Vn. Chimborazo	
Cununcpugyo	15 km W of Ríobamba	Quaternary		30 km SE of Vn. Chimborazo	
Guapan	3 km N of Azogues	Upper Cretaceous sediments near metamorphic contact.	Along N-S fault	No active volcanism	Near Hg deposit of Azogues
Baños (Cuenca)	9 km SW of Cuenca	Miocene volcanics	Along N-S fault, on edge of graben	No active volcanism	Au-Ag in quartz vein 500 m from deposit
Unnamed near Azogues	10 km W of Azogues	Pliocene volcanics	Along N-S fault	No active volcanism	Near Hg deposit of Azogues
Unnamed near San Bartolomé	10 km N of S. Bartolomé	Pliocene volcanics	?	No active volcanism	Near S. Bartolomé prospect, Pb, Zn, Ag, Sb, Bi, As
Portovelo	In Portovelo mine	Cretaceous sediments	?	No active volcanism	Mine Au, Ag, Cu, Pb, Zn, As
Aguas Calientes	On Río Amarillo near Portovelo Mine	Cretaceous sediments	?	No active volcanism	Near Portovelo mine
Río Bono	Near Portovelo	Cretaceous sediments	?	No active volcanism	Near Portovelo mine

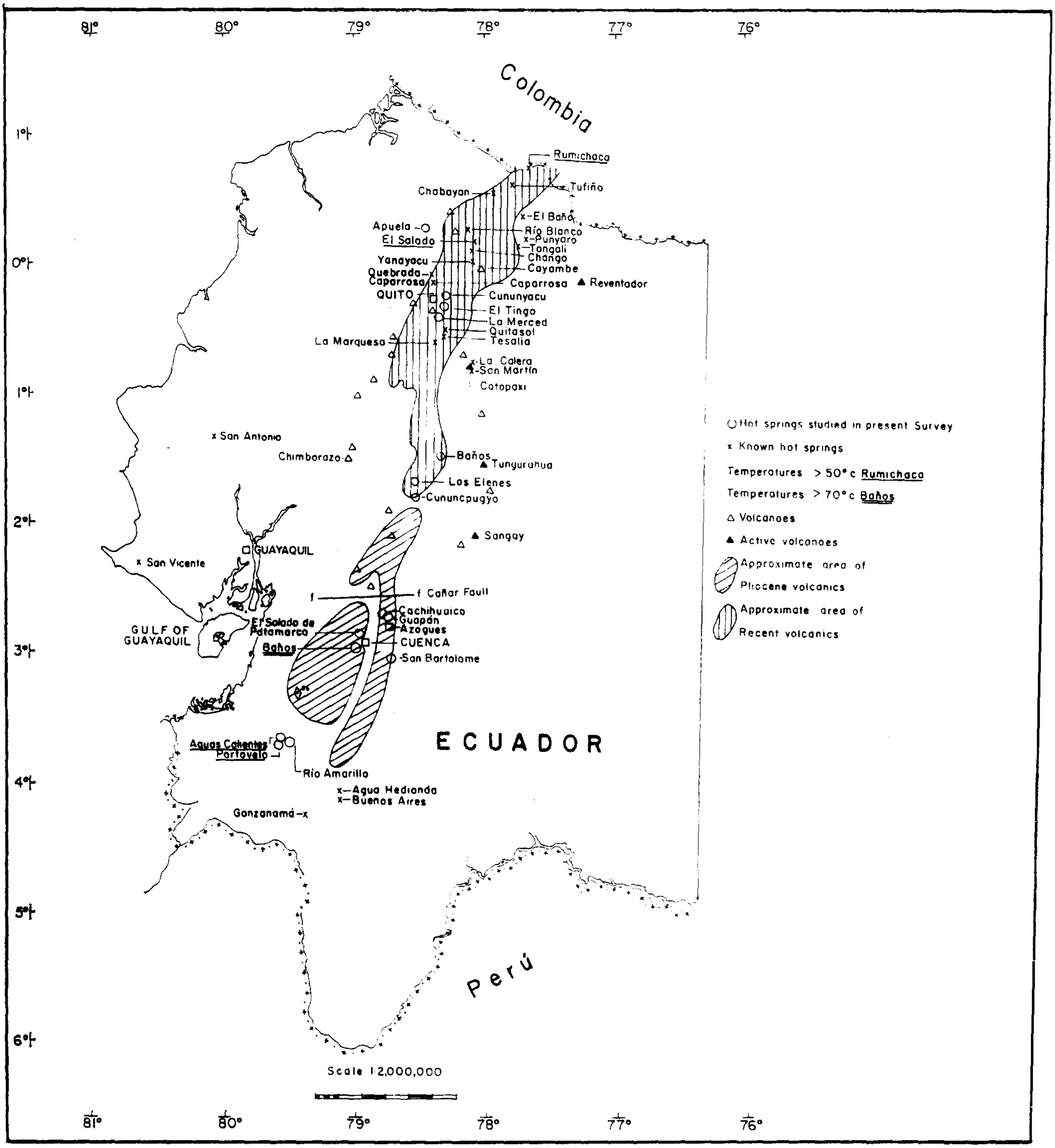

FIG. 1. — *Location of hot springs.*

of which the principal rock type is a black fossiliferous argillite which grades into black shales and is intercalated with limestone bands. It is possible, however, that the calcium carbonate is not derived from the solution of the sedimentary limestones but is related to magmatic activity. WHITE (1967) points out that during magmatic differentiation, calcium is taken up by the early minerals, and after crystallization albitization of the plagioclase can enrich the residual fluids in calcium, but it is uncertain how this fluid can be separated from a cooling magma chamber. Similar to the Ecuadorian springs are some springs in California where, despite the absence of limestone beds in the area, the spring waters carry large amounts of calcium carbonate.

Sulfate content of the waters is low, and this together with the high concentrations of Na, Ca, Cl and HCO_3 suggest a similarity with ore forming fluids. Furthermore, the concentrations of K, Li, As and B are those which may be expected from these types of fluids. Examples of the fluids related to ore deposits are amply demonstrated in the literature (WHITE 1955, 1967; WHITE, HEM, WARING 1963; ELLIS 1967; ROEDDER 1967) and evidence is not only derived from hot springs but also from fluid inclusions in minerals.

Numerous vein deposits are found in the southern belt and only sporadically in the northern area. Epithermal deposits are the most common and consist of complex sulfides of Zn, Pb, Ag, Cu, As, Sb, Bi and Hg, though not all these metals are present in one deposit. Other mineralization includes gold-quartz veins, disseminated pyrite in volcanic rocks, and one porphyry copper prospect. It is most likely that the epithermal deposits are related to the recent hot spring activity, dating from the Plio-Pleistocene, while the porphyry copper deposit may be older. We have no definite proof of the connection of the hot springs with mineralization but the nature of the ore deposits and the composition of the waters suggests that this might be so. In the Portovelo mine, hot waters are emerging along one of the underground levels. The sulfate concentration is high and also Cu, Zn, Pb, Ag and Fe are present in abnormal amounts. This is the only water known to be directly related to mineral deposit in this area.

Conclusions

Because of the limited nature of this study we can only give some tentative conclusions:

1. The hot springs of Ecuador may be broadly divided into three groups:

a) The coastal springs which were not studied and of which no further details are available.

b) The springs of the northern belt associated with recent volcanic activity. The waters are variable in composition and appear to be reheated meteoric waters because of the low concentrations of Li, As, and B. These springs usually do not deposit salts.

c) The springs of the southern belt are in an area where volcanic activity was intense during the Plio-Pleistocene. The springs are associated with travertine deposits, but there are also travertine deposits where the springs have dried up. The waters are high in Ca, HCO_3, Na, Cl but low in SO_4 and also have considerable amounts of Li, As and B. It is suggested that these springs are related to the numerous epithermal deposits of Zn, Pb, Ag, Cu, Sb, As, and Hg present in the area, and this should be the subject of further investigations.

2. The difference between the north and south springs is probably related to the volcanic history of the two areas. In the northern belt, the hot waters, which may be only heated groundwaters, have travelled further from the magma chamber and the original magmatic constituents have become extremely dilute. By contrast, in the southern belt, the volcanics are older and erosion has exposed part of the hot spring plumbing system which included the travertine and mineral deposits. If mineral deposits are present in the northern areas, they are probably at depth and so far remain unexposed. The porphyry copper deposit probably dates from the Upper Cretaceous and its relation to the recent cycle of volcanic activity is not known.

Acknowledgements

We thank JULIO GRANJA and ROGER DUPUIS for collecting some of the samples. This article was reviewed by PETER FOZZARD and CARLOS MOSQUERA and we appreciate their critical comments.

REFERENCES

DRESSEL L. 1876 — Estudios sobre algunas aguas minerales del Ecuador. *An. Univ. Central Quito*, 4, *136, 179, 292, 350, 409, 458, 606.*

ELLIS A. J. 1967 — The chemistry of some explored geothermal systems. *in: « Geochemistry of Hydrothermal Deposits », Holt, Rinehart, Winston, New York, 465.*

GENTEY L. 1906 — Analysis de las aguas minerales de Tesalia. *An. Univ. Central Quito, 22, 148.*

GOOSSENS P. 1970 a — The geology of Ecuador, an explicative note for the geological map of the Republic of Ecuador (1 : 500,000). *Ann. Soc. géol. Belg*, in press.

GOOSSENS P. 1970 b — A propos d'une tectonique transversale en Ecuador (Amerique du Sud). *Conf. solid Earth Problems, Buenos Aires.*

MUÑOZ J. E. 1949 — Aguas minerales de Ecuador. *Quito, Ecuador.*

MUÑOZ J. E. 1951 — Informe analitico de las fuentes de aguas minerales de la Provincia de Cotopaxi. *Latacunga, Ecuador.*

MUÑOZ J. E. 1957 — Compendio de hidrología general y aplicada. *Imprenta Municipal, Quito, Ecuador.*

MUÑOZ J. E. 1959 — Inventario de las aguas minero-medicinales de Ecuador. *Editorial Universitaria, Quito, Ecuador.*

O'ROURKE J. E. 1967 — Travertine deposits of southern Ecuador. *U. N. Mineral Project Ecuador, unpubl. Rep.*

ROEDDER E. 1967 — Fluid inclusions as samples of ore fluids. *in: « Geochemistry of Hydrothermal Deposits », Holt, Rinehart, Winston, New York, 515.*

SAUER W. 1965 — Geologia del Ecuador. *Edit. Ministerio Educación, Quito, Ecuador.*

U. N. DEVELOPMENT PROGRAMME 1969 — Technical Report N° 3, Clays and Travertine, (Operation N° 3, Cuenca). *United Nations. New York.*

VIVAR J. M. 1889 — Observaciones sobre el articulo « Aplicaciones médicas de algunas aguas minerales del Ecuador ». *An. Univ. Central, Quito, 3, 18.*

WANDEMBERG J. B. 1924 — El agua mineral de Tesalia. *An. Univ. Central, Quito, 32, 215.*

WHITE D. E. 1955 — Thermal springs and epithermal deposits. *Econ. Geol., 50th Anniv., 99.*

WHITE D. E. 1967 — Mercury and base-metal deposits associated with thermal and mineral waters. *in: « Geochemistry of Hydrothermal Deposits », Holt, Rinehart, Winston, New York, 575.*

WHITE D. E., HEM J. D., WARING G. A. 1963 — Chemical composition of sub-surface waters. *Prof. Pap. U. S. geol. Surv.*, 440-F.