SOURCE OF HEAT IN A DEEP ARTESIAN AQUIFER, BAHÍA BLANCA, ARGENTINA

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Abstract.—Artesian water from wells more than 500 meters deep in the Bahía Blanca area discharges at temperatures 12° to 26°C above expectable normal. The extra heat may be related to a fault through which deep-seated waters could rise or by which intrusive rocks could have been introduced at depth.

Part of the public water supply of the city of Bahía Blanca, southern Buenos Aires province, Argentina, is obtained by artesian flow from an aquifer 500 meters or more below the land surface. The temperature of the water discharged from 9 wells in and north of the city ranges from 55° to 59°C and average 56.6°C. This average is about 17°C higher than the expectable temperature calculated from the normal geothermal gradient for the region, 1°C per 28 m. Yet volcanic activity or other obvious sources of heat are unknown for hundreds of kilometers in any direction.

The authors present the principal know facts regarding the artesian water supply and postulate that the extra heat is related to a fault. This paper is based chiefly on the records of 19 wells drilled by the Dirección Nacional de Geología y Minería and its predecessor agencies, as reported by Salso and García (1958), and also on observations made in 1959 by the senior author, and Dr. García and Señor Amílcar F. Galván, of the Dirección Nacional de Geología y Minería of Argentina.

The city of Bahía Blanca is near the head of the bay of the same name on the Atlantic coast, about 560 kilometers southwest of Buenos Aires. It is near the seaward edge of a vast gently sloping plain where rocks are poorly exposed. The outcrop of the principal artesian aquifer has not been identified, but rocks probably equivalent to those of the underlying basement crop out in the Sierra de la Ventana, 50 km northeast of Bahía Blanca. These rocks are intricately folded quartzite and schist of Paleozoic age (Harrington, 1947). The basement rocks have been penetrated at depths of 291 to 812 in wells at Pelicurá, Algarrobo, Anzoategui, and at a well 21 km south of General San Martín (fig. 1). The aquifer that yields thermal water at Bahía Blanca has not been identified in these wells, however. Still farther northwest the basement rocks probably are within 50 to 200 of the land surface (fig. 1).

Although several aquifers underlie the coastal plain, only the principal aquifer, described in this paper, yields large supplies of water. The discovery well, drilled at Argerich in 1913 by the Dirección de Minería, was 711 m deep and initially flowed 348 cubic meters per hour. This well was damaged and was replaced in 1915 by a second well, 705 m deep, which initially flowed 500 cu m per hour and in 1959 was still flowing about 20 cu m per hour. More than 30 wells tap the highly productive aquifer in an area extending about 60 km west and 25 km southeast of Bahía Blanca. Northwest of Argerich, the aquifer terminates against a fault, which has been mapped on the basis of physiographic relations, seismic evidence, and test drilling: The proved and probable extent of the principal aquifer is shown on figure 1. The wells considered in this paper are at Bahía Blanca, near Grümbein, at Puerto Belgrano, at Argerich, and near Lake Chasicó (well Chasicó 1).

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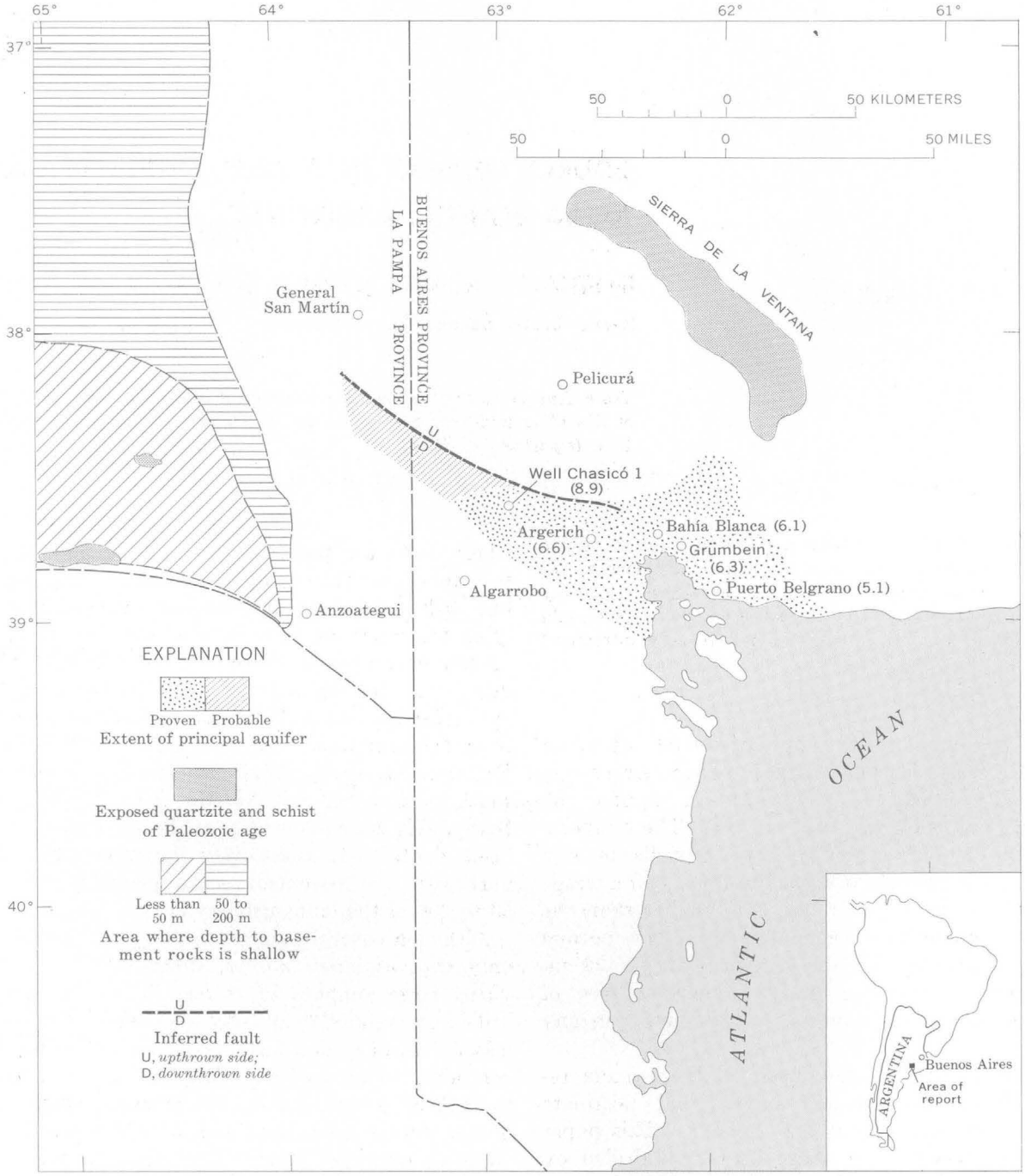

Base from Dirección Nacional de Geología y Minería, June 1958

FIGURE 1.—Map of the Bahía Blanca area, Argentina, showing geothermal gradient in degrees centigrade per 100 m depth (in parentheses), extent of thermal artesian aquifer, and distribution of basement rocks.

The principal aquifer consists of fine- to medium-grained sand, gravel, and conglomerate derived from quartzitic rocks, together with lenticular beds of red clay. It probably is of Miocene age. Known only in wells more than about 500 m deep, it has been penetrated completely in only two wells, where it is 283 and 382.5 m thick. Most other wells considered in this paper penetrate not more than 40 m of the aquifer. The top of the aquifer descends southeastward (seaward) about 0.8 m per km, and the deepest producing wells are at Puerto Belgrano.

Initial yields of wells that tap the principal aquifer range from 50 to 1,000 cu m per hour. The yields generally have declined progressively, in part, no doubt, because discharge causes reduction of head, but also because of encrustation of the well casing; most wells have not been cleaned out. Yields also decline as a result of competing discharge. The yield of one of the wells in Bahía Blanca declined when another 1.2 kilometers away, began to flow, and increased when the flow of the other was stopped.

CHEMICAL CHARACTER OF THERMAL WATER

At best, the chemical quality of the water is acceptable for drinking, but the quality is not uniform from well to well. The dissolved-solids content (residue at 180°C) in 17 samples ranged from about 300 to about 1,760 milligrams per liter. Large differences in the dissolved-solids content and in some individual constituents have been recorded in waters of adjacent wells and also in wells of almost equal depth (Salso and García, 1958, p. 23). The water from wells in the Bahía Blanca–Grümbein area on the whole contains less dissolved solids than the water at Argerich, to the west, or at Puerto Belgrano, to the southeast. Water from 3 of 13 wells sampled in the Bahía Blanca–Grümbein area contained more than 1,000 mg per 1 of dissolved solids. No analysis is available for the water from the westernmost well (Chasicó 1).

Thirteen analyses are complete enough to permit chemical classification of the waters. All are sodium waters containing substantial proportions of chloride and bicarbonate. Two waters can be classed as sodium bicarbonate, 2 as sodium chloride, and 9 as sodium chloride-bicarbonate waters. Sodium ranges from 56 to 98 percent of the total cations (in equivalents per million), as illustrated for the Bahía Blanca–Puerto Belgrano area on figure 2*A*. The "knot" in the upper part of the figure is due to abnormally low sodium content (offset by abnormally high calcium content) at one well. The distribution of chloride, in percent of total anions, is illustrated on figure 2*B*. The proportions of both sodium and chloride increase eastward and northward away from the sea. This suggests an independent source of sodium chloride inland; however, the water from most of the wells is not highly mineralized.

WATER TEMPERATURE AND GEOTHERMAL GRADIENT

The water temperatures generally were measured upon completion of each well and occasionally thereafter; they probably are comparable although spread over a period of years, for the temperature of water coming from depths greater than 500 m is not likely to vary greatly. The warmest water (68°C) comes from a well at Puerto Belgrano, the deepest of those for which records are available. The shallowest well, however, yields the highest temperature water in relation to depth (well Chasicó 1, fig. 1).

The water temperatures have been studied in terms of excess temperature above expectable normal temperature, and also in terms of geothermal gradient. The estimated excesses of temperature serve chiefly to show that the water is unusually warm, but they cannot be precise because they involve (a) an assumed "normal" geothermal gradient for the locality, and (b) an assumed mean annual air temperature of 15.5°C over the entire area. The same assumption as to mean annual air temperature is used in estimating the geothermal gradients, but no assumption as to "normal" geothermal gradient enters into this calculation. The calculations of geothermal gradient ignore the fact that the temperature of the rocks at moderate depth is likely to be a degree or two above mean annual air temperature (Van Orstrand, 1935, p. 88) and the fact that the lowest temperature in a well generally is not at the land surface but at a depth of about 30 m (McCutchin, 1930, p. 20).

The observed water temperatures probably represent somewhat different intervals within the aquifer, but in the absence of information as to permeability or other differences within the aquifer, all temperatures are assumed to represent that of water from the top of the aquifer. No obvious relation of water temperature to depth of aquifer, to thickness of aquifer penetrated, or to depth of well was noted; nor is there a simple relation between excess temperatures or geothermal gradients and these factors. When either excess temperatures or geothermal gradients are plotted on a map, they differ sufficiently within small areas to make the drawing of contours both difficult and dubious. Yet, for the area as a whole, certain major distinctions are apparent, as indicated by average gradients computed for Bahía Blanca, Grümbein, and Puerto Belgrano (fig. 1).

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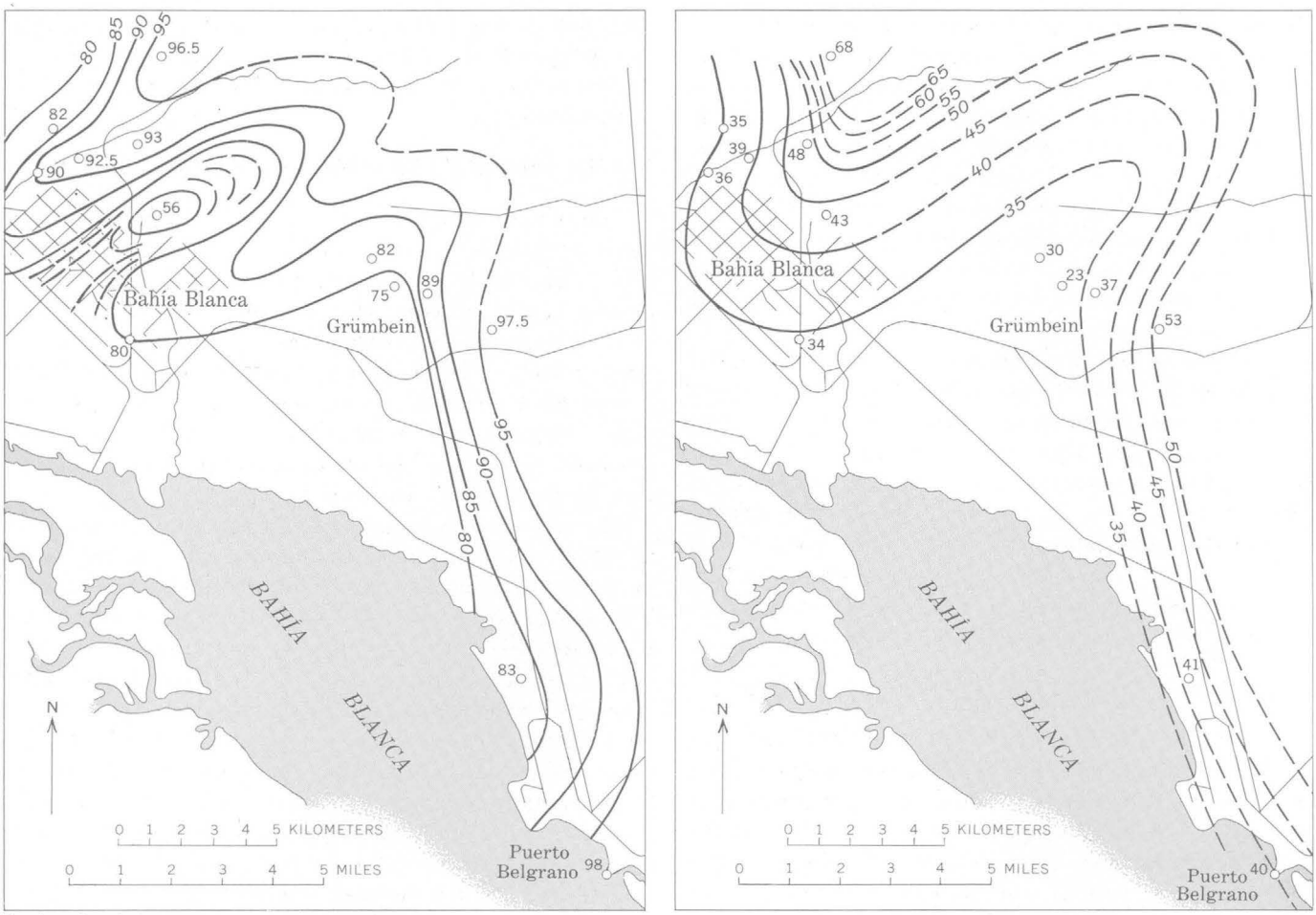

Base from Consejo Federal de Inversiones 1962, vol. 1, p. 139

A. Sodium

B. Chloride

FIGURE 2.—Map of the Bahía Blanca–Puerto Belgrano area, Argentina, showing relative concentration of sodium and chloride in water from deep wells. *A*, lines of equal sodium concentration, as percent of total cations; *B*, lines of equal chloride concentration, as percent of total anions; computed from equivalents per million.

A computation of excess temperature at well Chasicó 1 follows. An assumed normal geothermal gradient of 1 °C per 28 m of depth was computed on the basis of observations of temperature in different strata in the region. Dividing the depth to the aquifer, 507 m, by 28 gives 18 °C, the expected temperature increment due to depth. Adding the mean annual air temperature for the locality, 15 °C, gives 33.5 °C, the temperature expected at a depth of 507 meters; and subtracting this from the observed water temperature, 60° gives 27 °C, the excess at well Chasicó 1. Similar computations indicate that the excess at Argerich is about 21.7 °C; at Bahía Blanca, 15.8° to 19.5 °C; at Grümbein, 15.6° to 20.6 °C; and at Puerto Belgrano, 12.1° to 15.1 °C.

The computation of the temperature gradient for well Chasicó 1 starts with the observed discharge temperature, 60 °C. From this is subtracted the mean annual air temperature, 15 °C, to get the temperature increment due to depth, 45 °C. This divided by depth to top of aquifer, 507 m, gives the geothermal gradient, 0.089 °C per meter, or 8.9 °C per 100 m depth.

Arranged in order from northwest to southeast, the average computed gradients are as follows:

Location	*Geothermal gradient (degrees Centigrade per 100 m depth)*
Chasicó well 1	8. 9
Argerich (2 wells)	6. 6
Bahía Blanca (9 wells)	6. 1
Grümbein (3 wells)	6. 3
Puerto Belgrano (3 wells)	5. 1

Averaging the geothermal gradients does not conceal overlap of gradient ranges. None of the wells at Bahía Blanca has a gradient as high as those at Argerich or Chasicó 1, or as low as those at Puerto Belgrano. However, at Grümbein, the group nearest to Bahía Blanca, some of the wells have geothermal gradients in

the upper range of those at Bahía Blanca, but none of them exceed this range.

The highest geothermal gradient is nearest a fault that marks the boundary of the principal aquifer northwest of Argerich (fig. 1). Admittedly, this may not be the only fault in the region, but it is the only one now recognized with reasonable certainty. The fault may be a conduit through which deep-seated thermal waters rise into the aquifer, or through which intrusives have invaded either the basement rocks or the lower part of the sedimentary section. Whether deep-seated waters or an intrusive body provide the heat in the Bahía Blanca area is a matter for speculation. The following points, however, are pertinent.

(1) A fault at great depth is more likely to be closed than open and more likely to allow the passage of a trickle than a flood of water. The passage of enough thermal water to raise the temperature in the aquifer substantially at Bahía Blanca therefore may be questioned.

(2) Thermal water from great depth is more likely to be mineralized than fresh. If entering the aquifer in quantities sufficient to raise the temperature as much as indicated, such water conceivably could make the water in the aquifer too mineralized for use.

(3) An intrusive could introduce a large amount of heat, perhaps accompanied by only a relatively small amount of fluid. It could heat the aquifer and the water in it without greatly contaminating the water.

(4) Volcanic glass found in strata of Miocene age above the principal aquifer in well Chasicó 1 (Salso and García, 1958, p. 18) suggests that intrusion could have occurred somewhere in the region, but it is hardly proof that it occurred near Bahía Blanca. Volcanic ash in rocks of Tertiary and Quaternary age in the region generally has been attributed to volcanism in the Andes Mountains to the west. Volcanic ash from an eruption that occurred only a few years ago in the Andes was identified at Buenos Aires.

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