CONNOLLY, H. J. C., Preliminary survey of the Mazaruni and Puruni diamond fields of British Guiana, Part I, London (**1927**).

COUTTOLENC, M., Examen de la terre diamantifére de la mine de "de Beers": *Soc. Hist. Naturelle d'Autun, Bull.*, **5**, 127–151 (1892).

DANA, *System of Mineralogy* (by Palache, Berman and Frondel) 7th Ed., p. 147, John Wiley & Sons, New York (**1944**).

EHRENBERG, W., Die Grösse des Diamantgitters: *Zeits. Krist.*, **63**, 320–321 (1926).

FETTKE, C. R., AND STURGES, F. C., Notes on the structure of carbonado or black diamond: *Am. Mineral.*, **18**, no. 4, 172–174 (1933).

GERLOCH, W., Über die Struktur des "Schwarzen Diamants": *Zeit. Anorg. und Allgem. Chem.*, **137**, 331–332 (1924).

KSANDA, C. J., AND HENDERSON, E. P., Identification of diamond in the Canyon Diablo iron: *Am. Mineral.*, **24**, 677–680 (1939).

MOISSAN, H., Sur la presance du graphite, du carbonado, et le diamants microscopiques dans la terre bleue du Cap: *Comptes Rendu, Acad. Sci. de Paris*, **116**, 292–295 (1895).

SHIPLEY, R. M., Dictionary of Gems and Gemology, 2d ed., Gemological Institute of America, Los Angeles (**1945**).

SUTTON, J. R., Diamond, a Descriptive Treatise, Thos. Murby and Co., London (**1928**).

STUTZER, O., AND EPPLER, W. F., Der Lagerstätten der Edelsteine und Schmucksteine, Gebrüder Borntraeger, Berlin (**1935**).

WAGNER, P. A., The diamond fields of South Africa, *The Transvaal Leader*, Johannesburg (**1914**).

WILLIAMS, A. F., The Genesis of the Diamond, 2 vols., Ernest Benn Ltd., London (**1932**).

DOMESTIC SOURCES OF PIEZOELECTRIC CRYSTALLINE QUARTZ

HUGH H. WAESCHE*

An adequate supply of crystalline quartz of piezoelectric grade and size continues to be of fundamental importance to the U. S. Army Signal Corps. Current electronic development programs of the Armed Forces depend upon the use of quartz crystals in all applications where accurate frequency control is necessary. In peacetime this may not seem too significant, but in planning for possible national defense emergencies, an adequate supply of piezoelectric grade raw quartz is just as important as an adequate supply of some of the more publicized strategic minerals.

Prior to World War II, the Signal Corps accepted the use of quartz crystals for frequency control purposes in essentially all electronic communication, navigation and radar equipment operating in the audio and radio frequency spectra up to and including the ultra high frequency channels. Some equipments required a complement of 100 or more crystal units plus spares and replacements for satisfactory operation. As a result, over 70,000,000 crystal units were manufactured for the Army, Navy and Air Forces, requiring over 4,000,000 pounds of radio grade

* Geologist, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.

quartz, between January 1942 and V-J Day. Use of such a large quantity of crystal units was necessary in order to establish and maintain, with a minimum of effort, clear and definite frequency channels of greater stability than could be obtained by any other means. This policy was justified on the basis that quartz was without a peer as a frequency controlling element. Military and civilian uses of quartz in the field, as well as laboratory studies, have confirmed this premise and as of this date, no means of highly stable frequency control, superior to quartz, has been discovered. It appears certain that the demand for use of quartz for frequency control purposes will continue at a high level because its outstanding value in this service will be a strong consideration and determining factor in development and use of military electronic equipment.

One of the greatest difficulties in the past use of quartz has been that of supply. The only dependable source of acceptable raw material has been Brazil. During World War II, it was necessary to ship the quartz over difficult supply lines, including marine transportation subject to enemy naval attack. Late in 1942, this became such a serious problem that it was necessary to ship the quartz by air freight, which limited the quantity obtainable. That situation was alleviated somewhat by the clearing of the sea lanes through the Caribbean in 1943, but at no time since has this country been free of the necessity of stockpiling quartz for strategic purposes. "Quartz Crystal" has been listed invariably during the past two years as a "strategic mineral" on every public tabulation of minerals that must be stock-piled. Some relief from quantity requirements in the future may be obtained through design of equipment requiring fewer crystal units, use of substitutes for natural quartz, design of more dependable crystal units that would require less replacement, conservation of quartz through improved manufacturing methods, greater utilization of lower grade quartz, and design of crystal units utilizing less quartz. A program for conservation of this nature was initiated by the War Department, Office of the Chief Signal Officer in 1943, and was subscribed to throughout the duration of hostilities by all the agencies responsible for the use of piezoelectric grade quartz. This program resulted in an increased yield of eighty per cent per pound of quartz consumed. It is intended that this policy continue in effect insofar as Government uses are concerned.

Quartz is not the only piezoelectric crystalline material. Over one hundred and seventy-five substances have been reported by various investigators to have piezoelectric properties in varying degrees. Any crystal having no center of symmetry should be piezoelectric although many (such as cinnabar) are electrically conductive and therefore cannot be used for electronic frequency control purposes. Practically all the other

substances have various physical properties that make them unsuitable for frequency control applications. Three other minerals which offer promise for electronic, piezoelectric use are crystalline tourmaline, nepheline, and berlinite. However, none of these materials appear to occur plentifully in nature in suitable form. Tourmaline, for piezoelectric use, must be of the non-iron bearing variety. Nepheline and berlinite apparently do not occur in large, well formed crystals. The Signal Corps Engineering Laboratories would be interested in any information concerning the location and quantities of any of these minerals occurring in large, crystalline form, relatively clear and free from defects.

The Signal Corps has been so concerned over the future natural quartz supply for piezoelectric frequency control application, that it has launched a program for synthesis of substitute materials. Brush Development Company of Cleveland, Ohio, and Antioch College, Yellow Springs, Ohio, are well along on quartz synthesis. Edward Washken of Cambridge, Mass., is engaged in research for synthesis of nepheline and Baird Associates of Cambridge, Mass., is engaged in research for synthesis of tourmaline. The University of Minnesota and Squier Signal Laboratory of Fort Monmouth, N. J., are investigating the synthesis of berlinite. These projects (with the exception of Squier Signal Laboratory) are being sponsored by means of contracts with the Signal Corps Engineering Laboratories. The Naval Research Laboratories are making major contributions to piezoelectric crystal synthesis. Results to date have been gratifying but in no way affect the present Signal Corps desire to promote consideration for radio grade quartz wherever explorations of any kind are conducted in Central and North America.

It is well known by geologists, mining engineers, and mineralogists that quartz is one of the most abundant mineral constituents of the earth's crust; large quantities occur throughout Central and North America. Unfortunately, piezoelectric use of quartz is very exacting in its requirements, thus limiting usable quartz to only one of many varieties. It must be crystalline and must be essentially eye clear, free of impurities, physical defects and crystallographic variations, including twinning, within any given crystal. The dimensions of operating crystal plates, and manufacturing methods have limited the physical size of the quartz crystals heretofore used to a minimum of 100 grams by weight having a length parallel to the vertical crystallographic axis of at least two inches and a diameter, perpendicular to the vertical crystallographic axis, of at least one inch. Quartz of this size must exhibit at least one identifiable crystallographic face for economical use, although crystals over 200 grams can be economically processed whether "faced" or not. Obviously, the piezoelectric grade of this important mineral is rare in occurrence in

sizeable deposits. Limited, known sources in North and Central America have been confined largely to uneconomical deposits in Guatemala, Arkansas, and California. Usable crystals have been found singly or in very small quantities scattered throughout Central and North America and it is a reasonable geologic assumption that satisfactory sources, as yet undiscovered, may exist in these regions. Continued geologic exploration may be expected to reveal such sources; especially is this true when it is considered that much investigation of this nature remains to be done in some of the more remote or inaccessible localities (e.g., Alaska). Large deposits of piezoelectric grade quartz even in Continental United States may exist and this possibility cannot be dismissed.

Military and civilian officials of the Signal Corps have recognized and discussed the problems covered in the preceding paragraphs during the past several years. An active program on the part of the Signal Corps Engineering Laboratories calls for continuous liaison with the Geological Survey, Bureau of Mines, other Government organizations, including State Surveys, Geological and Mineralogical Societies, Educational Institutions and Mining Organizations. These groups, as well as individuals, are asked to be on the alert for sizeable bodies of radio grade quartz and to advise the Commanding Officer, Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey, of such findings. Signal Corps representatives will examine any North or Central American piezoelectric mineral source localities in coordination with the other interested Government agencies or groups indicated, if warranted. Quartz so located will be tested by the Signal Corps Engineering Laboratories for piezoelectric qualities. These Laboratories would also be interested in information regarding relatively large deposits of crystalline quartz of individual crystal sizes in the range of 30 to 100 grams.

PETROGRAPHY OF A SAMPLE OF BEDROCK FROM A DEEP WELL AT ROCKAWAY PARK, LONG ISLAND, NEW YORK[1]

CLAUDE M. ROBERTS

Further evidence as to the position and character of the bedrock of Long Island has been brought forth as the result of a recent petrographic study of a sample of the bedrock from the drilling of a deep well beneath Rockaway Park.

In 1939, one of two deep wells, Q 1030, drilled by the Department of

[1] Published by permission of the Director of the Geological Survey, United States Department of the Interior.