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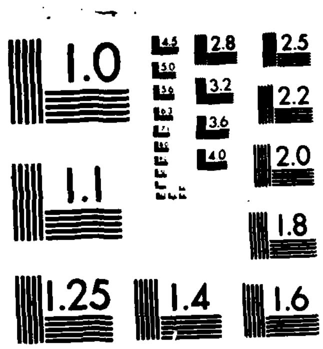

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THERMOPHYSICAL PROPERTIES OF SELECTED ROCKS

P. D. Desai, R. A. Navarro, S. E. Hasan,
C. Y. Ho, D. P. DeWitt, and T. R. West

CINDAS REPORT 23
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April 1974

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This report presents the available experimental data on four thermophysical properties of twelve rock types and also gives selected values for fifteen specific rock materials identified by geologic formation or geographic location. Sufficient specimen characterization and measurement information are provided to permit meaningful data evaluation and correlation. In addition, petrographic descriptions of the individual rock types and the specific rock material are also included. The fifteen specific rock materials constitute the ARPA and NASA suites of rocks, and the four

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Foreword

This Report was prepared by the Underground Excavation and Rock Properties Information Center (UERPIC), a national information/data center on rock properties, tunneling and excavation technology, and nuclear blast effects. It is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, and supported by Grants GI-34608X and GI-34608X1 from the National Science Foundation - Research Applied to National Needs (NSF-RANN). The report is one of several technical products which represent part of the major accomplishments of UERPIC in the period 1 June 1972 to 31 May 1974.

UERPIC was established on 1 June 1972 at CINDAS through an interdisciplinary effort at Purdue University involving senior investigators from three academic departments and CINDAS: Professor W. R. Judd (Rock Mechanics), Civil Engineering; Professor D. P. DeWitt, Mechanical Engineering; Professor T. R. West, Geosciences; and Professor Y. S. Touloukian, Director of CINDAS.

Abstract

This report presents the available experimental data on four thermophysical properties of twelve rock types and also gives selected values for fifteen specific rock materials identified by geologic formation or geographic location. Sufficient specimen characterization and measurement information are provided to permit meaningful data evaluation and correlation. In addition, petrographic descriptions of the individual rock types and the specific rock materials are also included. The fifteen specific rock materials constitute the ARPA and NASA suites of rocks, and the four thermophysical properties are thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat. The property data are extracted from 95 data source references covering the publication years from 1920 to 1972 and are presented in both graphical and tabular formats usually as a function of temperature. In some cases, however, data as a function of pressure or saturation are also given.

Preface

A need for complete information on thermophysical properties of rocks is becoming apparent in the fields of engineering materials and geosciences. Problems encountered in design and selection of underground nuclear waste disposal and nuclear test sites, hardened defense facilities and underground power plants, along with continued interest in thermal tunnelling techniques (both at elevated and cryogenic temperatures) have increased the demand for thermophysical rock data. In the geosciences, accurate values for heat flow in the earth's crust are needed to obtain a better understanding of the earth's history and its current make-up. Information is also needed to evaluate the newly developed theories on sea floor spreading and plate tectonics in addition to supplying details for the substantial deep sea rock coring program now underway. Geothermal power generation techniques and earthquake prediction analysis both depend to some degree on thermophysical properties and heat flow of rock masses. In all, these varied research activities have signaled the desire for an organized body of knowledge on the thermophysical properties of rocks. It is precisely to answer such an urgent need that this work is produced.

Rocks, however, are not single phase, pure substances exemplified by many metals, elemental materials, and certain man-made and natural compounds for which thermophysical properties have been compiled in the past. Rocks are heterogeneous materials, a mixture of several minerals which taken by themselves are commonly anisotropic substances. Hence, rocks must be properly characterized if meaningful evaluation and comparisons of their properties are to be made. Mineral composition and texture (or fabric) must be provided to insure proper comparisons between rock samples. Even if the correct lithologic (rock) name is applied to a sample (which certainly has not always been the case), sufficient differences in mineral composition and texture can occur within that rock group (such as granite) to cause significant differences in mechanical and thermophysical properties. Therefore, in this work detailed petrographic descriptions are supplied for the rocks along with the presentation of their thermophysical property data.

The above mentioned salient feature makes this work unique and especially useful. This work is the first of its kind and no such comprehensive compilation on thermophysical properties of rocks has ever been published. In the process of data extraction and evaluation, over two hundred research documents have been examined resulting in 95 source references which contain original experimental data and cover the publication years from 1920 to 1972.

Many colleagues have contributed to the preparation of this work in one way or another and their contributions are hereby acknowledged. The authors are particularly indebted to Professor R. F. Roy for his helpful comments and suggestions and to Mr. E. J. Hanley for his assistance in the extraction of the thermal diffusivity data.

Contents

List of Figures and Tables

* No figure given.

* No figure given.

I. Introduction

The purpose of this work is to present and review the available experimental data and information on four thermophysical properties of twelve rock types and to generate selected values for fifteen specific rock materials identified by geologic formation or geographic location. These fifteen rock materials constitute the ARPA* and NASA** suites of rocks which include a number of the commonly used materials employed in rock mechanics research in the United States. The rock types included here embrace all three major genetic divisions: igneous-plutonic (dacite, dunite, gabbro, granite, and granodiorite) and extrusive (basalt and rhyolite), sedimentary (limestone and sandstone), and metamorphic (marble, quartzite, and serpentinite).

The work comprises four sections. This Section I serves as an introduction to the subject. The experimental methods used by the various authors to obtain the thermophysical property data on rocks are briefly described in Section II, which is intended to provide supplemental information to the tables given in Section III, the core of this work.

The experimental data on the four thermophysical properties (thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat) of the twelve rock types are separately presented in Section III in both graphical and tabular formats. In most of the graphs the property data are shown as a function of temperature, but in a few graphs the property data as a function of pressure or saturation are given. The table gives not only the experimental data but also the specimen characterization and measurement information for each set of data. For specimen characterization, it gives the material name and specimen designation, specimen geometry, specific gravity, porosity, permeability, hardness, mineral and/or chemical composition, source of the material, specimen texture, heat treatment, etc. For the measurement, it provides information on the experimental method, direction of measurement, test environment, and other test conditions. In addition, Section III gives a detailed discussion of the petrography for each of the twelve rock types in general and for each of the fifteen selected specific rock materials in particular, for which selected values of the thermophysical properties are also presented in the graphs and in separate tables. The complete bibliographic citations for the references are given in Section IV.

* Advanced Research Projects Agency - This suite of rocks was selected for study by the U.S. Bureau of Mines.

** National Aeronautics and Space Administration - This suite of rocks was selected to represent rock materials which might be encountered during lunar exploration.

Since the thermophysical properties of rocks are the subject matter of this work. it is appropriate to discuss here briefly the nature of occurrence, mode of formation, and other geologic characteristics of these rock types, the range in thermophysical properties of these rocks, and the method of selection of the property values.

Nature of Occurrence and Mode of Formation of Rocks

Plutonic rocks are believed to form from crystallization of magma deep within the earth's interior; these rocks were emplaced and solidified in the earth's crust and later uplifted and brought to the earth's surface by mountain building forces. Extrusive rocks, as the term implies, were poured out on the surface of the earth through fractures and fissures. Molten material which outpours on the surface is connected to the deep-seated magma chamber below through volcanic feeder pipes. Much material of the sedimentary rocks is derived from the weathering and denudation of pre-existing rocks and these weathering products are laid down in depressions or basins primarily in an aqueous environment. Some sedimentary rocks are not derived from broken rock fragments however, but are organic and chemical precipitates. After deposition the sediments are subjected to pressure and temperature changes, lithification, and diagenesis to yield sedimentary rocks. Metamorphic rocks are formed as a result of temperature and pressure changes taking place within the earth's interior to which igneous and sedimentary rocks are subjected to during periods of mountain building activities.

General Geologic Characteristics of Rocks

Plutonic igneous rocks are characterized by a massive, crystalline texture and absence of any primary planer feature such as foliation. They have a low (< 1%-3%) porosity. Joints may be common and whenever they occur, their spacing, attitude, and frequency affects the thermophysical properties.

The extrusive igneous rocks are generally fine to medium grained with a partly to wholly crystalline texture; some varieties are holohyaline (e.g., obsidian). These rocks have wide porosity range and values of 85% have been noted in pumice. Joints are well-developed in most extrusive rocks and layered structure is not uncommon. Thermophysical properties of such rocks vary widely depending upon their porosity, prevalence of joints and micro-fractures, and orientation of test specimen with respect to the flow layering.

Sedimentary rocks are characterized by the presence of primary bedding planes and higher porosity (5%-30%). The thermophysical properties of these rocks are, to a large extent, dependent upon their porosity, nature and composition of cementing material, and orientation of the test specimen relative to the bedding plane.

The metamorphic rocks have characters intermediate between igneous and sedimentary rocks. This depends upon the type of the original rock from which these were derived, although quite frequently metamorphism has been so complete that any trace of the original rock is wholly obliterated. Such rocks behave more like plutonic rocks.

Range in Thermophysical Properties

Unlike well-characterized pure materials, or even well-defined alloys, rocks consist of a variety of mineral phases and a particular mineral assemblage distinguishes one rock type from the other. An understanding of the heterogeneity in composition, anisotropism of the fabric and diversity in mode of occurrence is, therefore, essential to appreciate the wide variation in the thermophysical properties of rocks. Even rocks with the same mineral and chemical composition may show considerable variations in their thermophysical characteristics. The main factors responsible for this variation are:

(1) Variation in chemical and mineralogic composition.

(2) Petrofabric.

(3) Structural defects including mega- and micro-features.

The limitations imposed by the above factors put a serious restriction on making any recommendation on selected thermophysical properties of a particular rock type. For, although a pre-Cambrian granite from, say, the Appalachian geological province may be similar to a granite of the same age from Alaska, yet they may show different thermophysical properties which could be a manifestation of the tectonic history of the region and the resulting stresses to which these two granites were subjected to.

It has been, nevertheless, our endeavor to generate, wherever possible, selected values for a particular rock type from a particular stratigraphic locality if their thermophysical properties varied within reasonable limits. This has been possible only in the case of those rocks for which sufficient information on composition, texture, specific gravity, porosity, and specimen geometry and orientation has been available in the referenced literature. Wherever possible selections have been made for the particular rock formation or quarry locations discussed in Section III. The task becomes formidable when the geologic information is insufficient. In these cases no attempt has been made to generate any selected values.

Method of Selection of Thermophysical Property Values

Selection is made based on the best available data. In some cases the quality of the data can be judged by the objective criteria. In others, contradictory data are found in which the choice cannot be made on these grounds. In such instances, weight is given to the reputation of the author or the laboratory that conducted the measurements. Where a given work is mentioned, but does not agree with this selection, the reader should realize that the work may be correct and the selection wrong but that compilations to date suggest the opposite situation. Wherever measurements are made on several samples of the same rock type but yield different results, a banded envelope indicating scatter is shown in the figure in addition to the selected curve. This band width is determined by the following:

(1) Experimental scatter for an individual specimen.

(2) Differing values for several specimens in a series of experiments.

(3) Differing values reported by the same or different investigator for similar rock samples.

Selected band width tends to form a constant percentage of the selected value. Consequently, for decreasing values with increasing temperature the band width usually decreases at higher temperature.

Units Used and Conversion Factors

In this work the thermophysical property values are given in the SI or cgs units to which the different units used by various authors for their original data have all been converted for uniformity of presentation.

To convert the property values presented in this work to values in other units the following conversion factors may be used.

To convert from	to	Multiply by
$W\ m^{-1}\ K^{-1}$	$Btu_{th}\ hr^{-1}\ ft^{-1}\ F^{-1}$	0.578176
$W\ m^{-1}\ K^{-1}$	$cal_{th}\ s^{-1}\ cm^{-1}\ C^{-1}$	2.39006×10^{-3}
$cm^2\ s^{-1}$	$ft^2\ s^{-1}$	1.07639×10^{-3}
$cm^2\ s^{-1}$	$m^2\ s^{-1}$	1×10^{-4}
$cal_{th}\ g^{-1}\ K^{-1}$	$Btu_{th}\ lb^{-1}\ F^{-1}$	1
$cal_{th}\ g^{-1}\ K^{-1}$	$J\ kg^{-1}\ K^{-1}$	4.184×10^3

II. Experimental Methods for Rocks

The experimental methods used by the various authors to obtain the property data compiled in this work are identified for the individual data sets and given under the column heading "Method Used" in the tables of the next section, which present not only the experimental data but also the specimen characterization and measurement information. The purpose of this section is to briefly describe these methods. Consequently, not all the existing methods are included here. For comprehensive reviews of experimental methods, the reader is referred to the reference works on thermal conductivity [106, 107], thermal diffusivity [108, 107-Vol. 2 Chapter 3], thermal expansion [109, 110], and on specific heat [111, 112].

A. METHODS FOR THERMAL CONDUCTIVITY MEASUREMENTS

The methods for the measurement of the thermal conductivity of rock can be classified into two categories: the steady state and the non-steady state methods.

1. STEADY STATE METHODS

In steady state methods, the test specimen is subjected to a steady heat flow and a temperature gradient which is time invariant. The thermal conductivity is determined by measuring the rate of heat flow per unit area and the temperature gradient across the specimen.

Some of the most commonly used steady state methods are described below.

a. Longitudinal Method

In this method the flow of heat is restricted in the axial direction of a rod (or disk) specimen. The radial heat loss or gain is prevented or minimized and evaluated. The thermal conductivity is then determined from the equation

$$k = -\frac{q/A}{\Delta T/\Delta x}$$

where k is the average thermal conductivity corresponding to the temperature $\frac{1}{2}(T_1+T_2)$, $\Delta T = T_2 - T_1$, q is the rate of heat flow, A is the cross-sectional area of the specimen, and Δx is the distance between points of temperature measurements for T_1 and T_2.

This method can be further divided into absolute and comparative methods according to the means of measuring the heat flow. In the absolute method, the rate of heat flow is directly determined, while in the comparative method the rate of heat flow is calculated from the temperature gradient over a reference standard sample of known thermal conductivity which is placed in series with the specimen.

b. Radial Method

Most of the specimens used in this method are in the form of a cylinder with a coaxial central hole containing a heater or a heat sink. The thermal conductivity is calculated from the expression

$$k = \frac{q \ln (r_2/r_1)}{2\pi L \ (T_1 - T_2)}$$

where L is the length of the central heater and T_1 and T_2 are temperatures measured at radii r_1 and r_2, respectively.

A varient of this method is the concentric cylinder method, which is used mainly to measure the thermal conductivity of a loose-filled material such as soil. This method can be comparative by using a cylindrical specimen surrounded by a concentric cylindrical reference standard sample of known thermal conductivity.

c. Thermal Comparator Method

The essential part of the thermal comparator is an insulated probe with a projecting tip. The probe is integral with a thermal reservoir held at a temperature about 15 to 20 degrees above room temperature. A surface thermocouple is mounted at the tip of the probe and is differentially connected to the thermal reservoir for the measurement of the temperature difference between the reservoir and the tip.

In operation, the probe is gently placed on the surface of the test material. Upon contact of the probe tip of known thermal conductivity k_1 and originally at temperature T_1 with the surface of the test material of thermal conductivity k_2 and at room temperature, T_2, the temperature of the probe tip drops quickly to an intermediate temperature, T, given by the expression

$$T_1 - T = (T_1 - T_2) \frac{k_2}{k_1 + k_2}$$

This temperature difference is registered by the emf reading of the differential thermocouple after a brief transient period (1 to 2 seconds) has elapsed.

From the emf readings of tests on a series of reference standard samples of known thermal conductivity, a calibration curve is obtained, and the thermal conductivity of an unknown specimen can thus be determined from the emf reading through the calibration curve.

2. NON-STEADY STATE METHODS

In non-steady state methods, the temperature distribution in the specimen varies with time. The rate of temperature change at certain positions along the specimen is measured in the experiment. Few of the non-steady state methods determine the thermal conductivity directly, and most of them determine the thermal diffusivity, from which the thermal conductivity is calculated with an additional knowledge of the density and specific heat of the test material. In this subsection, only the line heat source and probe methods which determine the thermal conductivity directly are discussed. Those transient heat flow and periodic heat flow methods which determine the thermal diffusivity will be discussed in the next section.

a. Line Heat Source Method

In this method a long thin heater wire which serves as a line heat source is embedded in a large specimen initially at uniform temperature. The heater provides a constant heat, q, per unit time and length, and the temperature at a point in the specimen is recorded as a function of time. The thermal conductivity is given by the expression

$$k = \frac{q}{4\pi\ (T_2 - T_1)} \ln \left(\frac{t_2}{t_1}\right)$$

where T_1 and T_2 are the temperatures measured at the times t_1 and t_2, respectively.

b. Probe Method

The probe method is a more practical line heat source method in which the line heat source is enclosed inside a probe for protection and for easy insertion into a sample. This method can be used for field measurements of the thermal conductivity of rock and soil.

B. METHODS FOR THERMAL DIFFUSIVITY MEASUREMENTS

The methods used for the measurement of thermal diffusivity fall into two major categories: the transient heat flow and the periodic heat flow methods. These methods can also be subdivided into longitudinal and radial methods according to the direction of heat flow.

1. TRANSIENT HEAT FLOW METHODS

In transient heat flow methods, heat is suddenly added to or removed from a specimen initially at a uniform temperature and the thermal diffusivity is determined from a measurement of the temperature as a function of time at one or more points along the specimen.

a. Longitudinal Method

In this method one end of a rod of uniform cross section and initially at a uniform temperature is subjected to a short heating pulse, and the thermal diffusivity, α, is calculated from a measurement of the temperatures as a function of time at properly chosen points along the rod. The one-dimensional heat flow equation

$$\frac{\partial T}{\partial t} = \alpha \frac{d^2 T}{d x^2}$$

may be used for the calculation with boundary conditions applying to a finite rod.

In a variant of this method, steady heating is provided at one end of a rod and the temperatures as a function of time at two or more points along the rod are observed.

b. Flash Method

Although the flash method is a variant of the longitudinal transient heat flow method using a small thin disk specimen geometry, it has a very special feature which makes it a class of its own. In the "flash" method, a flash of thermal energy is supplied to one of the surfaces of a disk specimen within a time interval that is short compared with the time required for the resulting transient flow of heat to propagate through the specimen.

In the measurement, a heat source such as flash tube or laser supplies a flash of energy to the front face of a thin disk specimen and the temperature as a function of time at the rear face is automatically recorded. Heat losses are minimized by making the measurement in a time so short that little cooling can occur. The thermal diffusivity is calculated from the expression

$$\alpha = \frac{0.139\ L^2}{t_{1/2}}$$

where L is the sample thickness and $t_{1/2}$ is the time required for the back face to attain half its maximum increase in temperature.

c. Radial Method

In this method a long cylindrical specimen initially at uniform temperature is heated either at the axis or at the outer surface and the temperatures as a function of time at different radial distances are measured.

If the outer surface of a long hollow cylindrical specimen of inner radius r_0 is heated at a constant rate and the temperatures T_1 and T_2 at two radii r_1 and r_2 within the specimen are measured, the thermal diffusivity is given by the expression

$$\alpha = \frac{1}{2\,(T_2-T_1)} \frac{\partial T}{\partial t} \left[\frac{1}{2}\,(r_2^2-r_1^2) - r_0^2 \ln \frac{r_2}{r_1}\right]$$

The above equation assumes that the specimen is isotropic and homogeneous with α independent of T and that $\partial T/\partial t$ is constant and there is no internal loss of heat.

In another variant of this method, a solid cylindrical specimen is placed within a heated enclosure and fitted with end guards to ensure that all heat flows radially inwards. The specimen is heated rapidly by a constant source of power and temperatures are measured at two points at the longitudinal center of the specimen with radii of r_1 and r_2. For times sufficiently long for a linear rate of temperature increase to be established

$$\alpha = \frac{r_2^2-r_1^2}{4\,(t_2-t_1)}$$

where t_2-t_1 is the time interval between the attainment of a specific temperature at r_2 and r_1.

2. PERIODIC HEAT FLOW METHODS

In periodic heat flow methods, the heat supplied to the specimen is modulated to have a fixed period. The resulting temperature wave which propagates through the specimen with the same period is attenuated as it moves along. Consequently, the thermal diffusivity can be determined from measurements of the amplitude decrement and/or phase difference of the temperature waves between certain points in the specimen. In most of the periodic heat flow methods, heat flow is in the longitudinal (axial) direction. However, methods with heat flow in the radial direction have also been used.

a. Longitudinal Method (Ångström Method)

The longitudinal periodic heat flow method was first developed by Ångström and is therefore called Ångström method. In his first experiments, the middle of a long rod was subjected to periodic heating and cooling for equal time periods and the temperatures as a function of time at two points on the same side of the middle of the rod were measured. Ångström showed that

$$\frac{k}{d\,C_p} = \frac{\pi L^2}{t \phi \ln \delta}$$

where d is density, C_p is the specific heat at constant pressure, L is the distance between the two observation points, t is the period of the temperature wave, ϕ is the phase lag of the temperature fluctuations at the two points, and δ is the amplitude ratio of the temperatures at these points. In his time, the quantity $\alpha \equiv k/d\,C_p$ had not been defined.

A long rod could equally well be heated and cooled periodically at one end as has been done in most later applications of the method.

Ångström's original method was improved and modified subsequently and several versions of the "Modified Ångström Methods" have since been reported.

The Ångström method which uses a long rod has its limitations. In some cases, specimens in the form of long rods may not be available, and in other cases such as in the measurements on poor conductors at high temperatures, heat guarding to prevent lateral heat losses for a long rod may be difficult. Consequently, methods using specimens in the form of small plate or disk have also been developed.

b. Radial Method

In this method the specimen in the form of a cylinder is heated by a heat source capable of producing a periodical temperature variation either at the axis or at the circumference and the radial temperature variations with time are measured. The thermal diffusivity may be calculated from the phase change of the temperature oscillations or from the amplitude variation of the oscillations with frequency.

C. METHODS FOR THERMAL LINEAR EXPANSION MEASUREMENTS

The thermal linear expansion, $\Delta L/L$, is the total length change from a reference temperature to a given temperature per length at reference temperature. 293 K is used as the reference temperature. The coefficient of thermal linear expansion, α, is the temperature derivative of the thermal linear expansion. Thus they are given by the expressions:

$$\frac{\Delta L}{L} = \frac{L_T - L_{293}}{L_{293}}$$

$$\beta = \frac{d}{dT}\left(\frac{\Delta L}{L}\right) = \frac{1}{L_{293}}\,\frac{dL}{dT}$$

A number of different methods for measuring the thermal linear expansion of solids were developed during the last 50 years. A variety of methods and modifications are required for various classes of materials. Among the methods used for rocks, dilatometric method, which is for intermediate sensitivity class, is the most commonly used. The interferometric method is one of the most accurate methods in the academic research laboratories with small specimens of very low thermal conductivity.

1. INTERFEROMETER

The most outstanding early method of any notable precision was due to Fizeau [104,105]. In this method the specimen is placed vertically between two transparent fused quartz plates, each about 4 mm thick and reasonably free from any imperfections. The surfaces of each plate should be flat within one-fifth of a fringe and inclined to each other at an agnel of 20' of arc. This is set in an electric furnace or a cooling chamber. When plates are illuminated normally with monochromatic light, a set of interference fringes is produced by the interference of light reflected between the lower surface of the upper plate and upper surface of lower plate. The fringes are observed by means of a viewing device. Changing the temperature of the specimen brings about a change in length which causes a corresponding movement of the interference fringes past a reference mark on the lower surface of the upper plate. From observed displacement of the fringes, the thermal linear expansion can be determined from the expression:

$$\frac{\Delta L}{L} = \frac{\lambda N}{2L} + \frac{A}{L}$$

where L is the initial length of the specimen, ΔL is the change in length, λ is the wave length of monochromatic light, N is the number of fringes that passed the reference mark, and A is the correction if the specimen is heated or cooled in other than vacuum.

2. DILATOMETER

This consists of a quartz tube used to support the specimen and a fused quartz rod to transmit the specimen's dimensional change with temperature to a dial recorder. Quartz is used because of its low thermal expansion. Extensometer is used for measuring length changes over a length of at least 0.05 inches. Dial indicator and linear variable transformer are used the most for measuring length changes, but many other types like optical levers, strain gage, and optical gratings are also used.

D. METHODS FOR SPECIFIC HEAT MEASUREMENTS

The specific heat, C_p, is the amount of energy required to raise the temperature of one unit of mass by one unit of temperature at constant pressure. There are several methods for the practical and precise determination of the specific heat of solids. Many variants, modifications, and improvements are reported in the literature. The most commonly used methods for rocks are as follows.

1. DROP ISOTHERMAL WATER CALORIMETER

In this method the specimen is heated and dropped directly into the calorimeter containing water and enclosed in an isothermal jacket. The top is covered by copper plates. The water is stirred to assume uniform temperature. The rise of temperature is measured accurately. The enthalpy change of the specimen is determined from the known heat capacity of the calorimeter and its temperature rise, and the specific heat is given by the expression

$$C_p = \frac{d\,(H_T - H_{298.15})}{dT}$$

where H is the enthalpy of the specimen.

2. DROP COPPER BLOCK CALORIMETER

In this method the sample is heated within a capsule of known heat content in a furnace to a measured temperature and dropped into a copper calorimeter whose heat capacity has been previously determined. The temperature of calorimeter is measured using a special bridge network of copper and manganin resistances. The heat released from the specimen is distributed to the copper calorimeter. The change in enthalpy of the specimen is measured in terms of the amount of heat absorbed by the copper block in changing from its initial to final temperature. Thus,

$$C_p = \frac{d}{dT}\,(H_T - H_{298.15})$$

3. ADIABATIC CALORIMETER

This method is suited for granular materials, fine powders, and materials with low thermal diffusivity and thermal conductivity. The calorimeter consists of a thin walled spherical shell made of two copper hemispheres welded together. At the center of this shell a heater element is placed which is made of a hollow copper sphere of 5 mm wall thickness enclosing the electrical heater coil wound onto a ceramic sphere. During the measurement, the gap between the two spheres is filled with test material which is introduced into the gap through a hole at the bottom of the calorimeter. The calorimeter is surrounded by a thermostat made of a thick walled copper sphere heated electrically and regulated very sensitively to follow the surface temperature of the calorimeter. The thermostat and guard heaters are adjusted to heat up the instrument to a desired temperature. As soon as this is reached, the power input is reduced until it just compensates the heat loss. The calorimeter itself follows the temperature change more slowly. Heater element on the calorimeter is turned on. Enough time is allowed to check that the temperature of all parts of the calorimeter increases at the same rate. The time needed to increase the temperature by a fixed millivolt increment is measured to get the heat capacity of the calorimeter. Then the calorimeter is filled with the specimen and the experiments are repeated. Knowing the heat capacity of the calorimeter, the heat capacity of the specimen can be derived as follows:

$$C_p = \frac{1}{m}\left[\frac{dQ/dt}{dT/dt} - W_c\right]$$

where dQ/dt is the heat input per unit time, W_c is the specific heat of the calorimeter, and m is the mass of the specimen.

III. Thermophysical Properties of Rocks

1. BASALTS

A. PETROGRAPHY

Basalts are the most abundant of all volcanic rocks and are the principal products of shield volcanoes of the Hawaiian type. They are fine-grained rocks and consist predominantly of plagioclase and pyroxene; olivine or quartz (or both) may be present, and glass is found in many. Tholeiitic basalt is a special type of calcalkali basalt. These are generally olivine-free or olivine poor and predominate among the plateau building lavas of shield areas of the world.

There is a wide variation in chemical and mineralogical composition of basalts and the compositions given below represent average values for plateau basalt.

Chemical Composition* (After Daly [99])

Oxide	Wt. Percent
SiO_2	48.80
TiO_2	2.19
Al_2O_3	13.98
Fe_2O_3	3.59
FeO	9.78
MnO	0.17
MgO	6.70
CaO	9.38
Na_2O	2.59
K_2O	0.69
H_2O	1.80
P_2O_5	0.33

Mineralogical Composition

Mineral	Vol. Percent
Plagioclase	40-60
Mafic minerals (pyroxenes and/or olivine)	55-35
Quartz, olivine, glass, apatite-iron-ores	in varying proportion

Dresser Basalt

The mineralogy and texture of basalt from Dresser, Wisconsin, given by Lindroth and Krawza [35] and by Hasan and West [101], is summarized below:

* Average of 43 analyses.

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Mineral Composition

Essential Minerals	Vol. Percent
Plagioclase (labrodorite)	45
Augite	34

Accessory Minerals	Vol. Percent
Serpentine	16
Fe-ore (magnetite)	3
Chlorite	2

Texture. The rock is holocrystalline, fine-grained, and ophitic. Olivine has almost wholly altered to serpentine and magnetite. Average grain size is 0.04 mm.

Tholeiitic Basalt

The mineralogy and texture of Tholeiitic basalt from N. E. of Madras, Oregon, given by Fogelson [98], is summarized below:

Mineral Composition

Essential Minerals	Vol. Percent
Plagioclase (An_{67}, An_{54})	39
Olivine	13.5
Augite	10.5

Accessory Minerals	Vol. Percent
Plagioclase microlites	12
Magnetite, Ilmenite	8
Glass	12
Chlorite	4
Quartz (as small inclusions in plagioclase)	1
Apatite	<1
Epidote	<1

Texture. Overall texture is merocrystalline; the interstitial glass, however, contains microlites of magnetite and plagioclase imparting a hyalopilitic texture to the matrix. Some plagioclase crystals occur as phenocrysts. Most of the crystals are subhedral except plagioclase of older generation which have rounded corners and re-entrants indicative of partial resorbtion. The grain size varies between 0.15 mm and 0.10 mm in length and 0.04 mm and 0.008 mm in diameter.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

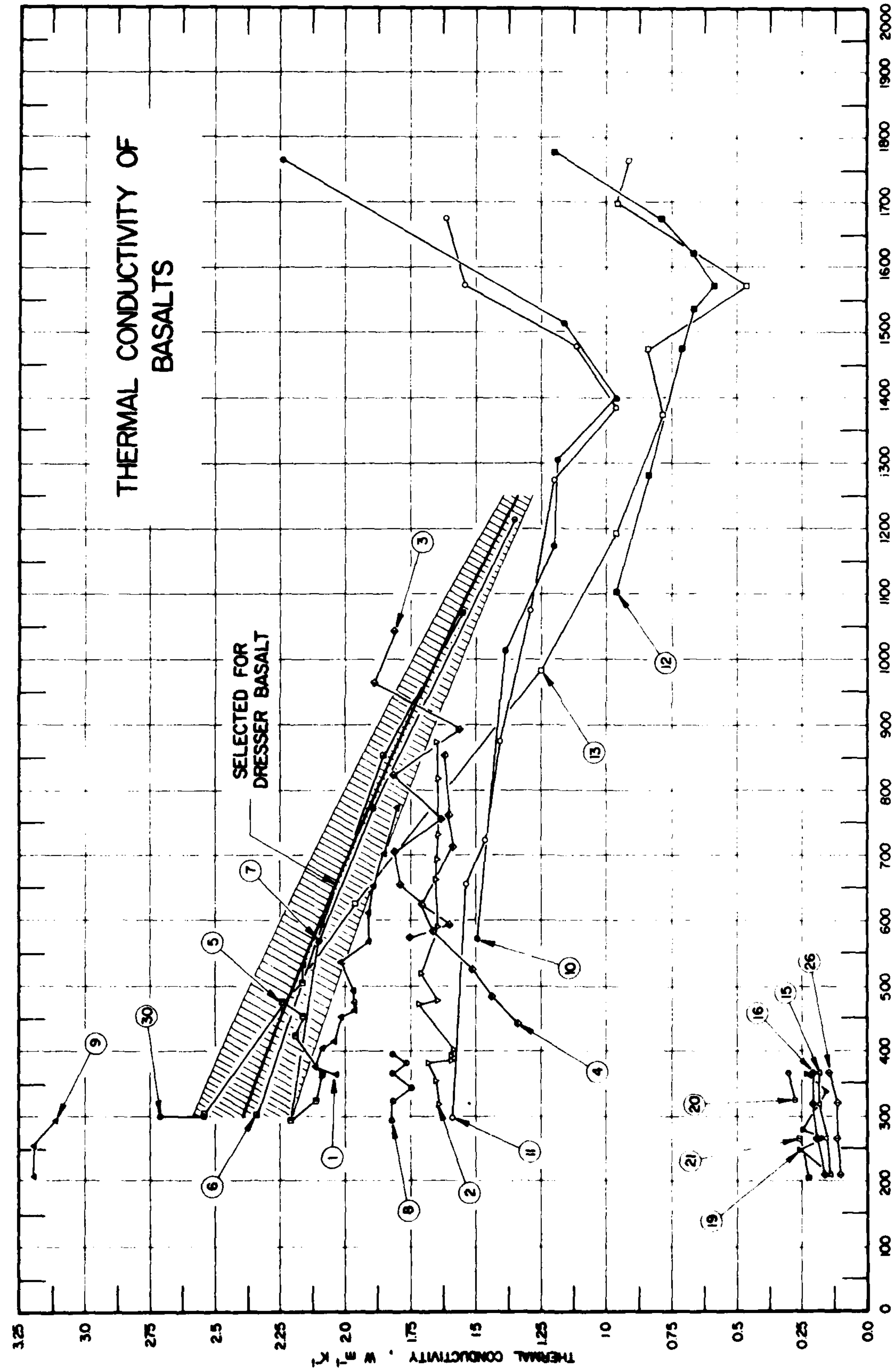

THERMAL CONDUCTIVITY OF BASALTS
SELECTED FOR DRESSER BASALT
TEMPERATURE, K
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
0.0 0.25 0.5 0.75 1.0 1.25 1.5 1.75 2.0 2.25 2.5 2.75 3.0 3.25
1 2 3 4 5 6 7 8 9 10 11 12 13 15 16 19 20 21 26 30

FIGURE I-K-T

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	6	Poole, H. H.		Cylinder						Steady	364	2.04	
		(1914)		3.67 cm						Radial	377	2.12	
				dia x						Absolute	406	2.09	
				28 cm							419	2.04	
				length							453	2.02	
											463	1.97	
											477	1.97	
											495	1.99	
											538	2.03	
											568	1.93	
											612	1.93	
											651	1.89	
											704	1.85	
											773	1.81	
2	6	Poole, H. H.		Cylinder						Steady	320	1.65	
		(1914)		3.6 cm dia						Radial	357	1.66	
				x 18.2 cm						Absolute	383	1.68	
				length							386	1.59	
											395	1.59	
											402	1.57	
											473	1.72	
											476	1.64	
											520	1.71	
											591	1.65	
											608	1.68*	
											663	1.66	
											668	1.65*	
											678	1.65*	
											695	1.64	
											733	1.64	
											820	1.65	
											873	1.65	
3	7	Stephens, D. R.	N. T. S.	Cylinder	2.68		Plagioclase		66	Steady	576	1.75	Source: Shot No. 12 Hole DB-C and
		(1963)	Basalt;	(L/D = 5)			Iron Minerals		26	Radial	595	1.60	Shot No. 13, DB-4 of Project
			Sample 1	45.7 cm			Olivine		8	Absolute	658	1.78	Buckboard.
				length							706	1.82	Texture: fine grained.
											751	1.64	Other: slat gray color; reported
											822	1.84	error ±5%.
											894	1.57	
											964	1.90	
											1043	1.82	
4	7	Stephens, D. R.	N. T. S.	Cylinder	2.68		Plagioclase		66	Steady	442	1.35	Source: Same as above.
		(1963)	Basalt;	(L/D = 5)			Iron Minerals		26	Radial	484	1.44	Texture: same as above.
			Sample 2	45.7 cm			Olivine		8	Absolute	529	1.51	Other: same as above.
				length							585	1.66	
											623	1.70	
											712	1.58	
											763	1.61	
											856	1.63	

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
5	5	Marovelli, R. L. and Veith, K. F. (1964)	Dresser Basalt, Block A	12.7-15.2 cm per side	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Nonsteady Line Heat Source	298 328 361 374 394 423 453 479 508 531	2.21 2.12 2.09 2.09* 2.09* 2.18 2.16 2.25 2.15 2.15	Source: Dresser, Wis. Texture: mottled gray-green, fine-grained.
6	5	Marovelli, R. L. and Veith, K. F. (1964) 1	Block C	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	302 597 855 1074	2.34 2.10 1.85 1.55	Source: same as above. Texture: same as above.
7	5	Marovelli, R. L. and Veith, K. F. (1964)	Block D	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	298 571 771 1217	2.21 2.11 1.88 1.36	Source: same as above. Texture: same as above.
8	5	Marovelli, R. L. and Veith, K. F. (1964)	Block B	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	294 328 346 367 383 392	1.83 1.83 1.75 1.84 1.76 1.81	Source: same as above. Texture: same as above.
9	5	Marovelli, R. L. and Veith, K. F. (1964)	Block E	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	208 254 298	3.21 3.20 3.10	Source: same as above. Texture: same as above.
10	15	Murase, T. and McBirney, A. R. (1970)	Columbia River Basalt	Platinum container, 5 cm dia x 5.5 cm high						Steady Radial Absolute	572 1014 1179 1305 1400 1515 1768	1.50 1.38 1.21 1.17 0.967 1.17 2.25	Source: Columbia River, Oregon. Other: values were corrected to zero porosity; initial measurements were made for molten rock at around 1500 C; cooling cycle.
11	15	Murase, T. and McBirney, A. R. (1970)	Same as above	Same as above						Same as above	300 656 727 878 1077 1277 1383 1480 1578 1679	1.58 1.54 1.46 1.42 1.30 1.21 0.967 1.13 1.54 1.62	Source: same as above. Other: same as above except heating cycle.

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
12	15	Murase, T. and McBirney, A.R. (1970)	Synthetic Lunar Sample	Platinum container, 5 cm dia x 5.5 cm high		3	Composition of Apollo 11, Sample 22			Steady Radial Absolute	1102 1283 1478 1539 1575 1624 1679 1779	0.962 0.841 0.720 0.678 0.598 0.678 0.799 1.21	Conductivity values were corrected to zero porosity; initial measurements were for molten rock at 1500 C; cooling cycle.
13	15	Murase, T. and McBirney, A.R. (1970)	Synthetic Lunar Sample	Platinum container, 5 cm dia x 5.5 cm high		3	Composition of Apollo 11, Sample 22			Steady Radial Absolute	306 628 828 984 1196 1377 1473 1573 1700 1766	2.55 1.96 1.63* 1.25 0.967 0.757 0.841 0.469 0.958 0.925	Same as curve 12 except heating cycle.
14	10	Tadokoro, Y. (1921)			2.659		SiO_2 Al_2O_3 FeO CaO MgO Fe_2O_3 MnO	69.46 11.67 9.43 5.00 2.47 1.00 0.49		Indirect	298	1.44	Source: Pvo. Tanba (Asia). Texture: dark grey colored, no vesicular cavities; phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly. *Other: data is obtained from measurements of diffusivity, specific heat and density.*
15	97	Bernett, E.C., Wood, H.L., Jaffe, L.D., and Martens, H.E. (1962)	Olivine Basalt		1.36					Indirect	210 265 319 366	0.137 0.156 0.182 0.180	Source: Pisgah Crater, San Bernardino, Calif. Other: particle size: 0.30–0.42 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat, and density.
16	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.56					Indirect	210 265 319 366	0.164 0.186 0.201 0.194	Source: same as above. Other: particle size: 0.30–0.42 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat and density.
17*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.56					Indirect	320 365	0.005 0.007	Source: same as above. Other: particle size 0.30–0.42 mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
18*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.56					Indirect	216 266 319 362	0.004 0.004 0.004 0.005	Source: same as above. Other: particle size 0.30–0.42 mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.

* Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
19	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.49					Indirect	209 250 267 280 338 367	0.142* 0.254 0.165* 0.246 0.156 0.228	Source: same as above. Other: particle size < 0.42 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat and density.
20	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.65					Indirect	325 367	0.275 0.303	Source: same as above. Other: particle size < 0.42 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat and density.
21	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.95					Indirect	207 266	0.223 0.256	Source: same as above. Other: particle size < 0.42mm; reported error ±15%; data measured at 5×10^{-6} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
22*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.49					Indirect	265 320 362	0.0017 0.0024 0.0029	Source: same as above. Other: particle size < 0.42 mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
23*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.65					Indirect	319 321 360 367	0.0041 0.0044 0.0044 0.0036	Source: same as above. Other: particle size < 0.42mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
24*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.57					Indirect	217 266	0.0015 0.0018	Source: same as above. Other: particle size < 0.42 mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
25*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.75					Indirect	242	0.0017	Source: same as above. Other: particle size < 0.42 mm; reported error ±15%; data measured at 5×10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
26	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.14					Indirect	210 266 320 367	0.100 0.117 0.118 0.143	Source: same as above. Other: particle size < 0.105 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat and density.

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
27*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.57					Indirect	209 266 319 365	0.161 0.183 0.195 0.235	Source: same as above. Other: particle size < 0.105 mm; reported error ±15%; data obtained from measurements of diffusivity, specific heat and density.
28*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.14					Indirect	319 363	0.0015 0.0016	Source: same as above. Other: particle size < 0.105 mm; reported error ±15%; data measured at 5 x 10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
29*	97	Bernett, E.C., et al. (1962)	Olivine Basalt		1.57					Indirect	213 264 318 362	0.0027 0.0026 0.0031 0.0031	Source: same as above. Other: particle size < 0.105 mm; reported error ±15%; data measured at 5 x 10^{-6} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
30	86	Navarro, R.A. and DeWitt, D.P. (1974)	Dresser Basalt							Nonsteady Line Heat Source	300 300	2.72 2.54	Source: Dresser, Wisconsin. Other: mercury and silicon grease used respectively as contact agents; reported error ±2% and ±5% respectively.
31*	17, 52	Wechsler, A.E and Glaser, P.E. (1964)	Basalt Powder							Nonsteady Line Heat Source	289	0.0018	Test Environment: evacuated air, 6.6 x 10^{-13} atmosphere. Other: particle size: 0.020 mm.
32*	17, 52	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above		1.27					Same as above	283	0.0020	Test Environment: evacuated air, 1.1 x 10^{-7} atmos. Other: particle size: 0.044–0.104 mm.
33*	17, 52	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above		1.27					Same as above	331	0.0027	Test Environment: evacuated air, 5.3 x 10^{-7} atmos. Other: same as above.
34*	17	Wechsler, A.E. and Glaser, P.E.	Same as above							Same as above	294 295	0.192 0.165	Test Environment: air, pressure 1.01 atmos. Other: particle size: 0.104–0.150 mm.
35*	17	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above							Same as above	302 303	0.0016 0.0015	Test Environment: evacuated air, 7.9 x 10^{-9} atmos. Other: same as above.
36*	17	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above							Same as above	284 341	0.0015 0.0020	Test Environment: evacuated air, 9.2 x 10^{-13} atmos. Other: same as above.
37*	17	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above							Same as above	281 282 329 331 334	0.0016 0.0015 0.0029 0.0021 0.0023	Test Environment: evacuated air, 6.6 x 10^{-13} atmos. Other: same as above.

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

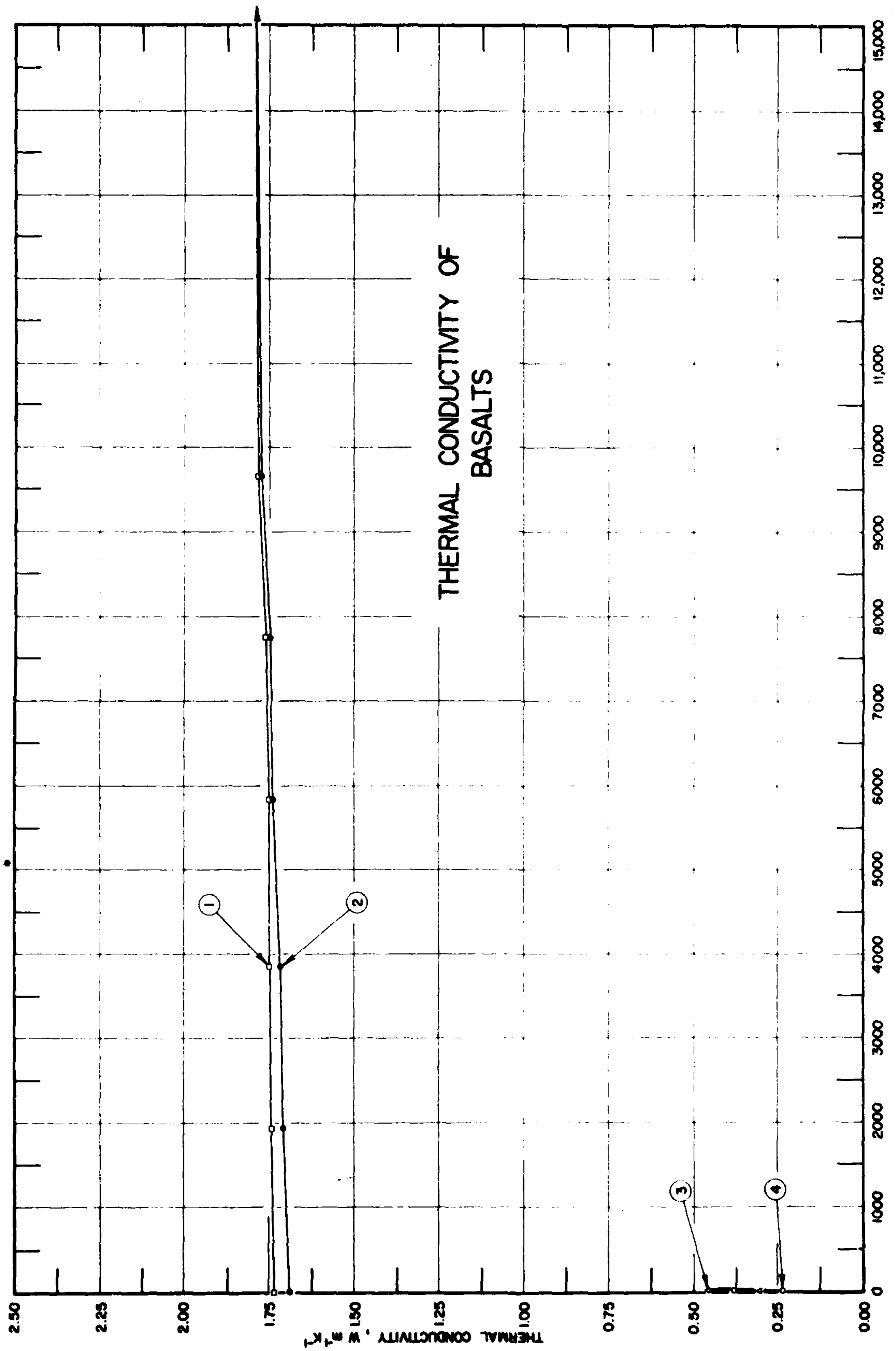
Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
38*	17	Wechsler, A.E. and Glaser, P.E. (1964)	Same as above							Same as above	280 300	0.0012 0.0015	Test Environment: evacuated air, 2.6×10^{-13} atmos. Other: same as above.
39*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.43					Same as above	184 189 229 231 295	0.00075 0.00084 0.00086 0.00092 0.00112	Test Environment: evacuated air, 7.9×10^{-11} atmos. Other: particle size: 0.044-0.074 mm; reported error ±8%.
40*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.43					Same as above	296 326	0.00122 0.00165	Test Environment: evacuated air, 2.0×10^{-9} atmos. Other: same as above.
41*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.43					Same as above	298 299	0.00126 0.00126	Test Environment: evacuated air, 2.6×10^{-9} atmos. Other: same as above.
42*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.43					Same as above	351	0.00144	Test Environment: evacuated air, 1.3×10^{-9} atmos. Other: same as above.
43*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.43					Same as above	231	0.00092	Test Environment: evacuated air, 9.2×10^{-11} atmos. Other: same as above.
44*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	175 177	0.00122 0.00128	Test Enviroment: evacuated air, 2.0×10^{-11} atmos. Other: particle size: 0.010-0.037 mm.
45*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	173	0.00117	Test Environment: evacuated air, 2.2×10^{-11} atmos. Other: same as above.
46*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	296	0.00172	Test Environment: evacuated air, 2.4×10^{-11} atmos. Other: same as above.
47*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	227 229	0.00142 0.00146	Test Environment: evacuated air, 2.6×10^{-11} atmos. Other: same as above.
48*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	296	0.00181	Test Environment: evacuated air, 3.9×10^{-11} atmos. Other: same as above.
49*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	297	0.00186	Test Environment: evacuated air, 7.9×10^{-11} atmos. Other: same as above.
50*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	300	0.00179	Test Environment: evacuated air, 1.3×10^{-9} atmos. Other: same as above.
51*	50	Wechsler, A.E. and Simon, I. (1966)	Same as above		1.36					Same as above	356 356	0.00197 0.00208	Test Environment: evacuated air, 3.9×10^{-9} atmos. Other: same as above.

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
52*	102	Johnson, S. A. (1974)	Tholeiitic Basalt		2.84	2				Steady Longitudinal Comparative	293	1.57	Source: N. E. of Madras, Oregon. Texture: asphanitic. Other: dry sample.
53*	102	Johnson, S. A. (1974)	Same as above		2.84	2				Same as above	293	1.54	Source: same as above. Texture: same as above. Other: sample saturated with water.
54*	73	Sass, J. H. (1964)	Golden Mile Basalt (Amphibolitic)	Disk 3.5 cm dia, 6 mm thick						Steady Longitudinal Comparative	301	4.1	Source: Kalgoorlie, Australia. Other: reported error ± 3.5%; average of 11 specimens tested.
55*	73	Sass, H. J. (1964)		Same as above			Plagioclase, Hornblende Pyroxene, Epidote, Chlorite, Fe-oxide		major minor	Steady Longitudinal Comparative	301	2.8	Source: Bore hole No. C-79 at Norseman, Australia. Other: reported error ± 1.6%; average of 7 specimens tested.
56*	73	Sass, J. H. (1964)	Golden Mile Basalt (Chloritic)	Same as above						Steady Longitudinal Comparative	301	4.4	Source: Kalgoorlie, Australia. Other: reported error ± 1.8%; average of 28 specimens tested.
57*	91	Glaser, P. E., Wechsler, A. E., and Germeles, A. E. (1965)	Basalt Lava		2.08					Steady Longitudinal Absolute	223	0.222	Other: measured at 1.32 x 10^{-6} atm pressure.
58*	91	Glaser, P. E., et al. (1965)	Olivine Basalt		1.5					Non-Steady Line Heat Source	223	0.0017	Other: powdered specimen, particle size 10-200 μ; measured at 1.32 x 10^{-6} atm pressure.
59*	75	Horai, K. I. and Baldridge, S. (1972)	Knippa Olivine Basalt	Disk 4.75 cm dia, 6.8 to 9.3 mm thick	3.156					Steady Longitudinal Comparative	296	2.29	Source: Uvalde, Texas. Other: reported error ± 5%.
60*	75	Horai, K. I. and Baldridge, S. (1972)	Same as above		3.158	0.1				Non-Steady Line Heat Source	296	2.30	Source: same as above. Texture: pulverized specimen with maximum grain size < 0.1 mm. Other: specimen water saturated; reported error ± 5%.

* Not shown in figure.



THERMAL CONDUCTIVITY OF BASALTS
THERMAL CONDUCTIVITY, W m⁻¹K⁻¹
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
PRESSURE, ATM
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
15,000
1
2
3
4

FIGURE 1-K-P

TABLE 1-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm.	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	24	Bridgman, P.W. (1924)	Diabasic Basalt	Cylinder, 1.27 cm O.D., 1.02 cm I.D., 2.5 cm long	2.924		Olivine		10	Steady Radial Absolute	0	1.73	Temperature of measurements: 348.15 K. Other: sample was subjected to hydrostatic pressure in a kerosene environment.
											1935	1.74	
											3871	1.75	
											5807	1.75	
											7742	1.76	
											9678	1.77	
											11614	1.78	
2	24	Bridgman, P.W. (1924)		Same as above	2.924		Olivine		10	Same as above	0	1.69	Temperature of measurements: 303.15 K. Other: sample was subjected to hydrostatic pressure in a petroleum-ether environment.
											1935	1.71	
											3871	1.72	
											5807	1.74	
											7742	1.75	
											9678	1.77	
											11614	1.79	
3	17	Wechsler, A.E. and Glaser, P.E. (1964)	Basalt Lava							Steady Longitudinal Absolute	0.000013	0.306	Temperature of measurements: 265 K. Other: sample was subjected to hydrostatic pressure in an air environment.
											0.00109	0.403	
											1.01	0.464	
4	24	Wechsler, A.E. and Glaser, P.E. (1964)	Basalt Lava							Same as above	0.0000001	0.227	Temperature of measurements: 220 K. Other: sample was subjected to hydrostatic pressure in an air environment.
											0.000006	0.220	
											0.00111	0.374	
											1.01	0.464	

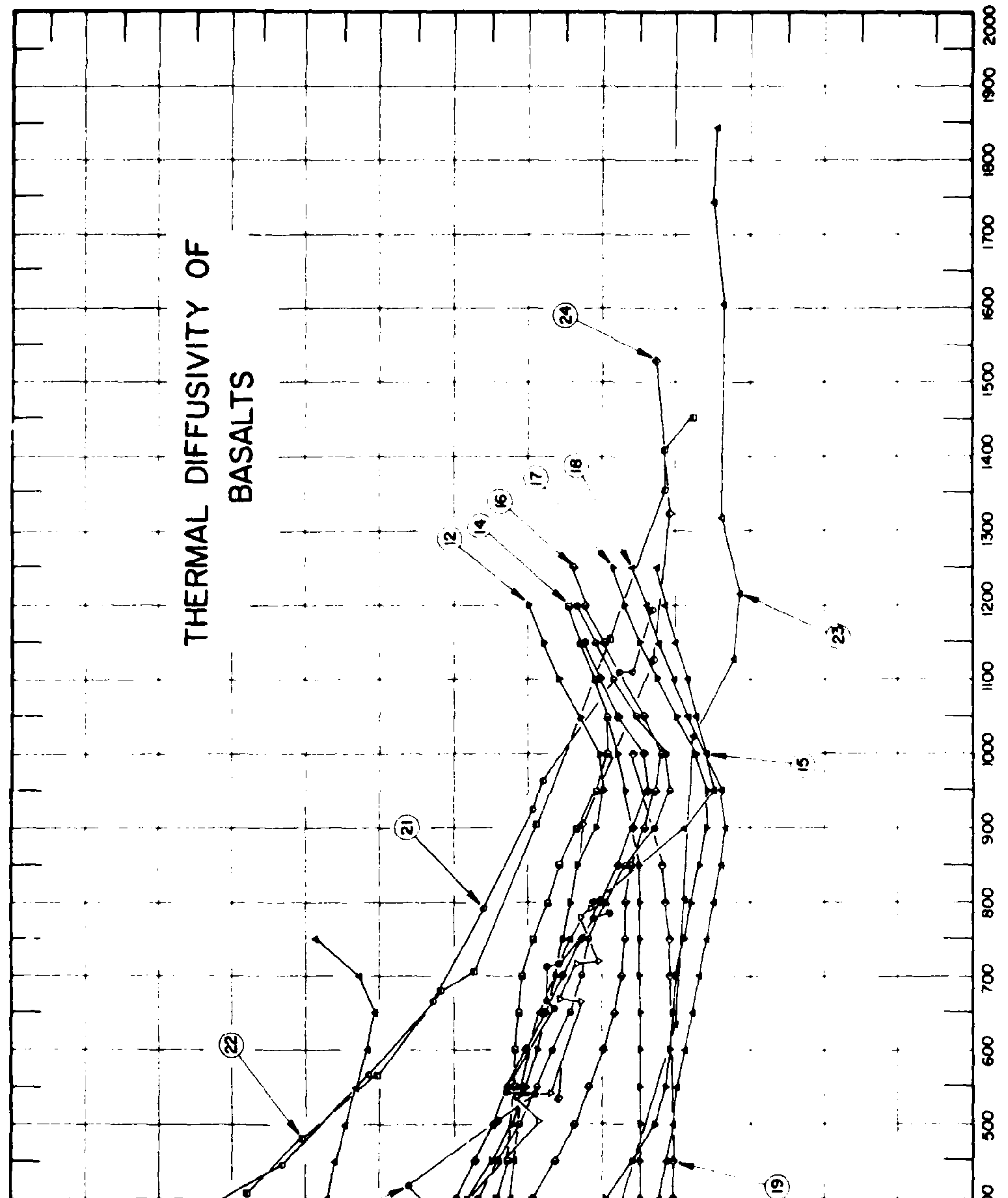

THERMAL DIFFUSIVITY OF BASALTS
TEMPERATURE, K
THERMAL DIFFUSIVITY, cm² sec⁻¹
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
0.000 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009 0.010 0.011 0.012 0.013

FIGURE 1-D-T

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm² s⁻¹)	Remarks
1	70	Dmitriev, A. P., Dukhovskoi, E. A., Novik, G. Ya., and Petrochenkov, R. G. (1971)		1 cm dia, 2 cm high	1.22					Periodic Heat Flow	293	0.0064	Test Environment: air atmosphere. Other: finely divided powder.
2	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.22					Periodic Heat Flow	293	0.0098	Test Environment: helium atmosphere. Other: same as above.
3	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.22					Periodic Heat Flow	293	0.00072	Other: measurements in 10^{-6} torr pressure.
4	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14					Periodic Heat Flow	293	0.00051	Other: same as above.
5	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14					Periodic Heat Flow	293	0.00445	Test Environment: air atmosphere.
6	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14					Periodic Heat Flow	293	0.0063	Test Environment: helium atmosphere.
7	30	Kanamori, H., Mizutani, H., and Fujii, N. (1969)		Cylinder 2.7 cm long, 1 cm dia						Angstrom	371 505 538 542 665 668 716 718 779 792	0.00705 0.00586 0.00616 0.00571 0.00530 0.00558 0.00537 0.00506 0.00531 0.00518	
8	30	Kanamori, H., et al. (1969)		Same as above						Angstrom	356 417 505 540 543 655 666 713 716 778 786	0.00700 0.00765 0.00643 0.00593 0.00634 0.00568 0.00577 0.00577 0.00560 0.00513 0.00490	
9	10	Tadokoro, Y. (1921)		Cube 60 mm by side	2.659		SiO_2 Al_2O_3 FeO CaO MgO Fe_2O_3 MnO	69.48 11.67 9.43 5.00 2.47 1.00 0.49		Periodic	298	0.00677	Source: Prov. Tanba. Texture: dark grey colored, no vesicular cavities, phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2\ s^{-1}$)	Remarks
10	49	Petrunin, G.I.,		Disk ~25	2.74	5.19	SiO_2	56.12		Periodic	350	0.00890	Source: Chinadiyeva (trans-
		Yurchak, R.I.,		mm dia,			Al_2O_3	16.47		Heat Flow	400	0.00875	Carpathian region).
		and Tkach, G.F.		~8 mm			CaO	8.55			450	0.00865	Texture: impregnations consisted
		(1970)		thick			FeO	5.56			500	0.00850	of plagioclase grains 13%,
							MgO	4.98			550	0.00835	pyroxene 2%.
							Fe_2O_3	2.65			600	0.00820	Rock Structure: porphyric.
							Na_2O	2.36			650	0.00810	Matrix: dolerite.
							K_2O	1.63			700	0.00830	
							H_2O	1.22			750	0.00890	
							TiO_2	0.39					
							MnO	0.10					
							P_2O_5	0.10					
							Plagioclase		69				
							Pyroxene		29				
11	49	Petrunin, G.I.,		Same as	2.67	8.87	SiO_2	51.68		Periodic	350	0.00725	Source: Akhuryan River (South
		et al.		above			Al_2O_3	17.35		Heat Flow	400	0.00700	Eastern Armenia).
		(1970)					CaO	8.30			450	0.00675	Texture: impregnations consisted
							FeO	5.96			500	0.00650	of plagioclase 4%, olivine 1%.
							MgO	5.53			550	0.00630	Rock Structure: porphyric.
							Na_2O	4.23			600	0.00605	Matrix: dolerite.
							Fe_2O_3	3.50			650	0.00580	
							K_2O	1.29			700	0.00555	
							TiO_2	1.23			750	0.00530	
							P_2O_5	0.51			800	0.00505	
							H_2O	0.32			850	0.00480	
							MnO	0.13			900	0.00460	
							Plagioclase		63		950	0.00440	
							Olivine		18		1000	0.00445	
							Monopyroxene		12		1050	0.00480	
											1100	0.00505	
							Secondary Minerals:				1150	0.00525	
							Apatite		1				
							Magnetite		1				
12	49	Petrunin, G.I.,		Same as	2.72	7.48	Plagioclase		55	Periodic	350	0.00715	Source: Sikhote-Alin'.
		et al.		above			Monopyroxene		40	Heat Flow	400	0.00685	Rock Structure: aphyric of uni-
		(1970)									450	0.00650	form texture.
											500	0.00625	Matrix: microlite.
											550	0.00605	
											600	0.00590	
											650	0.00575*	
											700	0.00565	
											750	0.00555	
											800	0.00545	
											850	0.00535	
											900	0.00510	
											950	0.00500	
											1000	0.00505	
											1050	0.00530	
											1100	0.00560	
											1150	0.00580	
											1200	0.00600	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
13	49	Petrunin, G.I.,		Same as	6.21	7.77	SiO_2	48.53		Periodic	350	0.00700	Source: Arzni (Armenia).
		et al.		above			Al_2O_3	18.00		Heat Flow	400	0.00670	Rock Structure: aphyric.
		(1970)					CaO	8.20			450	0.00645	Matrix: microdolerite.
							Fe_2O_3	6.85			500	0.00615	
							MgO	4.52			550	0.00590	
							Na_2O	4.50			600	0.00570	
							FeO	3.20			650	0.00545	
							TiO_2	0.80			700	0.00530	
							MnO	0.12			750	0.00520	
							Plagioclase		65		800	0.00500	
							Olivine		23		850	0.00470	
							Clinopyroxene		6		900	0.00430	
							Magnetite		4		950	0.00410	
							Glass		2		1000	0.00415	
											1050	0.00455	
											1100	0.00485	
											1150	0.00510	
											1200	0.00535	
14	49	Petrunin, G.I.,		Same as	2.50	15.25	SiO_2	58.85		Periodic	350	0.00665	Source: Akhuryan River (North-
		et al.		above			Al_2O_3	17.31		Heat Flow	400	0.00645	Western Armenia).
		(1970)					CaO	8.80			450	0.00630	Rock Structure: aphyric, some-
							Fe_2O_3	6.69			500	0.00625*	what spongy.
							MgO	5.40			550	0.00620	Matrix: dolerite.
							Na_2O	4.07			600	0.00620	
							FeO	2.96			650	0.00615	
							K_2O	1.25			700	0.00610	
							TiO_2	0.87			750	0.00595	
							H_2O	0.72			800	0.00575	
							P_2O_5	0.30			850	0.00560	
							MnO	0.15			900	0.00535	
							Plagioclase		60		950	0.00510	
							Olivine		18		1000	0.00495	
							Clinopyroxene		15		1050	0.00495	
							Glass		5		1100	0.00510	
							Magnetite		2		1150	0.00530	
											1200	0.00545	
15	49	Petrunin, G.I.,		Same as	2.44	14.38	SiO_2	51.08		Periodic	350	0.00630	Source: Yefremovka (South Georgia).
		et al.		above			Al_2O_3	16.75		Heat Flow	400	0.00625	Texture: impregnations of olivine
		(1970)					CaO	8.84			450	0.00620	grains (4%), size 0.6 mm, and
							MgO	6.34			500	0.00615*	plagioclase grains (1%), size
							FeO	6.00			550	0.00610	0.5 mm.
							Fe_2O_3	3.80			600	0.00600*	Rock Structure: aphyric.
							Na_2O	3.48			650	0.00585	Matrix: dolerite.
							TiO_2	1.38			700	0.00565*	
							K_2O	1.26			750	0.00545	
							MnO	0.14			800	0.00515	
							Plagioclase		63		850	0.00475*	
							Olivine		15		900	0.00390	
							Clinopyroxene		13		950	0.00350	
							Magnetite		3		1000	0.00360	
							Apatite		1		1050	0.00375	
											1100	0.00385	
											1150	0.00400	
											1200	0.00415	
											1250	0.00425	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm^2 s^{-1})	Remarks
16	49	Petrunin, G.I.,		Same as	2.60	8.12	SiO_2	52.52		Periodic	350	0.00625	Source: Baranchik (South-Eastern
		et al.		above			Al_2O_3	18.29		Heat Flow	400	0.00595	Armenia).
		(1970)					CaO	8.01			450	0.00565	Rock Structure: porphyric.
							Fe_2O_3	6.12			500	0.00540	Matrix: pylotoxite.
							MgO	4.92			550	0.00520	
							Na_2O	4.31			600	0.00500	
							FeO	2.69			650	0.00485	
							K_2O	1.44			700	0.00475	
							TiO_2	0.85			750	0.00470	
							H_2O	0.50			800	0.00470	
							P_2O_5	0.37			850	0.00465	
							MnO	0.11			900	0.00445	
							Plagioclase		50		950	0.00430	
							Rhambopyroxene		9		1000	0.00420	
							Apatite		1		1050	0.00445	
							Magnetite		1		1100	0.00475*	
							Plagioclase		1		1150	0.00500	
							Biotite		1		1200	0.00525	
							Hornblende		1		1250	0.00540	
17	49	Petrunin, G.I.,		Same as	2.51	11.70	SiO_2	52.68		Periodic	350	0.00540	Source: Akhuryan River (North-
		et al.		above			Al_2O_3	17.07		Heat Flow	400	0.00495	Western Armenia).
		(1970)					CaO	7.57			450	0.00460	Rock Structure: porphyric.
							Fe_2O_3	6.86			500	0.00430	Matrix: pylotoxite.
							Na_2O	4.83			550	0.00415	
							MgO	4.43			600	0.00410	
							K_2O	3.31			650	0.00405	
							FeO	1.17			700	0.00400	
							P_2O_5	0.86			750	0.00390	
							TiO_2	0.80			800	0.00380	
							H_2O	0.21			850	0.00370	
							MnO	0.13			900	0.00360	
							Plagioclase		62		950	0.00360	
							Olivine		16		1000	0.00375	
							Pyroxene		16		1050	0.00400	
							Magnetite		6		1100	0.00425	
											1150	0.00450	
											1200	0.00470	
											1250	0.00485	
18	49	Petrunin, G.I.,		Same as	2.59	10.99	SiO_2	51.08		Periodic	350	0.00430	Source: Gorlovka (Southern Georgia).
		et al.		above			Al_2O_3	16.75		Heat Flow	400	0.00425	Rock Structure: aphyric.
		(1970)					CaO	8.84			450	0.00415	Matrix: dolerite.
							MgO	6.34			500	0.00405	
							FeO	6.00			550	0.00400	
							Fe_2O_3	3.80			600	0.00390	
							Na_2O	3.48			650	0.00380	
							TiO_2	1.38			700	0.00370	
							K_2O	1.26			750	0.00360	
							MnO	0.14			800	0.00350	
							Plagioclase		60		850	0.00340	
							Pyroxene		30		900	0.00335	
							Olivine		5		950	0.00340	
							Mangetite		5		1000	0.00360*	
											1050	0.00385	
											1100	0.00405	
											1150	0.00425	
											1200	0.00440	
											1250	0.00460	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
19	49	Petrunin, G.I.,		Same as	2.67	8.87	SiO_2	51.68		Periodic	350	0.00405	Source: Akhuryan River (South-
		et al.		above			Al_2O_3	17.35		Heat Flow	400	0.00405	Eastern Armenia).
		(1970)					CaO	8.30			450	0.00405	Texture: impregnations consisted
							FeO	5.96			500	0.00405*	of plagioclase 1%, olivine 4%.
							MgO	5.53			550	0.00405*	Rock Structure: porphyric.
							Na_2O	4.23			600	0.00405*	Matrix: doleric.
							Fe_2O_3	3.50			650	0.00405*	
							K_2O	1.29			700	0.00410	
							TiO_2	1.23			750	0.00410	
							P_2O_5	0.51			800	0.00415	
							H_2O	0.32			850	0.00420	
							MnO	0.13			900	0.00430*	
											950	0.00445*	
							Plagioclase		63		1000	0.00460	
							Olivine		18		1050	0.00480*	
							Monoclinic				1100	0.00505*	
							Pyroxene		12		1150	0.00525*	
							Secondary Minerals:						
							Apatite		1				
							Magnetite		1				
20	49	Petrunin, G.I.,		Same as	2.50	15.25	SiO_2	58.85		Periodic	450	0.00450	Source: Akhuryan River (North-
		et al.		above			Al_2O_3	17.31		Heat Flow	500	0.00450	Western Armenia).
		(1970)					CaO	8.80			550	0.00450	Rock Structure: aphyric, some-
							Fe_2O_3	6.69			600	0.00450	what spongy.
							MgO	5.04			650	0.00450	Matrix: dolerite.
							Na_2O	4.07			700	0.00450	Other: this specimen was preheated
							FeO	2.96			750	0.00450	to 1200 K.
							K_2O	1.25			800	0.00450	
							TiO_2	0.87			850	0.00450	
							H_2O	0.72			900	0.00455	
							P_2O_5	0.30			950	0.00470	
							MnO	0.15			1000	0.00480	
							Plagioclase		60		1050	0.00495*	
							Olivine		18		1100	0.00510*	
							Clinopyroxene		15		1150	0.00530*	
							Glass		5		1200	0.00550*	
							Magnetite		2				
21	67	Bates, J.L.,		Disk 1 cm						Flash	299	0.120	Source: Dresser, Wisconsin.
		McNeilly, C.E.		dia, 0.076						Method	445	0.00933	
		and		cm long							566	0.00818	
		Rasmussen, J.J.									664	0.00729	
		(1970)									791	0.00661	
											923	0.00596	
											962	0.00581	
											1110	0.00478	
											1090	0.00460	
											1194	0.00432	
22	67	Bates, J.L., et al.		Same as						Flash	407	0.00982	Source: Dresser, Wisconsin.
		(1970)		above						Method	481	0.00908	
											567	0.00804	
											679	0.00721	
											705	0.00674	
											906	0.00589	
											1157	0.00490	
											1356	0.00414	
											1409	0.00415	
											1452	0.00378	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
23	67	Bates, J. L., et al. (1970)		Same as above						Flash Method	293	0.00554	Source: Dresser, Wisconsin.
											394	0.00477	
											634	0.00400	
											803	0.00389	
											1025	0.00377	
											1127	0.00321	
											1214	0.00313	
											1313	0.00340	
											1608	0.00335	
											1742	0.00349	
											1846	0.00343	
24	67	Bates, J. L., et al. (1970)		Same as above						Flash Method	534	0.00562	Source: Dresser, Wisconsin.
											904	0.00531	
											1127	0.00431	
											1323	0.00409	
											1531	0.00427	
25	42	Lindroth, D. P. (1974)	Tholeiitic	Disk 19.05 mm dia, 4 mm thick			SiO_2	51.0		Flash Method	298	0.00666	Test Environment: nitrogen at 760 torr pressure. Other: reported error ± 5%.
							Al_2O_3	14.0			383	0.00622	
							FeO	8.8					
							CaO	8.0					
							MgO	4.4					
							Fe_2O_3	3.4					
							Na_2O	3.4					
							TiO_2	2.7					
							K_2O	1.7					
							P_2O_5	1.4					
							H_2O^+	0.76					
							MnO	0.25					
							H_2O^-	0.10					
							CO_2	0.03					
							S	0.004					
26	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above			Flash Method	298	0.00654	Test Environment: nitrogen at 1.0×10^{-2} torr pressure. Other: same as above.
											383	0.00616	
27*	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above			Flash Method	383	0.00623	Test Environment: nitrogen at 7.0×10^{-7} torr pressure. Other: same as above.
28*	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above			Flash Method	298	0.00665	Test Environment: nitrogen at 7.0×10^{-8} torr pressure. Other: same as above.

* Not shown in figure.

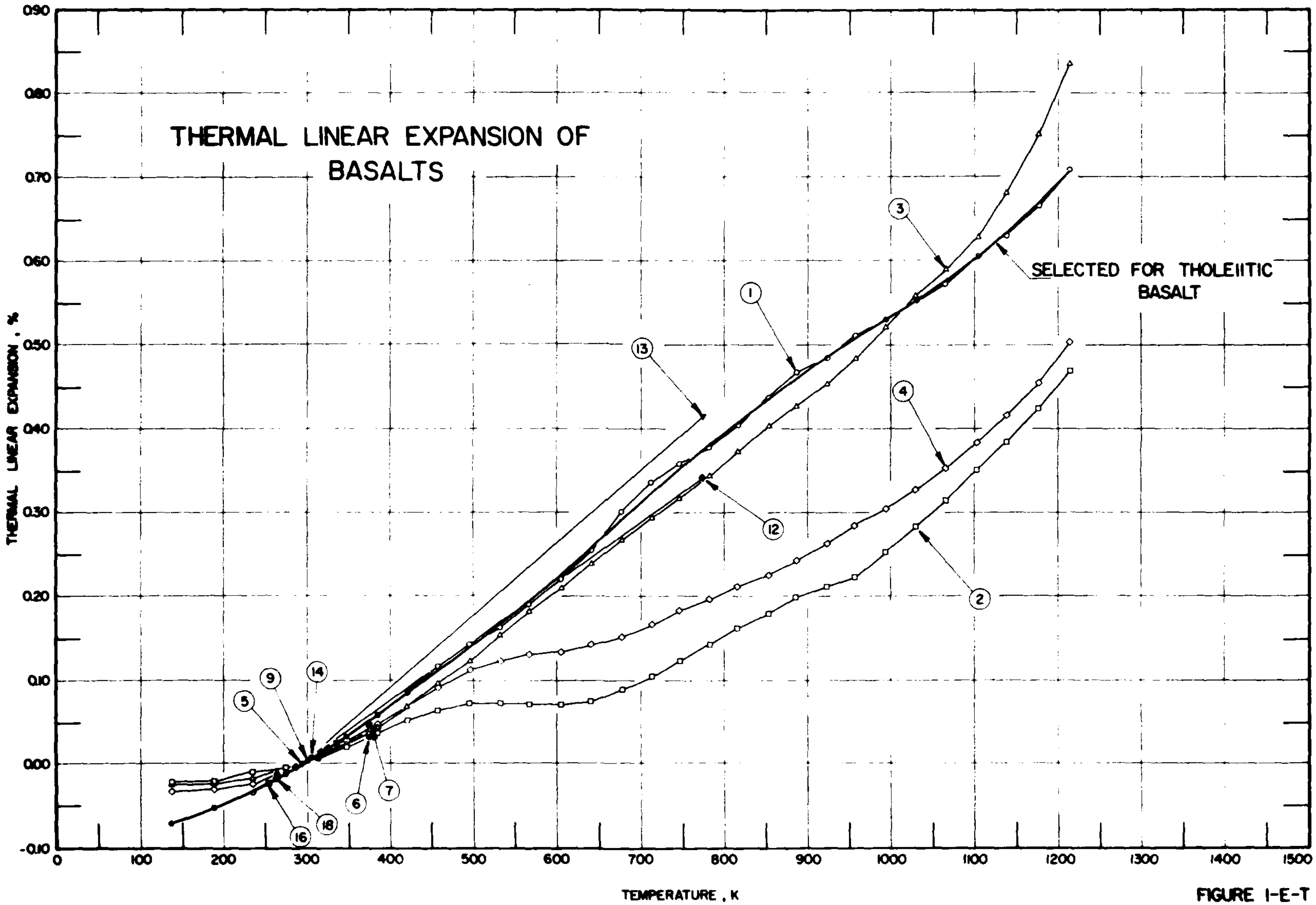

THERMAL LINEAR EXPANSION OF BASALTS
SELECTED FOR THOLEIITIC BASALT
THERMAL LINEAR EXPANSION, %
TEMPERATURE, K
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1
2
3
4
5
6
7
9
12
13
14
16
18

FIGURE I-E-T

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.	Tholeiitic		2.84	2	Plagioclase		39	Dilatometer	136	-0.071	Source: N.E. of Madras, Oregon.
		and Demou, S. G.	Basalt				Olivine		13.5		189	-0.053	Powder Density: 1.45 g cm^{-3}.
		(1972)					Plagioclase,				233	-0.035	Magnetic Susceptibility: 1400 x 10^{6}
							Microlites		12		273	-0.011	cgs units.
							Glass		12		311	0.009	Dielectric Constant: 3.02 (ratio).
							Augite		10.5		346	0.033	Specific Area: 0.8 m^2 g^{-1}.
							Magnetite and				383	0.059	Other: zero-point correction is
							Ilmenite		8		420	0.087	0.007%.
							Chlorite		4		458	0.117	
							SiO_2	51.0			495	0.143	
							Al_2O_3	14.0			531	0.163	
							FeO	8.8			568	0.191	
							CaO	8.0			604	0.221	
							MgO	4.4			640	0.257	
							Fe_2O_3	3.4			676	0.301	
							Na_2O	3.4			711	0.337	
							TiO_2	2.7			746	0.359	
							K_2O	1.7			781	0.379	
											817	0.405	
											852	0.437	
											887	0.469	
											922	0.495	
											958	0.511	
											994	0.531	
											1030	0.554	
											1066	0.573	
											1103	0.607	
											1139	0.631	
											1177	0.667	
											1214	0.709	
2*	41	Griffin, R. E.	Vesicular		2.25	20	Plagioclase		50	Dilatometer	136	-0.022	Source: S. of Bend, Oregon.
		and Demou, S. G.	Basalt No. 1				Pyroxene		20		189	-0.020	Powder Density: 1.37 g cm^{-3}.
		(1972)					Glass		15		233	-0.010	Magnetic Susceptibility: 340 x 10^{6}
							Plagioclase,				273	-0.005	cgs units.
							Microphenocrysts		10		311	0.008	Dielectric Constant: 2.63 (ratio).
							Olivine		<3		346	0.020	Specific Area: 0.8 m^2 g^{-1}.
							Magnetite		2		383	0.036	Other: zero-point correction is
							Hematite		<1		420	0.052	0.004%.
							SiO_2	54.4			458	0.064	
							Al_2O_3	16.8			493	0.072	
							CaO	7.67			531	0.072	
							FeO	5.39			568	0.072	
							MgO	4.94			604	0.072	
							Na_2O	2.43			640	0.076	
							TiO_2	1.13			676	0.090	
							K_2O	0.92			711	0.106	
											746	0.124	
											781	0.144	
											817	0.162	
											852	0.180	
											887	0.200	
											922	0.212	
											958	0.222	
											994	0.254	
											1030	0.284	
											1066	0.316	
											1103	0.352	
											1139	0.386	
											1177	0.426	
											1214	0.470	

*Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
3	41	Griffin, R. E.	Vesicular		2.22	24	Plagioclase	1	50	Dilatometer	136	-0.024	Source: S. of Bend, Oregon.
		and Demou, S. G.	Basalt				Olivine		25		189	-0.022	Powder Density: 1.52 g cm^{-3}.
		(1972)	Olivine No. 2				Pyroxene		15		233	-0.018	Magnetic Susceptibility: 350 x 10^6
							Magnetite		5		273	-0.008	cgs units
							Glass		5		311	0.008*	Dielectric Constant: 2.83 (ratio).
							Hematite		<1		346	0.024	Specific Area: 1.3 m^2 g^{-1}.
							SiO_2	47.6			383	0.044	Other: zero-point correction is
							Al_2O_3	17.0			420	0.070	0.004%.
							CaO	10.99			458	0.098	
							MgO	8.09			495	0.124	
							FeO	6.33			531	0.154	
							Fe_2O_3	3.56			568	0.182	
							Na_2O	2.29			604	0.210	
							TiO_2	1.42			640	0.240	
							K_2O	0.92			676	0.268	
											711	0.294	
											746	0.318	
											781	0.346	
											817	0.374	
											852	0.404	
											887	0.428	
											922	0.456	
											958	0.484	
											994	0.522	
											1030	0.560	
											1066	0.596	
											1103	0.630	
											1139	0.682	
											1177	0.752	
											1214	0.836	
4	41	Griffin, R. E.	Vesicular		1.52	46	Plagioclase			Dilatometer	136	-0.033	Source: Lava beds, National
		and Demou, S. G.	Basalt				(Labradorite)		45		189	-0.031	Monument, Calif.
		(1972)	Olivine No. 3				Olivine				233	-0.025	Powder Density: 1.31 g cm^{-3}.
							(Forsterite)		20		273	-0.011*	Magnetic Susceptibility: 260 x 10^6
							Plagioclase				311	0.009*	cgs units.
							(Bytownite,				346	0.027	Dielectric Constant: 2.45 (ratio).
							Microphenocrysts)		10		383	0.049	Specific Area: 0.7 m^2 g^{-1}.
							Glass		20		420	0.071*	Other: zero-point correction is
							Magnetite		5		458	0.093	0.003%.
							SiO_2	53.0			495	0.113	
							Al_2O_3	16.2			531	0.123	
							CaO	8.56			568	0.131	
							MgO	6.73			604	0.135	
							FeO	5.19			640	0.143	
							Fe_2O_3	3.26			676	0.153	
							Na_2O	3.01			711	0.167	
							K_2O	1.00			746	0.183	
							TiO_2	0.77			781	0.199	
											817	0.211	
											852	0.227	
											887	0.243	
											922	0.263	
											958	0.285	
											994	0.305	
											1030	0.329	
											1066	0.353	
											1103	0.383	
											1139	0.417	
											1177	0.457	
											1214	0.503	

* Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
5	32	Griffith, J.H. (1937)	Hornblende Basalt			0.44				Dilatometer	293 373	0.000 0.037	Source: Chaffee County, Colo.
6	32	Griffith, J H. (1937)	Olivine Basalt			0.22				Dilatometer	293 373	0.000* 0.032	Source: Jafferson County, Colo.
7	32	Griffith, J.H. (1937)	Olivine Basalt			22.06				Dilatometer	293 373	0.000* 0.048	Source: Mt. St. Helens, Wash.
8*	32	Griffith, J.H. (1937)	Porphyry Basalt			1.76				Dilatometer	293 373	0.000 0.037	Source: Lake County, Ore.
9	54	Mitchell, L.J. (1953)	Basalt Pebble from Gravel							Dilatometer	263 293 297	-0.0123 0.0000* 0.0015	Source: Hungryhorse Dam, Mont. Other: average of heating and cooling cycle.
10*	54	Mitchell, L.J. (1953)	Quarried "Table Mountain Basalt"							Dilatometer	263 293 297	-0.0120 0.0000 0.0016	Source: Golden, Colo. Other: average of heating and cooling cycle.
11*	54	Mitchell, L.J. (1953)	Basalt Pebble from Gravel							Dilatometer	263 293 297	-0.0102 0.0000 0.0014	Source: Republican River Gravel, Colo. Other: average of heating and cooling cycle.
12	56	Suleimenov, S.T., Abduvaliev, T., Sharafiev, M.Sh., and Tropina, L.G. (1966)	Tephrite Basalt				SiO_2 Al_2O_3 CaO Fe_2O_3 MgO SO_2 Ignition loss	45.42 15.68 11.14 9.15 6.67 0.33 6.52		Dilatometer	293 773	0.000* 0.342	Source: Daubabinsk, Chimkent. Texture: fine-grained glassy mass. Other: specimen melted between 1553-1623 K and 1% Cr_2O_3 added.
13	56	Suleimenov, S.T., et al. (1966)	Tephrite Basalt				SiO_2 Al_2O_3 CaO Fe_2O_3 MgO SO_2 Ignition loss	45.42 15.68 11.14 9.15 6.67 0.33 6.52		Dilatometer	293 773	0.000* 0.416	Source: Republican River Gravel, Colo. Texture: fine-grained glassy mass. Other: the above specimen with 2% waste chrome-magnesite brick.
14	58	Verbeck, G.J. and Hass, W.E. (1951)	Trap Rock							Dilatometer	298 302	0.0043* 0.0077	Source: Dresser, Wisconsin. Texture: average grain size 0.62 mm. Test environment: water. Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
15*	58	Verbeck, G.J. and Hass, W.E. (1951)	Trap Rock							Dilatometer	298 302	0.0039 0.0070	Source: Pennsylvania. Texture: average grain size 0.62 mm. Test environment: water. Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.

*Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
16	64	Hockman, A. and Kessler, D.W. (1950)	Basalt Porphyry				Plagioclase, High Fe Glass	major		Interferometer	253	-0.024	Source: Columbia National Forest, Washington.
											273	-0.012*	Texture: fine.
											293	0.000*	Other: moisture expansion due to immersion in water for 24 hr at 294.7 K is 0.0018%; heating cycle.
											333	0.024	
17*	64	Hockman, A. and Kessler, D.W. (1950)	Basalt Porphyry				Same as above			Interferometer	333	0.024	Source: same as above.
											293	0.000	Texture: same as above.
											273	-0.012	Other: same as above except cooling cycle.
18	64	Hockman, A. and Kessler, D.W. (1950)	Basalt Porphyry				Same as above			Interferometer	250	-0.021*	Source: same as above.
											262	-0.016	Texture: same as above.
											273	-0.010*	Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0018%.
											284	-0.004	
											293	0.000*	
											295	0.001*	
											305	0.006*	
											315	0.013	
											324	0.017	
											333	0.022*	
											338	0.026*	

* Not shown in figure.

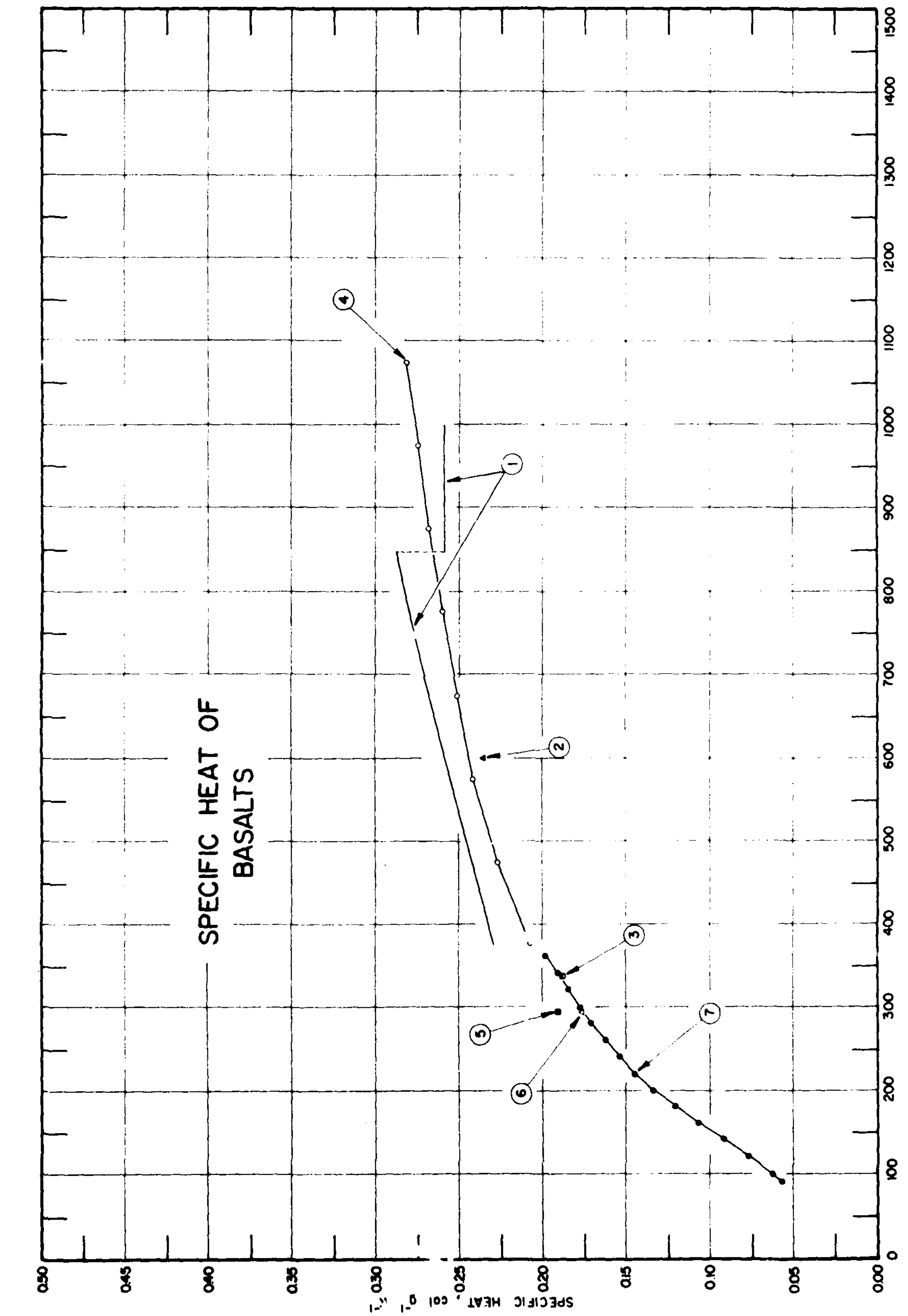

SPECIFIC HEAT OF BASALTS
TEMPERATURE, K
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
1
2
3
4
5
6
7

FIGURE 1-C-T

TABLE 1-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P. and Krawza, W.G. (1971)	Dresser Basalt		2.97		Plagioclase Pyroxene-Amphibole Magnetite SiO_2 Al_2O_3 CaO FeO Fe_2O_3 MgO	 48.42 15.23 8.35 6.70 6.60 6.14	50 45 5	Drop Copper Block	372 400 500 600 700 800 848 848 900 1000	0.230 0.233 0.246 0.258 0.270 0.283 0.288 0.258 0.258 0.258	Source: Dresser, Wisc. Texture: grain size 0.01-0.30 mm. Other: smooth values calculated from equation: $Cp = 0.216 + 0.123 \times 10^{-3} (T-273)$ for $373<T<848$ $Cp = 0.258$ for $848<T<1273$; transition near 848 K; reported error ±1.5%.
2	36	Svikis, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm	3.043		Epidote Quartz, Felspar Augite Chlorite Magnesite		42 23 20 10 5	Isothermal Water Calorimeter	600	0.236	Source: Canada. Texture: rock altered, irregularly banded and fine-grained. Other: average of two runs; mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of bath.
3	10	Tadokoro, Y. (1921)		Very thin plates 0.1-0.3 mm thick	2.569		SiO_2 Al_2O_3 FeO CaO MgO Fe_2O_3 MnO	69.48 11.67 9.43 5.00 2.47 1.00 0.49		Same as above	338	0.188	Source: Prov. Tanba (Asia). Texture: dark grey colored, no vesicular cavities; phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly. Other: average Cp by dropping specimen at 373 K in water at 303 K.
4	37	Leonidov, V.Ya. (1967)					SiO_2 Al_2O_3 FeO Fe_2O_3 TiO_2 MnO	52.05 15.16 5.16 4.48 0.82 0.10		Differential Thermal Analysis	374 472 573 673 775 873 973 1074	0.208 0.228 0.242 0.251 0.260 0.268 0.275 0.282	
5	70	Dmitriev, A.P., Dukhovskoi, E.A., Novik, G.Ya., and Petrochenkov, R.G. (1972)			1.22					Adiabatic Calorimeter	293	0.191	Texture: finely divided powder. Test environment: helium.
6	70	Dmitriev, A.P., et al. (1972)	Andesite-Basalt		1.14					Adiabatic Calorimeter	293	0.176	Texture: sand size particles. Test environment: helium.
7	71	Robie, R.A., Hemingway, B.S., and Wilson, W.H. (1970)	Vesicular Basalt		3.4					Adiabatic Calorimeter	90 100 120 140 160 180 200 220 240 260 280 300 320 340 360	0.0571 0.0633 0.0771 0.0922 0.1075 0.1217 0.1343 0.1451 0.1546 0.1632 0.1711 0.1786 0.1853 0.1917 0.1983	Source: Apollo 11 Lunar sample. Other: smooth values; reported error ± 0.4%.

C. SELECTED VALUES FOR DRESSER BASALT AND THOLEIITIC BASALT FROM MADRAS, OREGON

Thermal Conductivity. The data for different basalts follow similar trends. Conductivity seems to decrease with temperature for the region below the melting point. Selected values are for Dresser basalt based on the data of Navarro and DeWitt [86] and of Marovelli and Veith [5]. Room temperature measurement of Johnson [102] for Tholeiitic basalt showed the value practically unchanged when saturated with water. No selection was made for Tholeiitic basalt.

Thermal Diffusivity. The data for different basalts follow a similar trend. Results of Bates, McNeilly, and Rasmussen [67] for Dresser basalt show wide scatter for various runs for the same specimen. Results of Lindroth [42] for Tholeiitic basalt for small temperature range indicate that the values are independent of test pressure. No selection was made for either basalt.

Thermal Linear Expansion. Selected values are from Griffin and Demou [41] for Tholeiitic basalt. Their results indicate three very small anomalies of unknown origin. No measurement was reported for Dresser basalt.

Specific Heat. Heat content studies of Krawza and Lindroth [35] indicate a distinct phase transition near 848 K, near α-β quartz inversion point which is very surprising since the Dresser basalt which they studied did not contain free quartz, so no selection was made. No measurement was reported for the Tholeiitic basalt.

Selected Values for Dresser and Tholeiitic Basalts*

	Dresser Basalt	Tholeiitic Basalt
Temp. (K)	Thermal Conductivity (W m^{-1} K^{-1})	Thermal Linear Expansion $\Delta L/L_0$ (%)
150		-0.067
200		-0.048
293		0.000
300	2.38	0.003
400	2.31	0.071
500	2.19	0.142
600	2.09	0.219
700	1.98	0.309
800	1.88	0.393
900	1.76	0.467
1000	1.65	0.532
1100	1.53	0.598
1200	1.40	0.689

*No selections were made for other thermophysical properties.

2. DACITES

A. PETROGRAPHY

Together with rhyolites, dacites constitute the most abundant group of siliceous volcanic rocks. Both are rich in volcanic glass but dacite is less siliceous and more sodic. Commonly, pyroxene crystals occur in the glass. The following information on mineralogy and texture of dacite from W. of Bend, Oregon, is from Fogelson [98].

Mineral Composition

Essential Minerals	Vol. Percent
Labradorite (microlites)	40*
Glass	36
Labradorite (microphenocrysts)	15

Accessory Minerals	Vol. Percent
Pyroxene	5
Magnetite	3
Oxyhornblende	<1

Texture: The rock has a hypocrystalline, microporphyritic, hyalopilitic texture. Plagioclase microphenocrysts often tend to occur in clusters. They range in size from 0.2 to 2 mm in length. Pyroxenes are between 0.2 and 0.8 mm long and oxyhornblende measures 0.2 mm in the longer direction. Magnetite, occurring as cubes, is 0.2 mm on the edge.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity and thermal linear expansion are presented in the following pages.

* By strict definition this composition would place the rock in the basalt catagory but it was classified by the researcher as a dacite, probably based on field description.

TABLE 2-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DACITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	
1*	102	Johnson, S. A. (1974)			1.98	17				Steady Longitudinal Comparative	293	0.77	Source: W. of Bend, Oregon. Texture: glassy, with feldspar microphenocrysts. Other: dry sample.
2*	102	Johnson, S. A. (1974)			1.98	17				Same as above	293	1.06	Source: same as above. Texture: same as above. Other: sample saturated with water.

*No figure given.

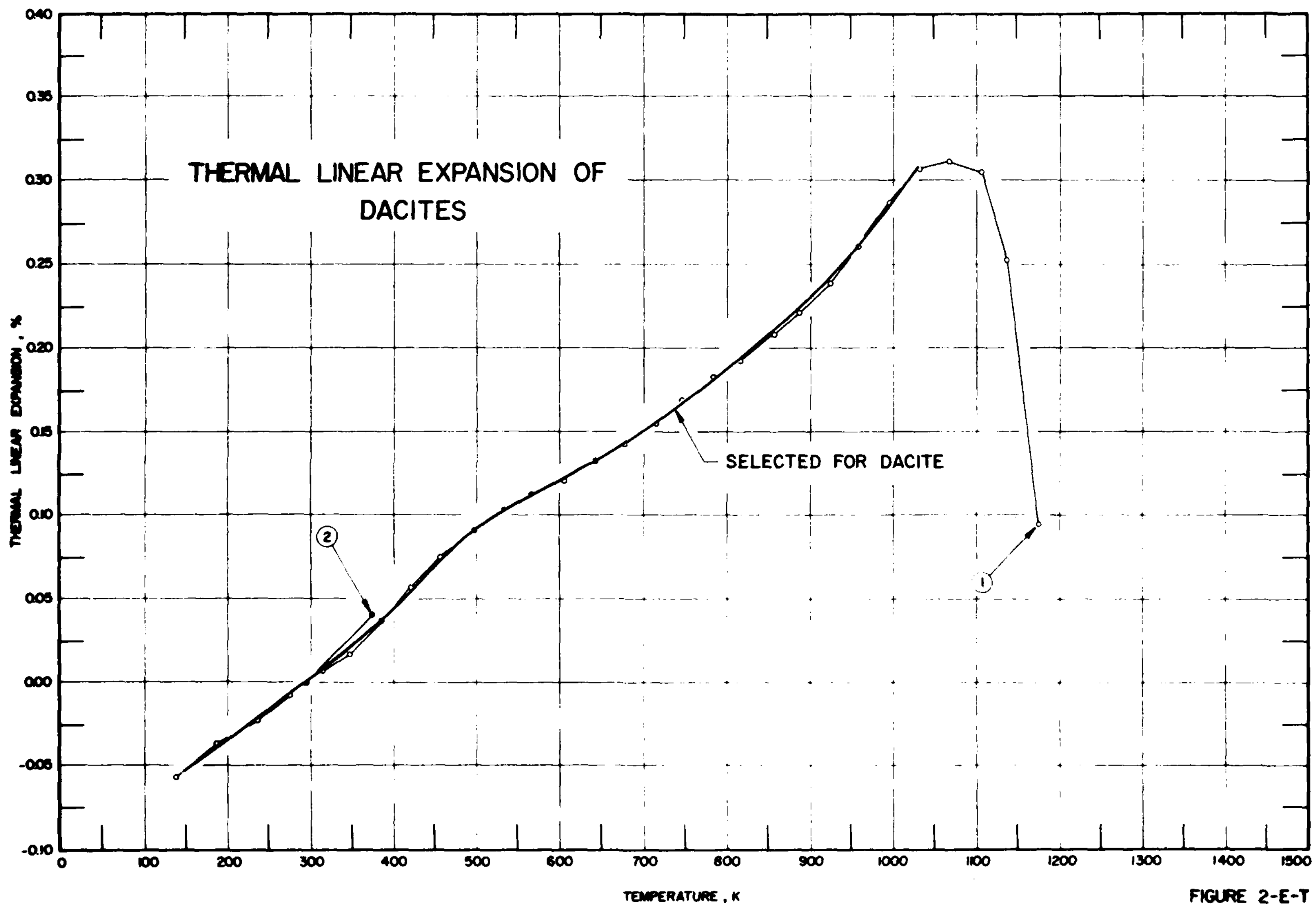

THERMAL LINEAR EXPANSION OF
DACITES
SELECTED FOR DACITE
1
2
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
THERMAL LINEAR EXPANSION, %
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
TEMPERATURE, K

FIGURE 2-E-T

TABLE 2-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF DACITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.			1.96,	17	Plagioclase,			Dilatometer	136	-0.057	Source: W. of Bend, Oregon.
		and Demou, S. G.			bulk		Labradorite		40		189	-0.037	Powder Density: 1.31 g cm^{-3}.
		(1972)					Glass		36		233	-0.023	Magnetic Susceptibility: 460 x 10^{6}
							Plagioclase,				273	-0.007	cgs units.
							Microphenocryst		15		311	0.007	Dielectric Constant: 2.63 ratio.
							Pyroxene		5		346	0.017	Specific Area: 0.5 m^2 g^{-1}.
							Magnetite		3		383	0.037	Other: zero-point correction is
							Oxyhornblende		<1		420	0.057	-0.003%.
							SiO_2	71.5			458	0.075	
							Al_2O_3	14.5			496	0.091	
							Na_2O	4.35			531	0.103	
							K_2O	2.81			568	0.113	
							CaO	2.05			604	0.121	
							FeO	1.92			640	0.133	
							Fe_2O_3	0.61			676	0.143	
							MgO	0.55			711	0.155	
							TiO_2	0.33			746	0.169	
											781	0.183	
											817	0.193	
											852	0.209	
											887	0.223	
											922	0.239	
											958	0.261	
											999	0.287	
											1030	0.307	
											1066	0.311	
											1103	0.305	
											1139	0.253	
											1177	0.095	
2	32	Griffith, J. H.			2.55	3.6				Dilatometer	293	0.000	Source: San Luis Obispo County,
		(1937)									373	0.040	Calif.

C. SELECTED VALUES FOR DACITE FROM BEND, OREGON

Thermal Conductivity. Results of Johnson [102] on dacite from W. of Bend, Oregon, at 293 K showed a marked increase in the value when saturated with water.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values for dacite from W. of Bend, Oregon, are from Griffin and Demou [41].

Specific Heat. No measurement was reported.

Selected Values for Dacite*
from W. of Bend, Oregon

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.052
200	-0.035
293	0.000
300	0.003
400	0.043
500	0.092
600	0.121
700	0.151
800	0.187
900	0.230
1000	0.287

*No selections were made for other thermophysical properties.

3. DUNITES (HARSBURGITES)

A. PETROGRAPHY

Dunite belongs to the ultramafic group of the plutonic igneous rocks, which are characterized by an abundance of mafic minerals (olivine, pyroxene) and small quantity of calcic plagioclase. Dunite is almost wholly composed of olivine. Harsburgite is composed of olivine and orthorhombic pyroxene. Spinel and serpentine are commonly present.

The chemical and mineralogical composition of dunite is given below.

Chemical Composition* (After Daly [99])

Oxide	Wt. Percent
SiO_2	40.49
TiO_2	0.02
Al_2O_3	0.86
Fe_2O_3	2.84
FeO	5.54
MnO	0.16
MgO	46.32
CaO	0.70
Na_2O	0.10
K_2O	0.04
H_2O	2.88
P_2O_5	0.05

Mineralogical Composition

Mineral	Vol. Percent
Mafics (olivine, pyroxene)	85-95
Ores (magnetite, ilmenite, chromite, etc.)	10-3
Calcic plagioclase	< 5

Dunite (Harsburgite)

The mineralogy and texture of this rock, given by Fogelson [98], is summarized below.

---

* Average of 10 analyses.

Mineral Composition

Essential Minerals	Vol. Percent
Olivine (forsterite)	60
Orthopyroxene (enstatite)	35

Accessory Minerals	Vol. Percent
Chromite	3
Serpentine	1
Magnetite	<<1

Texture. The rock is phaneritic, holocrystalline and has a mosaic texture. Grains are anhedral and equant to elongate. The rock is highly fractured but healed by serpentine. The rock is fine-grained and the average grain size varies from 6 mm to 0.2 mm in length and 0.2 mm to 0.022 mm in diameter.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, and specific heat are presented in the following pages.

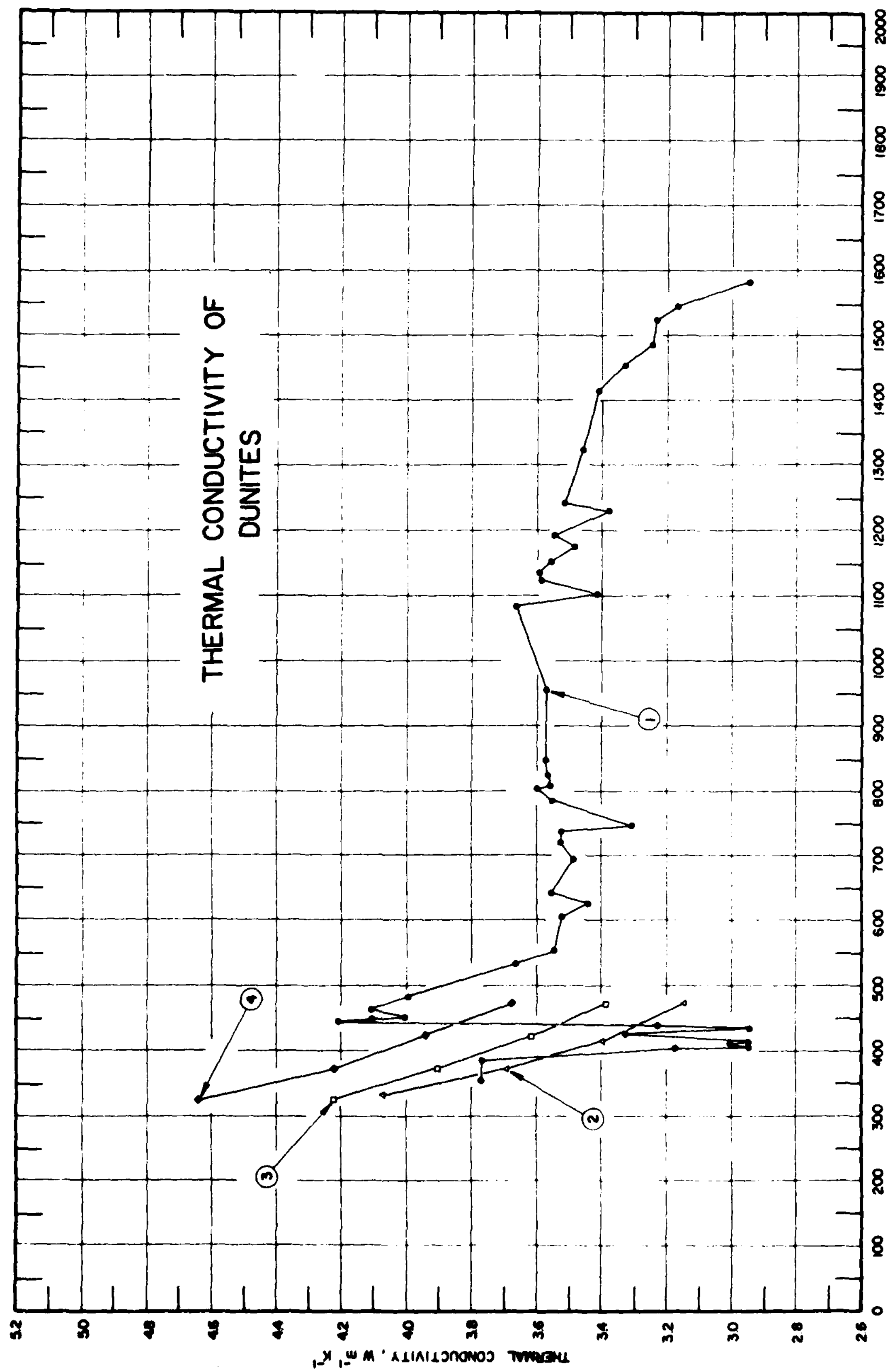

THERMAL CONDUCTIVITY OF DUNITES
TEMPERATURE, K
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
1
2
3
4

FIGURE 3-K-T

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
1	22	Kawada, K.		Cylinder			Olivine		90	Steady	355	3.77	Source: Karatsu, Northern Kyushu.
		(1966)		2.5 cm			Chromite		10	Radial	388	3.72	Other: the whole system was evac-
				dia x 5			Augite		1	Absolute	406	3.18	uated to 10^{-2} - 10^{-3} mm Hg and
				cm long							409	2.95	then argon gas was allowed in.
											411	3.09	
											413	2.95	
											427	3.33	
											429	3.24*	
											436	3.07*	
											437	2.95	
											440	3.23	
											446	4.22	
											450	4.13	
											452	4.04	
											461	4.13	
											482	4.00	
											532	3.67	
											554	3.55	
											607	3.53	
											629	3.44	
											641	3.56	
											694	3.49	
											720	3.53	
											738	3.53	
											747	3.31	
											787	3.56	
											803	3.60	
											809	3.56	
											825	3.57	
											846	3.57	
											952	3.57	
											1083	3.67	
											1102	3.42	
											1123	3.59	
											1137	3.60	
											1153	3.56	
											1179	3.49	
											1192	3.55	
											1197	3.52*	
											1230	3.38	
											1244	3.52	
											1324	3.46	
											1414	3.41	
											1454	3.33	
											1481	3.25	
											1523	3.24	
											1549	3.17	
											1583	2.95	
2	1	Birch, F. and	Dunite 1	Disk 3.8	3.252-		Olivine			Steady	334	4.08	Source: Balsam Gap, N.C.
		Clark, H.		cm dia x	3.269		(92 Mg_2SiO_4,			Longitudinal	374	3.70	Texture: mean crystal diameter
		(1940)		6 mm high			8 Fe_2SiO_4)		97	Absolute	419	3.40	1 mm.
							Serpentine		2		474	3.15	Other: values are extrapolated to
							Hornblende,						zero porosity; reported error
							Chromite,						± 4%.
							Carbonate		1				

* Not shown in figure.

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
3	1	Birch, F. and Clark, H. (1940)	Dunite 2	Disk 6 mm high x 3.8 cm dia	3.252-3.269		Same as above			Steady Longitudinal Absolute	327 371 424 471	4.23 3.91 3.62 3.39	Source: same as above. Texture: same as above. Other: same as above.
4	1	Birch, F. and Clark, H. (1940)	Dunite 3	Same as above	3.252-3.269		Same as above			Steady Longitudinal Absolute	327 371 427 473	4.65 4.23 3.95 3.68	Source: same as above. Texture: same as above. Other: same as above.
5*	75	Horai, K.I. and Baldridge, S. (1972)	Twin Sister Dunite	Disk 4.75 cm dia x 6.8 to 9.3 mm thick	3.319		Fosterite Ore		major minor	Steady Longitudinal Comparative	296	4.16	Source: Hamilton, Washington. Other: reported error ± 5%.
6*	75	Horai, K.I. and Baldridge, S. (1972)	Twin Sister Dunite		3.371	1.5	Same as above			Non-Steady Line Heat Source	296	4.23	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: water saturated; reported error ± 5%.
7*	See next page.												

* Not shown in figure.

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Pressure (atm)	Remarks
7*	39	Sawin, F.C. (1965)	North Carolina Dunite	Cylinder 9.5 mm dia x 6.4 cm length			Forsterite		90	Steady	307.6	7.80	7689	Source: North Carolina. Other: the granular appearance of the rock did not change even after subjecting it to several loading cycles with pressure >7895 atmosphere; pressurizing agent: nitrogen.
							Serpentine		Some	Radial	309.5	7.46	5754	
							Chromite		Little	Absolute	312.6	7.67	3760	
											313.8	7.46	9584	
											315.5	7.55	13324	
											316.0	7.25	11548	
											322.1	7.43	17766	
											324.1	7.32	15101	
											324.8	7.32	491	
											336.4	6.11	238	
											345.6	4.29	1	
											350.4	6.86	3839	
											357.5	7.33	987	
											363.3	4.58	122	
											364.5	5.78	491	
											386.2	6.32	13324	
											390.2	5.36	122	
											390.2	6.63	9574	
											391.2	6.01	211	
											393.2	7.54	7511	
											393.2	6.90	11548	
											400.2	6.71	5754	
											406.2	5.28	122	
											407.2	4.23	1	
											418.2	5.62	17762	
											420.2	6.14	15101	
											421.2	5.68	3839	
											425.2	6.86	959	
											459.2	6.11	456	
											465.2	5.70	9297	
											474.2	6.33	11449	
											475.2	5.69	7629	
											486.2	5.08	5774	
											496.2	5.49	15101	
											504.2	5.27	245	
											504.2	5.43	3839	
											531.2	4.73	17766	
											563.2	6.10	470	
											574.2	4.61	987	
											576.2	4.07	13028	
											590.2	5.15	11252	
											592.2	4.05	9584	
											602.2	3.83	17766	
											934.2	6.37	987	
8*	102	Johnson, S. A. (1974)	Harsburgite Dunite		3.19	1				Steady Longitudinal Comparative	293	3.63		Source: Riddle, Oregon. Texture: fine grained, some surface alteration. Other: dry sample.
9*	102	Johnson, S. A. (1974)	Same as above		3.19	1				Same as above	293	3.49		Source: same as above. Texture: same as above. Other: sample saturated with water.

* Not shown in figure.

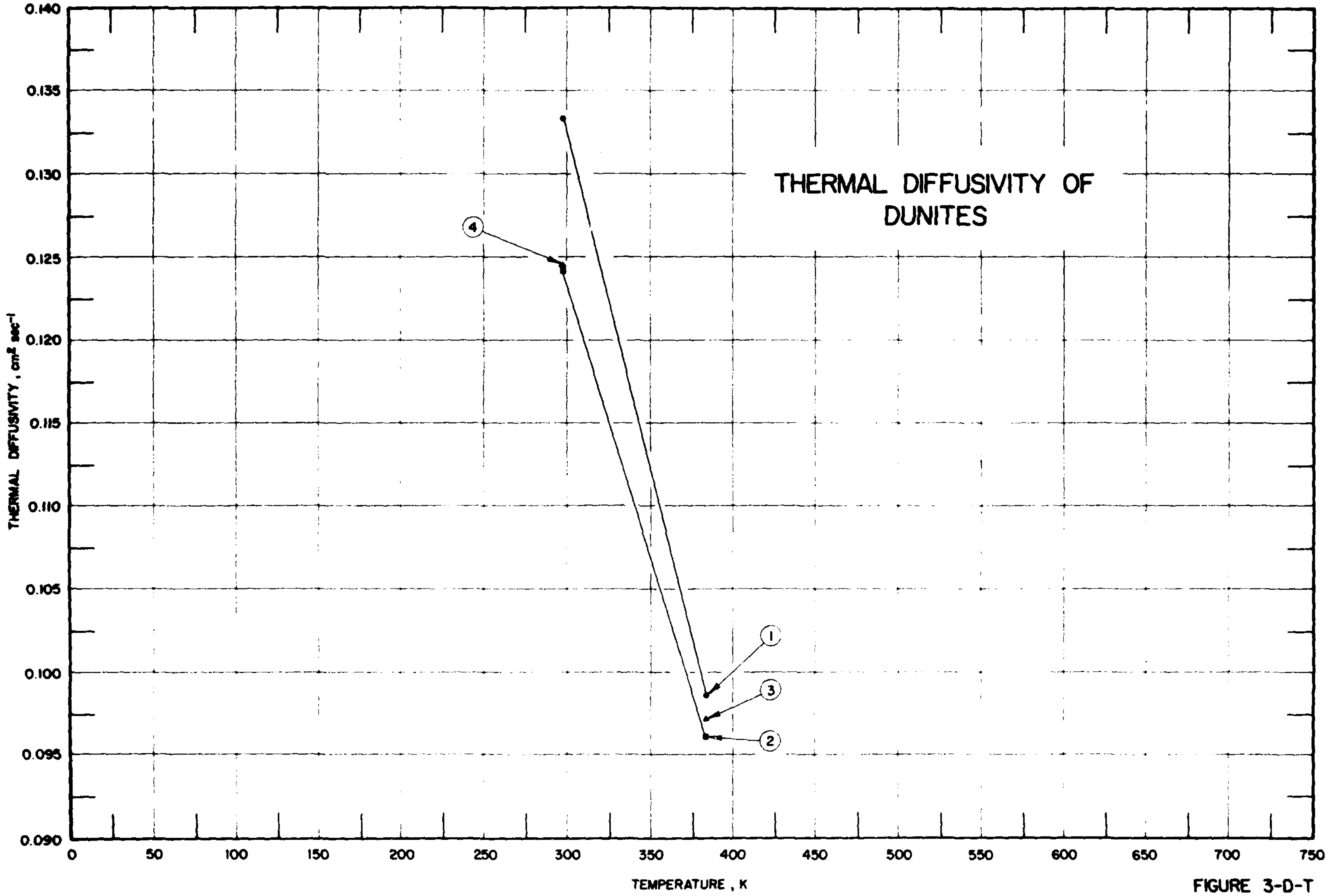

THERMAL DIFFUSIVITY OF
DUNITES
THERMAL DIFFUSIVITY, cm² sec⁻¹
TEMPERATURE, K
0.140
0.135
0.130
0.125
0.120
0.115
0.110
0.105
0.100
0.095
0.090
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
1
2
3
4

FIGURE 3-D-T

TABLE 3-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF DUNITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
1	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Disc 19.05 mm dia, 4 mm thick			MgO SiO_2 FeO H_2O- Fe_2O_3 Al_2O_3 CaO H_2O+ MnO CO_2 Na_2O P_2O_5 S	45.71 42.2 6.51 2.28 1.67 1.60 0.63 0.25 0.22 0.10 0.01 0.005 0.004		Flash Method	298 383	0.0134 0.0099	Source: Riddle, Oregon. Test Environment: nitrogen at 760 torr pressure. Other: reported error ± 5%.
2	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	298 383	0.0124 0.0096	Source: same as above. Test Environment: nitrogen at 1.0×10^{-2} torr pressure. Other: same as above.
3	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	383	0.0097	Source: same as above. Test Environment: nitrogen at 4.0×10^{-7} torr pressure. Other: same as above.
4	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	298	0.0124	Source: same as above. Test Environment: nitrogen at 6.0×10^{-9} torr pressure.

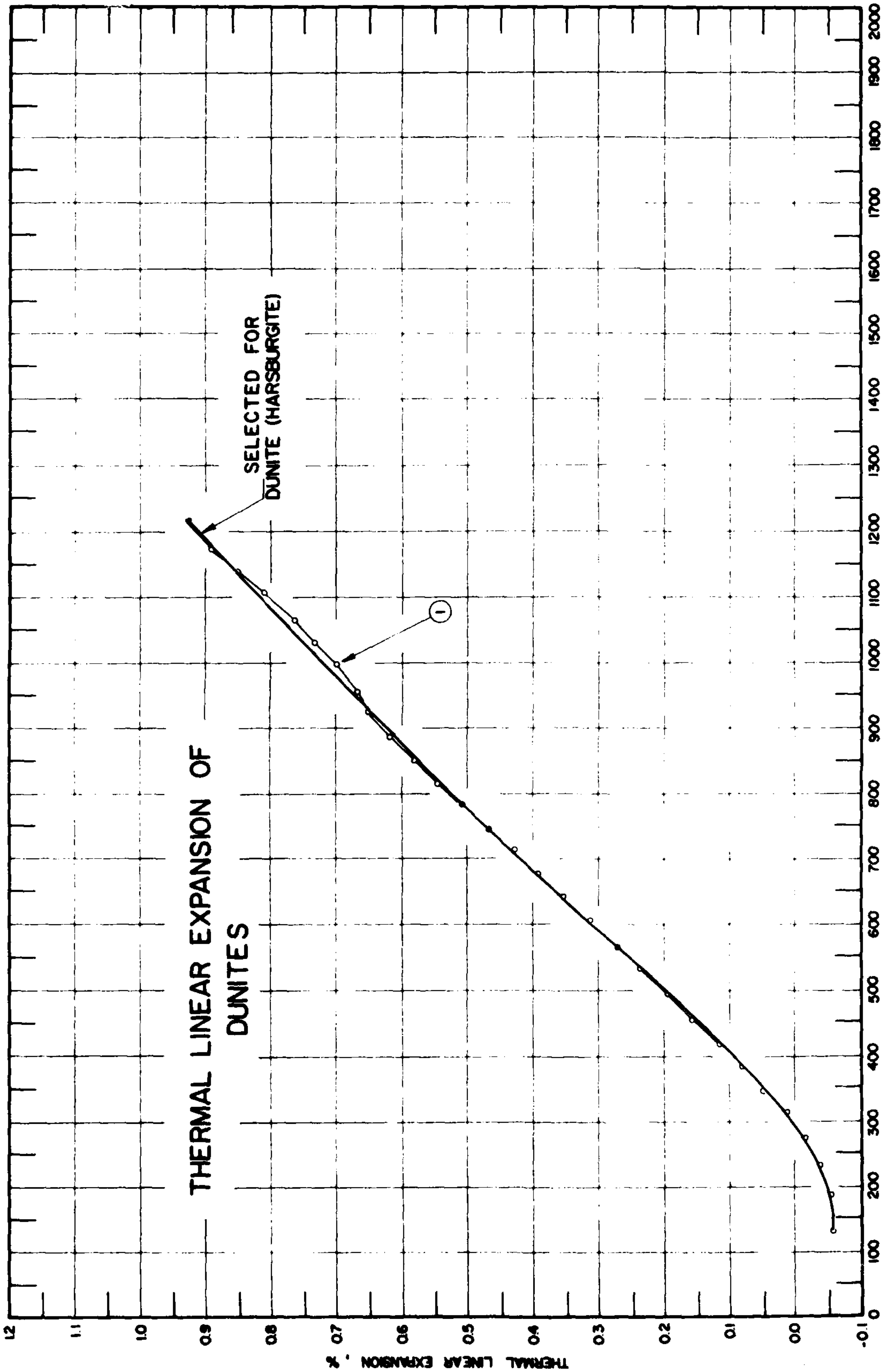

THERMAL LINEAR EXPANSION OF DUNITES
SELECTED FOR DUNITE (HARSBURGITE)
1
TEMPERATURE, K
THERMAL LINEAR EXPANSION, %
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2

FIGURE 3-E-T

TABLE 3-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF DUNITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.	Harzburgite		3.19	1	Olivine		60	Dilatometer	136	-0.059	Source: Riddle, Oregon.
		and Demou, S.G.					Orthopyroxene		35		189	-0.055	Powder Density: 1.69 g cm^{-3}.
		(1972)					Spinel				233	-0.039	Magnetic Susceptibility: 60 x 10^6
							(Chromite)		3		273	-0.013	cgs units.
							Serpentine		1		311	0.011	Dielectric Constant: 3.19 (ratio).
							MgO	45.71			346	0.047	Specific Area: 4.8 m^2 g^{-1}.
							SiO_2	42.2			383	0.081	Other: zero-point correction is
							FeO	6.51			420	0.117	0.005%.
							H_2O	2.53			458	0.159	
							Fe_2O_3	1.67			495	0.197	
							Al_2O_3	1.60			531	0.237	
							CaO	0.63			568	0.273	
											604	0.313	
											640	0.355	
											676	0.393	
											711	0.429	
											746	0.469	
											781	0.507	
											817	0.545	
											852	0.581	
											887	0.619	
											922	0.649	
											958	0.669	
											994	0.699	
											1030	0.733	
											1066	0.765	
											1103	0.811	
											1139	0.853	
											1177	0.893	
											1214	0.927	

C. SELECTED VALUES FOR DUNITE (HARSBURGITE) FROM RIDDLE, OREGON

Thermal Conductivity. Birch and Clark [1] indicate a sudden drop in the thermal conductivity for the temperature interval of their measurements, i.e., 334-474 K. Room temperature measurements of Johnson [102] on harsburgite show the value practically unchanged when saturated with water. No selection was made.

Thermal Diffusivity. Results of Lindroth [42] for small temperature range indicate that the values are independent of test pressure. No selection was made.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41].

Specific Heat. No measurement was reported.

Selected Values for Dunite (Harsburgite)*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.060
200	-0.050
293	0.000
300	0.004
400	0.093
500	0.198
600	0.310
700	0.421
800	0.522
900	0.622
1000	0.721
1100	0.818
1200	0.912

*No selections were made for other thermophysical properties.

4. GABBROS

A. PETROGRAPHY

Gabbro belongs to the alkali-rich basic igneous rock group. It is composed of basic plagioclase and pyroxene. Whenever quartz or olivine occurs in appreciable quantities the rock is termed quartz gabbro or olivine gabbro.

Gabbros are generally medium- to coarse-grained and holocrystalline. They occur as intrusive bodies in the form of sills, sheets, dikes, plugs, stock and other layered bodies. Gabbros show wide range in their chemical and mineralogical composition and the following compositions are for an average gabbro:

Chemical Composition* (After Daly [99])

Oxide	Wt. Percent
SiO_2	48.24
TiO_2	0.97
Al_2O_3	17.88
Fe_2O_3	3.16
FeO	5.96
MnO	0.13
MgO	7.51
CaO	10.99
Na_2O	2.55
K_2O	0.89
H_2O	1.45
P_2O_5	0.28

Mineralogical Composition

Mineral	Vol. Percent
Mafics (augite, hypersthene, or olivine, less commonly hornblende)	25-50
Plagioclase (labradorite or bytownite)	70-45
Fe-ores, biotite etc.	Accessory

Duluth Gabbro

The following account of mineralogy and texture of gabbro from N. of Duluth, Minnesota, given by Fogelson [98], is summerized below:

* Average of 41 analyses.

Mineral Composition

Essential Minerals	Vol. Percent
Plagioclase (labradorite An_{52})	50
Pyroxene (pigeonite)	35

Accessory Minerals	Vol. Percent
Magnetite	10
Olivine	5
Serpentine	<1
Pyrite	<<1

Texture. The rock has a phaneritic holocrystalline, anhedral-interstitial texture. Subhedral plagioclase laths are surrounded by anhedral grains of pyroxene, olivine and magnetite, imparting the anhedral-interstitial texture.

Plagioclase laths average 10 to 15 mm long and 1 mm wide, but they range from 0.3 mm long. Pyroxene is 1 to 2 mm in diameter and olivine measures 0.5 to 1.5 mm. Magnetite grains range between 0.1 and 1.5 mm in diameter, most of them are on the larger end of the range.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

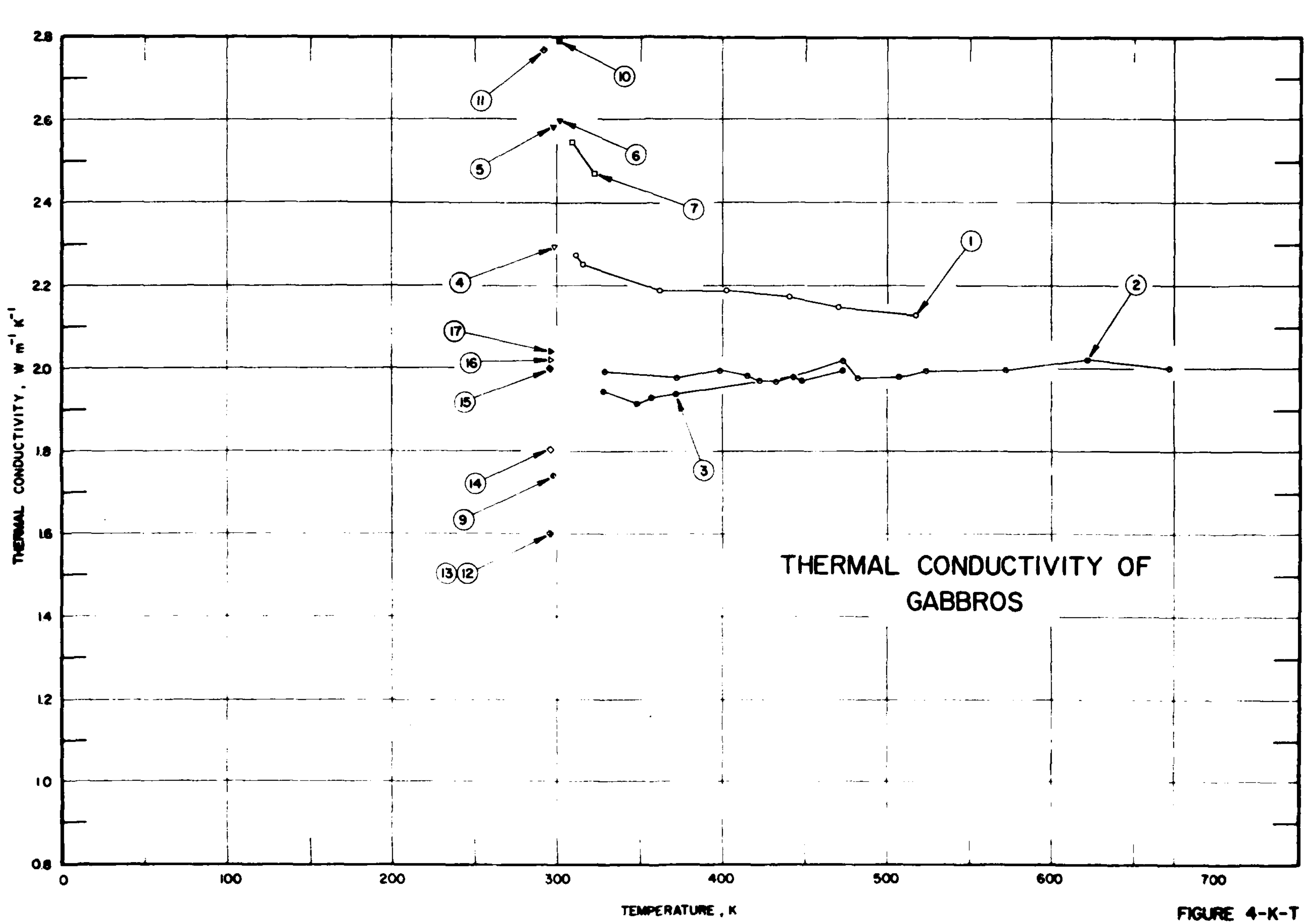

THERMAL CONDUCTIVITY OF GABBROS
THERMAL CONDUCTIVITY, W m^{-1} K^{-1}
TEMPERATURE, K
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0
100
200
300
400
500
600
700
1
2
3
4
5
6
7
9
10
11
12
13
14
15
16
17

FIGURE 4-K-T

TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	1	Birch, F. and Clark, H. (1940)		Disk 3.8 cm dia, 6.4 mm high	3.033		Ab$_{[illegible]}$An$_{[illegible]}$ Augite (Pyroxene) Hypersthene (Pyroxene) Biotite		51 32 15 0.5	Steady Longitudinal Absolute	311 315 361 402 440 470 517	2.27 2.25 2.19 2.19 2.17 2.15 2.14	Source: French Creek, Pa. Texture: mean crystal dia 5 mm. Test Environment: nitrogen or helium gas pressure: 96 cm Hg. Other: conductivity is correlated to account for the gas film resistance; reported error ± 4%.
2	1	Birch, F. and Clark, H. (1940)	Wisconsin Gabbro No. 2	Same as above	2.862-2.879		$Ab_{40}An_{60}$ Pyroxene (diallage) Olivine Biotite		72 14.1 11.4 1.2	Steady Longitudinal Absolute	329 371 399 415 422 432 473 481 507 524 572 623 672	1.99 1.98 1.99 1.98 1.97 1.97 2.02 1.98 1.98 1.99 1.99 2.02 2.00	Source: Mellen, Wis. Texture: mean crystal dia 0.5 mm. Other: same as curve 1.
3	1	Birch, F. and Clark, H. (1940)	Wisconsin Gabbro No. 1	Same as above	2.862-2.879		$Ab_{40}An_{60}$ Pyroxene (diallage) Olivine Biotite		72 14.1 11.4 1.2	Steady Longitudinal Absolute	328 349 356 372 443 449 473	1.95 1.92 1.93 1.94 1.98 1.97 1.99	Source: Mellen, Wis. Texture: mean crystal dia 3 mm. Other: same as curve 1.
4	13	Lorentzen, G. (1966)		Flat Surface						Thermal Comparator	298	2.30	Source: Norway.
5	13	Lorentzen, G. (1966)	Rodsand Gabbro	Flat Surface						Thermal Comparator	298	2.58	Source: Norway.
6	12	Lorentzen, G. (1964)		Parallelepiped 8 x 8 x 16 cm						Steady Longitudinal Absolute	300	2.60	Source: Rodsand (Scandinavia). Other: reported error ±2.5%; measured at 10^{-2} mm Hg pressure.
7	2	Nancarrow, H. A. (1933)		Cylinder 5 cm dia x 2 cm long	3.100					Steady Longitudinal Absolute	309 322	2.55 2.47	Source: Sligachan Skye.
8*	10	Tadokoro, Y. (1921)	Hornblende Gabbro		2.831		SiO_2 CaO MgO Al_2O_3 FeO Fe_2O_3 MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67		Indirect	298	3.03	Source: Prov. Chikuzen (Asia). Texture: coarse grained; diameter ranging between 8-2 mm. Other: dark green in color; data is obtained from measurements of diffusivity, specific heat and density.

* Not shown in figure.

TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBROS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
9	10	Tadokoro, Y. (1921)	Hornblende Gabbro		2.851		SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 MnO	51.84 19.28 9.46 7.59 7.55 2.13 0.48		Indirect	298	1.74	Source: Prov. Awadi (Asia). Texture: medium grained 3-0.5 mm. Other: dark colored essentially hornblende, biotite and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; data is obtained from measurements of diffusivity, specific heat and density.
10	73	Sass, H.J. (1964)		Disk 3.5 cm dia x 6 mm thick						Steady Longitudinal Comparative	301	2.8	Source: Bore hole at Norseman, Australia. Other: reported error ± 0.6%.
11	14	Misener, A.D., Thompson, L.G. D., and Uffen, R.J. (1951)	Hornblende Gabbro	Disk	3.08					Steady Longitudinal Comparative	291	2.77	Source: New Calumet Mine, Calumet Island, Quebec (depth 1350 ft).
12	75, 84	Horai, K.I. and Baldridge, S. (1972)	Olivine Gabbro	Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.815		Plagioclase (Ab_{45} An_{55}) Augite Magnetite Muscovite Olivine (Fo_{60} Fa_{40}) Biotite Chlorite Serpentine		81.70 7.84 2.46 2.34 2.06 1.96 1.07 0.56	Steady Longitudinal Comparative	296	1.60	Source: Tripyramid Mountain, New Hampshire. Other: reported error ± 5%.
13	75, 84	Horai, K.I. and Baldridge, S. (1972)	Olivine Gabbro		2.817	0.1	Same as above			Non-Steady Line Heat Source	296	1.60	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error ± 5%.
14	75, 84	Horai, K.I. and Baldridge, S. (1972)		Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.928		Plagioclase (Ab_{40} An_{60}) Augite Magnetite Hornblende Apatite Serpentine Biotite Chalcopyrite Muscovite Calcite Chlorite		70.90 8.29 6.03 5.30 3.80 2.67 2.17 0.32 0.26 0.18 0.08	Steady Longitudinal Comparative	296	1.82	Source: Cape Neddick, Maine. Other: reported error ± 5%.
15	75, 84	Horai, K.I. and Baldridge, S. (1972)			2.983	1.8	Same as above			Non-Steady Line Heat Source	296	2.00	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error ± 5%.

TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBROS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
16	75, 84	Horai, K.I. and Baldridge, S. (1972)	Olivine Gabbro	Disk 4.75 cm dia, 6.8 to 9.3 mm thick	3.061		Plagioclase (Ab_{47} An_{53})		51.19	Steady Longitudinal Comparative	296	2.02	Source: Tripyramid Mountain, New Hampshire. Other: reported error ± 5%.
							Augite		20.90				
							Magnetite		8.94				
							Apatite		6.33				
							Hornblende		5.32				
							Muscovite		2.79				
							Olivine (Fo_{54} Fa_{46})		1.48				
							Chlorite		1.27				
							Biotite		1.15				
							Serpentine		0.46				
							Chalcopyrite		0.14				
							Epidote		0.03				
17	75, 84	Horai, K.I. and Baldridge, S. (1972)	Olivine Gabbro		3.080	0.6	Same as above			Non-Steady Line Heat Source	296	2.04	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error ± 5%.
18*	102	Johnson, S.A. (1974)			3.11	1				Steady Longitudinal Comparative	293	2.21	Source: N. of Duluth, Minnesota. Texture: medium grained, feldspar has some orientation. Other: dry sample.
19*	102	Johnson, S.A. (1974)			3.11	1				Steady Longitudinal Comparative	293	2.17	Source: same as above. Texture: same as above. Other: sample saturated with water.

* Not shown in figure.

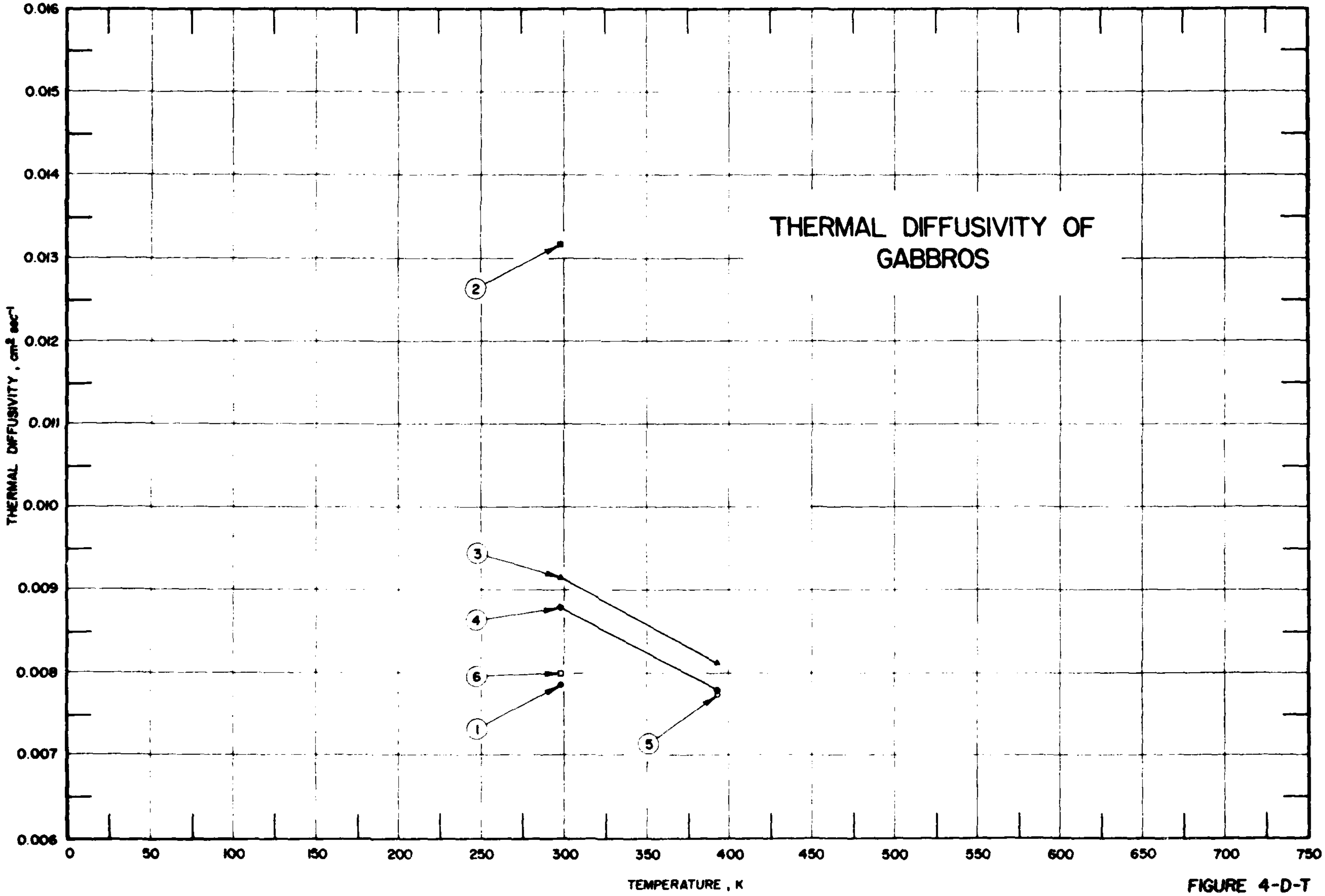

THERMAL DIFFUSIVITY OF
GABBROS
THERMAL DIFFUSIVITY, cm² sec⁻¹
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
TEMPERATURE, K
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
1
2
3
4
5
6

FIGURE 4-D-T

TABLE 4-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm^2 s^{-1})	Remarks
1	10	Tadokoro, Y. (1921)	Hornblende Gabbro	Cube 60 mm by side	2.851		SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 MnO	51.84 19.28 9.46 7.59 7.55 2.13 0.48		Periodic	~298	0.0079	Source: Prov. Awadi (Asia). Texture: dark colored, essentially of hornblende, biotite, and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; medium grained (3-0.5 mm).
2	10	Tadokoro, Y. (1921)	Hornblende Gabbro	Cube 60 mm by side	2.831		SiO_2 CaO MgO Al_2O_3 FeO Fe_2O_3 MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67		Periodic	~298	0.0132	Source: Prov. Chikuzen. Texture: dark green in color, coarse texture, ranging diameter between 8-2 mm.
3	42	Lindroth, D.P. (1974)		Disk 19.05 mm dia, 4 mm thick			SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 TiO_2 Na_2O CO_2 MnO K_2O H_2O+ H_2O- P_2O_5 S	43.3 13.1 11.50 9.97 7.33 6.46 5.97 1.76 0.26 0.22 0.12 0.12 0.10 0.02 0.054		Flash Method	298 383	0.0091 0.0081	Test Environment: nitrogen at 760 torr pressure.
4	42	Lindroth, D.P. (1974)		Same as above			Same as above			Flash Method	298 383	0.0087 0.0078	Test Environment: nitrogen at 1.0×10^{-6} torr pressure.
5	42	Lindroth, D.P. (1974)		Same as above			Same as above			Flash Method	383	0.0077	Test Environment: nitrogen at 1.5×10^{-7} torr pressure.
6	42	Lindroth, D.P. (1974)		Same as above			Same as above			Flash Method	298	0.0080	Test Environment: nitrogen at 4.5×10^{-6} torr pressure.

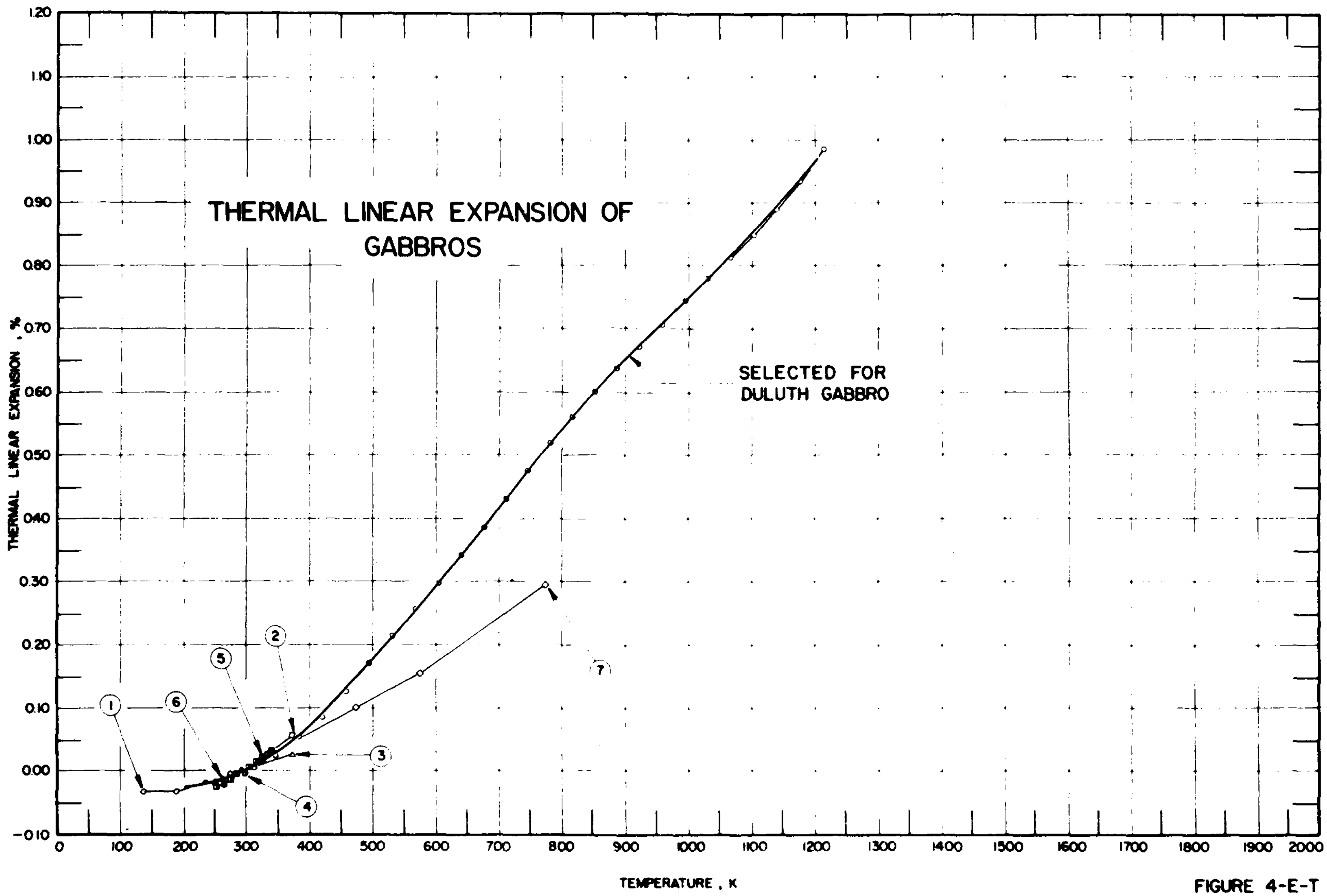

THERMAL LINEAR EXPANSION OF
GABBROS
SELECTED FOR
DULUTH GABBRO
THERMAL LINEAR EXPANSION, %
TEMPERATURE, K
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
1
2
3
4
5
6
7

FIGURE 4-E-T

TABLE 4-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.			3.11	<1	Plagioclase		50	Dilatometer	136	-0.032	Source: N. of Duluth, Minn.
		and Demou, S. G.					Pyroxene		35		189	-0.032	Powder Density: 3.11 g cm^{-3}.
		(1972)					Magnetite		10		233	-0.020	Magnetic Susceptibility: 3500 x 10^{6}
							Olivine		5		273	-0.006	cgs units.
							Serpentine		1		311	0.006	Dielectric Constant: 3.30 ratio.
							SiO_2	43.3			346	0.024	Specific Area: 0.6 m^2/g.
							Al_2O_3	13.1			383	0.057	Other: zero-point correction is
							CaO	11.5			420	0.088	0.002%.
							FeO	9.97			458	0.128	
							MgO	7.33			495	0.172	
							Fe_2O_3	6.46			531	0.216	
							TiO_2	5.97			568	0.258	
							Na_2O	1.76			604	0.298	
											640	0.342	
											676	0.386	
											711	0.432	
											746	0.476	
											781	0.520	
											817	0.562	
											852	0.600	
											887	0.638	
											922	0.674	
											958	0.708	
											994	0.746	
											1030	0.780	
											1066	0.814	
											1103	0.850	
											1139	0.890	
											1177	0.934*	
											1214	0.986*	
2	32	Griffith, J.H. (1937)	Gabbro-Gneiss		3.15	0.9				Dilatometer	293	0.000	Source: Ablemarle County, Va.
											373	0.058	
3	32	Griffith, J.H. (1937)	Orthoclase Quartz							Dilatometer	293	0.000	Source: Wichita Mts., Okla.
											373	0.027	
4	84	Mitchell, L.J. (1953)	Gabbro Pebble from Gravel							Dilatometer	263	-0.022	Source: Hungryhorse Dam, Mont.
											293	0.000*	Other: average of heating and cooling
											297	-0.003	cycle.
5	64	Hockman, A. and Kessler, D.W. (1950)	Gabbro				Plagioclase, Pyroxene	major†		Interferometer	251	-0.026	Source: St. Peters, Pa.
											262	-0.020*	Texture: fine.
											273	-0.013	Other: moisture expansion length
											284	-0.004	due to immersion in water for
											293	0.000*	24 hr at 294.7 K is 0.0056%;
											295	0.002*	average of heating and cooling
											305	0.008	cycle.
											315	0.015	
											324	0.021*	
											334	0.028*	
											339	0.031	

* Not shown in figure.
† In descending order of abundance.

TABLE 4-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GABBROS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
6	64	Hockman, A. and Kessler, D.W. (1950)	Hypersthene Gabbro				Plagioclase, Pyroxene, Hornblende	major†		Interferometer	250	-0.021	Source: Alhambra, California.
											262	-0.015	Texture: fine.
											267	-0.012*	Other: same as above except 0.0004%; average of heating and cooling cycle.
											273	-0.009*	
											284	-0.004*	
											293	0.000*	
											295	0.001*	
											305	0.007*	
											314	0.013*	
											324	0.018	
											333	0.023*	
											338	0.026*	
7	61	Iskandarov, E. (1968)								Dilatometer	473	0.101	Source: Khuramenskii Mountain.
											573	0.156	Texture: fine grained.
											773	0.296	Other: values obtained from the coefficients of thermal linear expansion.

* Not shown in figure.
† In descending order of abundance.

TABLE 4-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1*	10	Tadokoro, Y. (1921)	Hornblende	Very thin plates, 0.1-0.3 mm thick	2.851		SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 MnO	51.84 19.28 9.46 7.59 7.53 2.13 0.48		Drop Isothermal Water Calorimeter	338	0.186	Source: Prov. Awadi (Asia). Texture: dark colored, essentially of hornblende, biotite and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; medium grained (3-0.5 mm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
2*	10	Tadokoro, Y. (1921)	Hornblende	Same as above	2.831		SiO_2 CaO MgO Al_2O_3 FeO Fe_2O_3 MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67		Same as above	338	0.184	Source: Prov. Chikuzen (Asia). Texture: dark green in color, coarse texture, diameter ranging between 8-2 mm. Other: same as above.
3*	36	Svikis, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm	2.978		Ca-Felspar (An 50) Augite Quartz, K-Felspar, Na-Felspar Hornblende Magnetite Biotite		46 24 12 7 7 4	Isothermal Water Calorimeter	600	0.227	Source: Canada. Texture: homogenous, diabasic and medium grained. Other: average of two runs; mean Cp between 698 K, temp to which specimen is heated and 300 K, final temp of bath.

*No figure given.

C. SELECTED VALUES FOR DULUTH GABBRO

Thermal Conductivity. Several single room-temperature values reported in the literature indicate wide scatter. Room temperature measurements of Johnson [102] showed the value practically unchanged when saturated with water. No selection was made.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Values for most of the other gabbros do not show much variation.

Specific Heat. No measurement was reported for this gabbro.

Selected Values for Duluth Gabbro*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$, (%)
200	-0.027
293	0.000
300	0.002
400	0.073
500	0.179
600	0.294
700	0.418
800	0.539
900	0.651
1000	0.749
1100	0.852
1200	0.964

*No selections were made for other thermophysical properties.

5. GRANITES

A. PETROGRAPHY

One of the most abundant plutonic rocks of the earth's crust, granite contains a high percentage of feldspars, of which two-thirds or more is potash feldspar and the remainder albite-oligoclase. Quartz always consists of more than 10 percent and mafic minerals (amphibole, biotite, or both) are common accessories which usually account for less than 10 percent of the overall composition. Granites are generally medium- to coarse-grained and are characterized by the typical hypidiomorphic granular texture. The average chemical and mineralogical composition of granite is given below:

Chemical Composition* (After Daly [99])

Oxide	Wt. Percent
SiO_2	70.18
TiO_2	0.39
Al_2O_3	14.47
Fe_2O_3	1.57
FeO	1.78
MnO	0.12
MgO	0.88
CaO	1.99
Na_2O	3.48
K_2O	4.11
H_2O	0.84
P_2O_5	0.19

Mineralogical Composition

Mineral	Vol. Percent
Potash feldspar	30-60
Quartz	10-40
Sodic plagioclase (excluding perthite)	0-35**
Biotite, hornblende, ores, zircon, apatite, etc.	Accessory

The composition given above is for an average granite but considerable departure from these are noted, both in chemical and mineralogic composition.

* Average of 546 analyses.

** By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

Barre Granite

The chemical composition, mineralogy and texture of Barre granite (quartz monzonite) from Barre, Vermont, given by Birch and Clark [1], is summarized below:

Chemical Composition

Oxide	Wt. Percent
SiO_2	69.51
Al_2O_3	15.37
Fe_2O_3	2.65
CaO	1.76
Na_2O	5.38
K_2O	4.31
H_2O	1.02

Mineralogical Composition

Essential Minerals	Vol. Percent
Plagioclase ($Ab_{75}An_{25}$)	36.47*
Quartz	30.74
Microcline	19.84

Accessory Minerals	Vol. Percent
Biotite	7.31
Muscovite	4.30
Calcite (secondary)	0.57
Sphene	0.38
Apatite	0.24
Magnetite	0.08
Chlorite (secondary)	0.05
Chalcopyrite	0.02

Texture. The rock is medium-grained and has a hypidiomorphic granular texture. Average grain diameter of essential minerals is 0.4 mm and that of accessories less than 0.01 mm. Feldspar has turned cloudy due to alteration.

Westerly Granite

The chemical composition (after Horai and Baldridge [84]) and mineralogy and

*By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

texture of the Westerly Granite (quartz monzonite) from Westerly, Rhode Island, given by Hasan and West [101] is summarized below:

Chemical Composition

Oxide	Wt. Percent
SiO_2	72.70
TiO_2	0.26
Al_2O_3	14.05
Fe_2O_3	0.87
FeO	0.96
MnO	0.03
MgO	0.38
CaO	1.39
Na_2O	3.32
K_2O	5.48
H_2O	0.40
P_2O_5	0.09
CO_2	0.07

Mineralogical Composition

Essential Minerals	Vol. Percent
Plagioclase ($Ab_{80}An_{20}$)	37**
Microcline	31
Quartz	25

Accessory Minerals	Vol. Percent
Biotite	4
Muscovite	2
Magnetite, sphene, apatite, calcite*, chlorite*, epidote*	1

Texture. The rock is medium to fine-grained, holocrystalline, hypidiomorphic, granular. Feldspars are generally subhedral to euhedral and show some alteration along cleavage planes. They range in diameter from 0.3 to 0.7 mm; quartz measures 0.4 mm and micas are between 0.07 and 0.22 mm in diameter.

*Secondary.

**By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

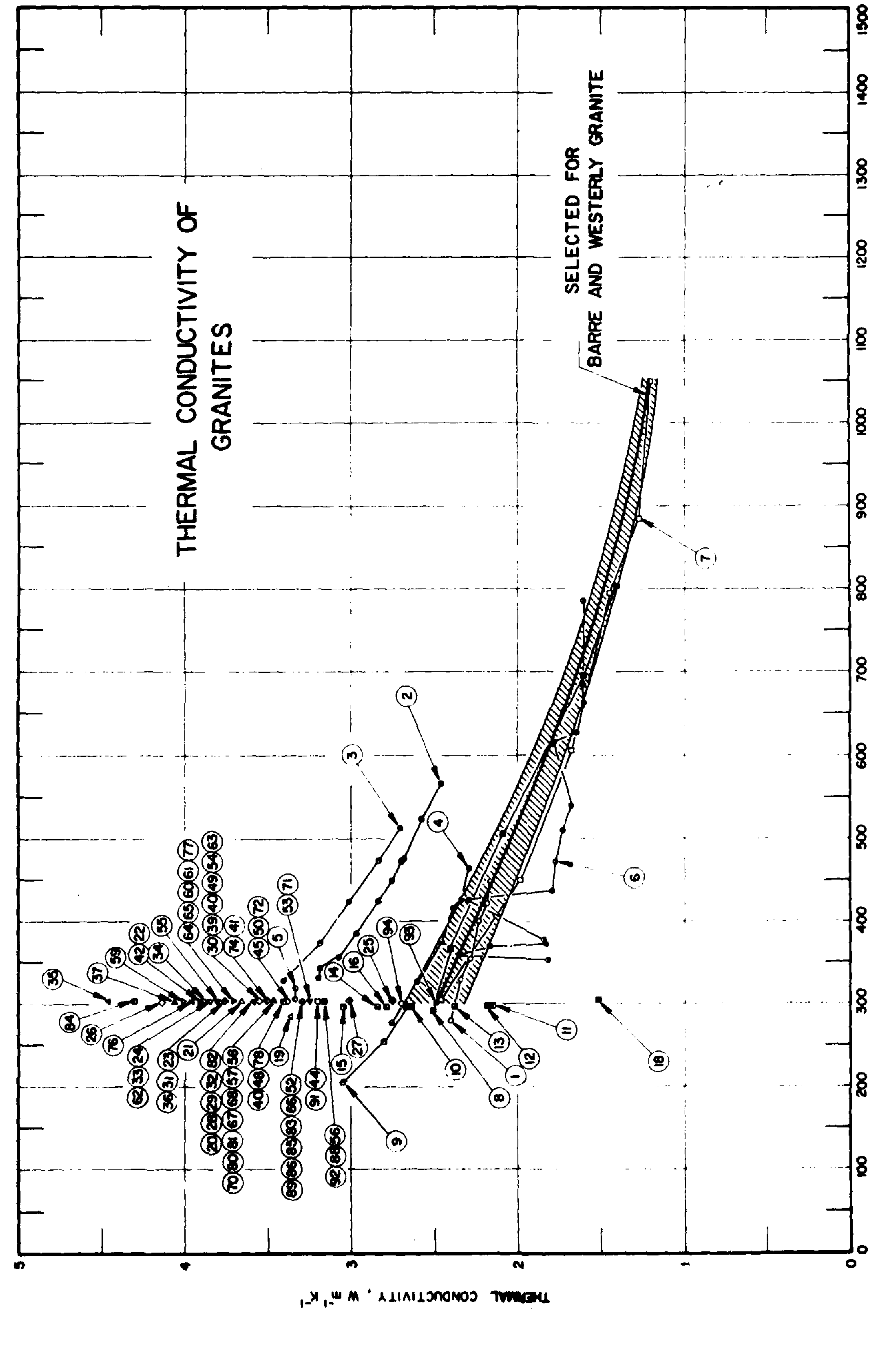

THERMAL CONDUCTIVITY OF GRANITES
SELECTED FOR
BARRE AND WESTERLY GRANITE
TEMPERATURE, K
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
0 1 2 3 4 5

FIGURE 5-K-T

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
1	1	Birch, F. and	Westerly	Disk 3.8	2.643		Albite		40	Steady	279	2.41	Source: Westerly, R.I.
		Clark, H.	Granite	cm dia,			Orthoclase			Absolute	329	2.35	Texture: mean crystal size 0.5 mm.
		(1940)		6 mm			(microcline)		33	Longitudinal	351	2.28	Test Environment: nitrogen or
				high			Quartz		19		400	2.24	helium; gas pressure: 96 cm Hg.
							Biotite		6		423	2.18	Other: conductivity is corrected
							Rest		2		449	2.17	to account for the gas film re-
													sistance; reported error ± 4%.
2	1	Birch, F. and	Rockport	Same as	2.609,		Orthoclase			Steady	331	3.21	Source: Rockport, Mass.
		Clark, H.	Granite 1	above	2.612		(microperthite)		64	Absolute	335	3.19	Texture: mean crystal diameter
		(1940)					Quartz		28	Longitudinal	357	3.07	1.5-2 mm.
							Amphibole		6		387	2.97	Test Environment: nitrogen or
							Rest		2		405	2.88	helium; gas pressure: 96 cm Hg.
											423	2.84	Other: same as above.
											450	2.76	
											473	2.70	
											479	2.69	
											527	2.57	
											569	2.46	
3	1	Birch, F. and	Rockport	Same as	2.609,		Same as			Steady	329	3.43	Source: same as above.
		Clark, H.	Granite 2	above	2.612		above			Absolute	377	3.18	Texture: same as above.
		(1940)								Longitudinal	423	3.02	Test Environment: same as above.
											473	2.84	Other: same as above.
											513	2.72	
4	1	Birch, F. and	Barre	Same as	2.648		Albite		37	Steady	278	2.77	Source: Barre, Vermont.
		Clark, H.	Granite	above			Quartz		26	Absolute	327	2.61	Texture: mean crystal diameter
		(1940)					Orthoclase		25	Longitudinal	377	2.46	1 mm.
							Biotite		9		418	2.38	Test Environment: same as above.
							Muscovite		3		424	2.34	Other: same as above.
											466	2.30	
5	2	Nancarrow, H.A.		Cylinder	2.58					Steady	306	3.39	Source: Newmay Quarry, Aberdeen-
		(1933)		5 cm dia,						Absolute	320	3.39	shire (from a depth of 270 ft).
				2 cm height						Longitudinal			Other: reported error ± 1%.
6	6	Poole, H.H.	Newry	Cylinder	2.625					Steady	352	1.83	Texture: medium grained.
		(1914)	Granite	15 cm						Radial	360	2.37	
				length,						Absolute	371	2.18	
				3.6 cm dia							372	1.83	
											378	1.84	
											427	2.30	
											438	1.79	
											472	1.77	
											510	1.74	
											591	1.66	
											619	1.78	
											627	1.64	
											663	1.61	
											668	1.61*	
											686	1.62	
											789	1.60	
7	5	Marovelli, R.L.	Rockville	12.7-15.2	2.68		Feldspar,			Non-Steady	305	2.47	Source: Rockville, Minnesota.
		and Veith, K.F.	Granite;	cm thick			Plagioclase			Line Heat	451	1.99	Texture: coarse grained, large
		(1964)	Block A	rock spec-			(Sodic end), and			Source	607	1.67	orthoclase phenocrysts.
				imens			Microcline		56		796	1.45	Other: color pink.
							Quartz		31		885	1.27	
							Biotite		12		1050	1.22	
							Zircon, Apatite,						
							Chlorite, Clays		1				

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
8	5	Marovelli, R. L. and Veith, K. F. (1964)	Rockville Granite; Block B	Same as above	2.68		Same as above			Non-Steady Line Heat Source	292 368 504 698 806	2.51 2.40 2.06 1.62 1.41	Source: same as above. Texture: same as above. Other: same as above.
9	5	Marovelli, R. L. and Veith, K. F. (1964)	Rockville Granite; Block C	Same as above	2.68		Same as above			Non-Steady Line Heat Source	206 253 295	3.06 2.82 2.67	Source: same as above. Texture: same as above. Other: same as above.
10	10	Tadokoro, Y. (1921)			2.654		SiO_2 Al_2O_3 Fe_2O_3 CaO MgO MnO	69.62 15.37 6.55 3.75 0.87 0.37		Indirect	298	2.52	Source: Prov. Nagato (Asia). Texture: crystals <0.5 mm dia. Other: contains quartz, orthoclase, perthite, acid plagioclase, biotite, hornblende; data is obtained from measurements of diffusivity, specific heat, and density.
11	10	Tadokoro, Y. (1921)			2.612		SiO_2 Al_2O_3 FeO CaO MnO Fe_2O_3 MgO	75.08 15.60 2.79 2.30 0.64 0.63 trace		Indirect	298	2.15	Source: Prov. Settu (Asia). Other: magnesite and apatite present as accessory constituents; data is obtained from measurements of diffusivity, specific heat, and density.
12	10	Tadokoro, Y. (1921)	Biotite Granite		2.59		SiO_2 Al_2O_3 MgO FeO CaO Fe_2O_3 MnO	74.96 16.41 3.09 2.28 2.04 0.80 0.23		Indirect	298	2.18	Source: Prov. Yamashiro (Asia). Texture: mineral grain size ranging between 1.0 and 2.0 mm. Other: data is obtained from measurements of diffusivity, specific heat, and density.
13	10	Tadokoro, Y. (1921)	Porphyry Granite		2.560		SiO_2 Al_2O_3 CaO Fe_2O_3 MgO MnO	71.20 19.12 3.92 1.54 0.91 0.74		Indirect	298	2.38	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in greyish green colored ground mass, their size ranging between 10 and 20 mm. Other: same as above.
14	20	Bullard, E.C. (1939)		Disk 3.5 cm dia, 8, 4, 1 mm thick	2.598		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	2.85	Source: Dubbeldevlei Bore 46, S. Africa, 2687-5080 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error ± 10%.
15	20	Bullard, E.C. (1939)		Same as above	2.647		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	3.05	Source: Dubbeldevlei Bore 47, S. Africa, 4000-4887 ft. Other: same as above.
16	20	Bullard, E.C. (1939)		Same as above	2.635					Steady Longitudinal Comparative	298	2.80	Source: Dubbeldevlei Bore 48, S. Africa, 4000-4887 ft. Other: same as above.
17*	20	Bullard, E.C. (1939)		Same as above	2.621		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	2.68	Source: Dubbeldevlei Bore 49, S. Africa, 4892-4934 ft. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
18	11	Mossahebi, M. (1966)		Cylinder						Non-Steady Ring Heat Source	303	1.51	Other: reported error <6%.
19	12	Lorentzen, G. (1964)								Steady Longitudinal Absolute	283	3.37	Source: Ekeberg, Oslo. Other: reported error ± 5%.
20	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 8.5 mm thick			Feldspar Quartz Biotite		49.2 35.6 15.2	Steady Longitudinal Comparative	301	3.60	Source: Australia, Bore Hole 10, Snowy River (depth 345 ft). Texture: coarse grained. Other: values are extrapolated to zero contact resistance.
21	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 5.0 mm thick			Feldspar Quartz Biotite		56.4 29.0 14.5	Steady Longitudinal Comparative	301	3.68	Source: same as above. Texture: same as above. Other: same as above.
22	46	Beck, A.E. (1956)		Disk >3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		61.8 29.9 8.3	Steady Longitudinal Comparative	301	3.93	Source: same as above. Texture: same as above. Other: same as above.
23	46	Beck, A.E. (1956)		Disk >3.8 cm dia x 8.5 mm thick			Feldspar Quartz Biotite		59.8 30.5 9.7	Steady Longitudinal Comparative	301	3.77	Source: same as above except depth 295 ft. Texture: same as above. Other: same as above.
24	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		49.1 32.6 18.3	Steady Longitudinal Comparative	301	3.85	Source: same as above. Texture: same as above. Other: same as above.
25	46	Beck, A.E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite		67.5 17.4 15.1	Steady Longitudinal Comparative	301	2.76	Source: same as above. Texture: same as above. Other: same as above.
26	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		50.3 42.5 7.2	Steady Longitudinal Comparative	301	4.14	Source: same as above except depth 345 ft. Texture: same as above. Other: same as above.
27	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Biotite Quartz		54.3 27.7 18.0	Steady Longitudinal Comparative	301	3.01	Source: same as above except depth 295 ft. Texture: same as above. Other: same as above.
28	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite Andalusite		53.7 29.7 16.6 trace	Steady Longitudinal Comparative	301	3.60	Source: same as above except depth 249 ft. Texture: average grain size except for xenolith is 1.5 mm; xenoliths consist of very fine grained almost monomineral patches of biotite, associated with small amounts of plagioclase. Other: same as above.
29	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite Andalusite		46.3 39.6 14.1 trace	Steady Longitudinal Comparative	301	3.60	Source: same as above. Texture: same as above. Other: same as above.
30	46	Beck A.E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite Andalusite		50.0 36.2 13.8 trace	Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
31	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite Andalusite		53.4 32.6 14.0 trace	Steady Longitudinal Comparative	301	3.77	Source: same as above. Texture: same as above. Other: same as above.
32	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.5 mm thick			Feldspar Quartz Biotite		54.1 37.0 8.9	Steady Longitudinal Comparative	301	3.60	Source: same as above except depth 198 ft. Texture: same as above. Other: same as above.
33	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Feldspar Quartz Biotite		51.5 35.4 13.1	Steady Longitudinal Comparative	301	3.85	Source: same as above. Texture: same as above. Other: same as above.
34	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		53.9 38.5 7.6	Steady Longitudinal Comparative	301	3.89	Source: same as above. Texture: same as above. Other: same as above.
35	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		51.2 46.1 2.7	Steady Longitudinal Comparative	301	4.48	Source: same as above. Texture: same as above. Other: same as above.
36	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.5 mm thick			Feldspar Quartz Biotite Andalusite		52.0 35.8 12.8 trace	Steady Longitudinal Comparative	301	3.77	Source: same as above except depth 149 ft. Texture: coarse grained; grain size of quartz: 0.5 mm; grain size of feldspar and quartz aggregated: 3.5 mm; fine grain xenolitic patches. Other: same as above.
37	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Feldspar Quartz Biotite Andalusite		48.6 32.5 18.9 trace	Steady Longitudinal Comparative	301	4.06	Source: same as above. Texture: same as above. Other: same as above.
38*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite Andalusite		59.3 25.2 15.5 trace	Steady Longitudinal Comparative	301	3.31	Source: same as above. Texture: same as above. Other: same as above.
39	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite Andalusite		53.7 33.0 13.3 trace	Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
40	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		60.0 26.7 13.3	Steady Longitudinal Comparative	301	3.43	Source: same as above except depth 142 ft. Texture: coarse grained. Other: same as above.
41	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		66.2 19.8 14.0	Steady Longitudinal Comparative	301	3.51	Source: same as above. Texture: same as above. Other: same as above.
42	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		59.1 30.8 10.1	Steady Longitudinal Comparative	301	3.93	Source: same as above. Texture: same as above. Other: same as above.
43*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		50.7 33.0 16.3	Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 100 ft. Texture: coarse grained; grain size of feldspar and mica: 3.0 mm; grain size of quartz: < 1.0 mm. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
44	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 7.0 mm thick			Feldspar Quartz Biotite		48.4 28.6 23.0	Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
45	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 3.5 mm thick			Feldspar Quartz Biotite		45.0 34.7 20.3	Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
46	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite		44.1 38.3 17.6	Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
47	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		60.0 25.2 14.8	Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
48	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite		63.4 22.3 14.3	Steady Longitudinal Comparative	301	3.43	Source: same as above. Texture: same as above. Other: same as above.
49	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.5 mm thick			Feldspar Quartz Biotite		50.5 35.6 13.9	Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
50	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite		59.4 31.3 9.3	Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
51*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 12.5 mm thick			Feldspar Quartz Biotite		56.6 28.7 14.7	Steady Longitudinal Comparative	301	3.35	Source: same as above except depth 48 ft. Texture: same as above. Other: same as above.
52	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		79.3 18.7 2.0	Steady Longitudinal Comparative	301	3.30	Source: same as above. Texture: same as above. Other: same as above.
53	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.5 mm thick			Feldspar Quartz Biotite		76.1 17.0 6.9	Steady Longitudinal Comparative	301	3.26	Source: same as above. Texture: same as above. Other: same as above.
54	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.0 mm thick			Feldspar Quartz Biotite		60.4 30.7 8.9	Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 38 ft. Texture: coarse grained. Other: same as above.
55	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite		55.0 37.6 7.4	Steady Longitudinal Comparative	301	3.81	Source: same as above. Texture: same as above. Other: same as above.
56	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		55.0 24.5 20.5	Steady Longitudinal Comparative	301	3.18	Source: same as above. Texture: same as above. Other: same as above.
57	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		65.4 28.2 6.4	Steady Longitudinal Comparative	301	3.47	Source: same as abobe. Texture: same as above. Other: same as above.
58	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 2.0 mm thick			Quartz Orthoclase Plagioclase Chlorite		55.0 25.0 20.0 5.0	Steady Longitudinal Comparative	301	3.43	Source: Australia, Bore Hole 13, Snowy Mountains (depth 495 ft). Texture: average grain size: 2 mm; chains of crystals of quartz and feldspar occur up to 8 mm long. Other: biotite completely altered to chlorite; composition estimated by eye from a slide; values are extrapolated to zero contact resistance.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
59	46	Beck, A. E. (1956,	Adamellite Granite	Disk >3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	4.02	Source: same as above. Texture: same as above. Other: same as above.
60	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: same as above.
61	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.76	Source: same as above. Texture: same as above. Other: same as above.
62	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 3.0 mm thick						Steady Longitudinal Comparative	301	3.85	Source: same as above except depth 316 ft. Other: values are extrapolated to zero contact resistance.
63	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 6.0 mm thick			Quartz Orthoclase Plagioclase Chlorite Muscovite		40 30 20 7 3	Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 56 ft. Texture: average grain size: 3.0 mm; grains up to 5.0 mm and chains of quartz more than 6.0 mm long. Other: one side of this disk consists of xenoliths containing 40% feldspar, 30% quartz, and 30% biotite; values are extrapolated to zero contact resistance.
64	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		53.7 38.5 7.8	Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: about 15% of one of the sides of this disk consists of xenolith containing 40% feldspar, 30% quartz, and 30% biotite; values are extrapolated to zero contact resistance.
65	46	Beck, A. E. (1956)	Adamellite Granite	Disk >3.8 cm dia x 1.5 mm thick			Quartz Orthoclase Plagioclase Chlorite Muscovite		40 30 20 7 3	Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: composition has been estimated by eye from a slide; quartz is strained, orthoclase kaolinized, plagioclase altered to paragonite; no xenolith is visible; values are extrapolated to zero contact resistance.
66	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Quartz Orthoclase Plagioclase Biotite		40 35 15 10	Steady Longitudinal Comparative	301	3.30	Source: Australia, Bore Hole 11, Snowy Mountains (depth 213 ft). Other: less than half the orthoclase which originally made up 35% of the rock has been replaced by muscovite; composition was determined by eye from a slide; values are extrapolated to zero contact resistance.
67	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.43	Source: same as above. Other: same as above.

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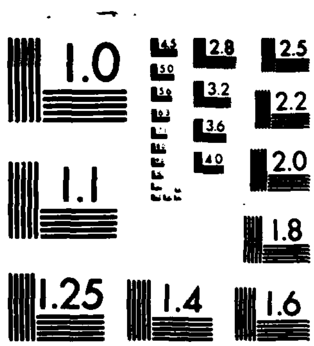

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TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
68	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Same as above			Steady Longitudinal Comparative	301	3.47	Source: same as above. Other: same as above.
69*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.22	Source: same as above. Other: same as above.
70	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 10.5 mm thick			Feldspar Quartz Biotite		71.6 19.5 8.9	Steady Longitudinal Comparative	301	3.47	Source: Australia, Bore Hole 13, Snowy Mountains (depth 56 ft). Texture: average grain size: 3 mm; grains up to 5 mm and chains of quartz no more than 8 mm long. Other: no xenolith is visible; values are extrapolated to zero contact resistance.
71	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 2.0 mm thick			Orthoclase Quartz Plagioclase Biotite		40 35 15 10	Steady Longitudinal Comparative	301	3.26	Source: Australia, Bore Hole 11, Snowy Mountains (depth 193 ft). Texture: average grain size: 1 mm; feldspar grain size is up to 2 mm, small grains of quartz form aggregates up to 10 mm in length. Other: about half the orthoclase which originally made up 35% of the rock has been replaced by muscovite; composition was determined by eye from a slide; values are extrapolated to zero contact resistance.
72	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.5 mm thick			Same as above			Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
73*	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.35	Source: same as above. Texture: same as above. Other: same as above.
74	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.51	Source: same as above. Texture: same as above. Other: same as above.
75*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		63.9 24.6 11.5	Steady Longitudinal Comparative	301	3.35	Source: Australia, Bore Hole 10, Snowy River (depth 465 ft). Texture: coarse grained. Other: values are extrapolated to zero contact resistance.
76	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite		53.8 34.5 11.7	Steady Longitudinal Comparative	301	3.97	Source: same as above. Texture: same as above. Other: same as above.
77	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		46.4 37.2 16.4	Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: same as above.
78	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		57.7 33.3 9.0	Steady Longitudinal Comparative	301	3.43	Source: same as above. Texture: same as above. Other: same as above.
79*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 11.5 mm thick			Feldspar Quartz Biotite		62.9 27.0 10.1	Steady Longitudinal Comparative	301	3.35	Source: same as above except depth 399 ft. Texture: same as above. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Mineral and/or Chemical Composition: Weight Percent	Mineral and/or Chemical Composition: Volume Percent	Method Used	Experimental Data: T, K	Experimental Data: Thermal Conductivity (W m⁻¹ K⁻¹)	Remarks
80	46	Beck, A.E. (1956)		Disk >3.8 cm dia x 9.5 mm thick			Feldspar Quartz Biotite		62.0 27.3 10.7	Steady Longitudinal Comparative	301	3.47	Source: same as above. Texture: same as above. Other: same as above.
81	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite		55.5 26.0 18.5	Steady Longitudinal Comparative	301	3.47	Source: same as above. Texture: same as above. Other: same as above.
82*	46	Beck, A.E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite		54.9 29.5 15.6	Steady Longitudinal Comparative	301	3.60	Source: same as above. Texture: same as above. Other: same as above.
83	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite		62.4 24.2 13.4	Steady Longitudinal Comparative	301	3.30	Source: same as above. Texture: same as above. Other: same as above.
84	46	Beck, A.E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite		51.1 40.5 8.4	Steady Longitudinal Comparative	301	4.31	Source: same as above. Texture: same as above. Other: same as above.
85	46	Beck, A.E. (1956)	Specimen 55; Contaminated Porphyritic Microgranite	Disk >3.8 cm dia x 2.0 mm thick			Quartz Plagioclase Biotite Orthoclase		36.0 29.0 25.1 9.9	Steady Longitudinal Comparative	301	3.30	Source: same as above except depth 398 ft. Texture: average grain size: 0.2 mm; occasional phenocrysts of plagioclase are up to 2.5 mm. Other: small amounts of andalusite are associated with biotite rich xenolithic patches and the whole rock appears to have been thermally metamorphosed; values are extrapolated to zero contact resistance.
86	46	Beck, A.E. (1956)	Specimen 56; same as above	Disk >3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.30	Source: same as above. Texture: same as above. Other: same as above.
87*	46	Beck, A.E. (1956)	Specimen 57; same as above	Disk > 3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
88	46	Beck, A.E. (1956)	Specimen 50; same as above	Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.18	Source: same as above. Texture: same as above. Other: same as above.
89	46	Beck, A.E. (1956)	Specimen 51; Porphyritic Muscovite Microgranite	Disk > 3.8 cm dia x 2.5 mm thick			Quartz Orthoclase Plagioclase Muscovite Biotite		37.6 34.3 18.2 5.4 4.5	Steady Longitudinal Comparative	301	3.30	Source: same as above except depth 350 ft). Texture: fine grain, 0.5 mm average size. Other: small amount of topaz present and this, together with common sericitization of the orthoclase, suggests that part of the muscovite is of pneumatolytic origin; composition was determined from a slide; values are extrapolated to zero contact resistance.
90	46	Beck, A.E. (1956)	Specimen 52; same as above	Disk > 3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.26	Source: same as above. Texture: same as above. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
91*	46	Beck, A. E. (1956)	Specimen 53; same as above	Disk >3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
92	46	Beck, A. E. (1956)	Specimen 54; same as above	Disk >3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.18	Source: same as above. Texture: same as above. Other: same as above.
93	86	Navarro, R. A. and DeWitt, D. P. (1974)	Barre Granite							Non-Steady Line Heat Source	300	2.50	Source: Barre, Vermont Other: contact agent: mercury; reported error ± 1%.
94	86	Navarro, R. A. and DeWitt, D. P. (1974)	Westerly Granite							Non-Steady Line Heat Source	300 300	2.70 2.51	Source: Westerly, R. I. Other: contact agent: mercury and silicon grease; reported error ± 3% and ± 5% respectively.
95*	75	Horai, K. I. and Baldridge, S. (1972)	Granite	Disk 47.5 mm dia, 6.8 to 9.3 mm thick	2.361	0.9	Perthite Quartz Plagioclase Hornblende, Biotite, Allanite, Feldspar, Ore		70 15 5 Minor	Steady Longitudinal Comparative	296	2.83	Source: Tripyramid Mountain, New Hampshire. Texture: xenomorphic-granular. Other: reported error ± 5%.
96*	75	Horai, K. I. and Baldridge, S. (1972)	Granite		2.655	0.9	Same as above			Non-Steady Line Heat Source	296	2.75	Source: same as above. Texture: same as above. Other: pulverized fragments with maximum grain size <0.1 mm; specimen water saturated; reported error ± 5%.
97*	75	Horai, K. I. and Baldridge, S. (1972)	Westerly Granite		2.642	1.4	Plagioclase‡ Orthoclase Quartz Enstatite-Ferrosilite Magnetite Corundum Ilmenite Apatite Calcite		34.30 33.64 29.26 1.20 0.65 0.34 0.28 0.18 0.16	Same as above	296	2.88	Source: Westerly, Rhode Island. Texture: fine-grained. Other: pulverized fragments with maximum grain size less than 0.1 mm; reported error ± 5%.
98*	75	Horai, K. I. and Baldridge, S. (1972)	Westerly Granite	Disk 47.5 mm dia, 6.8 to 9.3 mm thick	2.642	1.4	Same as above			Steady Longitudinal Comparative	296	2.71	Source: same as above. Other: reported error ± 5%.
99*	84	Horai, K. I. and Baldridge, S. (1972)	Barre Granite	Disk 4.75 cm dia	2.655		Plagioclase ($Ab_{75}An_{25}$) Quartz Microcline Biotite Muscovite Calcite Sphene Apatite Magnetite Chlorite Chalcopyrite		36.47 30.74 19.84 7.31 4.30 0.57 0.38 0.24 0.08 0.05 0.02	Same as above	296	2.87	Source: Barre, Vermont. Texture: hypidiomoprhic granular; medium-grained (<5 mm). Other: reported error ± 5%.

* Not shown in figure.
‡ Normative mineral composition.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m⁻¹ K⁻¹)	Remarks
100*	84	Horai, K.I. and Baldridge, S. (1972)	Westerly Granite	Same as above	2.631		Plagioclase Microcline Quartz Biotite Muscovite Magnetite Calcite Chlorite Sphene Epidote Apatite		32.98 29.98 28.83 3.73 3.16 0.66 0.42 0.11 0.06 0.03 0.03	Same as above	296	2.91	Source: Bradford, Rhode Island. Texture: hypidiomorphic granular; fine-grained (<1 mm). Other: reported error ± 5%.
101*	84	Horai, K.I. and Baldridge, S. (1972)	Westerly Granite		2.664	1.2	Same as above			Non-Steady Line Heat Source	296	2.90	Source: same as above. Texture: same as above. Other: pulverized fragments with maximum size <0.1 mm; reported error < 5%.
102*	84	Horai, K.I. and Baldridge, S. (1972)	Granite	Same as above	2.627		Plagioclase Quartz Microcline Muscovite Hornblende Biotite Epidote		34.71 30.87 20.32 6.80 6.63 0.50 0.17	Steady Longitudinal Comparative	296	2.69	Source: Stone Mountain, Georgia. Other: reported error ± 5%.
103*	84	Horai, K.I. and Baldridge, S. (1972)	Granite		2.743	4.2	Same as above			Non-Steady Line Heat	296	3.25	Source: same as above. Other: pulverized fragments with maximum size <0.1 mm; water saturated; reported error ± 5%.

*Not shown in figure.

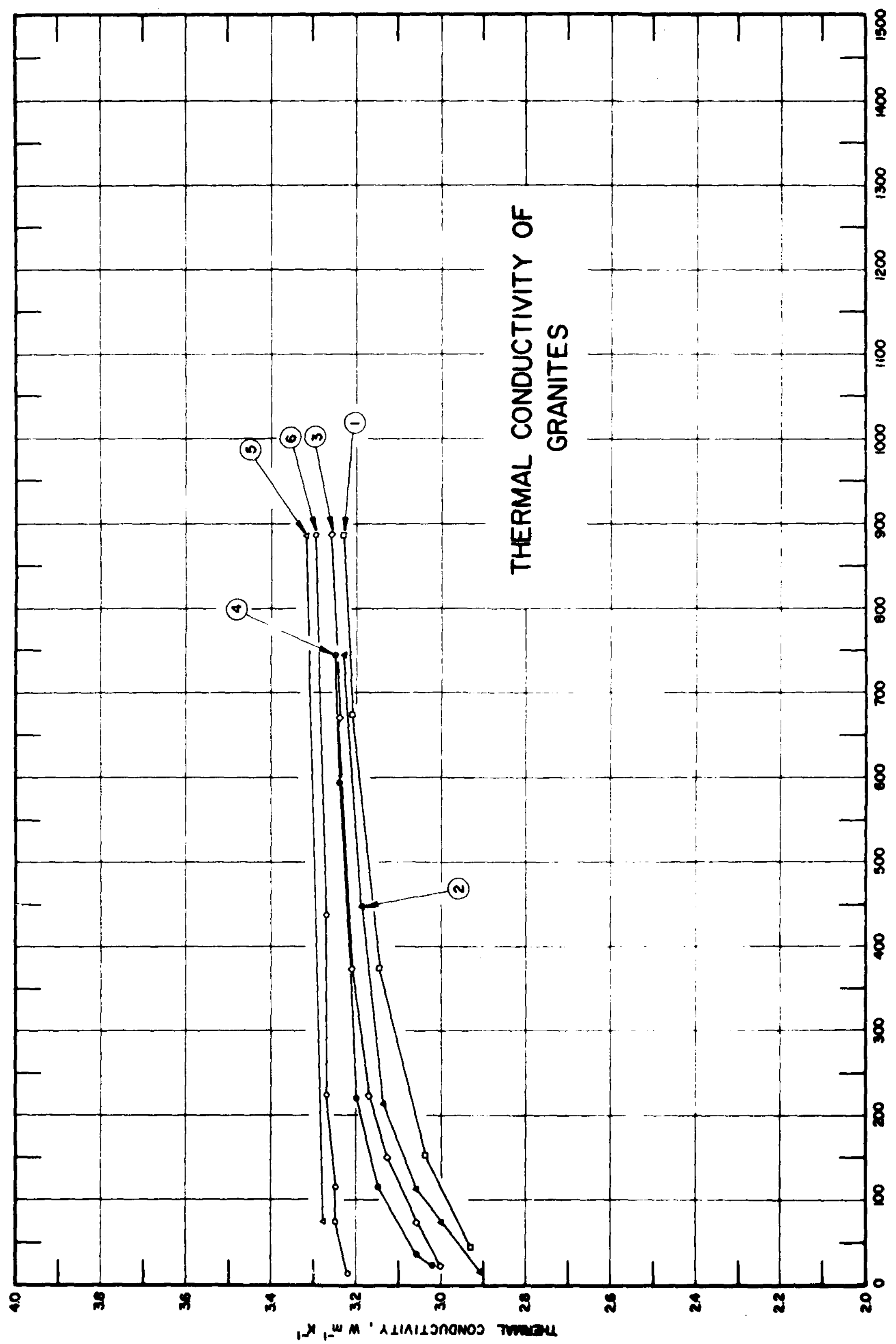

THERMAL CONDUCTIVITY OF GRANITES
PRESSURE, ATM
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
1
2
3
4
5
6

FIGURE 5-K-P

TABLE 5-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm	Thermal Conductivity ($Wm^{-1} K^{-1}$)	Remarks
1	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Cylinder 2.54 cm dia, 1.91 cm long		(See remarks)	Orthoclase Quartz Plagioclase with Anorthite Muscovite, Biotite, Chlorite		45 28 22 5	Steady Longitudinal Comparative	43 151 372 671 887	2.93 3.04 3.15 3.21 3.23	Source: hole drilled for Harvard Heat Flow Project near Casco, Maine. Porosity: total porosity: 0.7%; total porosity was found by measuring the weight before and after saturating it with CCl_4; crack porosity: 0.4%; crack porosity is found from pressure strain data. Temperature of Measurements: 298 K. Other: sample was saturated with water and subjected to axial pressure; reported error: ±1%; stress increasing.
2	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Same as above		(See remarks)	Same as above			Same as above	16 72 112 222 447 745	2.91 3.00 3.06 3.14 3.19 3.23	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress decreasing.
3	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	22 71 150 222 373 670 889	3.00 3.06 3.13 3.17 3.21 3.24 3.26	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress increasing.
4	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	22 36 113 220 594 744	3.02 3.06 3.15 3.20 3.24 3.25	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress decreasing.
5	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Same as above		(See remarks)	Same as above			Same as above	73 888	3.28 3.32	Source: hole drilled for Harvard Heat Flow Project near Casco, Maine. Porosity: total porosity: 0.7%; total porosity was found by measuring the weight before and after saturating it with CCl_4; crack porosity: 0.45%; crack porosity is found from pressure strain data. Temperature of Measurements: 298 K. Other: sample was subjected to axial pressure.
6	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	15 70 112 222 439 889	3.22 3.25 3.25 3.27 3.27 3.30	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above.

TABLE 5-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity (α cm^2 s^{-1})	Remarks
1*	10	Tadokoro, Y. (1921)		Cube, 60 mm by side	2.612		SiO_2 Al_2O_3 FeO CaO MnO Fe_2O_3 MgO	75.08 15.60 2.79 2.30 0.64 0.63 trace		Periodic Heat Flow	~298	0.0116	Source: Prov. Settu (Asia).
2*	10	Tadokoro, Y. (1921)		Same as above	2.654		SiO_2 Al_2O_3 Fe_2O_3 CaO MgO MnO	69.62 15.37 6.55 3.75 0.87 0.37		Same as above	~298	0.0145	Source: Prov. Nagato (Asia). Texture: very fine texture, individual crystals smaller than 0.5 mm diameter.
3*	10	Tadokoro, Y. (1921)	Granite Biotite	Same as above	2.590		SiO_2 Al_2O_3 MgO FeO CaO Fe_2O_3 MnO	74.96 16.41 3.09 2.28 2.04 0.80 0.23		Same as above	~298	0.0129	Source: Prov. Yamashiro (Asia). Texture: grain sizes ranging between 1.0 and 2.0 mm.
4*	10	Tadokoro, Y. (1921)	Hornblende Granite	Same as above	2.541		SiO_2 Al_2O_3 CaO FeO Fe_2O_3 MgO	65.00 16.48 6.14 4.68 4.58 3.09		Same as above	~298	0.00875	Source: Prov. Mikawa (Asia). Texture: particle size ranges from 5 to 10 mm.
5*	10	Tadokoro, Y. (1921)	Granite Porphyry	Same as above	2.560		SiO_2 Al_2O_3 CaO Fe_2O_3 MgO MnO	71.20 19.12 3.92 1.54 0.91 0.74		Same as above	~298	0.0123	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in greyish green colored ground mass, their size ranging between 10 to 20 mm.
6*	10	Tadokoro, Y. (1921)	Two Mica Granite	Same as above	2.533		SiO_2 Al_2O_3 Fe_2O_3 CaO MnO	79.62 15.53 1.37 0.93 0.53		Same as above	~298	0.00604	Source: Prov. Mikawa (Asia).
7*	12	Lorentzen, G. (1964)			1.810					Indirect	283	0.0169	Source: Ekeberg, Oslo, Sweden. Other: calculated from Cp and conductivity data.

* No figure given.

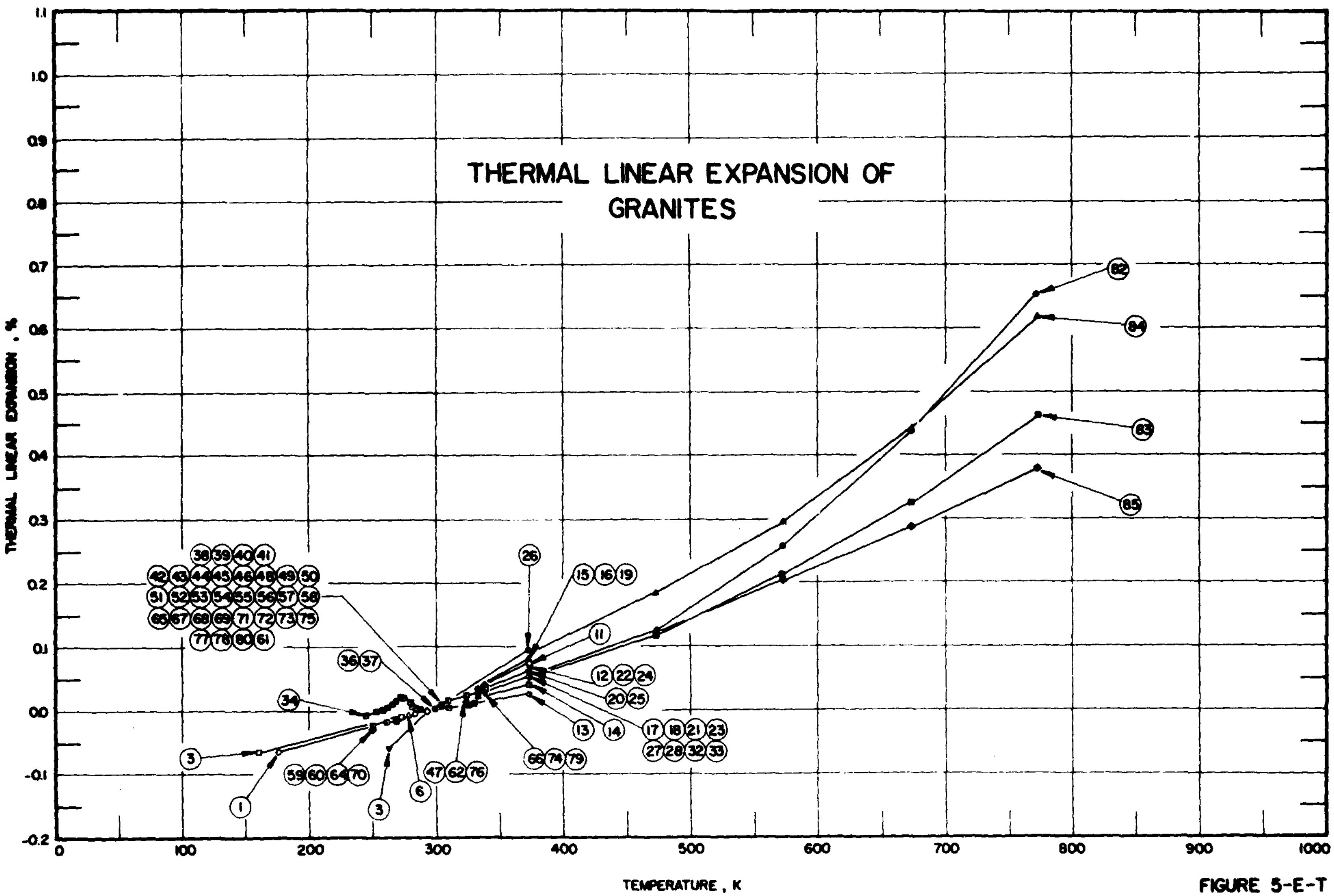

THERMAL LINEAR EXPANSION OF GRANITES
THERMAL LINEAR EXPANSION, %
TEMPERATURE, K
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
0
100
200
300
400
500
600
700
800
900
1000

FIGURE 5-E-T

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.34 cm long						Dilatometer	283 176	-0.005 -0.063	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values; for specimen snap-frozen in dilatometer.
2*	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.69 cm long						Dilatometer	253 196	0.000 -0.033	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values for specimen snap-frozen in dilatometer.
3	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.393 cm long						Dilatometer	273 161	-0.010 -0.064	Other: Specimen air-dried; contains 0.0012 gm water/gm rock.
4*	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.286 cm long						Dilatometer	258 213 123	0.000 0.018 0.050	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating values for pre-frozen specimen.
5*	44	Mellor, M. (1970)	Barre Granite	Same as above						Dilatometer	253 223 193	0.000 -0.020 -0.038	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values of specimen snap-frozen in dilatometer.
6	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.401 cm long						Dilatometer	278 159	-0.007 -0.061*	Other: Specimen effectively saturated with 0.00246 gm water/gm rock; average of heating and cooling values.
7*	44	Mellor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.391 cm long						Dilatometer	260 153 103	0.000 -0.040 -0.056	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating value for pre-frozen specimen.
8*	44	Mellor, M. (1970)	Barre Granite	Same as above						Dilatometer	258 187	0.000 -0.039	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling value for specimen snap-frozen in dilatometer.
9*	44	Mellor, M. (1970)	Barre Granite	Same as above						Dilatometer	263 178 118	0.000 -0.040 -0.063	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating values for pre-frozen specimen.
10*	44	Mellor, M. (1970)	Barre Granite	Same as above						Dilatometer	263 193	0.000 -0.042	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
11	32	Griffith, J. H. (1937)	Biotite Granite			0.88				Dilatometer	293 373	0.000 0.075	Source: Barre, Vermont.
12	32	Griffith, J. H. (1937)	Biotite Granite			1				Dilatometer	293 373	0.000* 0.068	Source: Westerly, R.I.
13	32	Griffith, J. H. (1937)	Biotite Granite			1.19				Dilatometer	293 373	0.000* 0.027	Source: Cripple Creek, Colo.

* Not shown in figure.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
14	32	Griffith, J.H. (1937)	Alkali Granite			1.01				Dilatometer	293 373	0.000* 0.042	Source: Quincy, Mass. Hardness: Shore No. 75.4.
15	32	Griffith, J.H. (1937)	Alkali Granite			0.88				Dilatometer	293 373	0.000* 0.063	Source: Quincy, Mass. Hardness: Shore No. 100.5.
16	32	Griffith, J.H. (1937)	Fluorite Granite			1.67				Dilatometer	293 373	0.000* 0.081	Source: Clinton County, N.Y.
17	32	Griffith, J.H. (1937)	Spring Creek Granite			2.23				Dilatometer	293 373	0.000* 0.053	Source: Cripple Creek, Colo.
18	32	Griffith, J.H. (1937)	Hornblende Granite			0.89				Dilatometer	293 373	0.000* 0.053	Source: Fredericksburg, Tex.
19	32	Griffith, J.H. (1937)	Amphibole Granite							Dilatometer	293 373	0.000* 0.086	Source: Hurricane Island, Me.
20	32	Griffith, J.H. (1937)	Granitoid Gneiss Granite							Dilatometer	293 373	0.000* 0.060	Source: Salisbury, N.C.
21	32	Griffith, J.H. (1937)	Porphyry Granite		2.67					Dilatometer	293 373	0.000* 0.049	Source: Winchester, Mass.
22	32	Griffith, J.H. (1937)	Binary Granite		2.68					Dilatometer	293 373	0.000* 0.070	Source: Concord, N.H.
23	32	Griffith, J.H. (1937)	Biotite Granite		2.64					Dilatometer	293 373	0.000* 0.052	Source: Picton Island, N.Y.
24	32	Griffith, J.H. (1937)	Biotite-Muscovite Granite			0.98				Dilatometer	293 373	0.000* 0.065	Source: Mount Airy, N.C.
25	32	Griffith, J.H. (1937)	Biotite-Muscovite Granite			0.64				Dilatometer	293 373	0.000* 0.059	Source: Peekskill, N.Y.
26	32	Griffith, J.H. (1937)	Biotite-Muscovite Granite			0.53				Dilatometer	293 373	0.000* 0.096	Source: Georgetown, Colo.
27	32	Griffith, J.H. (1937)	Biotite Granite			0.97				Dilatometer	293 373	0.000* 0.055	Source: Woodbury, Vt.
28	32	Griffith, J.H. (1937)	Biotite Granite			0.44				Dilatometer	293 373	0.000* 0.056	Source: Llano County, Tex.
29*	54	Mitchell, L.J. (1953)	Granite Pebble Gravel							Dilatometer	263 293 297	-0.011 0.000 0.001	Source: Cherry Creek Dam, Colo. Other: average of heating and cooling cycle.
30*	54	Mitchell, L.J. (1953)	Same as above							Dilatometer	263 293 297	-0.013 0.000 0.002	Source: Republican River, Colo. Other: average of heating and cooling cycle.
31	54	Mitchell, L.J. (1953)	Crushed Granite Breccia							Dilatometer	263 293 297	-0.060 0.000* 0.001*	Source: Davis Dam, Arizona. Other: average of heating and cooling cycle.
32	55	Louboer, P.J. and Bryden, J.G. (1972)									293 353	0.000* 0.051	Other: specimen oven dried.

* Not shown in figure.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
33	55	Loubser, P.J. and Bryden, J.G. (1972)									293 353	0.000 0.052	Other: water saturated specimen water absorption 0.20% (dry weight).
34	57	Johnson, W. and Parsons, W. (1944)								Interferometer	244 253 257 262 266 268 272 275 277 279 281 284 287 300 305 313 319 326 330	-0.007 -0.001 0.002 0.007 0.011 0.015 0.022 0.020 0.017* 0.013 0.009 0.006 0.002 0.000* 0.002* 0.004* 0.006 0.009 0.012	Source: Bill Williams Gravel, Parker Dam, Arizona. Texture: medium-grained; composed of orthoclase, microcline, quartz, perthite and allsite; biotite and pericite occure as accessory. Other: heat values; zero-point correction is -0.247%.
35*	57	Johnson, W. and Parsons, W. (1944)								Interferometer	275 287 294 305 309 314 322 328	-0.006 -0.002 0.000 0.004 0.007 0.010 0.014 0.018	Source: Bill Williams Gravel, Parker Dam, Arizona. Texture: medium-grained; composed of orthoclase, microcline, quartz, perthite and allsite; biotite and pericite occur as accessory. Other: cooling values; zero-point correction is -0.238%.
36	58	Verbeck, G.J. and Hass, W.E. (1951)								Dilatometer	298 302	0.004 0.007*	Source: Camak, Ga. Test environment: water. Texture: average grain size 0.62 mm. Other: specimen water saturated; mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
37	58	Verbeck, G.J. and Hass, W.E. (1951)								Dilatometer	298 302	0.004 0.008*	Source: Lithonia, Ga. Test environment: water. Texture: average grain size 0.62 mm. Other: specimen water saturated; mean thermal linear expansion calculated from one-third of experimental volumetric expansion.

*Not shown in figure.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
38	64	Hockman, A. and Kessler, D. W. (1950)	Biotite Granite				Orthoclase, Quartz, Oligoclase, Biotite	major†		Interferometer	250	-0.023	Source: Vinalhaven, Maine. Texture: fine to medium. Other: moisture expansion length change due to immersion in water at 294.7 K for 24 hr is 0.0018%; average of heating and cooling.
											262	-0.017	
											267	-0.016	
											273	-0.012*	
											273	-0.011*	
											284	-0.005*	
											293	0.000*	
											294	0.002*	
											305	0.009	
											314	0.016	
											324	0.023	
											333	0.030	
											338	0.034	
39	64	Hockman, A. and Kessler, D. W. (1950)	Biotite Granite				Orthoclase, Smoky Quartz, Oligolcase, Biotite	major†		Interferometer	250	-0.026	Source: Jonesboro, Maine. Texture: medium to coarse. Other: same as above except 0.0020%; average of heating and cooling.
											262	-0.020	
											267	-0.017	
											273	-0.013*	
											284	-0.006*	
											293	0.000*	
											293	0.002*	
											305	0.010	
											314	0.018	
											324	0.025	
											334	0.035	
											338	0.039	
40	64	Hockman, A. and Kessler, D. W. (1950)	Biotite Granite				Orthoclase, Microcline, Oligoclase, Quartz, Biotite	major†		Interferometer	250	-0.024	Source: Elberton, Georgia. Texture: medium to fine. Other: same as above except 0.0090%; heating cycle.
											262	-0.016	
											273	-0.009	
											284	-0.003*	
											293	0.000*	
											295	0.002*	
											305	0.007	
											315	0.013	
											325	0.019	
											334	0.027	
											339	0.030	
41	64	Hockman, A. and Kessler, D. W. (1950)	Biotite Granite				Same as above			Interferometer	339	0.030	Source: same as above. Texture: same as above. Other: same as above; cooling cycle.
											334	0.027	
											325	0.019	
											315	0.015	
											305	0.008	
											295	0.001	
											293	0.000*	
											284	-0.006*	
											273	-0.012*	
											262	-0.019	
42	64	Hockman, A. and Kessler, D. W. (1950)	Biotite Granite				Same as above			Interferometer	250	-0.026	Source: same as above. Texture: same as above. Other: same as above; heating cycle.
											262	-0.018	
											273	-0.010*	
											284	-0.005*	
											292	0.000*	
											295	0.001*	
											305	0.008	
											315	0.016	
											325	0.021	
											334	0.027	
											339	0.032	

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
43	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above			Interferometer	339	0.032	Source: same as above.
											334	0.027	Texture: same as above.
											325	0.021	Other: same as above; cooling cycle.
											315	0.019	
											305	0.011	
											295	0.003*	
											293	0.000*	
											284	-0.005*	
											273	-0.013*	
											263	-0.019	
44	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Microcline, Orthoclase, Quartz, Oligoclase, Biotite, Muscovite	major†		Interferometer	250	-0.025	Source: Woodbury, Vermont.
											262	-0.018	Texture: coarse
											272	-0.011*	Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K.
											284	-0.006*	
											293	0.000*	
											294	0.000*	
											304	0.007	
											314	0.013	
											323	0.020	
											333	0.028	
											337	0.032	
45	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Microcline, Orthoclase, Plagioclase (Albite-Oligoclase), Biotite	major†		Interferometer	250	-0.021	Source: Milford, Massachusetts.
											262	-0.015	Texture: same as above.
											273	-0.010*	Other: same as above.
											284	-0.004*	
											293	0.000*	
											294	0.001*	
											304	0.008	
											314	0.015	
											324	0.022	
											333	0.030	
46	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Microcline, Orthoclase, Smoky Quartz, Oligoclase, Biotite	major†		Interferometer	251	-0.023	Source: High Pine, Maine.
											262	-0.017	Texture: coarse.
											262	-0.015	
											273	-0.011*	
											273	-0.009*	
											284	-0.006*	
											284	-0.005*	
											293	0.000*	
											294	0.001*	
											304	0.008	
											314	0.014	
											323	0.021	
											333	0.029	
47	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Smoky Quartz (Oligoclase-Albite), Biotite	major†		Interferometer	250	-0.019*	Source: Redstone, N.H.
											262	-0.015*	Texture: coarse.
											262	-0.014*	
											273	-0.009*	
											273	-0.011*	
											284	-0.006*	
											284	-0.004*	
											293	0.000*	
											294	0.002*	
											304	0.007*	
											314	0.012*	
											324	0.018	
											333	0.025	

*Not shown in figure.

†In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
48	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Smoky Quartz (Oligoclase-Albite), Biotite, Muscovite	major†		Interferometer	250	-0.026	Source: Barre, Vermont. Texture: fine. Other: heating cycle.
											261	-0.018	
											273	-0.010*	
											284	-0.003*	
											293	0.000*	
											294	0.002*	
											304	0.008	
											314	0.014	
											323	0.021	
											333	0.028	
											337	0.032	
49	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above			Interferometer	337	0.032	Source: same as above. Texture: same as above. Other: cooling cycle.
											333	0.028	
											323	0.021	
											314	0.014	
											304	0.009	
											295	0.002*	
											293	0.000*	
											284	-0.006*	
											273	-0.013*	
											262	-0.020	
50	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above			Interferometer	250	-0.029	Source: same as above. Texture: same as above. Other: specimen dried at 353 K for 4 days and coated with synthetic waterproofing agent; average of heating and cooling.
											262	-0.022	
											273	-0.014*	
											284	-0.005*	
											293	0.000*	
											294	0.002*	
											305	0.010	
											314	0.017	
											324	0.023	
											333	0.031	
51	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Plagioclase, Microcline, Orthoclase, Perthite, Quartz, Biotite	major†		Interferometer	250	-0.025	Source: Graniteville, Mo. Texture: medium. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0012%.
											262	-0.018	
											273	-0.011*	
											284	-0.005*	
											293	0.000*	
											295	0.001*	
											306	0.008	
											315	0.014	
											325	0.021	
											334	0.029	
											339	0.033	
52	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Quartz, Microcline, Plagioclase, Biotite	major†		Interferometer	250	-0.027	Source: Marble Falls, Texas. Texture: coarse. Other: same as above except 0.0038%.
											262	-0.019	
											267	-0.018	
											273	-0.012*	
											284	-0.006*	
											293	0.000*	
											295	0.001*	
											305	0.009	
											315	0.016	
											325	0.024	
											334	0.032	
											339	0.037	

*Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
53	64	Hockman, A. and	Biotite				Oligoclase,			Interferometer	250	-0.021	Source: Mt. Airy, N.C.
		Kessler, D.W.	Granite				Orthoclase,				262	-0.015	Texture: medium.
		(1950)					Microcline,				267	-0.013	Other: same as above except 0.002%.
							Quartz,				273	-0.010*	
							Biotite	major†			284	-0.004*	
											293	0.000*	
											295	0.001*	
											305	0.008	
											315	0.013	
											325	0.020	
											334	0.027	
											339	0.031	
54	64	Hockman, A. and	Biotite				Orthoclase,			Interferometer	250	-0.029	Source: Salisbury, N.C.
		Kessler, D.W.	Granite				Microcline,				262	-0.021	Texture: same as above.
		(1950)					Plagioclase,				268	-0.018	Other: same as above.
							Quartz,				273	-0.016*	
							Biotite	major†			273	-0.014*	
											284	-0.008*	
											284	-0.006*	
											293	0.000*	
											295	0.001*	
											305	0.009	
											315	0.017	
											325	0.024	
											334	0.035	
											339	0.038	
55	64	Hockman, A. and	Biotite				Same as			Interferometer	251	-0.025	Source: Rion, S.C.
		Kessler, D.W.	Granite				above				262	-0.018	Texture: same as above.
		(1950)									267	-0.018	Other: same as above except 0.0066%.
											273	-0.014*	
											273	-0.011*	
											284	-0.005*	
											293	0.000*	
											295	0.001*	
											305	0.008	
											315	0.015	
											325	0.022	
											334	0.030	
											339	0.034	
56	64	Hockman, A. and	Biotite				Orthoclase,			Interferometer	250	-0.020	Source: Stonington, Maine.
		Kessler, D.W.	Granite				Microcline,				262	-0.015	Texture: coarse.
		(1950)					Smoky Quartz,				273	-0.010*	
							Oligoclase,				273	-0.008*	
							Biotite	major†			284	-0.004*	
											293	0.000*	
											294	0.002*	
											305	0.007	
											315	0.013	
											324	0.020	
											333	0.026	
											338	0.031	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
57	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above			Interferometer	250	-0.022	Source: Frankfort, Maine.
											261	-0.016	Texture: medium.
											272	-0.009*	
											284	-0.005*	
											293	0.000*	
											294	0.001*	
											304	0.008	
											314	0.015	
											324	0.023	
											333	0.032	
											338	0.037	
58	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Oligoclase, Biotite	major†		Interferometer	251	-0.029	Source: Newberry, S.C.
											262	-0.017	Texture: fine
											262	-0.014	Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0040%; average of heating and cooling.
											273	-0.012*	
											273	-0.010*	
											284	-0.005*	
											293	0.000*	
											295	0.001*	
											305	0.007	
											315	0.014	
											325	0.022	
											334	0.028	
59	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Quartz, Biotite	major†		Interferometer	251	-0.030	Source: Amberg, Wisconsin.
											262	-0.021*	Texture: medium.
											267	-0.019*	Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0032%.
											273	-0.015*	
											284	-0.006*	
											293	0.000*	
											295	0.002*	
											305	0.010*	
											315	0.018*	
											325	0.026*	
											334	0.034	
											339	0.039	
60	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above			Interferometer	251	-0.031	Source: Isle, Minnesota.
											262	-0.022*	Texture: medium to coarse.
											273	-0.014*	Other: same as above except 0.0034%.
											284	-0.006*	
											293	0.000*	
											295	0.002*	
											305	0.011*	
											315	0.019*	
											325	0.028	
											334	0.039	
61	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Quartz, Biotite, Plagioclase	major†		Interferometer	250	-0.025	Source: Rockville, Minnesota.
											262	-0.019	Texture: coarse.
											268	-0.016	Other: same as above except 0.0022%.
											273	-0.011*	
											284	-0.004*	
											293	0.000*	
											295	0.002*	
											305	0.009	
											315	0.014	
											325	0.022	
											334	0.028	
											339	0.033	

*Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
62	64	Hockman, A. and	Biotite				Orthoclase,			Interferometer	251	-0.019*	Source: Mt. Desert, Maine.
		Kessler, D.W.	Granite				Smoky Quartz,				262	-0.013*	Texture: fine.
		(1950)					Oligoclase,				267	-0.012*	Other: moisture expansion length
							Biotite	major†			273	-0.010*	change due to immersion in water
											273	-0.008*	for 24 hr at 294.7 K is 0.0025%;
											284	-0.006*	average of heating and cooling.
											284	-0.004*	
											293	0.000*	
											295	0.000*	
											305	0.006*	
											315	0.011*	
											324	0.016	
											334	0.023	
63	64	Hockman, A. and	Muscovite-				Microcline,			Interferometer	250	-0.034	Source: Concord, N.H.
		Kessler, D.W.	Biotite				Orthoclase,				262	-0.025	Texture: fine to medium.
		(1950)	Granite				Quartz,				273	-0.015*	Other: specimen dried at 353 K for
							Oligoclase-				284	-0.007*	4 days and coated with synthetic
							Albite,				293	0.000*	water proofing agent; average of
							Muscovite,				294	0.004*	heating and cooling.
							Biotite	major†			304	0.010	
											314	0.019	
											324	0.027	
											333	0.035	
64	64	Hockman, A. and	Muscovite-				Same as			Interferometer	250	-0.033	Source: same as above.
		Kessler, D.W.	Biotite				above				261	-0.024*	Texture: same as above.
		(1950)	Granite								272	-0.015*	Other: heating cycle.
											284	-0.006*	
											293	0.000*	
											294	0.002*	
											304	0.008*	
											314	0.017*	
											323	0.026	
											333	0.035	
65	64	Hockman, A. and	Muscovite-				Same as			Interferometer	333	0.035	Source: same as above.
		Kessler, D.W.	Biotite				above				323	0.026	Texture: same as above.
		(1950)	Granite								314	0.019	Other: cooling cycle.
											304	0.010	
											294	0.001*	
											293	0.000*	
											283	-0.007*	
											273	-0.016*	
											262	-0.023	
66	64	Hockman, A. and	Hornblende,				Orthoclase,			Interferometer	250	-0.020*	Source: Windsor, Vt.
		Kessler, D.W.	Biotite				Smoky Quartz,				261	-0.015*	Texture: same as above.
		(1950)	Granite				Plagioclase,				267	-0.012*	
							Hornblende,				273	-0.009*	
							Biotite	major†			283	-0.004*	
											293	0.000*	
											294	0.001*	
											304	0.007*	
											314	0.012*	
											323	0.018*	
											333	0.024*	
											337	0.027	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
67	64	Hockman, A. and	Riebeckite,				Orthoclase,			Interferometer	250	-0.024	Source: Quincy, Massachusetts.
		Kessler, D.W.	Aerigite				Smoky Quartz,				262	-0.020	Texture: coarse.
		(1950)	Granite				Reibeckite,				273	-0.013*	
							Aerigite,				283	-0.005*	
							Albite	major†			293	0.000*	
											294	0.001*	
											304	0.008	
											314	0.015	
											323	0.022	
											332	0.030	
68	64	Hockman, A. and	Biotite-				Albite,			Interferometer	250	-0.022	Source: Peekskill, N.Y.
		Kessler, D.W.	Muscovite				Oligoclase,				262	-0.016	Texture: medium to fine.
		(1950)	Granite				Quartz,				273	-0.012*	Other: moisture expansion length
							Orthoclase,				273	-0.010*	due to immersion in water for
							Biotite,				284	-0.007*	24 hr at 294.7 K is 0.0052%.
							Muscovite	major†			284	-0.005*	
											293	0.000*	
											294	0.001*	
											304	0.006	
											314	0.012	
											324	0.019	
											333	0.026	
69	64	Hockman, A. and	Biotite				Orthoclase,			Interferometer	251	-0.025	Source: Vinalhaven, Maine.
		Kessler, D.W.	Hornblende				Microcline,				262	-0.018	Texture: fine.
		(1950)	Granite				Smoky Quartz,				267	-0.016	Other: same as above except 0.0036%.
							Oligoclase,				273	-0.011*	
							Biotite,				283	-0.005*	
							Hornblende	major†			293	0.000*	
											294	0.001*	
											304	0.009	
											314	0.016	
											324	0.024	
											333	0.031	
											338	0.035	
70	64	Hockman, A. and	Biotite				Orthoclase,			Interferometer	250	-0.028	Source: Wasau, Wisconsin.
		Kessler, D.W.	Hornblende				Microcline,				262	-0.021*	Texture: medium.
		(1950)	Granite				Plagioclase,				267	-0.018*	Other: same as above except 0.0046%.
							Quartz,				273	-0.013*	
							Hornblende,				284	-0.005*	
							Biotite	major†			293	0.000*	
											295	0.002*	
											305	0.011*	
											315	0.019*	
											324	0.027*	
											333	0.034	
											338	0.039	

*Not shown in figure.
† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
71	64	Hockman, A. and	Biotite-				Microcline,			Interferometer	250	-0.026	Source: Long Cove, Maine.
		Kessler, D.W.	Muscovite				Orthoclase,				262	-0.021	Texture: fine to medium.
		(1950)	Granite				Quartz,				262	-0.019	
							Oligoclase,				273	-0.014*	
							Biotite,				273	-0.010*	
							Muscovite	major†			284	-0.005*	
											293	0.000*	
											294	0.001*	
											305	0.008	
											315	0.015	
											324	0.021	
											333	0.029	
											338	0.032	
72	64	Hockman, A. and	Biotite-				Same as			Interferometer	250	-0.023	Source: North Jay, Maine.
		Kessler, D.W.	Muscovite				above				261	-0.017	Texture: fine.
		(1950)	Granite								273	-0.011*	
											284	-0.006*	
											293	0.000*	
											294	0.002*	
											305	0.008	
											315	0.015	
											324	0.024	
											334	0.032	
73	64	Hockman, A. and	Biotite-				Orthoclase,			Interferometer	250	-0.022	Source: Fitzwilliams, N.H.
		Kessler, D.W.	Muscovite				Microcline,				261	-0.015	Texture: fine.
		(1950)	Granite				Quartz,				272	-0.010*	Other: heating cycle.
							Oligoclase,				284	-0.004*	
							Biotite,				293	0.000*	
							Muscovite	major†			294	0.001*	
											304	0.007	
											314	0.012	
											324	0.019	
											333	0.025	
											338	0.029	
74	64	Hockman, A. and	Biotite-				Same as			Interferometer	338	0.029	Source: same as above.
		Kessler, D.W.	Muscovite				above				314	0.014*	Texture: same as above.
		(1950)	Granite								305	0.008*	Other: cooling cycle.
											294	0.002*	
											293	0.000*	
											284	-0.004*	
											273	-0.010*	
											267	-0.012*	
75	64	Hockman, A. and	Muscovite				Orthoclase,			Interferometer	250	-0.023	Source: Stone Mt., Georgia.
		Kessler, D.W.	Granite				Microcline,				262	-0.016	Texture: medium.
		(1950)					Plagioclase,				267	-0.014	Other: moisture expansion length
							Quartz,				273	-0.010*	due to immersion in water for
							Muscovite,				284	-0.005*	24 hr at 294.7 K is 0.0034%.
							Biotite	major†			293	0.000*	
											294	0.001*	
											305	0.008	
											314	0.015	
											324	0.022	
											333	0.029	

*Not shown in figure.
† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
76	64	Hockman, A. and	Hornblende				Orthoclase,			Interferometer	250	-0.018*	Source: Rockport, Mass.
		Kessler, D. W.	Granite				Microcline,				262	-0.013*	Texture: coarse.
		(1950)					Smoky Quartz,				273	-0.008*	
							Hornblende,				284	-0.004*	
							Plagioclase				293	0.000*	
							(Albite-				294	0.001*	
							Oligoclase)	major†			304	0.007*	
											314	0.012*	
											323	0.018	
											333	0.024	
77	64	Hockman, A. and	Hornblende				Orthoclase,			Interferometer	250	-0.023	Source: Montello, Wisconsin.
		Kessler, D. W.	Granite				Microcline,				262	-0.016	Texture: fine.
		(1950)					Quartz,				273	-0.011*	Other: moisture expansion length
							Hornblende	major†			284	-0.007*	due to immersion in water for
											284	-0.005*	24 hr at 294.7 K is 0.0024%.
											293	0.000*	
											294	0.002*	
											305	0.007	
											315	0.014	
											324	0.021	
											334	0.026	
											338	0.030	
78	64	Hockman, A. and	Olivine				Oligoclase,			Interferometer	251	-0.027	Source: Vinalhavan, Maine.
		Kessler, D. W.	Norite				Microcline,				262	-0.020	Texture: fine.
		(1950)	Granite				Orthoclase,				267	-0.017	Other: same as above except 0.0008%.
							Quartz,				273	-0.014*	
							Biotite,				273	-0.012*	
							Muscovite	major†			284	-0.006*	
											293	0.000*	
											294	0.001*	
											304	0.009	
											314	0.016	
											324	0.025	
											334	0.032	
											336	0.036	
79	64	Hockman, A. and	Quartz				Orthoclase,			Interferometer	251	-0.022*	Source: Waterford, Conn.
		Kessler, D. W.	Monzonite				Plagioclase,				262	-0.016*	Texture: fine.
		(1950)	Granite				Quartz,				273	-0.009*	Other: same as above except 0.0066%.
							Biotite,				284	-0.004*	
							Hornblende	major†			293	0.000*	
											294	0.001*	
											305	0.007*	
											315	0.012*	
											324	0.018*	
											333	0.025*	
											338	0.028	
80	64	Hockman, A. and	Quartz				Soda-lime Feldspars			Interferometer	251	-0.025	Source: Hibbing, Minnesota.
		Kessler, D. W.	Monzonite				(Labradorite to				262	-0.020	Texture: medium.
		(1950)	Granite				Bytownite),				273	-0.012*	Other: same as above except 0.0044%.
							Hypersthene,				284	-0.005*	
							Olivine,				293	0.000*	
							Magnetite	† major			294	0.003*	
											304	0.009	
											314	0.015	
											323	0.022	
											333	0.028	
											337	0.032	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
81	64	Hockman, A. and Kessler, D.W. (1950)	Quartz Monzonite				Orthoclase, Plagioclase, Quartz, Biotite, Hornblende	major†		Interferometer	250	-0.023	Source: Waterford, Connecticut. Texture: fine. Other: specimen dried at 353 K for 4 days and coated with synthetic water proofing agent; average of heating and cooling.
											262	-0.017	
											273	-0.011*	
											284	-0.006*	
											284	-0.004*	
											293	0.000*	
											294	0.002*	
											304	0.008	
											314	0.014	
											324	0.020	
											333	0.027	
82	61	Iskandarov, E. (1968)	Leucocratic Granite							Dilatometer	373	0.057*	Source: Zirabulakskii Mountains. Other: values obtained from the coefficients of thermal linear expansion.
											473	0.128	
											573	0.260	
											673	0.441	
											773	0.656	
83	61	Iskandarov, E. (1968)	Biotite Granite							Dilatometer	373	0.052*	Source: same as above. Other: same as above.
											473	0.118	
											573	0.214	
											673	0.327	
											773	0.463	
84	61	Iskandarov, E. (1968)	Biotite Granite							Dilatometer	373	0.085	Source: Koitashskii Mountains. Other: same as above.
											573	0.298	
											673	0.444	
											773	0.620	
85*	61	Iskandarov, E. (1968)	Pyroxene-Peridotite Granite							Dilatometer	373	0.053*	Other: same as above.
											473	0.118*	
											573	0.204	
											673	0.289	
											773	0.381	

* Not shown in figure.
† In descending order of abundance.

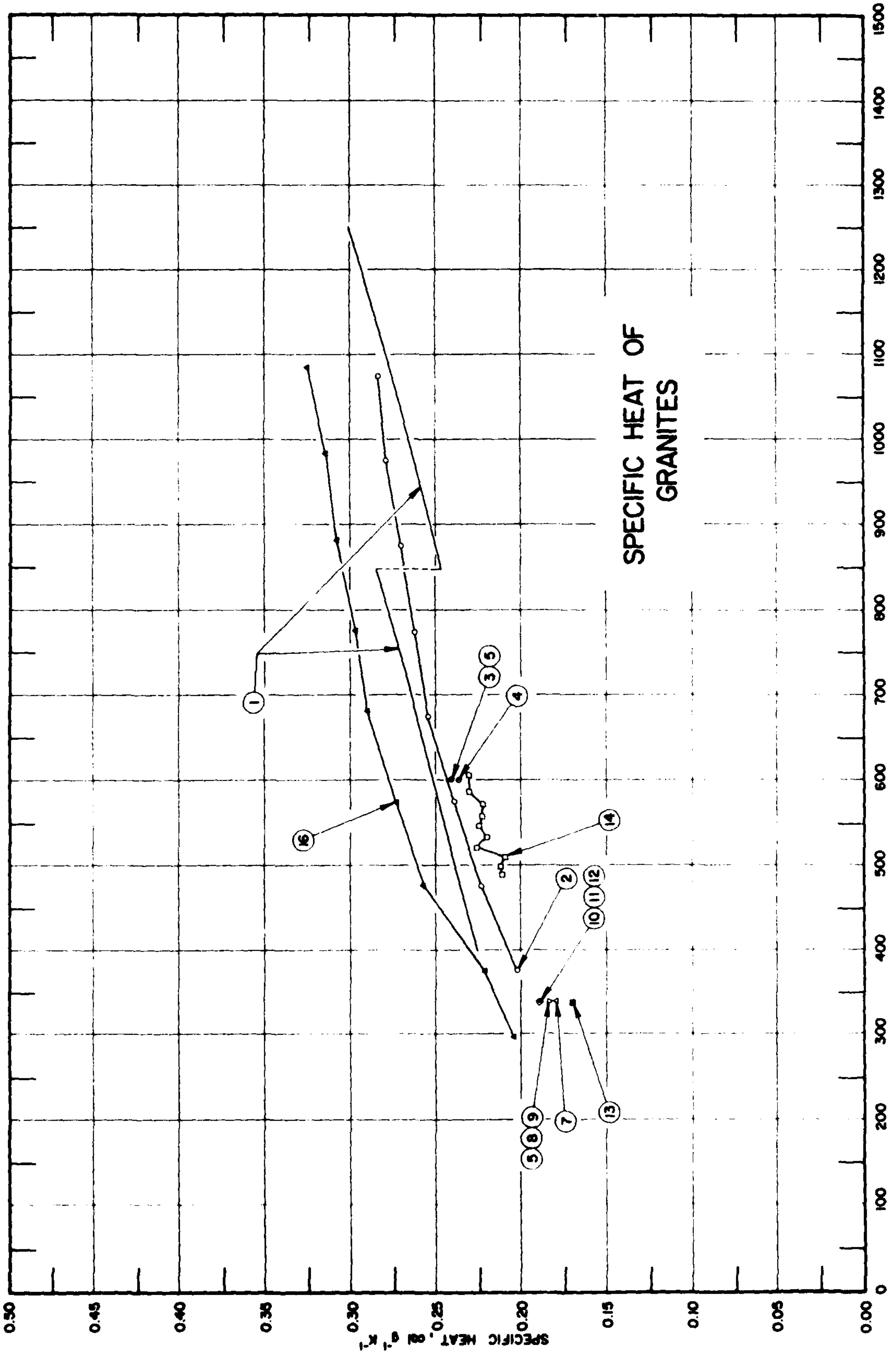

SPECIFIC HEAT OF GRANITES
SPECIFIC HEAT, cal g⁻¹ K⁻¹
TEMPERATURE, K
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1
2
3
4
5
7
8
9
10
11
12
13
14
16

FIGURE 5-C-T

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P.	Rockville		2.66		Microcline		34	Drop Copper	373	0.222	Source: Rockville, Minnesota.
		and	Granite				Quartz		30	Block	400	0.226	Texture: grain size 0.5-10.0 mm.
		Krawza, W.G.	"Quartz				Plagioclase		29		500	0.239	Other: smooth values calculated from
		(1971)	Monzonite"				Biotite		6		600	0.252	equation:
							Hornblende		1		700	0.265	$Cp = 0.209 + 0.131 \times 10^{-3} (T-273)$
											800	0.278	for $373 < T < 848$
							SiO_2	66.26			848	0.285	$Cp = 0.170 + 0.134 \times 10^{-3} (T-273)$
							Al_2O_3	15.62			848	0.247	for $848 < T < 1273$
							K_2O	4.85			900	0.253	derived from heat content data.
							Na_2O	3.51			1000	0.267	
							CaO	2.65			1100	0.280	
							FeO	2.58			1200	0.294	
							Fe_2O_3	1.04			1273	0.303	
2	37	Leodinov, V. Ya.					SiO_2	70.45		Differential	374	0.202	Other: reported error ± 2%.
		(1967)					Al_2O_3	14.41		Thermal	473	0.224	
							FeO	1.70		Analysis	573	0.239	
							Fe_2O_3	0.96			673	0.254	
							TiO_2	0.28			773	0.262	
											873	0.270	
											973	0.278	
											1073	0.284	
3	36	Svikis, V.D.		Block	2.649		Quartz		34	Isothermal	600	0.238	Source: Canada.
		(1962)		3.8 x 3.8			K-Feldspar		31	Water			Texture: hypidiomorphic, medium-grained, homogeneous.
				x 10.2 cm			Na-Feldspar		31	Calorimeter			Other: mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
							Biotite		3				
4	36	Svikis, V.D.	Albite	Same as	2.650		Na-Feldspar		45	Same as	600	0.241	Source: Canada.
		(1962)	Granite	above			Quartz		29	above			Other: average of two runs; mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
							K-Feldspar		21				
							Biotite		3				
							Muscovite		2				
5	36	Svikis, V.D.		Same as	2.660		Quartz		33	Same as	600	0.237	Source: Canada.
		(1962)		above			K-Feldspar		29	above			Texture: hypidiomorphic, medium-grained structure: homogeneous.
							Na-Feldspar		23				Other: mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
							Biotite		10				
6	10	Tadokoro, Y.		Very thin	2.654		SiO_2	69.62		Drop, Iso-	338	0.183	Source: Prov. Nagato (Asia).
		(1921)		plates 0.1-			Al_2O_3	15.37		thermal			Texture: very fine; crystals <0.5 mm.
				0.3 mm			Fe_2O_3	6.55		Water			Other: average Cp by dropping specimen at 373 K in water at 303 K.
				thick			CaO	3.75		Calorimeter			
							MgO	0.87					
							MnO	0.37					

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp (cal g^{-1} K^{-1})	Remarks
7	10	Tadokoro, Y. (1921)		Same as above	2.612		SiO_2 Al_2O_3 FeO CaO MnO Fe_2O_3 MgO	75.08 15.60 2.79 2.30 0.64 0.63 trace		Same as above	338	0.179	Source: Prov. Settu (Asia). Texture: magnetite and apatite present as accessory constituents. Other: average Cp by dropping specimen at 373 K in water at 303 K.
8	10	Tadokoro, Y. (1921)	Biotite Granite	Same as above	2.590		SiO_2 Al_2O_3 MgO FeO CaO Fe_2O_3 MnO	74.96 16.41 3.09 2.28 2.04 0.80 0.23		Same as above	338	0.184	Source: Prov. Yamashiro (Asia). Texture: grains of component minerals ranging between 1.0 and 2.0 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
9	10	Tadokoro, Y. (1921)	Gneiss Granite	Same as above	2.496		SiO_2 Al_2O_3 CaO Fe_2O_3 MnO MgO	75.89 13.86 3.20 1.20 0.57 trace		Same as above	338	0.185	Source: Prov. Yamashiro (Asia). Texture: fine grained (20-0.3 mm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1921)	Hornblende Granite	Same as above	2.541		SiO_2 Al_2O_3 CaO FeO Fe_2O_3 MgO	65.00 16.48 6.14 4.68 4.58 3.09		Same as above	336	0.189	Source: Prov. Mikawa (Asia). Texture: particle size ranges from 5-10 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
11	10	Tadokoro, Y. (1921)	Porphyry Granite	Same as above	2.560		SiO_2 Al_2O_3 CaO Fe_2O_3 MgO MnO	71.20 19.12 3.92 1.54 0.91 0.74		Same as above	338	0.188	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in greyish greencolor groundmass; their size ranging between 10-20 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
12	10	Tadokoro, Y. (1921)	Two Mica Granite	Same as above	2.533		SiO_2 Al_2O_3 Fe_2O_3 CaO MnO	79.62 15.53 1.37 0.93 0.53		Same as above	338	0.189	Source: Mikawa (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K.
13	12	Lorentzen, G. (1964)			1.810					Calorimeter Non-specified	383	0.169	Source: Ekeberg OSIO.
14	6	Poole, H. H. (1914)		Cylinder 15 cm long x 3.6 cm dia	2.625					Indirect	488 498 509 520 531 544 557 571 587 603	0.211 0.212 0.208 0.226 0.220 0.225 0.223 0.222 0.230 0.230	Other: Cp is obtained from thermal conductivity data and unsteady temperature response.

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp (cal g^{-1} K^{-1})	Remarks
15	87	Leodinov, V. Ya. (1965)					Plagioclase		35	Differential Thermal Analysis	293	0.205	Source: natural rock.
							Quartz		25		374	0.224	
							Biotite		5		473	0.258	
											572	0.274	
							SiO_2	70.45			679	0.290	
							Al_2O_3	14.41			783	0.297	
							Na_2O	3.81			881	0.307	
							K_2O	3.35			982	0.314	
							CaO	2.73			1083	0.325	
							FeO	1.70					
							MoO	1.25					
							Fe_2O_3	0.96					
							TiO_2	0.28					
16	88	Noritomi, K. and Nabetani, S. (1956)					SiO_2	73.74		Adiabatic	410	0.173	Source: Tanobata, NE of Iwaizumi Town, Iwate Prefecture, Japan. Other: show anomolies at 523 and 846 K; later one due to quartz inversion; data taken from smooth curve.
							Al_2O_3	10.83			453	0.171	
							Na_2O	3.72			503	0.186	
							K_2O	3.02			535	0.498	
							CaO	2.82			544	0.189	
							Fe_2O_3	2.46			583	0.199	
							FeO	1.50			612	0.218	
							MgO	1.38			672	0.218	
											773	0.240	
							Quartz		34.44		814	0.272	
							Albite		31.44		846	0.496	
							Orthoclase		17.79		849	0.241	
							Diopside		7.88		899	0.257	
							Magnetite		3.71				
							Ilmenite		0.46				
							Hyperstbene		0.30				

C. SELECTED VALUES FOR BARRE AND WESTERLY GRANITES

Thermal Conductivity. Values for Barre and Westerly granites seem to give similar results. Selected values for these granites are based on the data of Navarro and DeWitt [86] and of Birch and Clark [1]. The values for Rockville granite fall within the range of the above granites and moreover all the three types show overall similarity in mineralogical composition. So the selected values beyond the measured temperatures have been based on the values for the Rockville granite. Room-temperature values for several other types of granites are considerably higher.

Thermal Diffusivity. Room-temperature values are reported for other types of granites and none for Barre or Westerly granite.

Thermal Linear Expansion. The values of percent expansion for various types of granites vary from 0.02-0.1 mm near 373 K. Values of Hockman and Kessler [64] for Barre and Westerly granites fall in this range. No selections were made because of the small temperature range covered.

Specific Heat. Reported values for various granites fall within the range of experimental error. No measurement was reported for Barre or Westerly granite.

Selected Values for Barre and Westerly Granites*

Temp. (K)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)
300	2.497
400	2.258
500	2.035
600	1.825
700	1.645
800	1.481
900	1.345
1000	1.252

*No selections were made for other thermophysical properties.

6. GRANODIORITES

A. PETROGRAPHY

Granodiorites, together with granite, constitute the most abundant group of acid to intermediate plutonic igneous rocks. They occur in most of the batholitic masses of the orogenic belts. Granodiorites are generally coarse-grained and are composed of feldspars, plagioclase (andesine, albite), and quartz. The chemical and mineralogical composition of grandoiorite is given below:

Chemical Composition* (After Daly [99])

Oxide	Wt. Percent
SiO_2	65.01
TiO_2	0.57
Al_2O_3	15.94
Fe_2O_3	1.74
FeO	2.65
MnO	0.07
MgO	1.91
CaO	4.42
Na_2O	3.70
K_2O	2.75
H_2O	1.04
P_2O_5	0.20

Mineralogical Composition

Mineral	Vol. Percent
Plagioclase (albite, andesine)	25-45
Quartz	10-35
Orthoclase (and/or microcline)	5-33
Biotite, apatite, ores, etc.	Accessory

Chemically and mineralogically granodiorites are intermediate between granites and diorites.

St. Cloud Granodiorite

Granodiorite from St. Cloud, Minnesota has also been referred to as Charcoal Gray Granite. The mineralogy and texture, given by Woyski [103] and Hasan and West [101] is summarized below:

* Average of 40 analyses.

Mineral Composition

Essential Minerals	Vol. Percent
Plagioclase (oligoclase-andesine)	40
Quartz	25
Orthoclase, microcline, perthite	15

Accessory Minerals	Vol. Percent
Hornblende	10
Biotite	5
Fe-ore	2
Apatite, chlorite, zircon, sphene	3

Texture. Rock is medium-grained with a hypidiomorphic granular texture. Plagioclase occurs as euhedral to subhedral grains, often rectangular in outline. Their grain boundaries are sometimes corroded by quartz and alkali feldspars. Plagioclase grains are 0.3 mm in diameter and 1-5 mm long.

Bates Granodiorite

The mineralogy and texture of granodiorite, from Bates Station, E. of Madera, California, given by Fogelson [98], is summarized below:

Mineral Composition

Essential Minerals	Vol. Percent
Plagioclase (zoned An_{22-50})	40
Quartz	39
Orthoclase	8
Microcline	2

Accessory Minerals	Vol. Percent
Biotite	7
Muscovite	1
Zircon	1
Apatite	1
Ore mineral	1
Sphene	1
Chlorite (secondary)	1
Epidote (secondary)	1

Texture. The rock is medium-grained hypidiomorphic with a poikilitic texture. Myrmekitic intergrowth between quartz and plagioclase crystals are often present.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

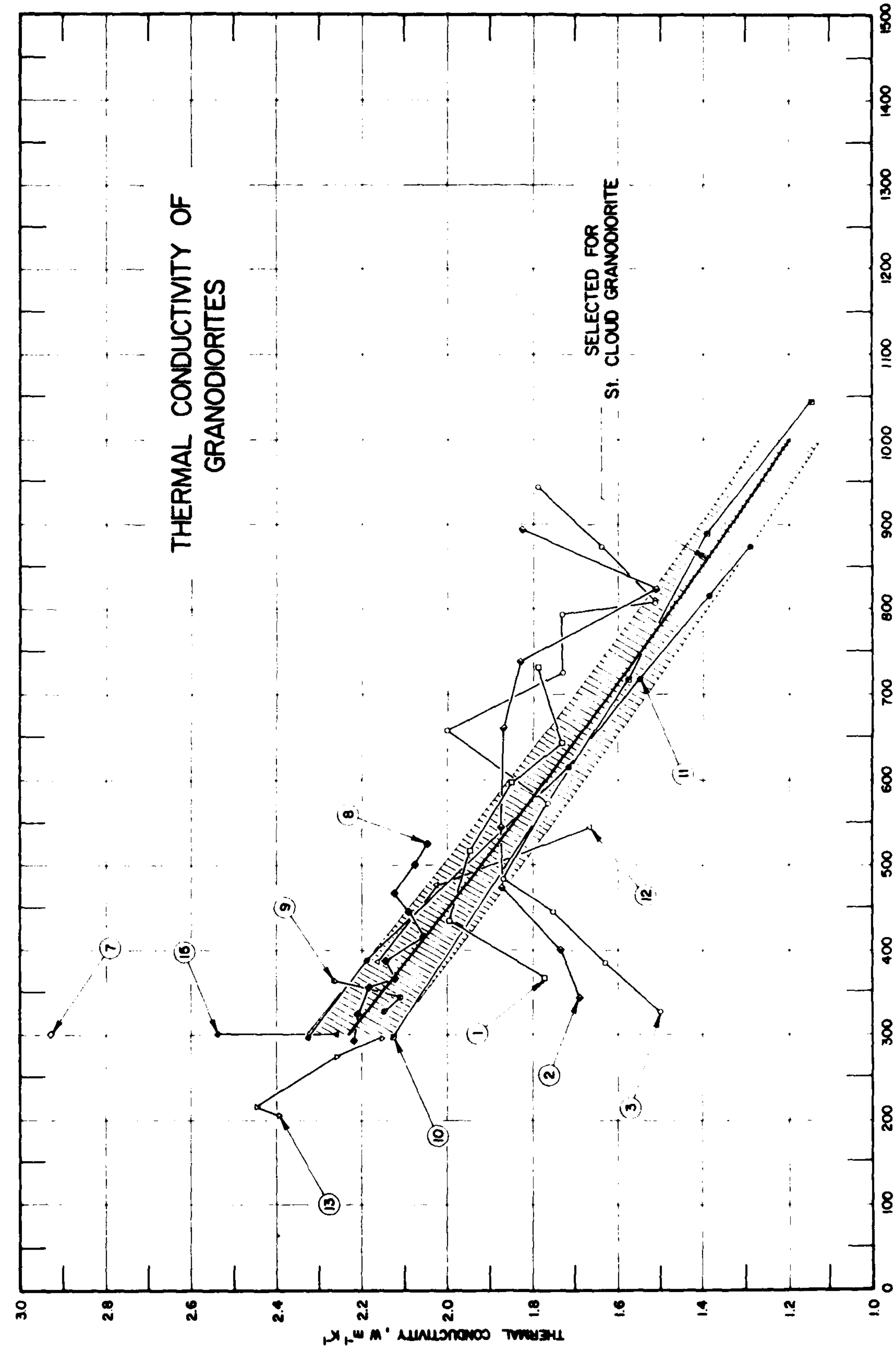

THERMAL CONDUCTIVITY OF
GRANODIORITES
SELECTED FOR
St. CLOUD GRANODIORITE
TEMPERATURE, K
THERMAL CONDUCTIVITY, W m^{-1} K^{-1}

FIGURE 6-K-T

TABLE 6-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
1	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 1	Cylinder (L/D= 5), 45.7 cm length	2.67		Plagioclase Orthoclase Quartz Biotite Other		34 28 27 9 2	Steady Radial Absolute	367 434 519 599 642 730	1.77 1.99 1.94 1.85 1.74 1.79	Source: U15b, exploratory hole, Area 15, at the 1000 ft level. Texture: coarse grained. Other: appearance: gray; reported error ± 5%.
2	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 2	Same as above	2.67		Same as above			Steady Radial Absolute	342 400 473 544 660 736 823 894	1.69 1.74 1.88 1.88 1.87 1.83 1.51 1.83	Source: same as above. Texture: same as above. Other: same as above.
3	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 3	Same as above	2.67		Same as above			Steady Radial Absolute	328 384 445 482 573 656 726 791 809 874 943	1.51 1.64 1.75 1.87 1.76 2.01 1.73 1.73 1.51 1.64 1.79	Source: same as above. Texture: same as above. Other: same as above.
4	46	Beck, A.E. (1956)	Microgranodiorite; Specimen 1	Disk > 3.8 cm dia, 2 mm thick			Plagioclase Quartz Orthoclase Biotite Chlorite Muscovite Epidote Interstitial Sericite, Carbonates, etc.		37.7 32.8 14.7 7.9 5.8 0.8 0.1 0.2	Steady *Longitudinal* Comparative	301	3.18	Source: Snowy Mountain, Australia; Bore Hole 10. Texture: average grain size 0.5 mm with a few grains of quartz and plagioclase as large as 3 mm. Other: value is extrapolated to zero contact resistance.
5	46	Beck, A.E. (1956)	Microgranodiorite; Specimen 2	Disk > 3.8 cm dia, 4 mm thick			Same as above			Same as above	301	3.01	Source: same as above. Texture: same as above. Other: same as above.
6 *	46	Beck, A.E. (1956)	Specimen 3	Disk > 3.8 cm dia, 4.5 mm thick			Same as above			Same as above	301	3.05 *	Source: same as above. Texture: same as above. Other: same as above.
7	46	Beck, A.E. (1956)	Specimen 4	Disk > 3.8 cm dia, 9 mm thick			Same as above			Same as above	301	2.93	Source: same as above. Texture: same as above. Other: same as above.
8	5	Marovelli, R.L. and Veith, K.F. (1964)	Gray Charcoal Granite; St. Cloud Granodiorite: Block A	12.7 cm to 15.2 cm on a side	2.73		Feldspar, Plagioclase (Sodic end) and Microcline Hornblende Quartz Biotite Clays, Zircon, Apatite, Sphene		63 17 16 3 1	Line Heat Source	294 323 356 367 387 416 446 469 500 526	2.23 2.22 2.19 2.12 2.15 2.06 2.09 2.12 2.07 2.04	Source: St. Cloud, Minn. Texture: medium grained. Other: appearance: gray.

TABLE 6-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES (continued)

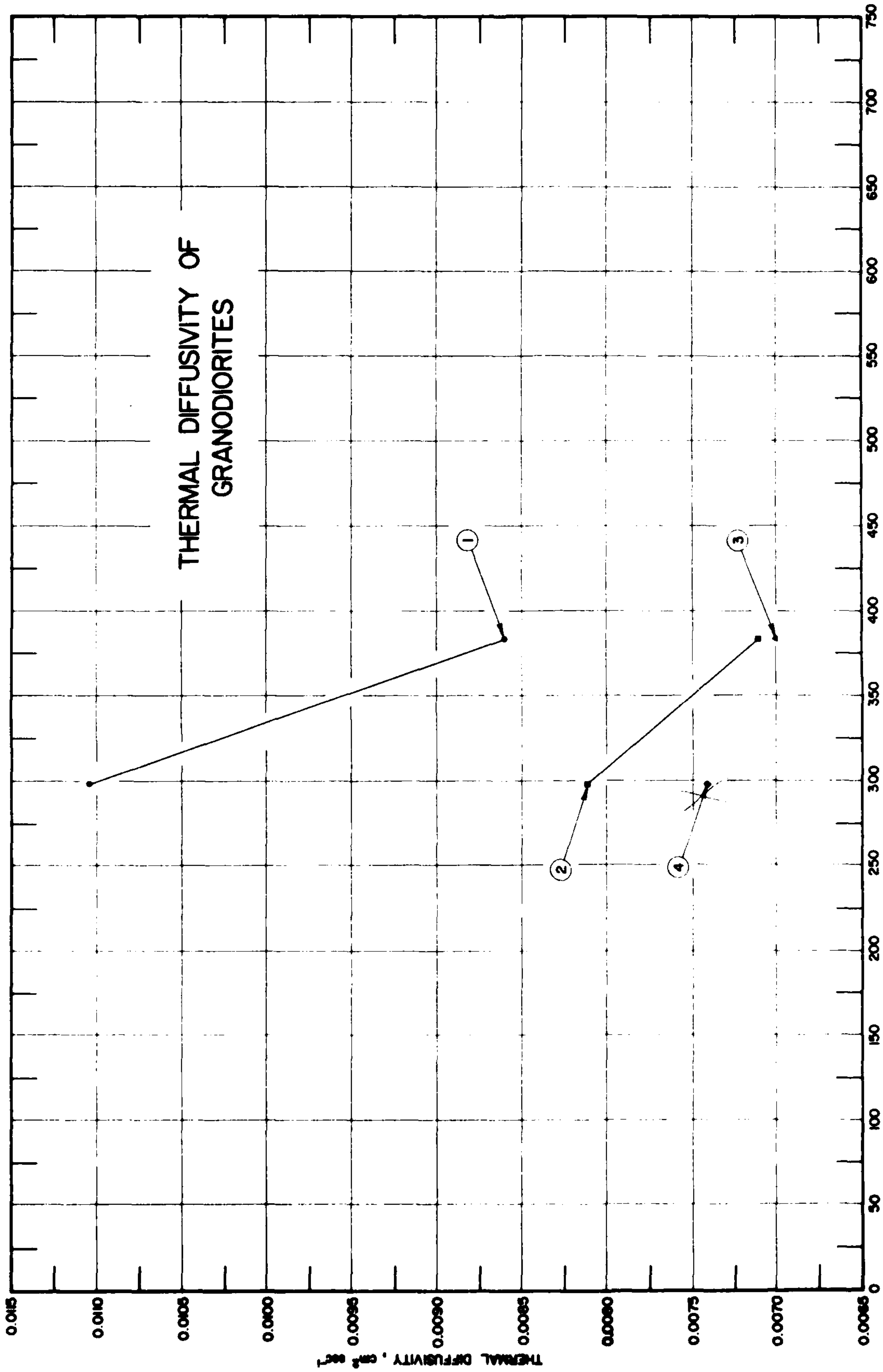
Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
9	5	Marovelli, R. L. and Veith, K. F. (1964)	Same as above: Block B	Same as above	Same as above		Same as above			Same as above	325 341 363	2.15 2.10 2.26	Source: same as above. Texture: same as above. Other: same as above.
10	5	Marovelli, R. L. and Veith, K. F. (1964)	Same as above: Block C	Same as above	Same as above		Same as above			Same as above	297 718 891 1146	2.12 1.57 1.39 1.14	Source: same as above. Texture: same as above. Other: same as above.
11	5	Marovelli, R. L. and Veith, K. F. (1964)	Same as above: Block D	Same as above	Same as above		Same as above			Same as above	297 388 613 717 818 872	2.32 2.19 1.72 1.54 1.39 1.28	Source: same as above. Texture: same as above. Other: same as above.
12	5	Marovelli, R. L. and Veith, K. F. (1964)	Same as above: Block E	Same as above	Same as above		Same as above			Same as above	385 476 544	2.16 2.02 1.66	Source: same as above. Texture: same as above. Other: same as above.
13	5	Marovelli, R. L. and Veith, K. F. (1964)	Same as above: Block F	Same as above	Same as above		Same as above			Same as above	206 216 273 296	2.39 2.45 2.26 2.16	Source: same as above. Texture: same as above. Other: same as above.
14*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.5 mm thick						Steady Longitudinal Comparative	301 301	3.81 3.68	Source: Australia Bore Hole 13, Snowy Mountains (depth 17 ft) Texture: average grain size 0-5 mm; subgneissic structure. Other: values are extrapolated to zero contact resistance.
15*	86	Navarro, R.A. and DeWitt, D. P. (1974)	St. Cloud Granodiorite							Non-Steady Line Heat Source	300 300	2.54 2.26	Source: St. Cloud, Minnesota. Other: contact agent: mercury and silicon grease; reported error ± 5% and ± 6% respectively.
16	102	Johnson, S. A. (1974)			2.58	1				Steady Longitudinal Comparative	293	2.44	Source: Bates Station, E. of Madera, California. Texture: crystalline. Other: dry sample.
17	102	Johnson, S. A. (1974)			2.58	1				Same as above	293	2.90	Source: same as above. Texture: same as above. Other: sample saturated with water.
18*	73	Sass, H.J. (1964)		Disk 3.5 cm dia, 6 mm thick			Feldspar (mostly plagioclase) Quartz Mica (mostly biotite)		58 29 13	Steady Longitudinal Comparative	301	3.2	Source: Bonnievale, Coolgardie, Australia; Bore hole BV-1. Texture: average grain size 1.5 to 2 mm. Other: average of six specimens; measured at 0.987 atm pressure; reported error ± 1.4%.
19*	75	Horai, K.I. and Baldridge, S. (1972)			2.626	1.9				Non-Steady Line Heat Source	296	3.49	Source: Tripyramid Mountain, New Hampshire. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: reported error ± 5%.

*Not shown in figure.

TABLE 6-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T,K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
20*	75	Horai, K.I. and Baldridge, S. (1972)		Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.577	1.9				Steady Longitudinal Comparative	296	3.30	Source: same as above. Other: reported error ± 5%.

* Not shown in figure.



THERMAL DIFFUSIVITY OF GRANODIORITES
1
2
3
4
TEMPERATURE, K
THERMAL DIFFUSIVITY, cm² sec⁻¹
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
0.015
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065

FIGURE 6-D-T

TABLE 6-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2\ s^{-1}$)	Remarks
1	42	Lindroth, D. P. (1974)		Disk 19.05 mm dia, 4 mm thick			SiO_2	70.0		Flash Method	298	0.0110	Source: Bate Station, E. of Madera, California.
							Al_2O_3	16.0			383	0.00860	Test Environment: nitrogen at 760 torr pressure.
							Na_2O	4.4					Other: reported error ± 5%.
							CaO	3.2					
							K_2O	2.2					
							FeO	2.1					
							MgO	0.64					
							H_2O+	0.47					
							TiO_2	0.34					
							H_2O-	0.2					
							P_2O_5	0.1					
							Fe_2O_3	0.07					
							MnO	0.04					
							CO_2	0.05					
2	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	298	0.00811	Source: same as above.
											383	0.00710	Test Environment: nitrogen at 1.0×10^{-4} torr pressure. Other: same as above.
3	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	383	0.00700	Source: same as above. Test Environment: nitrogen at 5.0×10^{-7} torr pressure. Other: same as above.
4	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	298	0.00766	Source: same as above. Test Environment: nitrogen at 7.0×10^{-4} torr pressure. Other: same as above.

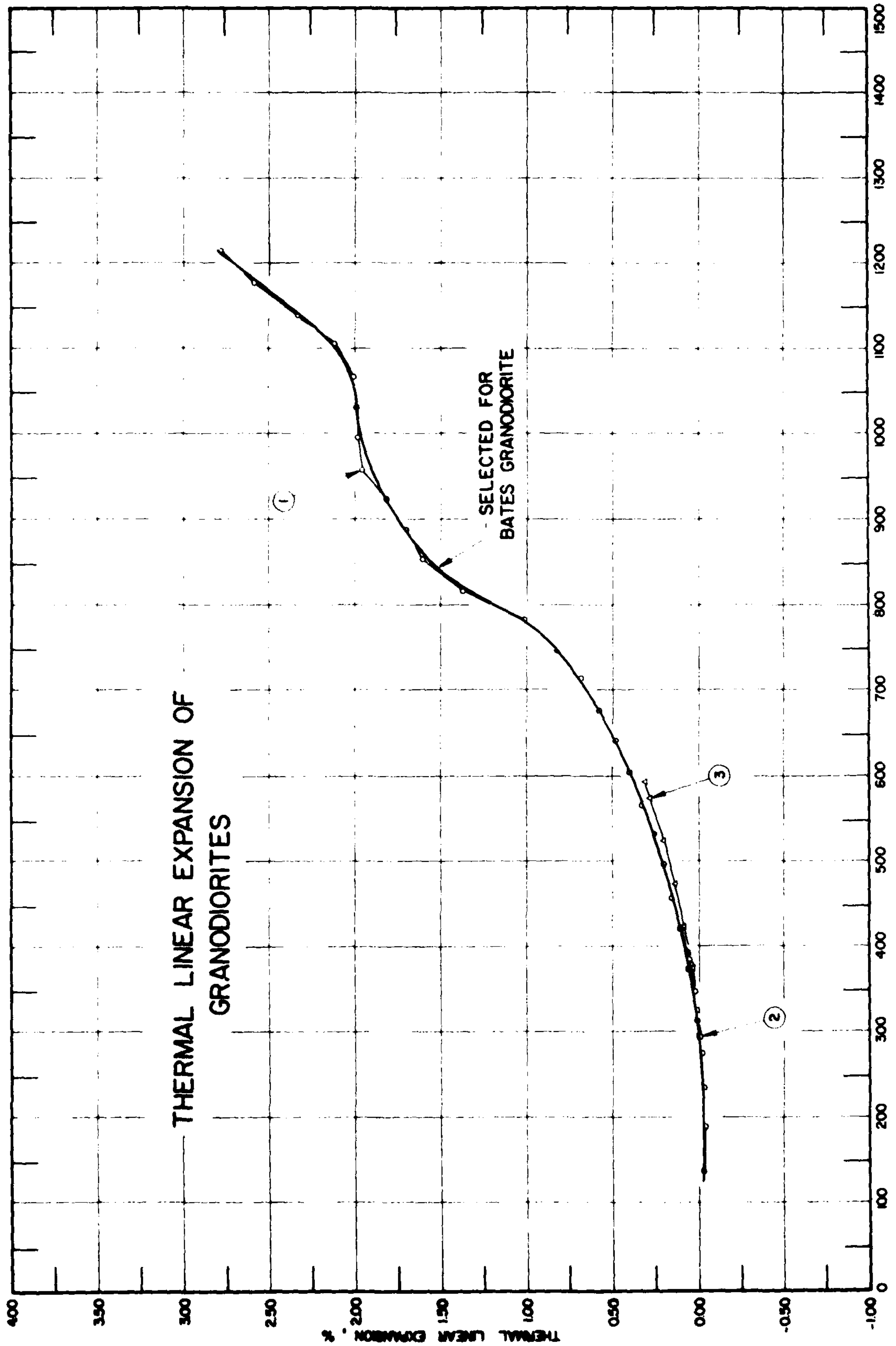

THERMAL LINEAR EXPANSION OF
GRANODIORITES
SELECTED FOR
BATES GRANODIORITE
1
2
3
THERMAL LINEAR EXPANSION, %
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
TEMPERATURE, K
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

FIGURE 6-E-T

TABLE 6-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.			2.58	1	Plagioclase		40	Dilatometer	136	-0.021	Source: Bates Station, E. of
		and Demou, S.G.					Quartz		39		189	-0.029	Madera, Calif.
		(1972)					Orthoclase		8		233	-0.021	Powder Density: 1.45 g cm^{-3}.
							Biotite		7		273	-0.013	Magnetic Susceptibility: 30 x 10^{6}
							Microcline		2		311	0.011	cgs units.
							Zircon		1		346	0.031	Dielectric Constant: 2.53 (ratio).
							Apatite		1		383	0.067	Specific Area: 0.6 m^2 g^{-1}.
											420	0.111	Other: zero-point correction is
							SiO_2	70			458	0.163	0.011%.
							Al_2O_3	16			495	0.215	
							Na_2O	4.4			531	0.271	
							CaO	3.2			568	0.335	
							K_2O	2.2			604	0.407	
							FeO	2.1			640	0.487	
							H_2O	0.67			676	0.583	
							MgO	0.64			711	0.691	
											746	0.835	
											781	1.023	
											817	1.379	
											852	1.611	
											887	1.707	
											922	1.833	
											958	1.963	
											994	1.991	
											1030	1.999	
											1066	2.015	
											1103	2.127	
											1139	2.347	
											1177	2.595	
											1214	2.799	
2	32	Griffith, J. H.								Dilatometer	293	0.000	Source: St. Cloud, Minn.
		(1937)									373	0.060	
3	63	Thirumalai, K.					Plagioclase		40		293	0.000*	Other: measurements in 10^{-5} torr
		and Demou, S.G.					Quartz		40		323	0.016	pressure.
		(1970)									373	0.048	
											423	0.088	
											473	0.143	
											523	0.206	
											573	0.283	
											591	0.311	
4*	63	Thirumalai, K.					Plagioclase		40		293	0.000	Other: measurements in nitrogen
		and Demou, S.G.					Quartz		40		323	0.016	atmosphere.
		(1970)									373	0.048	
											423	0.088	
											473	0.147	
											523	0.219	
											573	0.291	
											595	0.324	

* Not shown in figure.

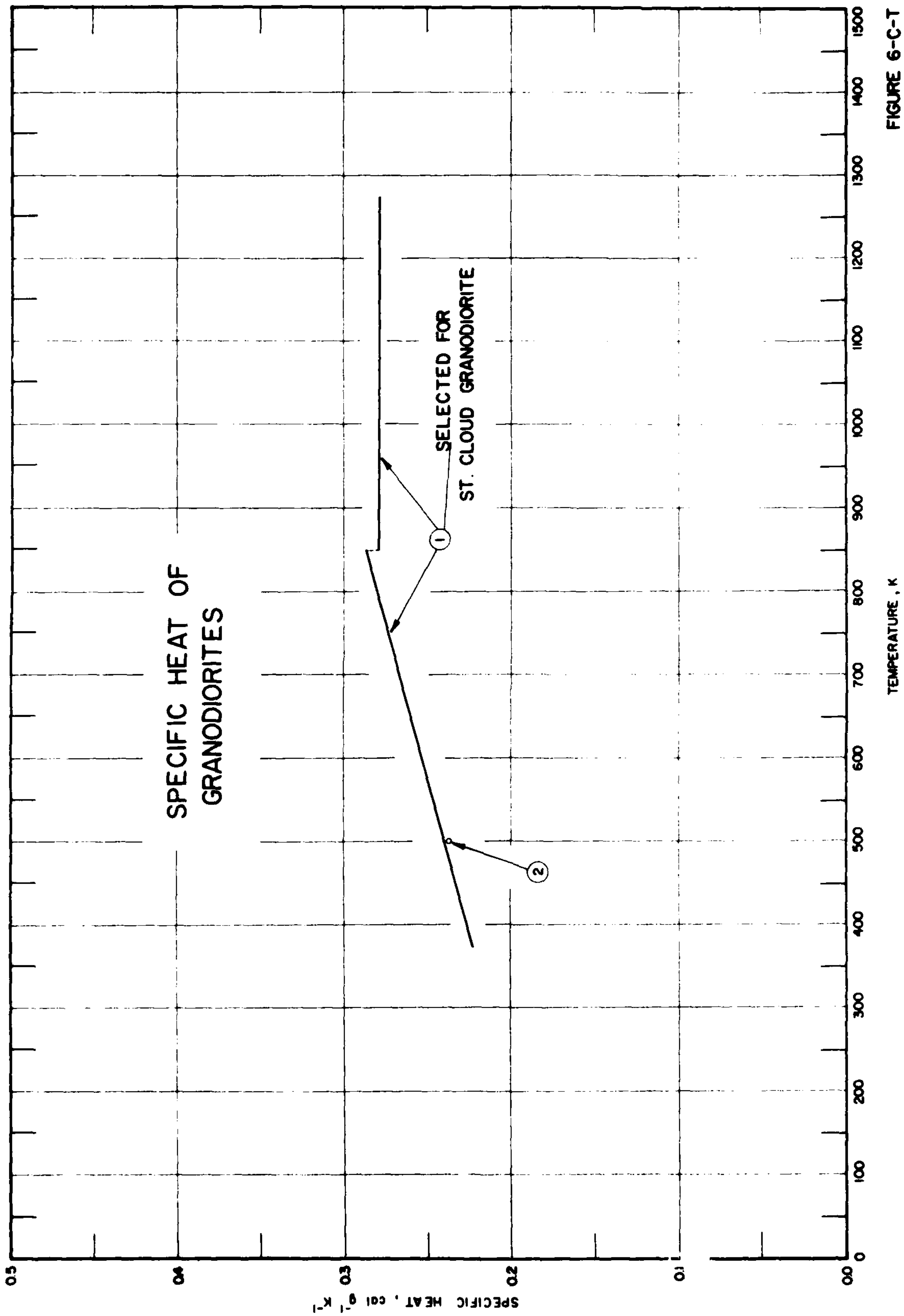

SPECIFIC HEAT OF GRANODIORITES
SELECTED FOR ST. CLOUD GRANODIORITE
1
2
TEMPERATURE , K
SPECIFIC HEAT , cal g⁻¹ K⁻¹
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
0.0 0.1 0.2 0.3 0.4 0.5

FIGURE 6-C-T

TABLE 6-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P. and Krawza, W.G. (1971)	Charcoal Gray Granite; "St. Cloud Granodiorite"		2.729		Microcline		46	Drop	370	0.223	Source: St. Cloud, Minn.
							Plagioclase		24	Copper	400	0.227	Texture: grain size 0.1-3.0 mm.
							Quartz		17	Block	500	0.241	Other: smooth values calculated from
							Biotite-				600	0.254	equation:
							Chlorite		9		700	0.268	$Cp = 0.210 + 0.136 \times 10^{-3} (T-273)$
							SiO_2	63.48			800	0.282	for $373<T<848$
							Al_2O_3	15.62			848	0.288	$Cp = 0.280$
							CaO	4.15			848	0.280	for $848<T<1273$
							K_2O	3.59			900	0.280	derived from heat content data;
							Na_2O	3.58			1000	0.280	transition near 848 K.
							FeO	2.70			1100	0.280	
							MgO	2.23			1200	0.280	
							Fe_2O_3	1.85			1273	0.280	
2	36	Svikis, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm size	2.766		Ca-Felspar		51	Isothermal Water Calorimeter	~500	0.237	Source: Canada.
							Quartz		21				Texture: hypidiomorphic and medium-grained in texture; homogenous structure.
							Hornblende		12				Other: mean Cp between 698 K, temp to which specimen is heated and 300 K, final temp of bath.
							Biotite		9				
							K-Felspar		4				
							Epidote, Sphene		3				

C. SELECTED VALUES FOR ST. CLOUD AND BATES GRANODIORITES

Thermal Conductivity. Selected values for St. Cloud granodiorite are based on the data of Navarro and DeWitt [86] and of Marovelli and Veith [5]. Results of Johnson [102] at 293 K on granodiorite from Bates Station indicate a slight increase in the value when saturated with water. No selection for Bates granodiorite was made.

Thermal Diffusivity. Data of Lindroth [42] on granodiorites from Bates Station indicate a slight dependence of thermal diffusivity on the environmental pressure. No selections were made due to insufficient data.

Thermal Linear Expansion. Selected values for granodiorite from Bates Station are based on the data of Griffin and Demou [41] and indicate a distinct anomaly near 848 K where the α-β quartz transition occurs. Results of Thirumalai and Demou [63] indicate that the thermal linear expansion is independent of environmental pressure. No measurement was found for St. Cloud granodiorite.

Specific Heat. Selected values for St. Cloud granodiorite are from the heat content studies of Lindroth and Krawza [35] and indicate an anomaly near 848 K where the α-β quartz transition occurs. No measurement was reported in the literature for other granodiorite.

Selected Values for St. Cloud and Bates Granodiorite*

	St. Cloud Granodiorite		Bates Granodiorite
Temp. (K)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Specific Heat ($cal\ g^{-1}\ K^{-1}$)	Thermal Linear Expansion $\Delta L/L_0$, (%)
150			-0.024
200			-0.022
293			0.000
300	2.227		0.002
400	2.075	0.227	0.085
500	1.920	0.241	0.225
600	1.768	0.254	0.385
700	1.619	0.268	0.650
800	1.475	0.282	1.175
900	1.330	0.280	1.753
1000	1.199	0.280	1.972
1100		0.280	2.125
1200			2.715

*No selections were made for other thermophysical properties.

7. LIMESTONES

A. PETROGRAPHIC

Limestones are calcareous sedimentary rocks composed of more than 50 percent carbonates, of which calcite ($CaCO_3$) is the principal constituent. Limestones are formed by several possible modes of deposition - mechanical, chemical, organic, and metasomatic. Accordingly, they vary widely in texture and mineral composition.

Bedford (Salem) Limestone Analysis

Chemical Composition (After Lindroth and Krawza [35])

Oxide	Wt. Percent
SiO_2	0.34
TiO_2	0.01
Al_2O_3	<0.06
Fe_2O_3	0.11
FeO	0.03
MnO	<0.05
MgO	0.56
CaO	55.02
Na_2O	0.03
K_2O	0.02
CO_2	42.75
H_2O	0.01
P_2O_5	0.004
S	0.062

Mineralogical Composition (After Hasan and West [101])

Mineral	Vol. Percent
Calcite (oolitic)	36
Calcite (recrystallized)	62
Voids	1-2

Texture. The calcite is clastic and shows oolitic texture; fossil shell fragments are commonly present. The oolites have a dirty appearance which is due to the presence of some clay minerals. Secondary calcite is fresh and clear. The original oolites are cemented by fine-grained calcite. The oolites are 0.4 mm in diameter and the recrystallized calcite is 0.32 mm on an average; voids are generally less than 0.05 mm.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

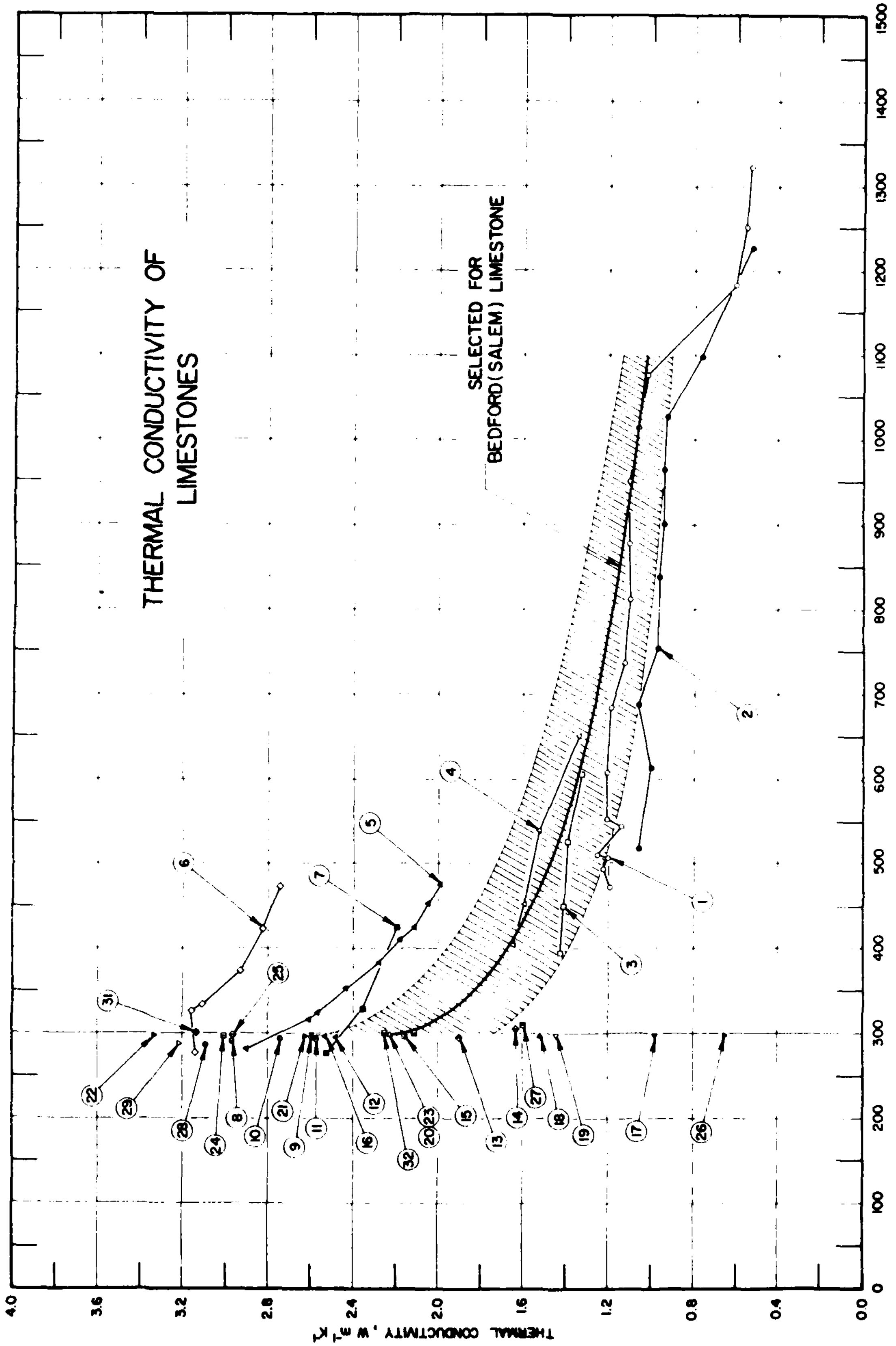

THERMAL CONDUCTIVITY OF LIMESTONES
SELECTED FOR BEDFORD (SALEM) LIMESTONE
THERMAL CONDUCTIVITY, W m^{-1} K^{-1}
TEMPERATURE, K

FIGURE 7-K-T

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	7	Stephens, D.R. (1963)	Indiana Limestone	Cylinder 9.1 cm dia x 45.7 cm length	2.30		Calcite Quartz Hematite		98.4 1.0 0.6	Steady Radial Absolute	472 492 508 510 544 551 608 682 736 811 878 950 1012 1076 1181 1251 1322	1.19 1.23 1.20 1.26 1.14 1.20 1.20 1.19 1.12 1.10 1.10 1.10 1.07 1.03 0.606 0.560 0.531	Source: Indiana. Texture: fine grained. Other: tan in color; reported error ± 6%.
2	7	Stephens, D.R. (1963)	Indiana Limestone	Same as above	2.30		Calcite Quartz Hematite		98.4 1.0 0.6	Steady Radial Absolute	519 612 687 753 839 900 964 1027 1099 1227	1.05 1.00 1.06 0.970 0.966 0.937 0.941 0.924 0.765 0.523	Source: same as above. Texture: same as above. Other: same as above.
3	8	Niven, C.D. (1940)	Bluish-Grey Limestone	Disk 20.3 cm dia x 2.5 cm thick	2.67		$MgCO_3$	22		Steady Longitudinal Absolute	396 450 528 605	1.43 1.41 1.40 1.33	Source: Queenston, Ontario. Other: the sample is a mixture of dolomite and calcite.
4	8	Niven, C.D. (1940)	Buff Limestone	Same as above	2.56		$MgCO_3$	30		Steady Longitudinal Absolute	392 403 452 540 650	1.41** 1.64 1.60 1.53 1.34	Source: Longford Mills, Ontario. Texture: coarse grained. Other: the sample is a mixture of dolomite and calcite.
5	1	Birch, F. and Clark, H. (1940)		Disk 6 mm high x 3.8 cm dia	2.605					Steady Longitudinal Absolute	281 316 324 353 382 410 425 451 476	2.90 2.61 2.57 2.44 2.28 2.18 2.12 2.05 1.99	Source: Solenhofen Bavaria. Texture: mean crystal diameter 0.001-0.01 mm. Other: values are extrapolated to zero porosity.
6	1	Birch, F. and Clark, H. (1940)		Same as above	2.688					Steady Longitudinal Absolute	276 325 332 372 422 472	3.15 3.16 3.11 2.93 2.82 2.75	Source: Nazareth, Pennsylvania. Direction of Measurements: parallel to bedding. Other: values are extrapolated to zero porosity.
7	1	Birch, F. and Clark, H. (1940)		Same as above	2.688					Steady Longitudinal Absolute	277 329 425	2.53 2.36 2.20	Source: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

** Value obtained after exposure to high temperature test.

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
8	14	Misener, A.D., Thompson, L.G.D., and Uffen, R.J. (1951)		Disk	2.71					Steady Longitudinal Absolute	289	2.97	Source: C.N.E. Oil Well, Toronto, Ontario (depth 990 ft).
9	14	Misener, A.D., et al. (1951)		Disk	2.71					Steady Longitudinal Absolute	293	2.60	Source: same as above except depth 890 ft.
10	14	Misener, A.D., et al. (1951)		Disk	2.72					Steady Longitudinal Absolute	292	2.75	Source: same as above except depth 796 ft.
11	14	Misener, A.D., et al. (1951)		Disk	2.70					Steady Longitudinal Absolute	291	2.58	Source: same as above except depth 794 ft.
12	14	Misener, A.D., et al. (1951)		Disk	2.67					Steady Longitudinal Absolute	296	2.48	Source: same as above except depth 575 ft.
13	14	Misener, A.D., et al. (1951)		Disk	2.68					Steady Longitudinal Absolute	294	1.90	Source: same as above except depth 568 ft.
14	11	Mossahebi, M. (1966)		Cylinder						Unsteady Ring Heat Source	303	1.63	Other: reported error <6%.
15	10	Tadokoro, Y. (1921)			2.672		$CaCO_3$ SiO_2 Fe_2O_3 Al_2O_3	97.21 1.30 1.00 0.66		Indirect	298	2.15	Source: Prov. Awa (Asia). Texture: fine grained (0.01 mm) except in vein portions (0.3 to 1.5 mm); color light gray with white veins ranging in diverse direction; very compact, no trace of bedding plane; honey comb structure is observed. Other: data is obtained from measurements of diffusivity, specific heat and density.
16	10	Tadokoro, Y. (1921)			2.655		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Indirect	298	2.54	Source: Prov. Chikuzen (Asia). Other: same as above.
17	10	Tadokoro, Y. (1921)	Coral Limestone		2.212		$CaCO_3$ SiO_2 Fe_2O_3 MnO	97.43 1.09 0.88 trace		Indirect	298	0.878	Source: Bonins Island (Asia). Texture: color white, porous structure but not uniform throughout the test piece. Other: same as above.
18	10	Tadokoro, Y. (1921)	Gritty Limestone		2.456		$CaCO_3$ SiO_2 Al_2O_3 Fe_2O_3 FeO MnO	53.96 30.92 9.58 3.54 1.33 0.23		Indirect	298	1.52	Source: Prov. Bonins Island (Asia). Texture: compact and homogeneous with no trace of bedding plane; essentially composed of fine grain calcite and angular fragments (0.3-0.1 mm in size) of acid plagioclase. Other: color light gray; data is obtained from measurements of diffusivity, specific heat and density.

TABLE 7-K-T. TEMPERATURE DEPENDENCEOF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
19	10	Tadokoro, Y. (1921)	Ogasawara Limestone		2.155		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Indirect	298	1.45	Source: Bonins Island (Asia). Texture: fine grain (0.01 to 0.005 mm); structure somewhat porous. Other: color white with light pink tone; data is obtained from measurements of diffusivity, specific heat and density.
20	10	Tadokoro, Y. (1921)	Oolitic Limestone		2.610		$CaCO_3$ Al_2O_3 SiO_2 Fe_2O_3	94.98 3.79 1.84 0.27		Indirect	298	2.23	Source: Prov. Musashi (Asia). Texture: oolitic structure distinctly observed; bedding plane indiscernible, calcite vein with average thickness of 10 mm transverse; calcite aggregates range in diameter between 2.5 and 0.3 mm. Other: light buff grey in color; data is obtained from measurements of diffusivity, specific heat and density.
21	10	Tadokoro, Y. (1921)	Tanba Limestone		2.628		$CaCO_3$ SiO_2 Al_2O_3 Fe_2O_3	74.65 23.08 0.18 0.082		Indirect	298	2.23	Source: Prov. Tanba (Asia). Texture: compact and fine in texture; white colored calcite veins of less fine texture and 0.5-3.0 mm thickness traverse the test piece in various directions; size of individual grains ranging mostly between 0.1-0.01 mm except in vein portions where crystals of 0.5 mm are not rare. Other: color dark grey; data is obtained from measurements of diffusivity, specific heat and density.
22	18	Benfield, A.E. (1939)	Impure Shelly Limestone	Disk 2.5 cm dia x 0.1-1.4 cm long	2.70					Steady Longitudinal Comparative	298	2.63	Source: Hankham, depth 572 ft. Other: reported error ± 8.9%.
23	18	Benfield, A.E. (1939)	Same as above	Same as above	2.63					Steady Longitudinal Comparative	298	3.32	Source: Hankham, depth 582 ft. Other: reported error ± 5.9%.
24	19	Mongelli, F. (1969)	Dolomite Grey-Nut Brown Limestone	Cylinder with length >8 cm	2.7					Indirect	298	3.01	Source: Bari, Italy. Texture: compact and fine grained. Other: age: middle Cretaceous; thermal contact was improved.
25	19	Mongelli, F. (1969)	Organogen Limestone	Same as above	2.6					Indirect	298	2.97	Source: Carpino (Foggia), Italy. Texture: subcrystalline. Other: rose white color; age: Jurassic; thermal contact was improved.
26	20	Thomson, W.T. (1940)	Fossiliferous Limestone		2.74					Indirect	310.94	0.68	Source: Riley County, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity.

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m^{-1} K^{-1})	
27	23	Thomson, W.T. (1940)			2.60					Indirect	311	1.60	Source: Ohio. Other: conductivity is obtained by knowing specific heat and thermal diffusivity; reported error ± 10%.
28	13	Lorentzen, G. (1966)	Specimen 1aA	Flat Surface						Thermal Comparator	289	3.10	Source: Norway.
29	13	Lorentzen, G. (1966)	Specimen 1bA	Flat Surface						Thermal Comparator	289	3.22	Source: Norway.
30	13	Lorentzen, G. (1966)	Specimen 3bA	Flat Surface						Thermal Comparator	289	4.42	Source: Norway.
31	12	Lorentzen, G. (1964)		Block 40 cm dia x 25 cm thick	2.576					Non-Steady Line Heat Source	300	3.14	Source: Brevik (Scandinavia).
32	86	Navarro, R.A. and DeWitt, D.P. (1974)	Salem Limestone							Non-Steady Line Heat Source	300 300	2.15 2.25	Source: Bedford, Indiana. Other: contact agent: mercury; bore diameter 3.2 and 6.5 mm; reported error ± 3% and ± 1% respectively.

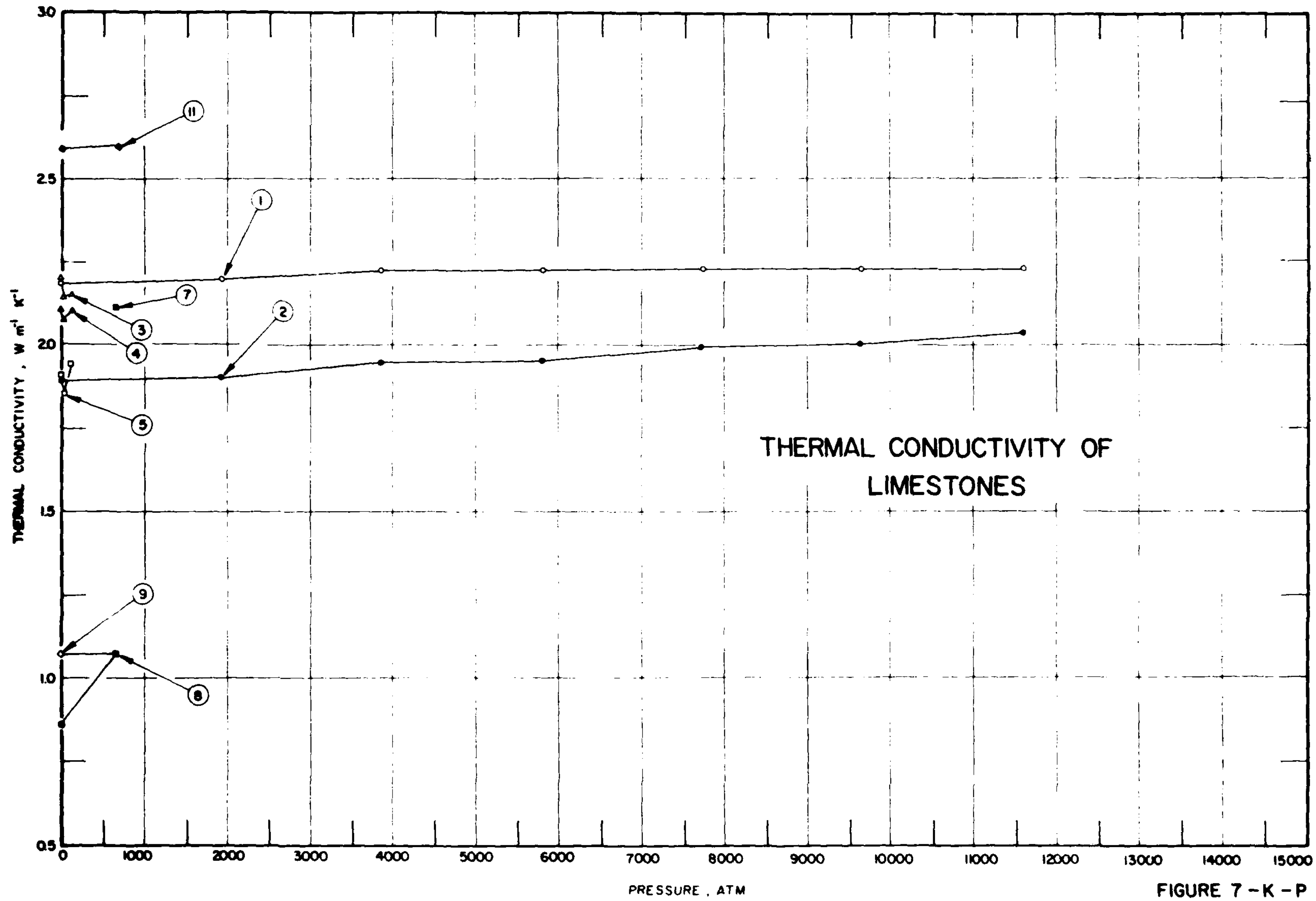

THERMAL CONDUCTIVITY OF LIMESTONES
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
PRESSURE, ATM
3.0
2.5
2.0
1.5
1.0
0.5
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
1
2
3
4
5
7
8
9
11

FIGURE 7-K-P

TABLE 7-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
1	24	Bridgman, P.W. (1924)	Solenhofen Limestone	Cylinder 1.27 cm O.D., 1.02 cm I.D., 2.5 cm long	2.602		Nearly pure $CaCO_3$			Steady Radial Absolute	0 1935 3871 5807 7742 9678 11614	2.19 2.19 2.20 2.20 2.20 2.21 2.21	Temperature of Measurements: 303.15 K. Other: sample was subjected to hydrostatic pressure in a petroleum ether environment.
2	24	Bridgman, P.W. (1924)	Solenhofen Limestone	Same as above	2.602		Nearly pure $CaCO_3$			Same as above	0 1935 3871 5807 7742 9678 11614	1.89 1.91 1.94 1.96 1.99 2.01 2.03	Temperature of Measurements: 348.15 K. Other: sample was subjected to hydrostatic pressure in a kerosene environment.
3	28	Khan, A.M. and Fatt, I. (1964)	Solenhofen Limestone	Cylinder 3 cm dia, 1.9 cm long						Steady Longitudinal Absolute	0 28 42 56 84 110	2.20 2.14 2.17* 2.20* 2.19* 2.17	Temperature of Measurements: 306.15 K. Other: sample was subjected to axial pressure in an air environment.
4	28	Khan, A.M. and Fatt, I. (1964)	Solenhofen Limestone	Same as above						Same as above	0 28 42 56 84 109	2.11 2.07 2.10* 2.11* 2.13* 2.11	Temperature of Measurements: 319.15 K. Other: sample was subjected to axial pressure in an air environment.
5	28	Khan, A.M. and Fatt, I. (1964)	Solenhofen Limestone	Same as above						Same as above	0 27 42 56 84 109	1.91 1.86 1.87* 1.91* 1.89* 1.94	Temperature of Measurements: 337.15 K. Other: sample was subjected to axial pressure in an air environment.
6*	16	Clark, H. (1941)	Bedford Limestone	Disks 3.8 cm dia, 0.65 cm high	2.31	13.2				Same as above	1 680	1.84 1.97	Source: Bedford, Indiana. Temperature of Measurements: 318 K. Other: values for density and porosity are for the specimen before compression.
7	16	Clark, H. (1941)	Bedford Limestone	Same as above	2.31	13.2				Same as above	1 680	2.10* 2.12	Source: same as above. Temperature of Measurements: 318 K. Other: values for density and porosity correspond to the uncompressed dry specimen.
8	16	Clark, H. (1941)	Bermuda Limestone	Same as above	1.55	43.0				Same as above	1 680	0.88 1.07	Source: Bermuda. Temperature of Measurements: 318 K. Other: density and porosity values refer to the uncompressed specimen.

*Not shown in figure.

TABLE 7-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		P, atm	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	
9	16	Clark, H. (1941)	Bermuda Limestone	Same as above	1.55	43.0				Same as above	1 680	1.075 1.075*	Source: Bermuda. Temperature of Measurements: 318 K. Other: values for porosity and density refer to the dry uncompressed specimen; water saturated specimen.
10*	16	Clark, H. (1941)	Solenhofen Limestone	Same as above	2.60	3.4				Same as above	1 680	2.104 2.589	Source: Solenhofen. Temperature of Measurements: 318 K. Other: values listed for density and porosity were obtained before compression.
11	16	Clark, H. (1941)	Solenhofen Limestone	Same as above	2.60	3.4				Same as above	1 680	2.589 2.589	Source: same as above. Temperature of Measurements: 318 K. Other: the values listed for density and porosity correspond for the dry specimen before compressing it; water saturated specimen.

*Not shown in figure.

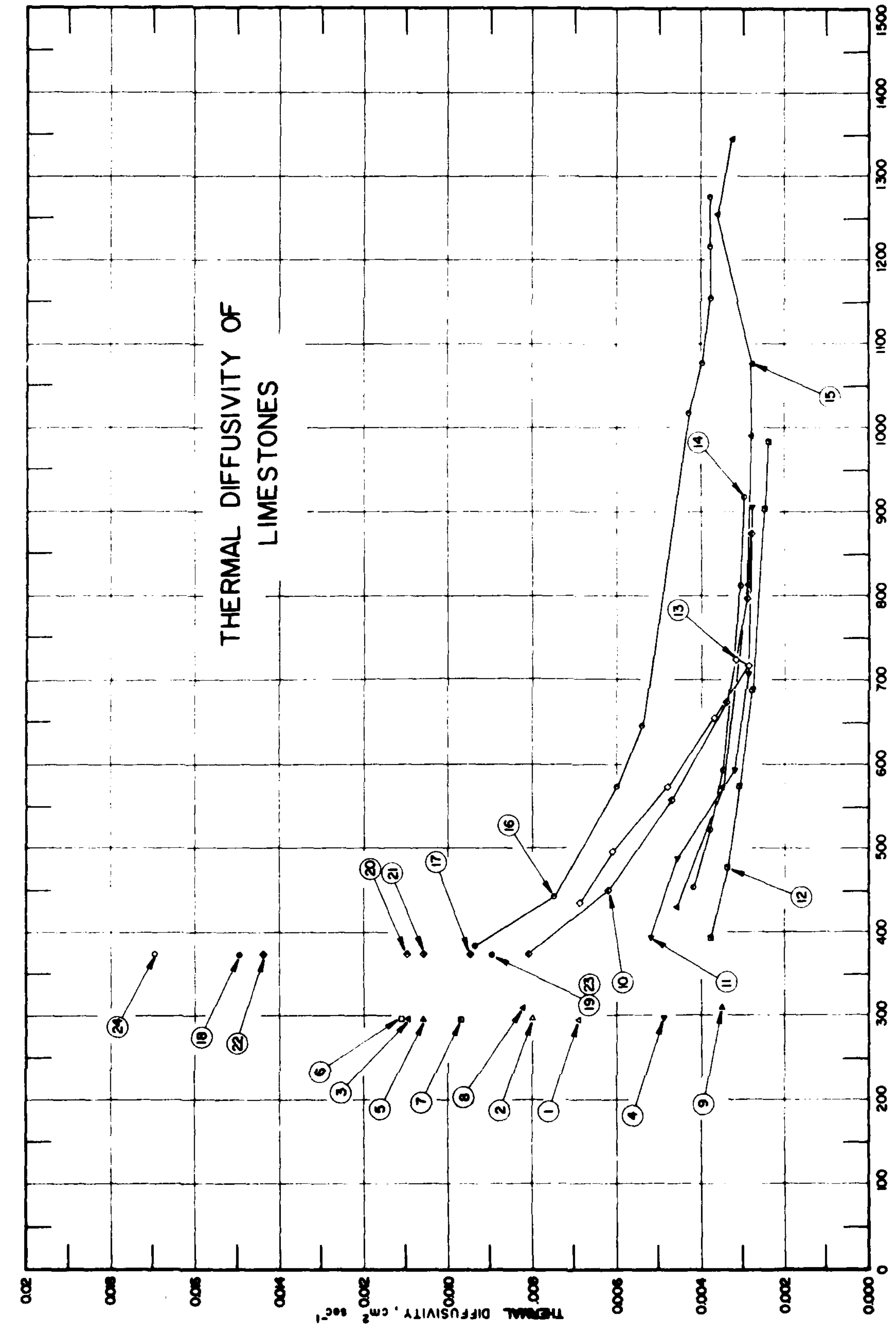

THERMAL DIFFUSIVITY OF LIMESTONES
TEMPERATURE, K
THERMAL DIFFUSIVITY, cm² sec⁻¹
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0.018
0.02

FIGURE 7-D-T

TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($cm^2\ s^{-1}$)	
1	10	Tadokoro, Y. (1921)	Gritty Limestone	Cube 60 cm by side	2.456		$CaCO_3$ SiO_2 Al_2O_3 Fe_2O_3 FeO MnO	53.96 30.92 9.58 3.54 1.33 0.23			~298	0.0069	Source: Prov. Boniss Island. Texture: light grey colored, compact and homogeneous with no trace of bedding plane, essentially composed of fine grain calcite and angular fragments (0.3-0.1 mm in size) of acid plagioclase.
2	10	Tadokoro, Y. (1921)	Ogasawara Limestone	Same as above	2.155		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Periodic	~298	0.0080	Source: Boniss Island (Asia). Texture: color white with light pink tone, structure somewhat porous, very fine texture (0.01-0.005 mm).
3	10	Tadokoro, Y. (1921)	Oolitic Limestone	Same as above	2.610		$CaCO_3$ Al_2O_3 SiO_2 Fe_2O_3	94.98 3.79 1.84 0.27		Periodic	~298	0.0110	Source: Prov. Musashi (Asia). Texture: light buff grey in color and oolitic structure distinctly observed; bedding plane indiscernible; calcite vein with average thickness of 10 mm traverse the test piece parallel to one set of the cubical boundary planes; calcite aggregates range in diameter between 2.5 and 0.3 mm.
4	10	Tadokoro, Y. (1921)	Coral Limestone	Same as above	2.212		$CaCO_3$ SiO_2 Fe_2O_3 MnO	97.43 1.09 0.88 trace		Periodic	~298	0.0049	Source: Boniss Island (Asia). Texture: color white, porous structure but not uniform throughout the test piece.
5	10	Tadokoro, Y. (1921)		Same as above	2.672		$CaCO_3$ SiO_2 Fe_2O_3 Al_2O_3	97.21 1.30 1.00 0.66		Periodic	~298	0.0106	Source: Prov. Awa (Asia). Texture: color light grey with white veins ranging in diverse direction; very compact, no trace of bedding plane; very fine texture (0.01 mm) except in vein portions where it is coarser (0.3-1.5 mm), honey comb structure is observed.
6	10	Tadokoro, Y. (1921)		Same as above	2.655		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Periodic	~298	0.0117	Source: Prov. Chikuzen (Asia).
7	12	Lorentzen, G. (1964)			2.576					Indirect	296	0.0097	Source: Brevik (Scandinavia).
8	23	Thomson, W.T. (1940)		Cylinder 2.54 cm dia x 20.3 cm long	2.60					Radial Heat Flow	310.9	0.0082	Source: Ohio. Other: the specimen was heated to about 180 F and then cooled to room temp. by blowing air with a fan; thermal diffusivity was calculated for a section of this transient state; reported error ± 10%.

TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm^2 s^{-1})	Remarks
9	23	Thomson, W.T. (1940)		Cylinder 2.54 cm dia x 20.3 cm long	2.74					Radial Heat Flow	310.9	0.0035	Source: Riley County, Kansas. Other: the specimen was heated to approx. 330 K and then cooled to room temp. by blowing air with a fan; thermal diffusivity was calculated for a section of *this transient state.*
10	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 1	Cylinder 3.37 cm dia x 5.72 cm long	2.21	18.6	CaO CO_2 MgO SiO_2 Al_2O_3 Fe_2O_3	55.19 43.77 0.45 0.30 0.07 0.03		Transient Radial	373.7 450.4 559.3 671.5 798.7 873.7	0.0081 0.0062 0.0047 0.0034 0.0029 0.0028	Direction of Measurements: parallel to bedding planes. Other: reported error ± 8%.
11	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 1	Same as above	2.21	18.6	Same as above			Transient Radial	391.5 486.5 593.2 705.9 905.4	0.0052 0.0046 0.0032 0.0029 0.0028	Direction of Measurements: same as above. Other: same as above.
12	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 1	Same as above	2.21	18.6	Same as above			Transient Radial	391.5 477.6 575.9 689.8 903.7 982.6	0.0038 0.0034 0.0031 0.0028 0.0025 0.0024	Direction of Measurements: same as above. Other: same as above.
13	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	435.4 498.7 571.5 653.7 718.7 722.6	0.0069 0.0061 0.0048 0.0037 0.0029 0.0032	Direction of Measurements: same as above. Other: same as above.
14	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	454.3 521.5 594.3 812.0 919.3	0.0042 0.0038 0.0035 0.0031 0.0030	Direction of Measurements: same as above. Other: same as above.
15	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	430.4 572.0 813.7 990.4 1078.7 1258.7 1345.4	0.0046 0.0035 0.0029 0.0028 0.0028 0.0036 0.0033	Direction of Measurements: same as above. Other: same as above.
16	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	384.8 442.6 574.3 645.4 1019.8 1079.3 1157.6 1217.6 1278.7	0.0094 0.0075 0.0060 0.0054 0.0043 0.0040 0.0038 0.0038 0.0038	Direction of Measurements: same as above. Other: same as above.
17	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	3.77					Transient Radial	372	0.0095	Source: Joint Highway Research Project Code No. 47-2S. Other: dry specimen.

TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm^2 s^{-1})	Remarks
18	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	3.77					Transient Radial	372	0.015	Source: same as above. Other: water saturated specimen.
19	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.77					Transient Radial	372	0.0090	Source: Joint Highway Research Project Code No. 67-2S. Other: dry specimen.
20	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.77					Transient Radial	372	0.011	Source: same as above. Other: water saturated specimen.
21	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.87					Transient Radial	372	0.0106	Source: Joint Highway Research Project Code No. 1-1S. Other: dry specimen.
22	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.87					Transient Radial	372	0.0144	Source: same as above. Other: water saturated specimen.
23	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.87					Transient Radial	372	0.0090	Source: Joint Highway Research Project Code No. 9-1S. Other: dry specimen.
24	92	Fox, R.G., Jr. and Dolch, W.L. (1951)		Sphere 3.8 cm dia	2.87					Transient Radial	372	0.0170	Source: same as above. Other: water saturated specimen.

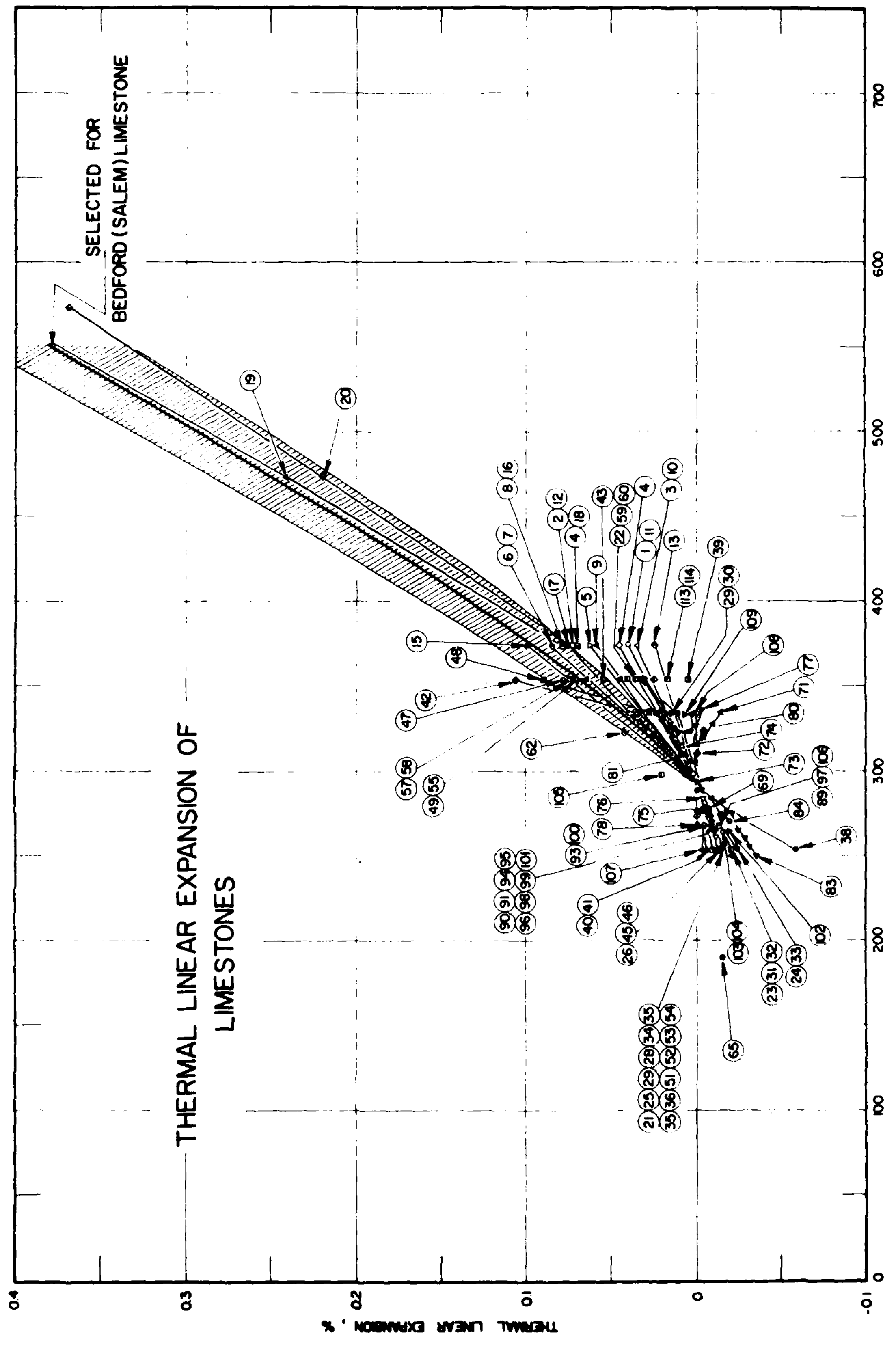

THERMAL LINEAR EXPANSION OF LIMESTONES
SELECTED FOR BEDFORD (SALEM) LIMESTONE
TEMPERATURE, K
THERMAL LINEAR EXPANSION, %
0.4
0.3
0.2
0.1
0
-0.1
0
100
200
300
400
500
600
700

FIGURE 7-E-T

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	32	Griffith, J.H. (1937)	Crystalline Limestone		2.68	1.2				Dilatometer	298 373	0.002 0.039	Source: Rutland, Va.
2	32	Griffith, J.H. (1937)	Argillaceous Limestone		2.80	2.2				Dilatometer	298 373	0.005 0.073	Source: Rochester, N. Y.
3	32	Griffith, J.H. (1937)	Pale Gray Limestone		2.66	4.4				Dilatometer	298 373	0.002* 0.035	Source: Concrete, Colo.
4	32	Griffith, J.H. (1937)	Oolitic Limestone		2.66	1.8				Dilatometer	298 373	0.003* 0.045	Source: Batesville, Ark.
5	32	Griffith, J.H. (1937)	Oolitic Limestone		2.66	13.7				Dilatometer	298 373	0.004* 0.062	Source: Bedford, Ind.
6	32	Griffith, J.H. (1937)	Dolomitic Limestone		2.74	0.3				Dilatometer	298 373	0.005* 0.084	Source: Gouverneur, N. Y.
7	32	Griffith, J.H. (1937)	Dolomitic Limestone		2.76	4.0				Dilatometer	298 373	0.005* 0.084	Source: Rochester, N. Y.
8	32	Griffith, J.H. (1937)	Birdseye Limestone		2.12	0.7				Dilatometer	298 373	0.003* 0.053	Source: Watertown, N. Y.
9	32	Griffith, J.H. (1937)								Dilatometer	298 373	0.004* 0.058	Source: Boulder County, Colo.; Hardness: Shore No. 56.5.
10	32	Griffith, J.H. (1937)								Dilatometer	298 373	0.002* 0.034	Source: Onondaga County, N. Y.; Hardness: Shore No. 64.2.
11	32	Griffith, J.H. (1937)	Coral Limestone		2.70	1.4				Dilatometer	298 373	0.003* 0.040	Source: LeRoy, N. Y.; Hardness: Shore No. 58.5.
12	32	Griffith, J.H. (1937)	Coral Limestone		2.68	0.8				Dilatometer	298 373	0.004* 0.071	Source: Jeffersonville, Ind.
13	32	Griffith, J.H. (1937)	Gray Limestone		2.71	0.7				Dilatometer	298 373	0.002* 0.024	Source: Valcour Island, N. Y.
14	32	Griffith, J.H. (1937)	Gray Limestone		2.70	0.7				Dilatometer	298 373	0.004* 0.069	Source: Ruth, Nevada
15	32	Griffith, J.H. (1937)	Encrinal Limestone		2.71	1.9				Dilatometer	298 373	0.006* 0.098	Source: Lockport, N. Y.
16	32	Griffith, J.H. (1937)	Encrinal Limestone		2.70	1.3				Dilatometer	298 373	0.005* 0.081	Source: Trenton Falls, N. Y.
17	32	Griffith, J.H. (1937)	Breccia Limestone		2.8	18.8				Dilatometer	298 373	0.005* 0.075	Source: Boulder County, Colo.; Hardness: 27.3 shore units
18	32	Griffith, J.H. (1937)	Argillaceous Limestone							Dilatometer	298 373	0.004* 0.068	Source: Portageville, N. Y.
19	33	Souder, W.H. and Hidnert, P. (1919)	Indiana Limestone	Rod of uniform cross section						Dilatometer	298 373 473 573	0.004* 0.072* 0.242 0.462*	Other: heating test.
20	33	Souder, W.H. and Hidnert, P. (1919)	Indiana Limestone	Rod of uniform cross section						Dilatometer	573 473 373 298	0.370 0.220 0.080* 0.005*	Other: cooling test.

*Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
21	43	Harvey, R. D. (1967)	Livingston Formation Limestone	Cylinder 2.54 cm dia x 10.2 cm length			Calcite Quartz, Clay Dolomite	98.4 1.7 N. D.		Dilatometer	253 293 333 353	-0.015 0.000 0.017 0.030	Source: Fairmont Quarry, Illinois. Texture: median grain size 0.01 mm; psuedobreccia texture; microfossiliferous showing patchy network of sparry calcite mosaic set in very fine-grained calcite; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: rate of heating 0.10 to 0.11 F/minute.
22	43	Harvey, R. D. (1967)	Kinkaid Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	97.0 3.0 N. D.		Dilatometer	253 293 333 353	-0.016* 0.000* 0.017* 0.035	Source: Buncombe Quarry, Illinois. Texture: median grain size 0.01 mm; microfossiliferous with scattered coarse grained crinoid fragments; sample free of joints and other obvious imperfections. Direction of Measurements: same as above. Other: same as above.
23	43	Harvey, R. D. (1967)	Same as above	Same as above			Calcite Quartz, Clay Dolomite	77.9 13.1 9		Dilatometer	253 293 333 353	-0.021 0.000* 0.023 0.040	Source: same as above. Texture: median grain size 0.01 mm; microfossils and fossil fragments occur in thin laminations; sample free of joints and other obvious imperfections. Direction of Measurements: same as above. Other: same as above.
24	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.023 0.000* 0.025* 0.044	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
25	43	Harvey, R. D. (1967)	St. Louis Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	96.1 3.9 N. D.		Dilatometer	253 293 333 353	-0.017 0.000* 0.018 0.031	Source: Alton Quarry, Illinois. Texture: median grain size 0.003 mm; equant granular limestone; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
26	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.013 0.000* 0.016* 0.026	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
27	43	Harvey, R. D. (1967)	Omega Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	98.4 1.6 N. D.		Dilatometer	253 293 333 353	-0.015 0.000* 0.016 0.028	Source: Omega Quarry, Illinois. Texture: median grain size 0.010 mm; rock shows fine-grained texture with scattered sparry calcite fossil fragments; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
28	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000* 0.016 0.028	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
29	43	Harvey, R. D. (1967)	St. Genevieve Formation; Fredonia Member	Same as above			Calcite Quartz, Clay Dolomite	98.5 1.5 N. D.		Dilatometer	253 293 333 353	-0.013* 0.000* 0.014 0.027*	Source: Anna Quarry, Illinois. Texture: median grain size 0.010 mm; medium- to coarse-grained calcite surrounded by very fine-grained calcite, cemented by sparry calcite; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
30	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.012* 0.000* 0.013 0.030*	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
31	43	Harvey, R. D. (1967)	Nachusa Formation "Dolomitic" Limestone	Same as above			Calcite Dolomite Quartz, Clay	55 35.3 9.7		Dilatometer	253 293 333 353	-0.019 0.000* 0.021 0.040	Source: Polo Quarry (lowest 5 ft), Illinois. Texture: median grain size 0.06 mm; interlayered with medium-grained mosaic, globular structure; gray; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
32	43	Harvey, R. D. (1967)	Quimbys Mill Formation "Dolomitic" Limestone	Same as above			Calcite Dolomite Quartz, Clay	60 35.3 2.7		Dilatometer	253 293 333 353	-0.021 0.000* 0.022 0.038	Source: Lowell, Illinois. Texture: median grain size 0.010 mm; interbedded fine-grained calcite and medium-grained dolomite mosaic, dense; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
33	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.023 0.000* 0.025* 0.043	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
34	43	Harvey, R. D. (1967)	Salem Formation Rocher Member	Same as above			Calcite Quartz, Clay Dolomite	98.1 1.9 N. D.		Dilatometer	253 293 333 353	-0.013 0.000 0.015 0.030	Source: Prairie du Rocher Quarry, Illinois. Texture: median grain size 0.030 mm; fossil fragments cemented by sparry calcite with few large crinoidal grains; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
35	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.028	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
36	43	Harvey, R. D. (1967)	Salem Formation Kidd Member	Same as above			Calcite Quartz, Clay Dolomite	97.8 2.2 N. D.		Dilatometer	253 293 333 353	-0.016 0.006 0.017 0.027	Source: same as above. Texture: median grain size 0.04 mm mm; fossiliferous limestone cemented with sparry calcite; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
37	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.029	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
38	43	Harvey, R. D. (1967)	Ullin Formation; Harrodsburg Member	Same as above			Calcite Dolomite Quartz, Clay	95.0 4 0.6		Dilatometer	253 293 333 353	-0.058 0.000* 0.011 0.033	Source: Mill Creek Quarry, Ill. Texture: median grain size 0.06 mm; finely crystalline crinoidal and bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
39	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.009 0.000* 0.016* 0.005	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
40	43	Harvey, R. D. (1967)	Burlington Formation; Quincy Bed Member	Same as above			Calcite Dolomite Quartz, Clay	95.6 3 1.4		Dilatometer	253 293 333 353	-0.006 0.000* 0.016* 0.064	Source: Quincy Quarry, Illinois. Texture: coarse grained; crinoidal fragments with secondary overgrowths and very fine-grained bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
41	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.007 0.000* 0.017* 0.063	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
42	43	Harvey, R. D. (1967)	Burlington Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	83.7 13 3.3		Dilatometer	253 293 333 353	-0.017* 0.000* 0.034 0.106	Source: Monmouth Quarry (upper level), Illinois. Texture: median grain size 0.54 mm; crinoidal, with recrystallized microspar matrix; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
43	43	Harvey, R. D. (1967)	Kimmswick Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	95.7 3 1.3		Dilatometer	253 293 333 353	-0.011* 0.000* 0.019* 0.057	Source: Thebes, Illinois. Texture: median grain size 0.52 mm; coarse-grained mosaic of unequant particles and scattered patches of fine-grained microspar and fossil fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
44*	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.016 0.000 0.025 0.066	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
45	43	Harvey, R. D. (1967)	Wapsipinicon Formation; Davenport Member	Same as above			Calcite Quartz, Clay Dolomite	99.0 1.0 N. D.		Dilatometer	253 293 333 353	-0.015 0.000* 0.016* 0.025	Source: Milan Quarry, Illinois. Texture: median grain size 0.005 mm; very fine-grained and equant granular limestone; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
46	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000* 0.015* 0.024	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
47	43	Harvey, R. D. (1967)	Kimmswick Formation, "Gray" Limestone	Same as above			Calcite Dolomite Quartz, Clay	86.2 12 1.8		Dilatometer	253 293 333 353	-0.004* 0.000* 0.019* 0.077	Source: Valmeyer Quarry, Illinois. Texture: median grain size 0.22 mm; coarse grained; mosaic of partly recrystallized crinoidal fragments and few finely recrystallized bryozoans; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
48	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.012* 0.000* 0.027 0.089	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
49	43	Harvey, R. D. (1967)	Kimmswick Formation "Buff" Limestone	Same as above			Calcite Dolomite Quartz, Clay	96.0 3 1.0		Dilatometer	253 293 333 353	-0.012* 0.000* 0.023* 0.070	Source: same as above. Texture: median grain size 0.22 mm; mosaic of partly recrystallized crinoid fragments with some fine grained bryozoan fragments and microspar; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
50*	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.011 0.000 0.024 0.080	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
51	43	Harvey, R. D. (1967)	Girardeau Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	86.6 10 3.4		Dilatometer	253 293 333 353	-0.016 0.000 0.017 0.030	Source: Thebes, Illinois. Texture: median grain size 0.008 mm; very fine-grained and equant grains with scattered fine crystalline grains; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
52	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.016 0.000 0.017 0.030	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
53	43	Harvey, R. D. (1967)	St. Clair Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	97.4 2.6 N.D.		Dilatometer	253 293 333 353	-0.015 0.000 0.016 0.030	Source: Gale Quarry, Illinois. Texture: median grain size 0.007 mm; few scattered medium-grained fossil fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
54	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.031	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
55	43	Harvey, R. D. (1967)	Moccasin Springs Formation; "Reef" Limestone	Same as above			Calcite Dolomite Quartz, Clay	96.7 2 1.3		Dilatometer	253 293 333 353	-0.008* 0.000* 0.019* 0.068	Source: Baldwin, Illinois, drill core from 1600 ft depth. Texture: median grain size 0.81 mm; coarse-grained crystalline mosaic of unequant calcite particles; specimen free of joints and other obvious imperfections. Direction of Measurements: perpendicular to bedding. Other: same as above.
56*	43	Harvey, R. D. (1967)	Lower Devonian Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	93.2 3.8 3		Dilatometer	253 293 333 353	-0.019 0.000 0.026 0.064	Source: Phillipstown, Illinois, drill core from 5464 ft depth. Texture: median grain size 0.62 mm; coarse-grained crinoidal, unequant mosaic with few laminations of finer particles; specimen free of joints and other obvious imperfections. Direction of Measurements: perpendicular to bedding. Other: same as above.
57	43	Harvey, R. D. (1967)	Burlington Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	94.1 3 2.9		Dilatometer	253 293 333 353	-0.012* 0.000* 0.022* 0.074	Source: Monmouth Quarry (lower level), Illinois. Texture: median grain size 0.57 mm; coarse-grained mosaic with patches of fine-grained bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
58	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.012* 0.000* 0.022* 0.074	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
59	43	Harvey, R. D. (1967)	Nachusa Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	70 20.9 9.1		Dilatometer	253 293 333 353	-0.017* 0.000* 0.019* 0.033	Source: Polo Quarry (5-10 ft above quarry floor), Illinois. Texture: median grain size 0.02 mm; very fine grained with medium-grained sparry calcite fossil fragments, dense, mottled brown and gray; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
60	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.018 0.000 0.019 0.033	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
61*	43	Harvey, R. D. (1967)	Kimmswick Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	93.1 6 0.9		Dilatometer	253 293 333 353	-0.006 0.000 0.011 0.039	Source: Ashley, Illinois; drill core from 4400 ft depth. Texture: median grain size 0.072 mm; coarse-grained, crinoidal, with numerous recrystallized bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: perpendicular to bedding. Other: same as above.
62	43	Harvey, R. D. (1967)	Salem Limestone							Dilatometer	293.2 322.6	0.000* 0.042	Source: Bedford, Indiana.
63*	44	Mellor, M. (1970)		Cylinder 2.54 cm dia x 10.24 cm long						Dilatometer	253 233	0.000 -0.008	Source: Indiana. Other: specimen effectively saturated with 0.0054 gm water/rock; heating value; specimen prefrozen slowly.
64*	44	Mellor, M. (1970)		Same as above						Dilatometer	253 233	0.000 -0.013	Source: same as above. Other: same as above except average of heating and cooling values; specimen snap-frozen in dilatometer.
65*	44	Mellor, M. (1970)		Same as above						Dilatometer	293 288 188	0.000* -0.001 -0.016	Source: same as above. Other: specimen contains 0.0091 gm water/rock; average of heating and cooling runs.
66*	44	Mellor, M. (1970)		Same as above						Dilatometer	263 183	0.000 -0.023	Source: same as above. Other: specimen contains 0.0377 gm water/rock; heating value; specimen prefrozen slowly.
67*	44	Mellor, M. (1970)		Same as above						Dilatometer	263 203 178	0.000 -0.031 -0.042	Source: same as above. Other: same as above except average of heating and cooling values; specimen snap-frozen in dilatometer.
68*	44	Mellor, M. (1970)		Same as above						Dilatometer	253 213 183	0.000 -0.023 -0.037	Source: same as above. Other: specimen contains 0.0469 gm water/rock; snap-frozen in dilatometer; average of heating and cooling cycles.
69	53	Willis, F. and De Reus, M. E. (1939)								Optical Lever	277 293 333	-0.007 0.000* 0.019*	
70*	53	Willis, F. and De Reus, M. E. (1939)								Optical Lever	277 293 333	-0.005 0.000 0.012	

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
71	57	Johnson, W. and	Banded				Calcite		98	Interferometer	249	-0.020	Source: Winn Parish, Louisiana.
		Parsons, W.	Limestone				Quartz		Trace		274	-0.013	Texture: fine- to medium-grained.
		(1944)					Limonite		Trace		279	-0.008	Other: heating values; zero-point
							Carbonaceous matter		Trace		288	-0.002	correction is -0.071%.
											304	0.004	
											319	-0.004	
											327	-0.008	
											334	-0.013	
72	57	Johnson, W. and	Banded				Calcite		98	Interferometer	323	-0.004	Source: Winn Parish, Louisiana.
		Parsons, W.	Limestone				Quartz		Trace		310	-0.000	Texture: fine- to medium-grained.
		(1944)					Limonite		Trace		298	0.001*	Other: cooling values; zero-point
							Carbonaceous matter		Trace		278	-0.004	correction is -0.067%.
											265	-0.011	
73	57	Johnson, W. and					Calcite		99	Interferometer	253	-0.016*	Source: North LeRoy, New York.
		Parsons, W.					Carbonaceous matter,				271	-0.009	Texture: fine grained.
		(1944)					Kaolin, Quartz		<3		292	0.000*	Other: heating curve; zero-point
											311	0.008	correction is -0.079%.
											326	0.016	
											336	0.020	
74	57	Johnson, W. and					Calcite		99	Interferometer	328	0.016	Source: North LeRoy, New York.
		Parsons, W.					Carbonaceous matter,				313	0.008	Texture: fine grained.
		(1944)					Kaolin, Quartz		<3		294	0.000*	Other: cooling curve; zero-point
											281	-0.007*	correction is -0.079%.
75	57	Johnson, W. and					Calcite		95	Interferometer	253	-0.013*	Source: Mille Roche, Canada.
		Parsons, W.					Quartz		4		269	-0.008	Texture: variable grain size;
		(1944)					Carbonaceous matter,				282	-0.004*	commonly fine grained.
							Pyrite		1		295	0.011*	Other: heating curve; zero-point
											305	0.005	correction is -0.034%.
											316	0.009*	
											324	0.013	
											333	0.016*	
76	57	Johnson, W. and					Calcite		95	Interferometer	332	0.016*	Source: Mille Roche, Canada.
		Parsons, W.					Quartz		4		314	0.008*	Texture: variable grain size;
		(1944)					Carbonaceous matter,				296	0.001*	commonly fine grained.
							Pyrite		1		283	-0.004	Other: cooling curve; zero-point
											270	-0.009*	correction is -0.034%.
											261	-0.012	
77	57	Johnson, W. and					Calcite		98	Interferometer	251	-0.010*	Source: Winn Parish, Louisiana.
		Parsons, W.					Barite		Trace		279	-0.005*	Texture: fine- to medium-grained.
		(1944)									284	-0.002*	Other: heating values; zero-point
											306	0.004*	correction is -0.022%.
											326	0.001	
											336	-0.003	
78	57	Johnson, W. and					Calcite		98	Interferometer	324	0.000*	Source: Winn Parish, Louisiana.
		Parsons, W.					Barite		Trace		306	0.004*	Texture: fine- to medium-grained.
		(1944)									300	0.004	Other: cooling values; zero-point
											292	0.003*	correction is -0.023%.
											268	-0.001	
79*	57	Johnson, W. and					Mainly Calcite			Interferometer	251	-0.013	Source: Jordanville, New York.
		Parsons, W.									275	-0.007	Texture: variable but commonly
		(1944)									298	0.001	medium-grained.
											313	0.007	Other: heating curve; zero-point
											324	0.012	correction is -0.054%.
											334	0.019	

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
80	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite			Interferometer	322 311 296 280 268	0.012 0.007* 0.001* -0.005* -0.009*	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: cooling curve; zero-point correction is -0.054%.
81	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite				251 263 280 295 309 320 330 333	-0.017* -0.012* -0.005* 0.001* 0.007 0.014 0.020 0.022*	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: heating curve; zero-point correction is -0.102%.
82*	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite			Interferometer	309 298 282 268	0.009 0.002 -0.005 -0.012	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: cooling curve; zero-point correction is -0.102%.
83	57	Johnson, W. and Parsons, W. (1944)	Dolomitic "Siliceous" Limestone				Dolomite, Calcite Opal Chalcedeny	Major 10 10		Interferometer	249 255 260 265 275 284 292 302 308 318 325 332	-0.036 -0.032 -0.028 -0.024 -0.016 -0.009* -0.001* 0.006* 0.014* 0.022 0.029 0.036	Source: Paso Robles, California. Texture: very fine. Direction of Measurements: parallel to bedding plane. Other: heating curve; zero-point correction is -0.136%.
84	57	Johnson, W. and Parsons, W. (1944)	Dolomitic "Siliceous" Limestone				Dolomite, Calcite Opal Chalcedeny	Major 10 10		Interferometer	328 321 313 304 298 289 280 270	0.034 0.026 0.019 0.011* 0.004* -0.004* -0.011* -0.019	Source: Paso Robles, California. Texture: very fine. Direction of Measurements: parallel to bedding plane. Other: cooling curve; zero-point correction is -0.135%.
85*	58	Verbeck, G.J. and Hass, W.E. (1951)	Dolomitic Limestone							Dilatometer	298 302	0.005 0.008	Source: New York. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
86*	58	Verbeck, G.J. and Hass, W.E. (1951)	Dolomitic Limestone							Dilatometer	298 302	0.005 0.009	Source: Elmhurst, Illinois. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
87*	58	Verbeck, G.J. and Hass, W.E. (1951)	Dolomitic Limestone							Dilatometer	298 302	0.006 0.010	Source: Thornton, Illinois. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
88*	54	Mitchell, L.J. (1953)	Pebble from Aggregate							Dilatometer	263 293 297	-0.011 0.000 0.001	Source: Hungry Horse Dam, Mont. Other: average of heating and cooling cycle.
89	54	Mitchell, L.J. (1953)								Dilatometer	267 293 297	-0.013 0.000* 0.002*	Source: tunnel at Hungry Horse Dam, Mont. Other: average of heating and cooling cycle.
90	54	Mitchell, L.J. (1953)	Quarried "Cedar bluff" Limestone							Dilatometer	267 293 297	-0.009 0.000* 0.001*	Source: Fort Riley, Kansas. Other: average of heating and cooling cycle.
91	54	Mitchell, L.J. (1953)								Dilatometer	267 293 297	-0.007 0.000* 0.001*	Source: Pikeview, Colorado. Other: average of heating and cooling cycle.
92*	54	Mitchell, L.J. (1953)								Dilatometer	267 293 297	-0.011 0.000 0.001	Source: Pikeview, Colorado. Other: average of heating and cooling cycle.
93	54	Mitchell, L.J. (1953)								Dilatometer	267 293 297	-0.004 0.000* 0.000*	Source: Pikeview, Colorado. Other: average of heating and cooling cycle.
94	54	Mitchell, L.J. (1953)	Quarried "Cottonwood" Limestone							Dilatometer	267 293 297	-0.008 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
95	54	Mitchell, L.J. (1953)	Quarried "Cottonwood" Limestone							Dilatometer	267 293 297	-0.008 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
96	54	Mitchell, L.J. (1953)	Quarried "Cottonwood" Limestone							Dilatometer	267 293 297	-0.007 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
97	54	Mitchell, L.J. (1953)	Pebble from gravel							Dilatometer	267 293 297	-0.013 0.000* 0.002*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
98	54	Mitchell, L.J. (1953)	Pebble from chalky gravel							Dilatometer	267 293 297	-0.006 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
99	54	Mitchell, L.J. (1953)	Pebble from opaline gravel							Dilatometer	263 293 297	-0.006 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
100	54	Mitchell, L.J. (1953)	Pebble from argillaceous gravel							Dilatometer	263 293 297	-0.004 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
101	54	Mitchell, L.J. (1953)	Quarried Limestone							Dilatometer	263 293 297	-0.006 0.000* 0.001*	Source: Angostura Dam, S.D. Other: average of heating and cooling cycle.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

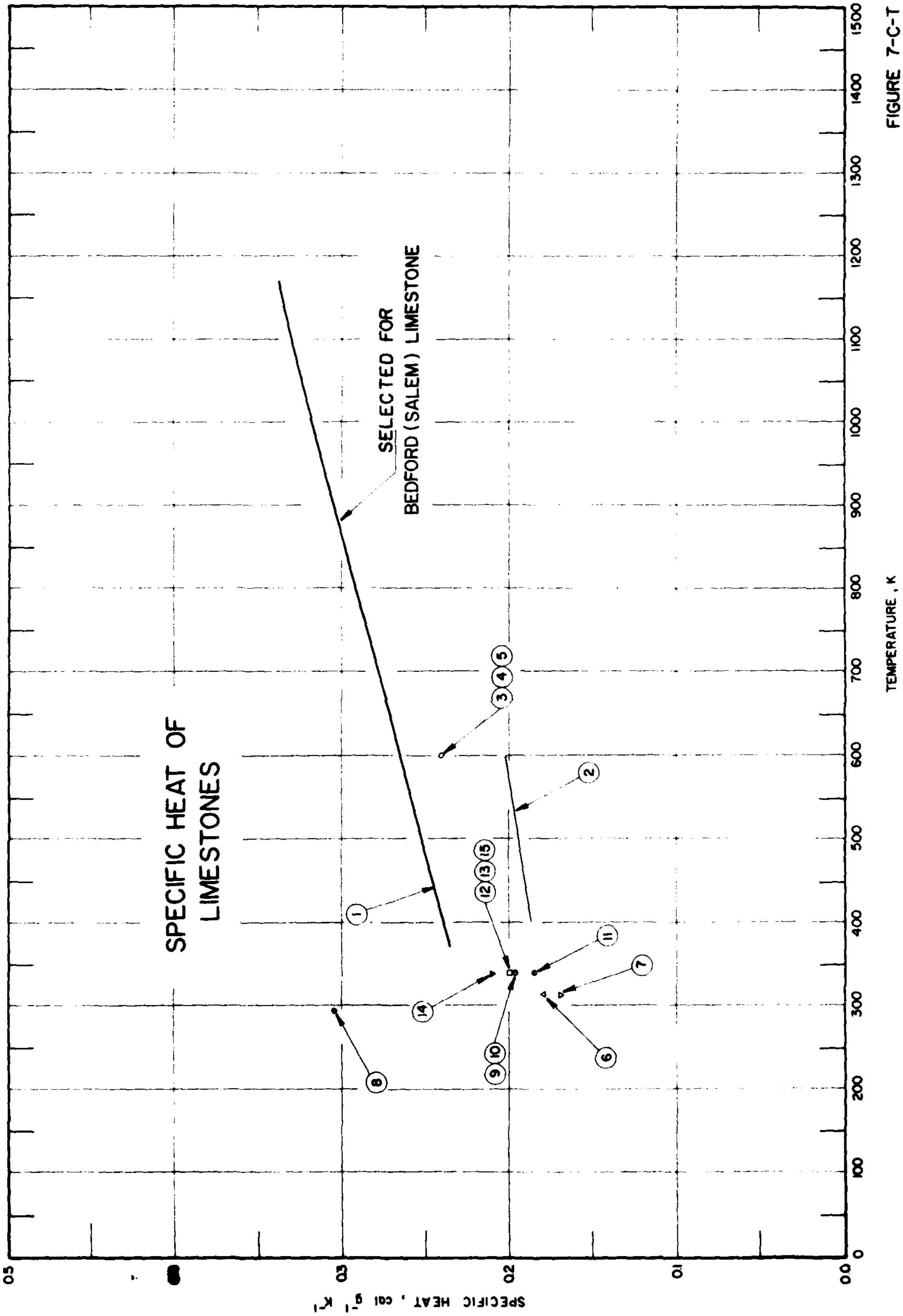
Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
102	54	Mitchell, L.J. (1953)	Siliceous Magnesium Limestone							Fulcrum-type Extensometer	263 293 297	-0.019 0.000* 0.003*	Source: California. Other: average of heating and cooling cycle.
103	54	Mitchell, L.J. (1953)	Siliceous Magnesium Limestone							Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002*	Source: California. Other: average of heating and cooling cycle.
104	54	Mitchell, L.J. (1953)	Siliceous Magnesium Limestone							Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002*	Source: California. Other: average of heating and cooling cycle.
105	54	Mitchell, L.J. (1953)	Sandy Limestone Pebble							Fulcrum-type Extensometer	263 293 297	-0.016* 0.000* 0.021	Source: gravel from Palisades Dam, Idaho. Other: average of heating and cooling cycle.
106	54	Mitchell, L.J. (1953)	Kaibab Limestone							Fulcrum-type Extensometer	263 293 297	-0.012 0.000* 0.002*	Source: near Glen Canyon, Ariz. Other: average of heating and cooling cycle.
107	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.003 0.000* 0.003	Source: Rockwood, Alabama. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%; heating cycle.
108	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.000 0.000 0.000	Source: Rockwood, Alabama. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%; cooling cycle.
109	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.007* 0.000* 0.007	Source: Rockwood, Alabama. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%; heating cycle.
110*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.012 0.000 -0.006	Source: Rockwood, Alabama. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%; cooling cycle.
111*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.011 0.000 0.011	Source: Bedford, Indiana. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; heating cycle.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
112*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.014 0.000 -0.007	Source: Bedford, Indiana. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; cooling cycle.
113	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.017 0.000 0.017	Source: Bedford, Indiana. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; heating cycle.
114	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	-0.017 0.000 0.008	Source: Bedford, Indiana. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; cooling cycle.

* Not shown in figure.



SPECIFIC HEAT OF LIMESTONES
SELECTED FOR BEDFORD (SALEM) LIMESTONE
SPECIFIC HEAT, cal g⁻¹ K⁻¹
TEMPERATURE, K
0.0
0.1
0.2
0.3
0.5
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1
2
3 4 5
6
7
8
9 10
11
12 13 15
14

FIGURE 7-C-T

TABLE 7-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P. and Krawza, W.G. (1971)	Bedford "Salem" Limestone		2.32		Calcite Organic CaO CO_2 MgO Fe_2O_3	 55.02 42.75 0.56 0.11	90 10	Drop Copper Block	373 400 500 600 700 800 900 1000 1100 1143	0.236 0.239 0.252 0.265 0.278 0.291 0.304 0.317 0.330 0.336	Source: Bedford, Ind. Texture: grain size 0.25-1.0 mm. Other: smooth values calculated from equation: $Cp = 0.223 + 0.130 \times 10^{-3} (T-273)$; for $373 < T < 1143$ derived from heat content data.
2	38	Dhar, P.R., Gupta, I.N., and Mahapatra, U.P.								Adiabatic Calorimeter	400 500 600	0.187 0.195 0.202	Source: Madhya Pradesh, India. Other: smooth values calculated from equation.
3	36	Svikis, V.D.		Block, 3.8 x 3.8 x 10.2 cm size	2.728		Calcite Dolomite Clay		94 4 2	Isothermal Water Calorimeter	600	0.241	Source: Canada. Texture: fine-grained rock, locally bonded. Other: average of two runs; mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of bath.
4	36	Svikis, V.D.		Same as above	2.752		Calcite Dolomite Impurities		72 27 1	Isothermal Water Calorimeter	600	0.243	Source: Canada. Texture: fine-grained, homogenous. Other: average of two runs; mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of bath.
5	36	Svikis, V.D.		Same as above	2.740		Calcite Dolomite Diopside, Quartz, Graphite		88 10 1	Isothermal Water Calorimeter	600	0.241	Source: Canada. Texture: recrystallized, coarse-grained and homogenous. Other: average of two runs; mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of bath.
6	23	Thomson, W.T. (1940)			2.60					Calorimeter (not specified)	311	0.180	Reported error: ±10%.
7	23	Thomson, W.T. (1940)			2.74					Same as above	311	0.169	Same as for curve 6.
8	12	Lorentzen, G. (1964)			2.576					Same as above	296	0.305	Source: Brevik (Scandinavia).
9	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.655		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Drop Isothermal Water Calorimeter	338	0.198	Source: Prov. Chikuzen (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1921)		Same as above	2.672		$CaCO_3$ SiO_2 Fe_2O_3 Al_2O_3	97.21 1.30 1.00 0.66		Same as above	338	0.198	Same as for curve 9.
11	10	Tadokoro, Y. (1921)	Coral Limestone	Same as above	2.212		$CaCO_3$ SiO_2 Fe_2O_3 MnO	97.43 1.09 0.88 trace		Same as above	338	0.185	Source: Boniss Island (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K; color white, porous structure but not uniform throughout the test piece.

TABLE 7-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
12	10	Tadokoro, Y. (1921)	Oolitic Limestone	Very thin plates, 0.1-0.3 mm thick	2.610		$CaCO_3$ Al_2O_3 SiO_2	94.98 3.79 1.84		Drop, Isothermal Water Calorimeter	338	0.201	Source: Prov. Musashi (Asia). Texture: light buff grey in color and oolitic structure distinctly observed; bedding plane indiscernible; calcite vein with average thickness of 10 mm traverse the test piece parallel to one set of the cubicla bounding planes; calcite aggregates range in diameter between 2.5 and 0.3 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
13	10	Tadokoro, Y. (1921)	Ogasawara Limestone	Same as above	2.155		$CaCO_3$ SiO_2 Fe_2O_3	99.93 0.11 trace		Same as above	338	0.201	Source: Boniss Island (Asia). Texture: color white with light pink tone, structure somewhat porous; very fine texture (0.01-0.005 mm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
14	10	Tadokoro, Y. (1921)	Gritty Limestone	Same as above	2.456		$CaCO_3$ SiO_2 Al_2O_3 Fe_2O_3 FeO MnO	53.96 30.92 9.58 3.54 1.33 0.23		Same as above	338	0.211	Source: Prov. Boniss Island (Asia). Texture: light grey colored, compact and homogenous with no trace of bedding plane; essentially composed of fine grain calcite and angular fragments (0.3-0.1 mm in size) of acid plagioclase. Other: average Cp by dropping specimen at 373 K in water at 303 K.
15	10	Tadokoro, Y. (1921)		Same as above	2.628		$CaCO_3$ SiO_2 Al_2O_3 Fe_2O_3 MnO	74.65 23.08 0.18 0.082 trace		Same as above	338	0.200	Source: Prov. Tanba (Asia). Texture: color dark grey, compact and fine in texture; white colored calcite veins of less fine texture and 0.5 to 3.0 mm thickness traverse the test piece in various directions; size of individual grains ranging mostly between 0.1-0.01 mm except in vein portions where crystals of 0.5 mm are not rare. Other: average Cp by dropping specimen at 373 K in water at 303 K.

C. SELECTED VALUES FOR BEDFORD (SALEM) LIMESTONE

Thermal Conductivity. Reported data for several types of limestones show a marked decrease in conductivity from room temperature to 500 K and then decrease slowly with temperature up to 1100 K. The sharp decrease of the thermal conductivity after that is due to decomposition of $CaCO_3$. The selected values are based on the data of Stephens [7] and of Navarro and DeWitt [86].

Thermal Diffusivity. Values between 300-400 K for various types of limestone scatter a lot. The values of Somerton and Boozer [72, 89, 90] indicate a wide scatter on the various samples of the same specimen. Consequently, no selection was made.

Thermal Linear Expansion. Reported data for several types of limestones from 250 to 375 K follow a similar trend and scatter within the range of the experimental error. Selected values are based on the data of Souder and Hidnert [33], Harvey [43], Mellor [44], and of Hockman and Kessler [64].

Specific Heat. Selected values are from the heat content studies of Lindroth and Krawza [35]. The other types of limestones investigated seem to have lower C_p values near room temperature.

Selected Values for Bedford (Salem) Limestone*

Temp. (K)	Thermal Conductivity ($W\ m^{-1} K^{-1}$)	Thermal Linear Expansion $\Delta L/L_0$ (%)	Specific Heat ($cal\ g^{-1} K^{-1}$)
293		0.000	
300	2.210	0.007	
400	1.669	0.134	0.237
500	1.475	0.294	0.250
600	1.344	0.381	0.262
700	1.252		0.277
800	1.182		0.290
900	1.125		0.304
1000	1.075		0.318
1100			0.330

*No selections were made for other thermophysical properties.

8. MARBLES

A. PETROGRAPHY

Holston or Tennessee marble is the commercial name given to the recrystallized, pure Holston Limestone. It is composed of over 98 percent calcite, most of which is recrystallized.

Chemical Composition (After Lindroth and Krawza [35])

Oxide	Wt. Percent
SiO_2	0.06
TiO_2	0.01
Al_2O_3	<0.06
Fe_2O_3	0.11
FeO	0.03
MnO	<0.05
MgO	0.28
CaO	55.86
Na_2O	0.02
K_2O	0.01
CO_2	43.48
H_2O	0.04
P_2O_5	0.057
S	0.016

Mineralogical Composition (After Hasan and West [101])

Mineral	Vol. Percent
Calcite (recrystallized)	51
Calcite (primary)	48
Ferruginous and clayey material	1

Texture. Average grain size ranges between 0.07 and 0.75 mm diameter. Fossil shell fragments make up about 6-8 percent of total calcite; most of the original carbonate of shells have been replaced by calcite. Authigenic growth is common in the secondary recrystallized calcite. Some voids are present which are the result of shrinkage in volume owing to recrystallization of calcite.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

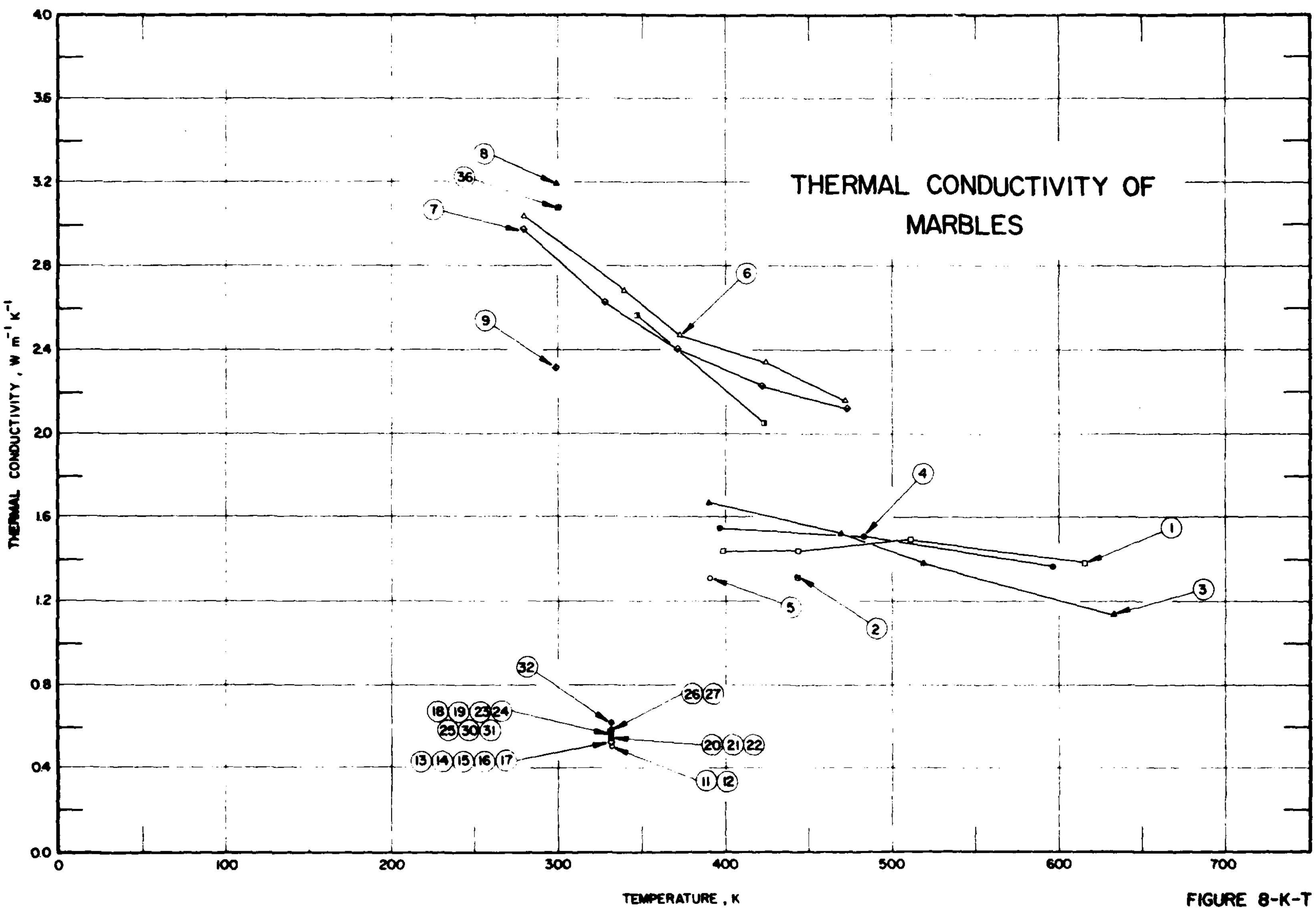

THERMAL CONDUCTIVITY OF MARBLES
THERMAL CONDUCTIVITY, W m^-1 K^-1
TEMPERATURE, K
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
0
100
200
300
400
500
600
700
1
2
3
4
5
6
7
8
9
36
32
26 27
18 19 23 24
25 30 31
13 14 15 16 17
20 21 22
11 12

FIGURE 8-K-T

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	8	Niven, C.D. (1940)	Missisquoi Marble; "White"	Disk 20.3 cm dia x 2.5 cm thick	2.76		Pure Calcite, with little organic mattes			Steady Longitudinal Absolute	398 443 511 615	1.44 1.44 1.50 1.38	Source: Phillipsburg, Quebec.
2	8	Niven, C.D. (1940)	Missisquoi Marble; "White"	Same as above	2.76		Pure Calcite, with little organic mattes			Steady Longitudinal Absolute	444	1.31	Source: Phillipsburg, Quebec. Other: value obtained after being exposed to high temperature test.
3	8	Niven, C.D. (1940)	Deschambault "Brown"	Same as above	2.66		$CaCO_3$ plus organic matter such as oils	98		Steady Longitudinal Absolute	390 469 519 633	1.67 1.53 1.38 1.14	Source: St. Marc des Carriers, Quebec. Texture: coarse grained.
4	8	Niven, C.D. (1940)	Silvertone "Black"	Same as above	2.77		$CaCO_3$ and some organic matter	96		Steady Longitudinal Absolute	398 484 596	1.56 1.51 1.37	Source: St. Albert, Ontario.
5	8	Niven, C.D. (1940)	Silvertone "Black"	Same as above	2.77		$CaCO_3$ and some organic matter	96		Steady Longitudinal Absolute	390	1.31	Source: St. Albert, Ontario. Other: this value was obtained after exposure to high temperature test.
6	1	Birch, F. and Clark, H. (1940)		Disk 3.8 cm dia x 6 mm thick	2.688-2.637					Steady Longitudinal Absolute	279 338 372 424 472	3.05 2.69 2.48 2.34 2.16	Source: Proctor, Vermont. Direction of Measurements: parallel to bedding. Other: values are extrapolated to zero porosity.
7	1	Birch, F. and Clark, H. (1940)		Same as above	2.688, 2.637					Steady Longitudinal Absolute	278 327 371 422 473	2.99 2.63 2.41 2.23 2.12	Source: Proctor, Vermont. Direction of Measurements: perpendicular to bedding. Other: same as above.
8	13	Lorentzen, G. (1966)		Flat Surface						Thermal Comparator	298	3.20	Source: Fauske, Norway.
9	10	Tadokoro, Y. (1921)					$CaCO_3$ Al_2O_3 Fe_2O_3 MgO SiO_2	96.02 1.55 0.49 0.39 0.29		Indirect	296	2.32	Source: Prov. Mino (Asia). Other: color white, a member of paleozoic group; data is obtained from measurements of diffusivity, specific heat and density.
10	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.12 apparent	59.3				Steady Longitudinal Absolute	331	0.502	Other: powder specimen of grain size 0.104-0.124 mm.
11	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.12 apparent	59.3				Steady Longitudinal Absolute	331	0.502	Other: powder specimen of grain size 0.074-0.044 mm.
12	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.13 apparent	58.9				Steady Longitudinal Absolute	330	0.502	Other: powder specimen of grain size 0.104-0.074 mm.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
13	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.15 apparent	58.2				Steady Longitudinal Absolute	333	0.519	Other: powder specimen of grain size 0.295-0.208 mm.
14	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.15 apparent	58.2				Steady Longitudinal Absolute	332	0.519	Other: powder specimen of grain size 0.028-0.147 mm.
15	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.18 apparent	57.1				Steady Longitudinal Absolute	334	0.526	Other: powder specimen of grain size 0.589-0.295 mm.
16	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.18 apparent	57.1				Steady Longitudinal Absolute	330	0.526	Other: powder specimen of grain size 0.124-0.104 mm.
17	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.19 apparent	56.7				Steady Longitudinal Absolute	330	0.526	Other: powder specimen of grain size 0.074-0.044 mm.
18	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.22 apparent	55.6				Steady Longitudinal Absolute	332	0.537	Other: powder specimen of grain size 0.295-0.208 mm.
19	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.22 apparent	55.6				Steady Longitudinal Absolute	331	0.538	Other: powder specimen of grain size 0.208-0.147 mm.
20	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.26 apparent	54.2				Steady Longitudinal Absolute	331	0.550	Other: powder specimen of grain size 0.589-0.295 mm.
21	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.26 apparent	54.2				Steady Longitudinal Absolute	330	0.543	Other: powder specimen of grain size 0.124-0.104 mm.
22	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.27 apparent	53.8				Steady Longitudinal Absolute	330	0.550	Other: powder specimen of grain size 0.104-0.074 mm.
23	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.32 apparent	52				Steady Longitudinal Absolute	328	0.561	Other: powder specimen of grain size 0.104-0.074 mm.
24	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.32 apparent	52				Steady Longitudinal Absolute	330	0.562	Other: powder specimen of grain size 0.074-0.044 mm.
25	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.32 apparent	52				Steady Longitudinal Absolute	333	0.562	Other: powder specimen of grain size 0.589-0.044 mm.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
26	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.40 apparent	49.1				Steady Longitudinal Absolute	333	0.587	Other: powder specimen of grain size 0.589–0.044 mm.
27	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.40 apparent	49.1				Steady Longitudinal Absolute	329	0.587	Other: powder specimen of grain size 0.074–0.044 mm.
28*	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.07 apparent	61.1				Steady Longitudinal Absolute	332	0.493	
29*	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.25 apparent	54.6				Steady Longitudinal Absolute	331	0.545	
30	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.29 apparent	53.1				Steady Longitudinal Absolute	333	0.556	
31	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.36 apparent	50.5				Steady Longitudinal Absolute	330	0.578	
32	59	Marathe, M.N. and Tendolkar, G.S. (1953)			1.47 apparent	46.5				Steady Longitudinal Absolute	332	0.614	
33	65	Carman, A.P. and Nelson, R.A. (1921)	Alabama Marble (White)	Cylinder 19 cm dia x 61 cm long	2.71		$CaCO_3$ $MgCO_3$	Dominant Minor		Steady Radial Absolute	348 423	2.57 2.06	Source: Illinois. Texture: sugary. Other: specimen heated in oven at 130 C for 4 hr to get rid of moisture.
34	66	Krischer, O. and Esdorn, H. (1956)		1.52 cm thick	2.68					Indirect	298 318 337	2.94 2.71 2.61	Other: reported error ± 2%.
35	68	Eucken, A. (1911)								Steady Longitudinal Absolute	83 195 273	6.08 3.52 2.99	
36	86	Navarro, R.A. and DeWitt, D.P. (1974)	Holston Limestone (Marble)							Non-Steady Line Heat Source	300	3.08	Sou... oxville, Tennessee. Othe... ...tact agent: mercury; reported error ± 3%.

* Not shown in figure.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
37*	16	Clark, H. (1941)		Disk 3.3 cm dia x 6 mm thick	2.67	1.1				Steady Longitudinal Absolute	318	2.42	Source: Danby, Vermont. Test Environment: air, normal pressure.
38*	16	Clark, H. (1941)		Same as above	2.67	1.1				Steady Longitudinal Absolute	318	2.74	Source: same as above. Test Environment: air, sample subjected to 680.5 atmos. axial pressure.
39*	16	Clark, H. (1941)		Same as above	2.67	1.1				Steady Longitudinal Absolute	318	2.69	Source: same as above. Test Environment: water saturated, normal pressure.
40*	16	Clark, H. (1941)		Same as above	2.67	1.1				Steady Longitudinal Absolute	318	2.77	Source: same as above. Test Environment: water saturated, sample subjected to 680.5 atmos. axial pressure.

* Not shown in figure.

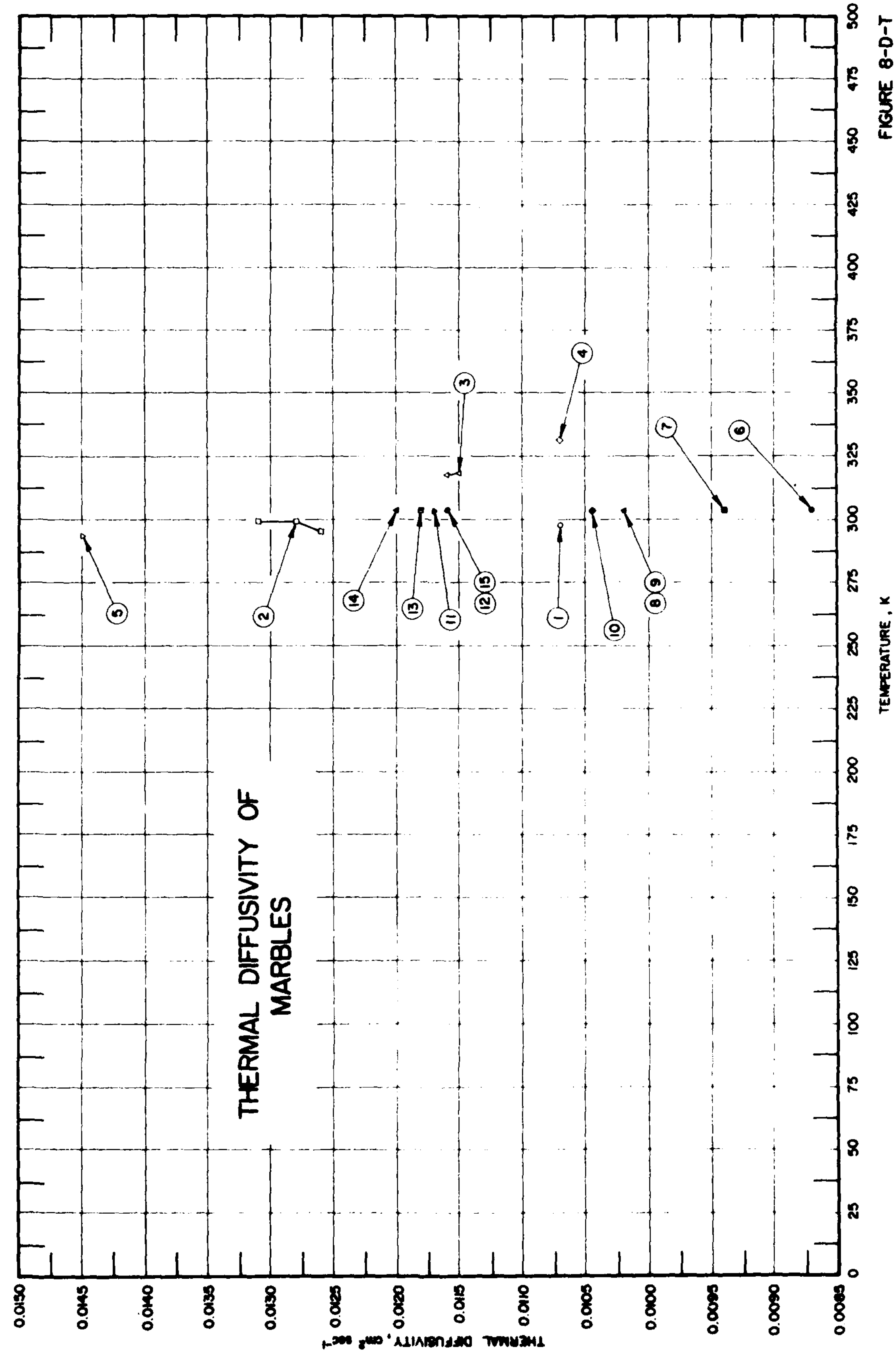

THERMAL DIFFUSIVITY OF MARBLES
TEMPERATURE, K
THERMAL DIFFUSIVITY, cm² sec⁻¹
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500
0.0150 0.0145 0.0140 0.0135 0.0130 0.0125 0.0120 0.0115 0.0110 0.0105 0.0100 0.0095 0.0090 0.0085
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

FIGURE 8-D-T

TABLE 8-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
1	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.699		$CaCO_3$ Al_2O_3 Fe_2O_3 MgO SiO_2	96.02 1.55 0.49 0.39 0.29		Periodic Heat Flow	~298	0.0107	Source: Prov. Mino (Asia). Texture: color white, a member of Paleozoic group.
2	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680					Unsteady Method	296 299 299	0.0126 0.0128 0.0131	
3	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680					Unsteady Method	317 318	0.0116 0.0115	
4	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680					Unsteady Method	337	0.0107	
5	93	Strong, H.M., Bundy, F.P., and Vovenkerk, H.P. (1960)								Indirect	293	0.0145	Other: calculated from specific heat and thermal conductivity ("Hot Plate Method" to find specific heat and conductivity).
6	94	Pierce, B.O. and Willson, R.W. (1900)	Carrara Marble	60 cm sq x 6 cm high						Indirect	303	0.0087	Other: calculated from specific heat and thermal conductivity ("Wall Method" to find specific heat and thermal conductivity).
7	94	Pierce, B.O. and Willson, R.W. (1900)	Mexican Onyx Marble	Same as above						Indirect	303	0.0094	Other: same as above.
8	94	Pierce, B.O. and Willson, R.W. (1900)	Vermont Statuatory Marble	Same as above						Indirect	303	0.0102	Other: same as above.
9	94	Pierce, B.O. and Willson, R.W. (1900)	American White Marble	Same as above						Indirect	303	0.0102	Other: same as above.
10	94	Pierce, B.O. and Willson, R.W. (1900)	Egyptian Marble	Same as above						Indirect	303	0.0107	Other: same as above.
11	94	Pierce, B.O. and Willson, R.W. (1900)	Sienna Marble	Same as above						Indirect	303	0.0117	Other: same as above.
12	94	Pierce, B.O. and Willson, R.W. (1900)	Bardiglio Marble	Same as above						Indirect	303	0.0116	Other: same as above.
13	94	Pierce, B.O. and Willson, R.W. (1900)	Vermont Cloudy White Marble	Same as above						Indirect	303	0.0118	Other: same as above.
14	94	Pierce, B.O. and Willson, R.W. (1900)	Vermont Dove Colored Marble	Same as above						Indirect	303	0.0120	Other: same as above.
15	94	Pierce, B.O. and Willson, R.W. (1900)	Lisbon Marble	Same as above						Indirect	303	0.0118	Other: same as above.

TABLE 8-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF MARBLES (*continued*)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($cm^2\ s^{-1}$)	
16*	94	Pierce, B.O. and Willson, R.W. (1900)	American Black Marble	Same as above						Indirect	303	0.0119	Other: same as above.
17*	94	Pierce, B.O. and Willson, R.W. (1900)	Belgian Marble	Same as above						Indirect	303	0.0133	Other: same as above.
18*	94	Pierce, B.O. and Willson, R.W. (1900)	African Rose Ivory Marble	Same as above						Indirect	303	0.0130	Other: same as above.
19*	94	Pierce, B.O. and Willson, R.W. (1900)	Tennessee Fossili-ferous Marble	Same as above						Indirect	303	0.0130	Other: same as above.
20*	94	Pierce, B.O. and Willson, R.W. (1900)	Knoxville Pink Marble	Same as above						Indirect	303	0.0131	Other: same as above.
21*	94	Pierce, B.O. and Willson, R.W. (1900)	St. Baume Marble	Same as above						Indirect	303	0.0134	Other: same as above.
22*	95	Pyk, S. and Stalhane, B. (1932)		5 cm dia, 0.73 cm thick						Transient Method	350	0.0093	

* Not shown in figure.

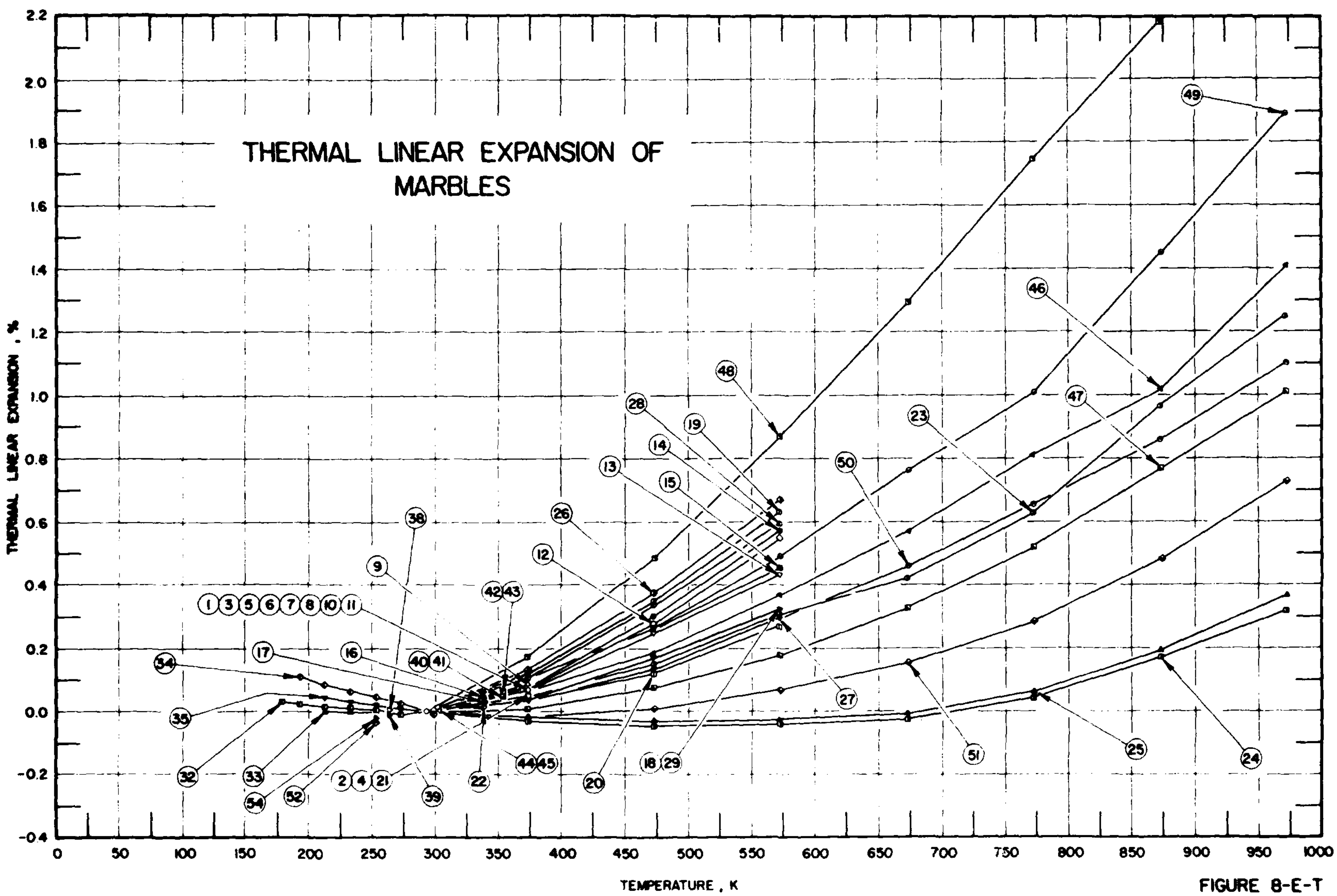

THERMAL LINEAR EXPANSION OF
MARBLES
THERMAL LINEAR EXPANSION , %
TEMPERATURE , K
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1 3 5 6 7 8 10 11
2 4 21
18 29
42 43
44 45
40 41
9
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FIGURE 8-E-T

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	32	Griffith, J. H. (1937)	Napoleon Gray Marble			2.0				Dilatometer	293 373	0.000 0.073	Source: Phenix, Mo.
2	32	Griffith, J. H. (1937)	White Yule Marble			0.5				Dilatometer	293 373	0.000* 0.056	Source: Marble, Colorado.
3	32	Griffith, J. H. (1937)	Dolomitic Marble			0.8				Dilatometer	293 373	0.000 0.072	Source: Lee, Mass.
4	32	Griffith, J. H. (1937)	Pink and Gray Banded Marble			0.4				Dilatometer	293 373	0.000* 0.055	Source: Hewitts, N.C.
5	32	Griffith, J. H. (1937)	French Gray Marble			0.6				Dilatometer	293 373	0.000* 0.069	Source: Plattsburg, N.Y.
6	32	Griffith, J. H. (1937)	St. Lawrence Marble			0.3				Dilatometer	293 373	0.000 0.065	Source: Gouverneur, N.Y.
7	32	Griffith, J. H. (1937)	Pittsford Valley Marble			0.5				Dilatometer	293 373	0.000 0.065	Source: Florence, Vt.
8	32	Griffith, J. H. (1937)	Variegated Dolomitic Marble			0.4				Dilatometer	293 373	0.000 0.063	Source: Swanton, Vt.
9	32	Griffith, J. H. (1937)	Travertine Marble			1.94				Dilatometer	293 373	0.000* 0.089	Source: Suisun, Calif.
10	32	Griffith, J. H. (1937)	Travertine Marble			0.21				Dilatometer	293 373	0.000 0.063	Source: Great Salt Lake, Utah.
11	32	Griffith, J. H. (1937)	Tennessee Marble							Dilatometer	293 373	0.000* 0.076	Source: Near Knoxville, Tenn.
12	33	Souder, W. H. and Hidnert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.6 43.58 0.07 0.26 0.06		Dilatometer	298 373 473 573	0.005 0.080* 0.280 0.550	Source: Asbury, Tenn. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
13	33	Souder, W. H. and Hidnert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.6 43.58 0.07 0.26 0.06		Dilatometer	573 473 373 298	0.430 0.250 0.080* 0.005*	Source: Asbury, Tenn. Direction of Measurements: specimen cut parallel to the bed. Other: cooling cycle.
14	33	Souder, W. H. and Hidnert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section			CaO CO_2 Al_2O_3 MgO Fe_2O_3	55.6 43.58 0.26 0.07 0.06		Dilatometer	298 373 473 573	0.005* 0.080* 0.300 0.570	Source: Asbury, Tenn. Direction of Measurements: specimen cut perpendicular to the bed. Other: heating cycle.
15	33	Souder, W. H. and Hidnert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section			CaO CO_2 Al_2O_3 MgO Fe_2O_3	55.6 43.58 0.26 0.07 0.06		Dilatometer	573 473 373 298	0.442 0.252* 0.072* 0.004*	Source: Asbury, Tenn. Direction of Measurements: specimen cut perpendicular to the bed. Other: cooling cycle.
16	33	Souder, W. H. and Hidnert, P. (1919)	Dorset Gray Marble				CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.4 43.46 0.35 0.06 0.04		Dilatometer	293 338	0.000* 0.045	Source: Dorset, Vt. Other: Measurements in oil; heating cycle.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
17	33	Souder, W. H. and Hidnert, P. (1919)	Dorset Gray Marble				CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.4 43.46 0.35 0.06 0.04		Dilatometer	338 293	0.031 0.000*	Source: Dorset, Vt. Other: measurements in oil; cooling cycle.
18	33	Souder, W. H. and Hidnert, P. (1919)	Hollister Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.54 43.75 0.46 0.09 0.03		Dilatometer	298 373 473 573	0.0025* 0.040 0.170 0.320	Source: Florence, Vt. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
19	33	Souder, W. H. and Hidnert, P. (1919)	Rutland Blue Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.9 43.8 0.27 0.06 0.02		Dilatometer	298 373 473 573	0.008* 0.12 0.35 0.63	Source: Rutland, Vt. Direction of Measurements: specimen cut perpendicular to the bed. Other: heating cycle.
20	33	Souder, W. H. and Hidnert, P. (1919)	Rutland Blue Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.9 43.8 0.27 0.06 0.02		Dilatometer	573 473 373 298	0.272 0.122 0.032* 0.002*	Source: Rutland, Vt. Direction of Measurements. specimen cut perpendicular to the bed. Other: cooling cycle.
21	33	Souder, W. H. and Hidnert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.00 43.18 0.41 0.09 0.04		Dilatometer	293 338	0.000 0.045	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
22	33	Souder, W. H. and Hidnert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.00 43.18 0.41 0.09 0.04		Dilatometer	338 293	0.022 0.000*	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to the bed. Other: cooling cycle.
23	34	Rosenholtz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.047* 0.155 0.309 0.420 0.625 0.965 1.254	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in E-W orientation.
24	34	Rosenholtz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* -0.030 -0.044 -0.040 -0.024 0.041 0.170 0.320	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in N-S orientation.
25	34	Rosenholtz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* -0.021 -0.033 -0.027 -0.005 0.062 0.195 0.367	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in vertical orientation.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
26	33	Souder, W. H.		Rod of			CaO	55.9		Dilatometer	298	0.008*	Source: Rutland, Vt.
		and Hidnert, P.		Uniform			CO_2	43.8			373	0.128	Direction of Measurements: spec-
		(1919)		Cross			MgO	0.27			473	0.378	imen cut parallel to bed.
				Section			Al_2O_3	0.06			573	0.668	Other: heating cycle; measure-
							Fe_2O_3	0.02					ments in oil.
27	33	Souder, W. H.		Rod of			CaO	55.9		Dilatometer	573	0.292	Source: Rutland, Vt.
		and Hidnert, P.		Uniform			CO_2	43.8			473	0.132	Direction of Measurements: spec-
		(1919)		Cross			MgO	0.27			373	0.032*	imen cut parallel to bed.
				Section			Al_2O_3	0.06			298	0.002*	Other: cooling cycle; measurements
							Fe_2O_3	0.02					in oil.
28	33	Souder, W. H.	Pittsford	Rod of			CaO	54.49		Dilatometer	298	0.007*	Source: Pittsford, Vt.
		and Hidnert, P.	Italian	Uniform			CO_2	43.65			373	0.112	Direction of Measurements: spec-
		(1919)	Marble	Cross			MgO	1.33			473	0.342	imen cut perpendicular to bed.
				Section			Al_2O_3	0.20			573	0.592	Other: heating cycle; measure-
							Fe_2O_3	0.05					ments in oil.
29	33	Souder, W. H.	Pittsford	Rod of			CaO	54.49		Dilatometer	573	0.328	Source: Pittsford, Vt.
		and Hidnert, P.	Italian	Uniform			CO_2	43.65			473	0.158	Direction of Measurements: spec-
			Marble	Cross			MgO	1.33			373	0.048	imen cut perpendicular to bed.
				Section			Al_2O_3	0.20			298	0.003	Other: cooling cycle; measurements
							Fe_2O_3	0.05					in oil.
30*	33	Souder, W. H.	Riverside	Rod of			CaO	55.4		Dilatometer	298	0.006	Source: Proctor, Vt.
		and Hidnert, P.	Marble	Uniform			CO_2	43.76			373	0.104	Direction of Measurements: spec-
		(1919)		Cross			MgO	0.35					men cut perpendicular to bed.
				Section			SiO_2	0.26					Other: heating cycle; measure-
							Al_2O_3	0.10					ments in oil.
							Fe_2O_3	0.01					
31*	33	Souder, W. H.	Florentine	Rod of			CaO	55.6		Dilatometer	298	0.005	Source: Florence, Vt.
		and Hidnert, P.	Blue Marble	Uniform			CO_2	43.94			373	0.085	Direction of Measurements: spec-
		(1919)		Cross			MgO	0.44					imen cut perpendicular to bed.
				Section			Al_2O_3	0.07					Other: heating cycle; measure-
							Fe_2O_3	0.01					ments in oil.
32	33	Souder, W. H.	Cumberland	Rod of			CaO	55.8		Dilatometer	298	0.002*	Source: Meadow, Tenn.
		and Hidnert, P.	Pink Marble	Uniform			CO_2	42.65			293	0.000*	Direction of Measurements: spec-
		(1919)		Cross			Al_2O_3	0.45			273	-0.008	imen cut perpendicular to bed.
				Section			Fe_2O_3	0.16			253	0.006	Other: cooling cycle; test 1.
							MgO	0.06			233	0.012	
											213	0.018	
											193	0.022	
											178	0.035	
33	33	Souder, W. H.	Cumberland	Rod of			CaO	55.8		Dilatometer	298	0.001*	Source: Meadow, Tenn.
		and Hidnert, P.	Pink Marble	Uniform			CO_2	42.65			293	0.000*	Direction of Measurements: spec-
		(1919)		Cross			Al_2O_3	0.45			273	-0.004*	imen cut perpendicular to bed.
				Section			Fe_2O_3	0.16			253	0.000*	Other: cooling cycle; test 2.
							MgO	0.06			233	0.000	
											213	0.004	
34	33	Souder, W. H.	Silver Gray	Rod of			CaO	55.0		Dilatometer	298	-0.006	Source: Tate, Ga.
		and Hidnert, P.	Marble	Uniform			CO_2	43.18			293	0.000*	Direction of Measurements: spec-
		(1919)		Cross			MgO	0.41			273	0.026	imen cut parallel to bed.
				Section			Al_2O_3	0.09			253	0.046	Other: cooling cycle; test 1.
							Fe_2O_3	0.04			233	0.066	
											213	0.086	
											193	0.110	

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
35	33	Souder, W.H. and Hidnert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO_2 MgO Al_2O_3 Fe_2O_3	55.0 43.18 0.41 0.09 0.04		Dilatometer	298 293 273 253 233 213	0.002* 0.000* 0.008 0.020 0.032 0.046	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to bed. Other: cooling cycle; test 2.
36*	33	Souder, W.H. and Hidnert, P. (1919)	Victoria Pink Marble	Rod of Uniform Cross Section			CaO CO_2 Al_2O_3 Fe_2O_3 MgO	55.38 43.52 0.14 0.06 Trace		Dilatometer	298 293 273 253	0.002 0.000 -0.008 -0.010	Source: Knoxville, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 1.
37*	33	Souder, W.H. and Hidnert, P. (1919)	Victoria Pink Marble	Rod of Uniform Cross Section			CaO CO_2 Al_2O_3 Fe_2O_3 MgO	55.38 43.52 0.14 0.06 Trace		Dilatometer	298 293 273 253 233 213	0.001 0.000 -0.006 -0.004 0.004 0.008	Source: Knoxville, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 2.
38	54	Mitchell, L.J. (1953)	Georgia Commercial Marble								263 293 297	0.003 0.000* 0.000*	Source: Georgia. Direction of Measurements: parallel to the bedding. Other: avg of heating and cooling cycle.
39	54	Mitchell, L.J. (1953)	Georgia Commercial Marble								263 293 297	-0.007 0.000* 0.001*	Source: Georgia. Direction of Measurements: perpendicular to the bedding. Other: avg of heating and cooling cycle.
40	55	Louhser, P.J. and Bryden, J.G. (1972)	Onyx Marble							Dilatometer	293 353	0.000* 0.052	Other: specimen oven dried.
41	55	Louhser, P.J. and Bryden, J.G. (1972)	Onyx Marble							Dilatometer	293 353	0.000 0.053	Other: water saturated specimen, water absorption 0.13% (dry weight).
42	55	Louhser, P.J. and Bryden, J.G. (1972)	Carrara Marble							Dilatometer	293 353	0.000 0.061	Other: specimen oven dried.
43	55	Louhser, P.J. and Bryden, J.G. (1972)	Carrara Marble							Dilatometer	293 353	0.000 0.063	Other: water saturated specimen, water absorption 0.10% (dry weight).
44	58	Verbeck, G.J. and Hass, W.E. (1951)	"Tate" Gray Marble							Dilatometer	298 302	0.003* 0.005	Source: Georgia. Texture: average grain size 0.62 mm. Test enviroment: water. Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
45	58	Verbeck, G.J. and Hass, W.E. (1951)	"Tate" White Marble							Dilatometer	298 302	0.003* 0.005	Source: same as above. Texture: same as above. Test environment: same as above. Other: same as above.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
46	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.052* 0.182 0.367 0.570 0.817 1.099 1.413	Source: Commercial Quarry, Crestmore, Calif. Texture: grain size 2-3 mm. Direction of measurement: 900' elevation, 2700' East, and 1500' North. Riverside Cement Co. coordinates, field sample surface dipped 27° E and the strike was N 10° E, specimen N-S orientation cut from this sample. Other: first heating-cooling cycle.
47	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.017 0.079 0.179 0.325 0.519 0.770 1.085	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.
48	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.17 0.483 0.871 1.295 1.745 2.188 2.665*	Source: same as above. Texture: same as above. Direction of measurement: same as above except specimen cut in E-W orientation. Other: first heating-cooling cycle.
49	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.101* 0.264 0.492 0.763 1.081 1.455 1.894	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.
50	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.030* 0.138* 0.286* 0.459 0.655 0.860 1.102	Source: same as above. Texture: same as above. Direction of measurement: same as above except specimen cut in vertical orientation. Other: first heating-cooling cycle.
51	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble							Dilatometer	293 373 473 573 673 777 873 973	0.000* -0.002* 0.012 0.070 0.157 0.282 0.483 0.734	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
52	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.035 0.000* 0.035*	Source: South Dover, N.Y. Direction of measurement: "A" direction (random). Other: heating cycle.
53*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.037 0.000 -0.018	Source: same as above. Directiọn of measurement: perpendicular to the above direction. Other: cooling cycle.
54	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.021 0.000* 0.021*	Source: same as above. Direction of measurement: perpendicular to the above direction. Other: heating cycle.
55*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.024 0.000 -0.012	Source: same as above. Direction of measurement: same as above. Other: cooling cycle.

* Not shown in figure.

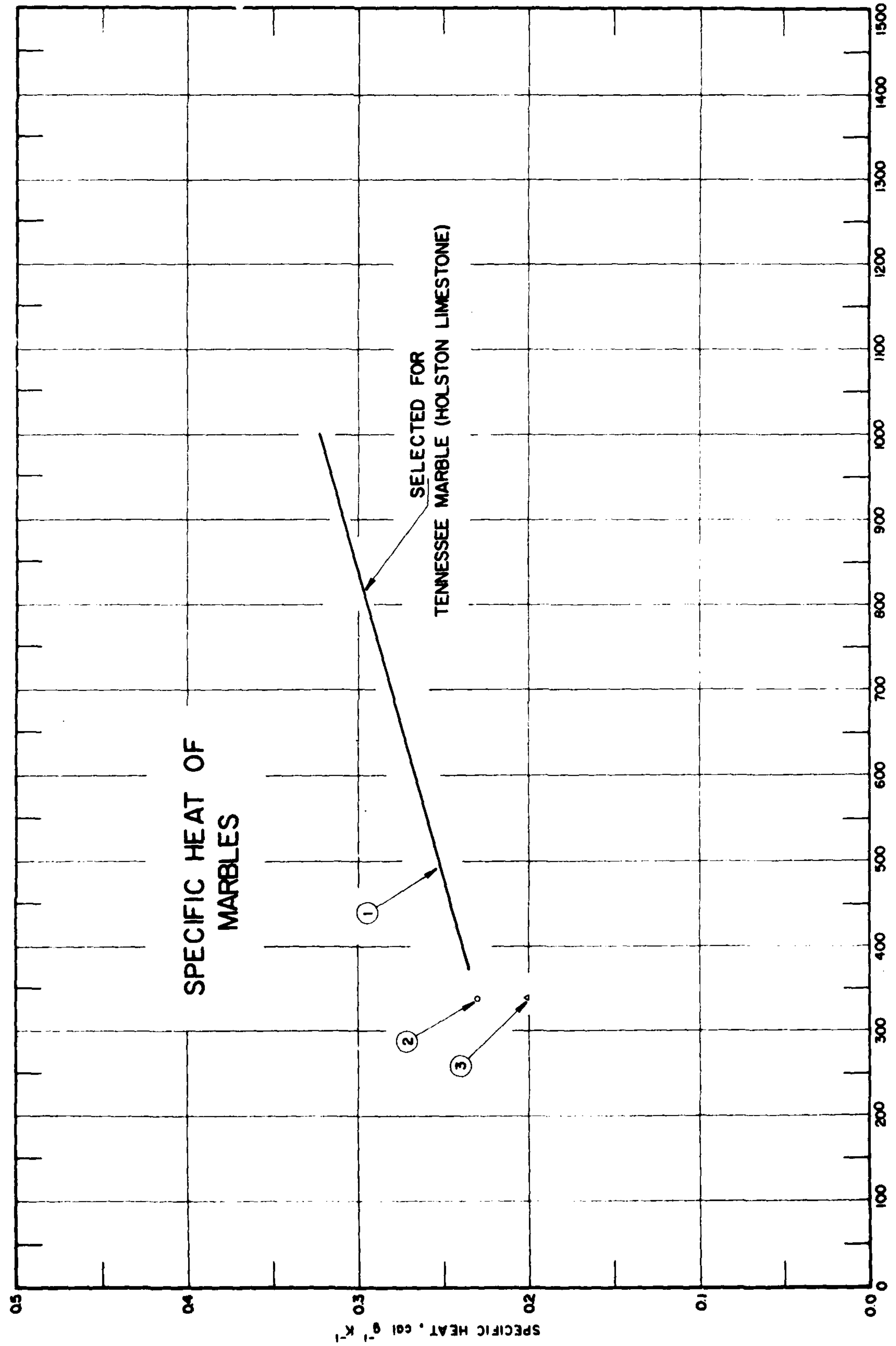

SPECIFIC HEAT OF MARBLES
SELECTED FOR TENNESSEE MARBLE (HOLSTON LIMESTONE)
1
2
3
TEMPERATURE, K
SPECIFIC HEAT, cal g⁻¹ K⁻¹
0.0
0.1
0.2
0.3
0.4
0.5
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

FIGURE 8-C-T

TABLE 6-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P. and Krawza, W.G. (1971)	Tennessee "Holston" Marble		2.68		Calcite		99	Drop Copper Block	373	0.236	Source: Knoxville, Tenn.
							Pyrite or Magnetite		<1		400	0.240	Texture: grain size 0.2-1.5 mm.
											500	0.253	Other: smooth values calculated from equation:
							CaO	55.86			600	0.267	$Cp = 0.222 + 0.139 \times 10^{-3} (T-273)$
							CO_2	43.48			700	0.281	for $373<T<1143$
							MgO	0.28			800	0.295	derived from heat content data.
							Fe_2O_3	0.11			900	0.309	
							P_2O_5	0.06			1000	0.323	
											1100	0.337	
2	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.699		$CaCO_3$	96.02		Drop Isothermal Water Calorimeter	338	0.202	Source: Prov. Mino (Asia).
							Al_2O_3	1.55					Texture: color white, a member of Paleozoic group.
							Fe_2O_3	0.49					Other: average Cp by dropping specimen at 373 K in water at 303 K.
							MgO	0.39					
							SiO_2	0.29					
3	62	Champoussin, J.-C. and Sicard, L.								Indirect	333	0.232	Other: obtained from experimental values of diffusivity and density.

C. SELECTED VALUES FOR TENNESSEE MARBLE (HOLSTON LIMESTONE)

Thermal Conductivity. Measurements on the several types of marbles follow similar trends and vary considerably from each other. Room temperature value of Navarro and DeWitt [86] for Holston Limestone falls in that range. No selection was made.

Thermal Diffusivity. Room temperature values on several types of marbles are between 0.009-0.013 $cm^2\ s^{-1}$ but none are reported for Holston Limestone.

Thermal Linear Expansion. Measurements have been reported on the various types of marbles, especially at higher temperatures. They vary considerably from each other. The thermal linear expansion values are much lower during second heating-cooling cycle. No measurement was reported for Holston Limestone.

Specific Heat. Selected values are based on the data of Lindroth and Krawza [35].

Selected Values for Marble (Holston Limestone)*

Temp. (K)	Specific Heat ($cal\ g^{-1}\ K^{-1}$)
400	0.238
500	0.253
600	0.267
700	0.281
800	0.294
900	0.308
1000	0.323

*No selections were made for other thermophysical properties.

9. QUARTZITES

A. PETROGRAPHY

Quartzites are metamorphic rocks consisting predominantly of quartz, although some rocks labeled quartzites contain as much as 40 percent other mineral. There is, therefore, a wide variation in mineralogical composition and depending upon the degree of metamorphism, source material, and tectonic environment, each quartzite may have its own characteristic mineral assemblage. The following chemical analysis of Sioux Quartzite is from Lindroth and Krawza [35]:

Chemical Composition

Oxide	Wt. Percent
SiO_2	97.84
TiO_2	0.02
Al_2O_3	0.87
Fe_2O_3	0.27
FeO	0.25
MnO	<0.05
MgO	0.05
CaO	0.81
Na_2O	0.02
K_2O	0.03
H_2O	0.08
P_2O_5	0.009
S	0.011

The red Sioux Quartzite from Jasper, Minnesota is also known as Jasper Quartzite. It is an orthoquartzite and composed essentially of quartz. The following petrographic account of Sioux Quartzite, given by Hasan and West [101], is summarized below:

Mineralogical Composition

Mineral	Vol. Percent
Quartz	98-99
Chert	≃1
Hematite, zircon, etc.	<1

Texture. The original quartz grains have been recrystallized. At some places they show preferred orientation due to alignment of grains along the c-axis. The individual quartz grains are about 0.28 mm in diameter; they are welded together by chert and hematite. The quartz grains are rounded to subrounded.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

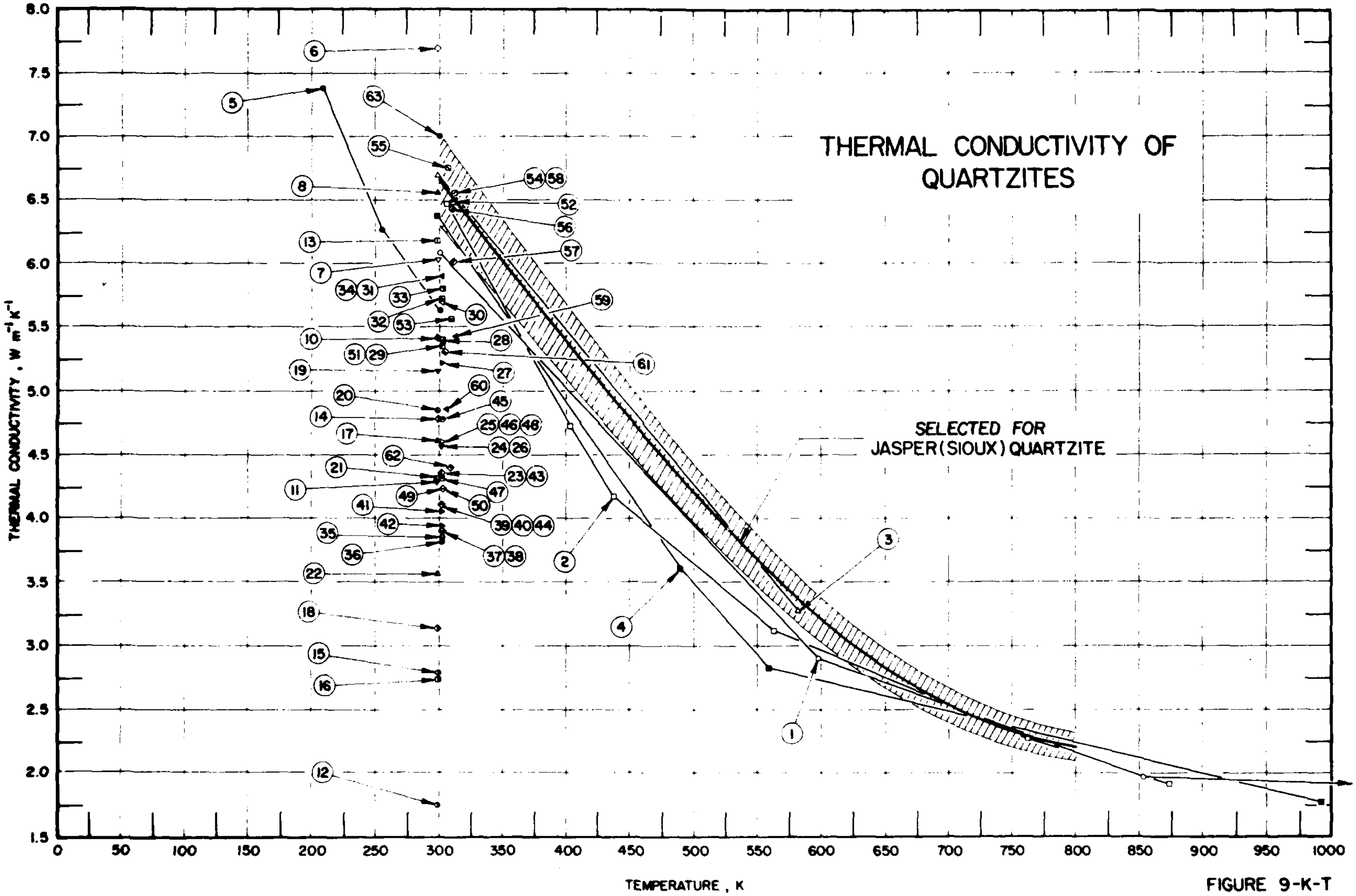

THERMAL CONDUCTIVITY OF
QUARTZITES
SELECTED FOR
JASPER(SIOUX) QUARTZITE
THERMAL CONDUCTIVITY, W m^-1 K^-1
TEMPERATURE, K

FIGURE 9-K-T

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m⁻¹ K⁻¹)	Remarks
1	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block A	12.7-15.2 cm per side	2.64		Quartz Calcite, Zircon, Hematite, Sericite, Clays		97-98 2-3	Line Heat Source	300 597 852 1074	6.09 2.90 1.97 1.94*	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
2	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block B	Same as above	2.64		Quartz Calcite, Zircon, Hematite, Sericite, Clays		97-98 2-3	Line Heat Source	305 404 438 563 763 873	6.47 4.72 4.18 3.11 2.29 1.91	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
3	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block C	Same as above	2.64		Quartz Calcite, Zircon, Hematite, Sericite, Clays		97-98 2-3	Line Heat Source	299 581	6.70 3.27	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
4	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block D	Same as above	2.64		Quartz Calcite, Zircon, Hematite, Sericite, Clays		97-98 2-3	Line Heat Source	299 489 559 993	6.38 3.60 2.85 1.76	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
5	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block E	Same as above	2.64		Quartz Calcite, Zircon, Hematite, Sericite, Clays		97-98 2-3	Line Heat Source	208 255 300	7.39 6.26 5.63	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
6	20	Bullard, E.C. (1939)	Witwater-srand Quartzite	Disk 3.5 cm dia x 8, 4, 1 mm thick	2.667					Steady Longitudinal Comparative	298	7.70	Source: Gerhardminnebron; Bore 25, 4540 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error: ±3.7%.
7	20	Bullard, E.C. (1939)	Witwater-srand Quartzite	Same as above	2.714					Same as above	298	6.02	Source: Gerhardminnebron; Bore 36, 7963 ft. Other: same as above.
8	20	Bullard, E.C. (1939)	Witwater-srand Quartzite	Same as above	2.692		Quartz Others		73 27	Same as above	298	6.57	Source: Gerhardminnebron; Bore 26, 4991 ft. Other: same as above.
9*	20	Bullard, E.C. (1939)	Witwater-srand Quartzite	Same as above	2.673		Quartz Others		78 22	Same as above	298	8.03	Source: Gerhardminnebron; Bore 27, 5356 ft. Other: same as above.
10	10	Tadokoro, Y. (1921)	Variegated Quartzite		2.454		SiO_2 Fe_2O_3 Al_2O_3 $CaCO_3$	95.62 2.95 1.13 trace		Indirect	298	5.41	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 3 mm dia. Other: data is obtained from measurements of diffusivity, specific heat and density.

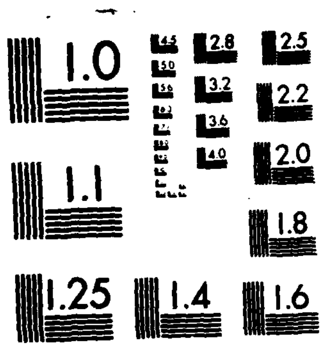
*Not shown in figure.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
11	10	Tadokoro, Y. (1921)	Red Quartzite		2.45		SiO_2 Al_2O_3 Fe_2O_3 CaO	92.79 3.26 2.26 1.38		Indirect	298	4.29	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red, very fine texture; hematite, sericite and epidote occurs as accessory constituents. Other: data obtained from measurements of diffusivity, specific heat and density.
12	10	Tadokoro, Y. (1921)	Powder Quartzite		1.887		SiO_2 Fe_2O_3 Al_2O_3 MgO	93.66 3.48 1.40 0.65		Indirect	298	1.75	Source: Prov. Chikuzen (Asia). Other: the test piece is made of white quartzite prepared for casting mold; data is obtained from measurements of diffusivity, specific heat and density.
13	20	Bullard, E.C. (1939)	Black Reef Quartzite	Disks 3.5 cm dia, 8,4,1 mm thick	2.642					Steady Longitudinal Comparative	298	6.19	Source: Gerhardminnebron; Bore 24, 4194 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error: ±3.7%.
14	10	Tadokoro, Y. (1921)			2.764		SiO_2 Fe_2O_3 Al_2O_3	96.16 2.68 0.52		Indirect	298	4.78	Source: Kwantung, Manchuria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color greyish white; accessory components: quartz, muscovite, kaolinite, limonite. Other: data obtained from measurements of diffusivity, specific heat and density.
15	10	Tadokoro, Y. (1921)			2.734		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31		Indirect	298	2.78	Source: Kwantung, Manchuria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color greyish white. Other: data obtained from measurements of diffusivity, specific heat and density.
16	10	Tadokoro, Y. (1921)			2.627		SiO_2 Fe_2O_3 CaO	94.56 2.15 1.84		Indirect	298	2.73	Source: Same as above. Other: data is obtained from measurements of diffusivity, specific heat and density.
17	10	Tadokoro, Y. (1921)			2.566		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace		Indirect	298	4.60	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey; essentially quartz; granularity ranges between 3.0 to 0.05 mm. Other: data obtained from measurements of diffusivity, specific heat and density.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
18	10	Tadokoro, Y. (1921)			2.523		SiO_2 Al_2O_3 Fe_2O_3 CaO MgO	94.43 2.28 1.77 0.85 0.39		Indirect	298	3.13	Source: Prov. Illizen(Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey, very fine texture; quartz grains range from 0.92 to 0.005 mm. Other: data obtained from measurements of diffusivity, specific heat and density.
19	10	Tadokoro, Y. (1921)			2.343		SiO_2 Fe_2O_3 CaO	98.34 1.32 0.28		Indirect	298	5.15	Source: Prov. Chikuzen (Asia). Other: color white; data is obtained from measurement of diffusivity, specific heat and density.
20	13	Lorentzen, G. (1966)		Flat Surfaces						Thermal Comparator	298	4.85	Source: Kvaenangen (Norway).
21	48	Saas, J.H. and LeMarne, A.E. (1963)								Steady Longitudinal Comparative	298	4.31	Source: Zinc Corporation. Other: values extrapolated to zero resistance; reported error: ±5%.
22	48	Saas, J.H. and LeMarne, A.E. (1963)		Disk 3.5 cm dia x 0.6-0.7 cm thick						Steady Longitudinal Comparative	298	3.55	Source: Broken Hills, New South Wales. Other: value extrapolated to zero resistance; reported error: ±5%.
23	46	Beck, A.E. (1956)	Shattered Quartzite	Disk > 3.8 cm dia, 6.0 mm thick			Quartz Calcite Others		60.0 5.0 35.0	Steady Longitudinal Comparative	300.9	4.35	Source: Australia, Bore Hole 17, Snowy Mountains, depth 163 ft. Texture: average grain size 0.02 mm.
24	46	Beck, A.E. (1956)	Same as above	Disk > 3.8 cm dia, 8.0 mm thick			Same as above			Same as above	300.9	4.56	Source: same as above. Texture: same as above.
25	46	Beck, A.E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick			Quartz Biotite Magnetite		60.0 35.0 5.0	Same as above	300.9	4.60	Source: same as above. Texture: same as above.
26	46	Beck, A.E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick			Same as above			Same as above	300.9	4.56	Source: same as above. Texture: same as above.
27	46	Beck, A.E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick						Same as above	300.9	5.22	Source: Australia, Bore Hole 16, Snowy Mountains, depth 150 ft. Other: values are extrapoled to zero contact resistance.
28	46	Beck, A.E.		Disk > 3.8 cm dia, 4.0 mm thick						Same as above	300.9	5.40	Source: same as above. Other: same as above.



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
29	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick						Steady Longitudinal Comparative	300.9	5.35	Source: same as above. Other: same as above.
30	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick			Quartz Feldspar Biotite		75.0 15.0 10.0	Same as above	300.9	5.69	Source: Australia Bore Hole 16, Snowy Mountain, depth 74 ft. Texture: average grain size 0.06 mm. Other: composition has been estimated by eye from a slide; values are extrapolated to zero contact resistance.
31	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick			Same as above			Same as above	300.9	5.90	Source: same as above. Texture: same as above. Other: same as above.
32	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick			Same as above			Same as above	300.9	5.73	Source: same as above. Texture: same as above. Other: same as above.
33	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick			Same as above			Same as above	300.9	5.81	Source: same as above. Texture: same as above. Other: same as above.
34	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick			Same as above			Same as above	300.9	5.90	Source: same as above. Texture: same as above. Other: same as above.
35	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick						Same as above	300.9	3.85	Source: Australia Bore Hole 15, Snowy Mountain, depth 251 ft. Other: values are extrapolated to zero contact resistance.
36	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick						Same as above	300.9	3.81	Source: same as above. Other: same as above.
37	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick						Same as above	300.9	3.89	Source: same as above. Other: same as above.
38	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	3.89	Source: same as above. Other: same as above.
39	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 1.5 mm thick						Same as above	300.9	4.10	Source: Australia Bore Hole 15, Snowy Mountain, depth 145 ft. Other: values are extrapolated to zero contact resistance.
40	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick.						Same as above	300.9	4.10	Source: same as above. Other: same as above.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
41	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick						Steady Longitudinal Comparative	300.9	4.06	Source: Australia Bore Hole 15, Snowy Mountain, depth 145 ft. Other: values are extrapolated to zero contact resistance.
42	46	Beck, A. E.		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	3.93	Source: same as above. Other: same as above.
43	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 1.5 mm thick						Same as above	300.9	4.35	Source: Australia Bore Hole 12, Snowy Mountain, depth 341 ft. Other: values are extrapolated to zero contact resistance.
44	46	Beck, A. E. (1956)		> 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.10	Source: same as above. Other: same as above.
45	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.5 mm thick						Same as above	300.9	4.77	Source: Australia Bore Hole 12, Snowy Mountain, depth 250 ft. Other: values are extrapolated to zero contact resistance.
46	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.60	Source: same as above. Other: same as above.
47	46	Beck, A. E. (1956)		> 3.8 cm dia, 2.0 mm thick						Same as above	300.9	4.31	Source: Australia Bore Hole 12, Snowy Mountain, depth 71 ft. Other: values are extrapolated to zero contact resistance.
48	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick						Same as above	300.9	4.60	Source: same as above. Other: same as above.
49	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick						Same as above	300.9	4.23	Source: same as above. Other: same as above.
50	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.23	Source: same as above. Other: same as above.
51	82	Carte, A. E. (1954)	Witwatersrand Quartzite							Steady Longitudinal Comparative	303	5.35	Source: Klerksdorp, Transvaal, South Africa. Other: mean thermal conductivity for 11 samples.
52	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.71					Steady Longitudinal Comparative	310	6.48	Source: LR1, NNW of Odendaalsrus, S. Africa at 6321 ft depth. Texture: fine-grained. Direction of Measurement: perpendicular to bedding.
53	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.65					Same as above	309	5.56	Source: same as above except 5871 ft depth. Texture: same as above. Direction of Measurement: same as above.

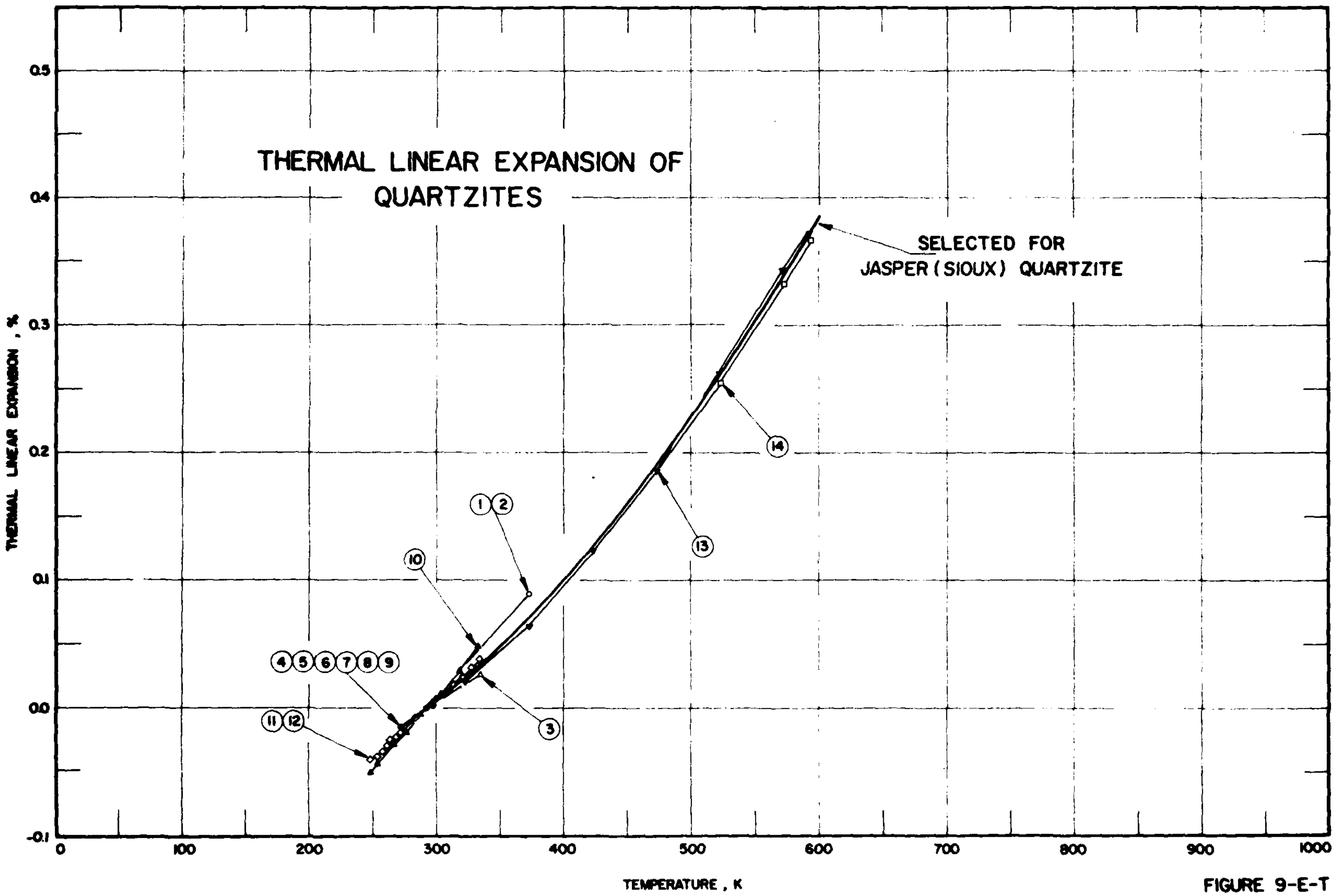
TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
54	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.69					Steady Longitudinal Comparative	311	6.57	Source: Bore hole, LR1, NNW of Odendalsrus, S. Africa at 5570 ft depth. Direction of Measurement: perpendicular to bedding. Other: reported error 2.6%.
55	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.64					Same as above	306	6.78	Source: same as above except 5361 ft depth. Direction of Measurement: same as above.
56	47	Mossop, S.C. and Gafner, G. (1951)	Chloritic	Disk 3.5 cm dia	2.67		Quartz Chlorite		81 19	Same as above	309	6.44	Source: same as above except 4856 ft depth. Direction of Measurement: same as above.
57	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.65					Same as above	311	6.02	Source: same as above except 4620 ft depth. Direction of Measurement: same as above. Other: reported error 2.6%.
58	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.65		Quartz Chlorite Pyrite (Accessory)		94 6	Same as above	312	6.57	Source: same as above except 4415 ft depth. Direction of Measurement: same as above.
59	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.59		Quartz Chlorite		91 9	Same as above	312	5.44	Source: same as above except 6563 ft depth. Texture: fine-grained. Direction of Measurement: same as above.
60	47	Mossop, S.C. and Gafner, G. (1951)	Chloritic	Disk 3.5 cm dia	2.68		Quartz Chlorite		75 25	Same as above	305	4.85	Source: same as above except 901 ft depth. Texture: medium-grained. Direction of Measurement: same as above. Other: reported error 1.9%.
61	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.65					Same as above	305	5.31	Source: same as above except 699 ft depth. Texture: same as above. Direction of Measurement: same as above.
62	47	Mossop, S.C. and Gafner, G. (1951)		Disk 3.5 cm dia	2.66		Quartz Chlorite Feldspar Sericite		77 13 5 5	Same as above	308	4.39	Source: same as above except 496 ft depth. Texture: same as above. Direction of Measurement: same as above. Other: reported error 0.9%.
63	86	Navarro, R.A. and DeWitt, D.P. (1974)	Sioux Quartzite							Non-Steady Line Heat Source	300	7.04	Source: Jasper, Minnesota. Other: contact agent: mercury; reported error ± 3%.

TABLE 9-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
1*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.343		SiO_2 Fe_2O_3 CaO	98.34 1.32 0.28		Periodic Heat Flow	~298	0.0276	Source: Prov. Chikuzen (Asia). Texture: color white.
2*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.523		SiO_2 Al_2O_3 Fe_2O_3 CaO MgO	94.43 2.28 1.77 0.85 0.39		Periodic Heat Flow	~298	0.0165	Source: Prov. Ilizen (Asia). Texture: metamorphosed sedimentary rock of the paleozoic group; color light grey; very fine texture; quartz grains range from 0.92 to 0.005 mm.
3*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.566		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace		Periodic Heat Flow	~298	0.0251	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey; essentially quartz; granularity ranges between 3.0-0.05 mm.
4*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.627		SiO_2 Fe_2O_3 CaO Al_2O_3	94.56 2.15 1.84 0.90		Periodic Heat Flow	~298	0.0138	Source: Kwantung Manchuria (Asia).
5*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.734		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31		Periodic Heat Flow	~298	0.0123	Source: same as above. Texture: color greyish white; metamorphosed sedimentary rock of paleozoic group.
6*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.764		SiO_2 Fe_2O_3 Al_2O_3	96.16 2.68 0.52		Periodic Heat Flow	~298	0.0227	Source: same as above. Texture: metamorphosed sedimentary rock of plaeozoic group; color greyish white; accessory components: quartz, muscovite, kaolinite, limonite.
7*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	1.887		SiO_2 Fe_2O_3 Al_2O_3 MgO	93.66 3.48 1.40 0.65		Periodic Heat Flow	~298	0.0124	Source: Prov. Chikuzen (Asia). Texture: the test piece is made of white quartzite prepared for casting mould.
8*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.45		SiO_2 Al_2O_3 Fe_2O_3 CaO	92.79 3.26 2.26 1.38		Periodic Heat Flow	~298	0.0229	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red; very fine texture; hematite, sericite, and epidote occur as accessory constituents.
9*	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.454		SiO_2 Fe_2O_3 Al_2O_3 $CaCO_3$	95.62 2.95 1.13 trace		Periodic Heat Flow	~298	0.0314	Source: same as above. Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 3 mm diameter.

* No figure given.



THERMAL LINEAR EXPANSION OF QUARTZITES
SELECTED FOR JASPER (SIOUX) QUARTZITE
1 2
10
4 5 6 7 8 9
11 12
3
13
14
THERMAL LINEAR EXPANSION, %
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
100
200
300
400
500
600
700
800
900
1000
TEMPERATURE, K

FIGURE 9-E-T

TABLE 9-E-T. *TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZITES*

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	32	Griffith, J. H.	Baraboo							Dilatometer	293	0.000*	Source: Baraboo, Wisconsin.
		(1937)	Quartzite								373	0.088	
2	32	Griffith, J. H.								Dilatometer	293	0.000	Source: Dell Rapid, S. D.
		(1937)									373	0.086	
3	53	Willis, F. and								Optical Lever	277	-0.011	
		DeReus, M. E.									293	0.000	
		(1939)									333	0.027	
4	54	Mitchell, L. J.	Pebble from							Dilatometer	263	-0.014	Source: Cherry Creek Dam, Colo.
		(1953)	Gravel								293	0.000*	Other: average of heating and
											297	0.002	cooling cycle.
5	54	Mitchell, L. J.	Pink							Dilatometer	263	-0.012	Source: gravel at Palisades Dam,
		(1953)	Quartzite								293	0.000	Colo.
			Pebble								297	0.002	Other: same as above.
6	54	Mitchell, L. J.	Gray							Dilatometer	263	-0.016	Source: same as above.
		(1953)	Quartzite								293	0.000	Other: same as above.
			Pebble								297	0.002	
7	54	Mitchell, L. J.	Black							Dilatometer	263	-0.015	Source: same as above.
		(1953)	Quartzite								293	0.000	Other: same as above.
			Pebble								297	0.002	
8	54	Mitchell, L. J.								Dilatometer	263	-0.013	Source: Wolf Creek, siding of
		(1953)									293	0.000	Union Pacific Railroad.
											297	0.002	Other: same as above.
9	57	Johnson, W. and					Quartz		94	Interferometer	248	-0.051	Source: Potomac River gravel,
		Parsons, W.					*Chlorite*		5		254	-0.043	Maryland - Virginia.
		(1944)					Chalcedony,				266	-0.029	Texture: greenish-grey and fine-
							Mica,				276	-0.019	grained.
							Limonite		<3		288	-0.005	Other: heating curve; zero-point
											302	0.011	correction is -0.111%.
											318	0.029	
											331	0.048	
10	57	Johnson, W. and					Same as			Interferometer	315	0.028	Source: same as above.
		Parsons, W.					above				300	0.010	Texture: same as above.
		(1944)									286	-0.008	Other: cooling curve; zero-point
											277	-0.020*	correction is -0.108%.
11	57	Johnson, W. and	Micaceous				Quartz		55	Interferometer	249	-0.041	Source: Spokane gravel, Irvin,
		Parsons, W.	"Calcareous"				Calcite		25		254	-0.038	Washington.
		(1944)	Quartzite				Microcrystalline				257	-0.034*	Other: heating curve; zero-point
							Quartz and				261	-0.030	correction is -0.181%.
							Sericite		20		264	-0.026*	
							Muscovite		2		267	-0.023*	
							Titanite		trace		271	-0.019	
							Leucoxene		trace		275	-0.017*	
											283	-0.009	
											291	-0.002*	
											299	0.005*	
											306	0.012*	
											314	0.018	
											321	0.024*	
											327	0.032	
											334	0.039	

* Not shown in figure.

TABLE 9-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
12*	57	Johnson, W. and Parsons, W. (1944)	Micaceous "Calcareous" Quartzite				Same as above			Interferometer	330	0.030	Source: same as above. Other: cooling curve; zero-point correction is -0.181%.
											323	0.029	
											316	0.022	
											310	0.016	
											304	0.008	
											293	-0.002	
											285	-0.009	
											277	-0.015	
											273	-0.019	
13	63	Thirumalai, K. and Demou, S.G. (1970)	Sioux Quartzite				Quartz		98		293	0.000*	Other: measurements in 10^{-6} torr atmosphere.
											323	0.020	
											373	0.063	
											423	0.123	
											473	0.187	
											523	0.262	
											573	0.344	
											593	0.372	
14	63	Thirumalai, K. and Demou, S.G. (1970)	Sioux Quartzite				Quartz		98		293	0.000*	Other: measurements in nitrogen atmosphere.
											323	0.020*	
											373	0.067*	
											423	0.123*	
											473	0.188*	
											523	0.255	
											573	0.333	
											594	0.368	

* Not shown in figure.

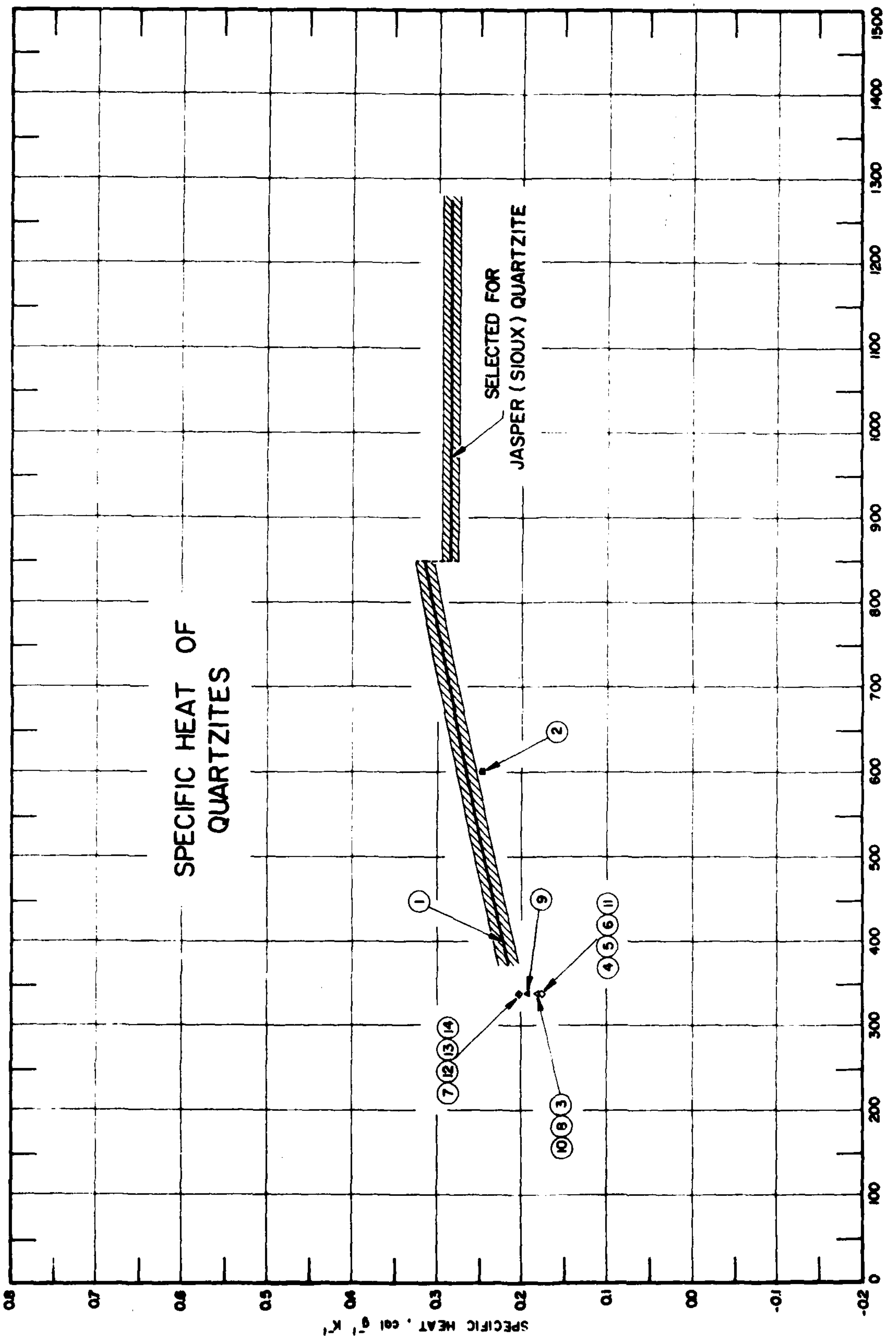

SPECIFIC HEAT OF QUARTZITES
SELECTED FOR JASPER (SIOUX) QUARTZITE
1
2
9
4 5 6 11
7 12 13 14
10 8 3
TEMPERATURE, K
SPECIFIC HEAT, cal g⁻¹ K⁻¹
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

FIGURE 9-C-T

TABLE 9-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp (cal g^{-1} K^{-1})	Remarks
1	35	Lindroth, D.P. and Krawza, W.G. (1971)	Jasper "Sioux" Quartzite		2.64		Quartz Other SiO_2 Al_2O_3 CaO Fe_2O_3	 97.84 0.87 0.81 0.27	99 1	Drop Copper Block	370 400 500 600 700 800 848 848 900 1000 1100 1200 1273	0.217 0.223 0.243 0.263 0.283 0.303 0.312 0.283 0.283 0.283 0.283 0.283 0.283	Source: Jasper, Minnesota. Texture: grain size 0.1-1.0 mm. Other: smooth values calculated from equation: $Cp = 0.198 + 0.199 \times 10^{-3} (T-273)$ for $373<T<848$ $Cp = 0.283$ for $848<T<1273$; derived from heat content data; transition near 848 K.
2	36	Svikis, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm size	2.665		Quartz Muscovite		93 7	Isothermal Water Calorimeter	600	0.249	Source: Canada. Texture: fine-grained and shows strain effects; foliation is seen locally. Other: mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of bath.
3	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.343		SiO_2 Fe_2O_3 CaO	98.34 1.32 0.28		Drop Isothermal Water Calorimeter	338	0.184	Source: Prov. Chikuzen (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K.
4	10	Tadokoro, Y. (1921)		Same as above	2.523		SiO_2 Al_2O_3 Fe_2O_3 CaO MgO	94.43 2.28 1.77 0.85 0.39		Same as above	338	0.179	Source: Prov. Iizen (Asia). Texture: metamorphosed sedimentary rock of the paleozoic group; color light grey, very fine texture; quartz grains range from 0.92 to 0.095 mm. Other: same as above.
5	10	Tadokoro, Y. (1921)		Same as above	2.566		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace		Same as above	338	0.178	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey; essentially quartz; granularity ranges between 3.0-0.05 mm. Other: same as above.
6	10	Tadokoro, Y. (1921)		Same as above	2.627		SiO_2 Fe_2O_3 CaO Al_2O_3	94.56 2.15 1.84 0.90		Same as above	338	0.179	Source: Kwantung, Manchuria (Asia). Other: same as above.
7	10	Tadokoro, Y. (1921)		Same as above	2.734		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31		Same as above	338	0.201	Source: same as above. Texture: color greyish white; metamorphosed sedimentary rock of paleozoic group. Other: same as above.

TABLE 9-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
8	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.764		SiO_2 Fe_2O_3 Al_2O_3	96.16 2.68 0.52		Drop Isothermal Water Calorimeter	338	0.181	Source: Kwantung, Manchoria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color greyish white; accessory components: quartz, muscovite, kaolinite, limonite. Other: average Cp by dropping specimen at 373 K in water at 303 K.
9	10	Tadokoro, Y. (1921)	Powder Quartzite	Same as above	1.887		SiO_2 Fe_2O_3 Al_2O_3 MgO	93.66 3.48 1.40 0.65		Same as above	338	0.194	Source: Prov. Chikuzen (Asia). Texture: the test piece is made of white quartzite prepared for casting mold. Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1921)	Red Quartzite	Same as above	2.45		SiO_2 Al_2O_3 Fe_2O_3 CaO	92.79 3.26 2.26 1.38		Same as above	338	0.183	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red, very fine texture; hematite, sericite and epidote occur as accessory constituents. Other: average Cp by dropping specimen at 373 K in water at 303 K.
11	10	Tadokoro, Y. (1921)	Variegated Quartzite	Same as above	2.454		SiO_2 Fe_2O_3 Al_2O_3 $CaCO_3$	95.62 2.95 1.13 trace		Same as above	338	0.179	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 3 mm diameter. Other: average Cp by dropping specimen at 373 K in water at 303 K.
12	47	Mossop, S.C. and Gafner, G. (1951)		5 x 1.2 x 1.2 cm	2.65					Adiabatic	337	0.200	Source: Bore hole Loraine, NNW of Odendaalsrus, South Africa, at 699 ft. Other: Cp between 369 and 305.9 K
13	47	Mossop, S.C. and Gafner, G. (1951)		5 x 1.2 x 1.2 cm	2.64					Adiabatic	337	0.201	Source: Bore hole Loraine, NNW of Odendaalsrus, South Africa, at 5261 ft. Other: Cp between 368.9 and 307.2 K.
14	47	Mossop, S.C. and Gafner, G. (1951)		5 x 1.2 x 1.2 cm	2.59					Adiabatic	338	0.203	Source: Bore hole Loraine, NNW of Odendaalsrus, South Africa, at 6563 ft. Other: Cp between 368.9 and 307.4 K.

C. SELECTED VALUES FOR JASPER (SIOUX) QUARTZITE

Thermal Conductivity. Values of Marovelli and Veith [5] for Jasper (Sioux) Quartzite containing 97-98 volume percent quartz are considerably lower than the values for pure quartz, and somewhat lower than the room-temperature value of Navarro and DeWitt [86]. Therefore, slightly higher values than those reported by Marovelli and Veith [5] were selected.

Thermal Diffusivity. Room temperature values of Tadokoro [10] for quartzites from Asia are between 0.012-0.031 $cm^2\ s^{-1}$. No selection was made.

Thermal Linear Expansion. Selected values from Thirumalai and Demou [86] indicate that the thermal linear expansion is independent of environmental pressure. Results of Griffith [32] for Baraboo, Wisconsin Quartzite yield slightly higher values.

Specific Heat. Selected values are from the heat content studies of Lindroth and Krawza [35] and indicate an anomaly at 848 K near α-β quartz transition. Values for other types of quartzites are slightly lower.

Selected Values for Jasper (Sioux) Quartzite*

Temp. (K)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Thermal Linear Expansion $\Delta L/L_0$ (%)	Specific Heat ($cal\ g^{-1}\ K^{-1}$)
293		0.000	
300	6.700	0.006	
400	5.397	0.100	0.222
500	4.212	0.229	0.244
600	3.217	0.286	0.267
700	2.542		0.286
800	2.196		0.306
900			0.284
1000			0.283
1100			0.282
1200			0.282

*No selections were made for other thermophysical properties.

10. RHYOLITES

A. PETROGROPHY

Rhyolite is an extrusive acid volcanic rock, holocrystalline to hypocrystalline with an aphanitic matrix which is predominantly glass in a vitrophyre. The mineralogical and chemical composition of rhyolite and granite is similar, although average chemical composition of rhyolite indicates higher silica and alkalis and lower quantities of lime, magnesia, and iron than granite.

Chemical Composition (After Fogelson [98])

Oxide	Wt. Percent
SiO_2	70.1
TiO_2	0.26
Al_2O_3	14.9
Fe_2O_3	2.77
FeO	0.44
MnO	0.18
MgO	0.20
CaO	1.33
Na_2O	5.74
K_2O	2.60
H_2O	0.61
P_2O_5	0.05
CO_2	<0.10
S	0.011

The mineralogy and texture of porphyritic rhyolite vitrophyre from Newberry Caldera, Oregon, given by Fogelson [98], is summarized below:

Mineralogical Composition

Mineral	Vol. Percent
Glass and crystallites	95
Plagioclase microphenocrysts (albite or oligoclase)	4
Pyroxene (augite)	<1
Magnetite	<1
Hematite	$\ll 1$

Texture. The rock is hyaline and microporphyritic. The glassy matrix is filled with acicular crystallites. Tiny vesicles occur within the rock and iron-stained alteration haloes surround them. The rock is fine-grained and the plagioclase microphenocrysts are from 0.1 to 1.5 mm long; pyroxene grains are from 0.2 to 1 mm long and the magnetite grains measure from 0.001 to 0.2 mm on the edge.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

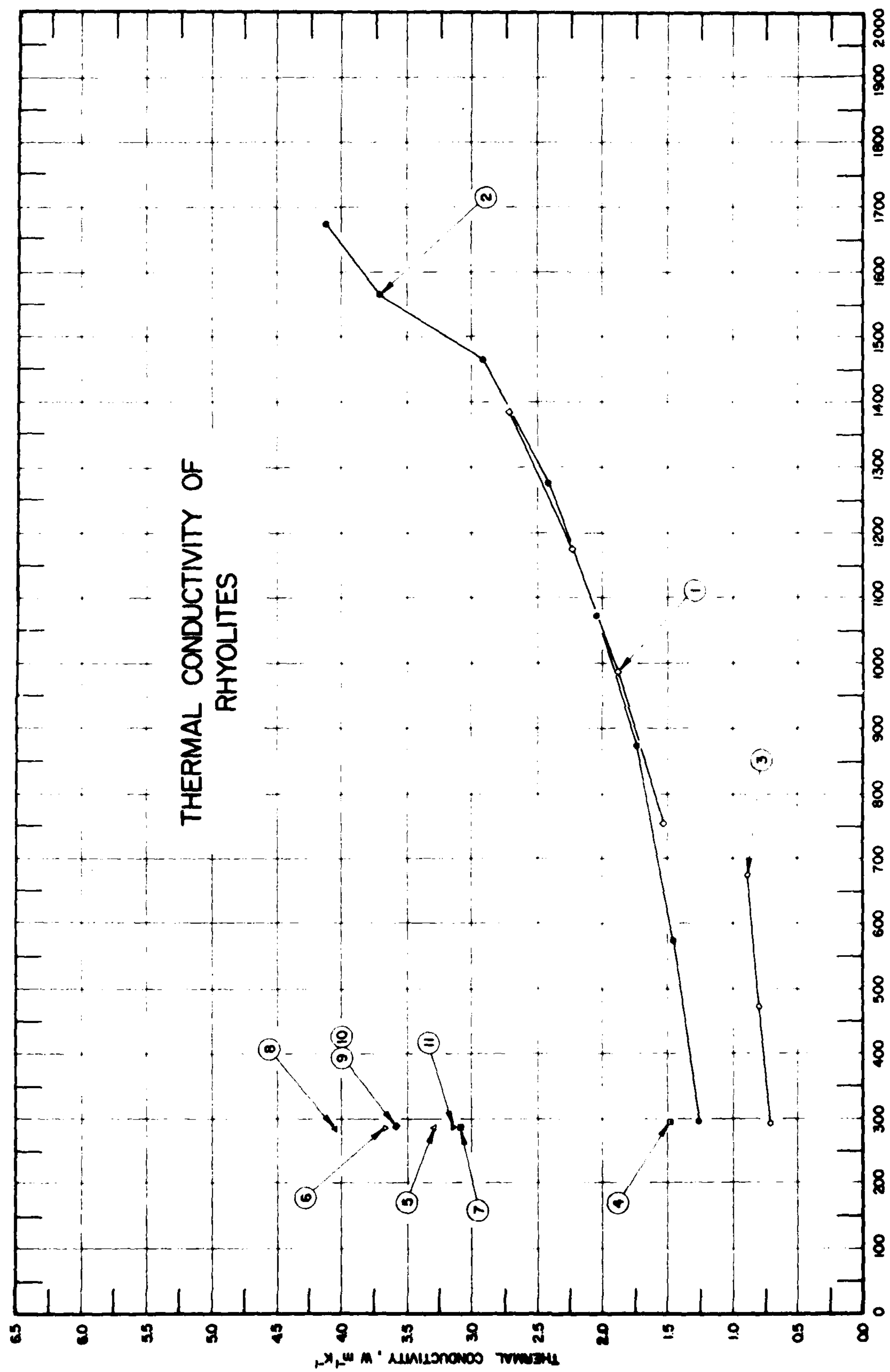

THERMAL CONDUCTIVITY OF
RHYOLITES
THERMAL CONDUCTIVITY, W m⁻¹K⁻¹
TEMPERATURE, K
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
1
2
3
4
5
6
7
8
9
10
11

FIGURE 10-K-T

TABLE 10-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
1	15	Morase, T. and McBirney, A.R. (1970)	Rhyolite Obsidian	Platinum container, 5 cm dia x 5.5 cm high		3				Steady Radial Absolute	752 987 1176 1384	1.54 1.88 2.24 2.71	Source: Newberry Caldera, Oregon. Other: conductivity values were extrapolated to zero porosity; heating cycle.
2	15	Morase, T. and McBirney, A.R. (1970)	Rhyolite Obsidian	Platinum container, 5 cm dia x 5.5 cm high		3				Steady Radial Absolute	299 574 872 1074 1277 1465 1567 1671	1.26 1.46 1.74 2.04 2.42 2.91 3.72 4.13	Source: Newberry Caldera, Oregon. Other: conductivity values were extrapolated to zero porosity; initial measurements were for molten rock at 1400 C; cooling cycle.
3	17	Wechsler, A.E. and Glasser, P.E. (1964)	Altered Rhyolite	Cylinder 10.2 cm dia x 15.2 cm long						Nonsteady Line Heat Source	293 473 673	0.71 0.80 0.88	
4	10	Tadokoro, Y. (1921)			2.432		SiO_2 Al_2O_3 Fe_2O_3 CaO FeO MnO	72.27 11.34 5.52 3.32 3.26 0.30		Indirect	298	1.49	Source: Prov. Etchu (Asia). Texture: dark grey color and very compact in texture, fine veins of quartz and epidote present. Other: data is obtained from measurements of diffusivity, specific heat and density.
5	14	Misener, A.D., Thompson, L.G.D., and Uffen, R.J. (1951)	Brecciated Rhyolite	Disk	2.90					Steady Longitudinal Comparative	289	3.297	Source: Delnite Mine, Timmins, Ontario (depth 1500 ft).
6	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.84					Steady Longitudinal Comparative	289	3.66	Source: Delnite Mine, Timmins, Ontario (depth 2750 ft).
7	14	Misener, A.D., et al. (1951)	Brecciated Rhyolite	Disk	2.82					Steady Longitudinal Comparative	289	3.09	Source: Delnite Mine, Timmins, Ontario (depth 300 ft).
8	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.90					Steady Longitudinal Comparative	289	4.05	Source: McIntyre Mine, Timmins, Ontario (depth 1250 ft).
9	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.82					Steady Longitudinal Comparative	290	3.347	Source: Delnite Mine, Timmins, Ontario (depth 1500 ft).
10	14	Misener, A.D., et al. (1951)		Disk	2.81					Steady Longitudinal Comparative	289	3.36	Source: Delnite Mine, Timmins, Ontario (depth 1250 ft).
11	14	Misener, A.D., et al. (1951)		Disk	2.85					Steady Longitudinal Comparative	288	3.14	Source: Delnite Mine, Timmins, Ontario (depth 1000 ft).

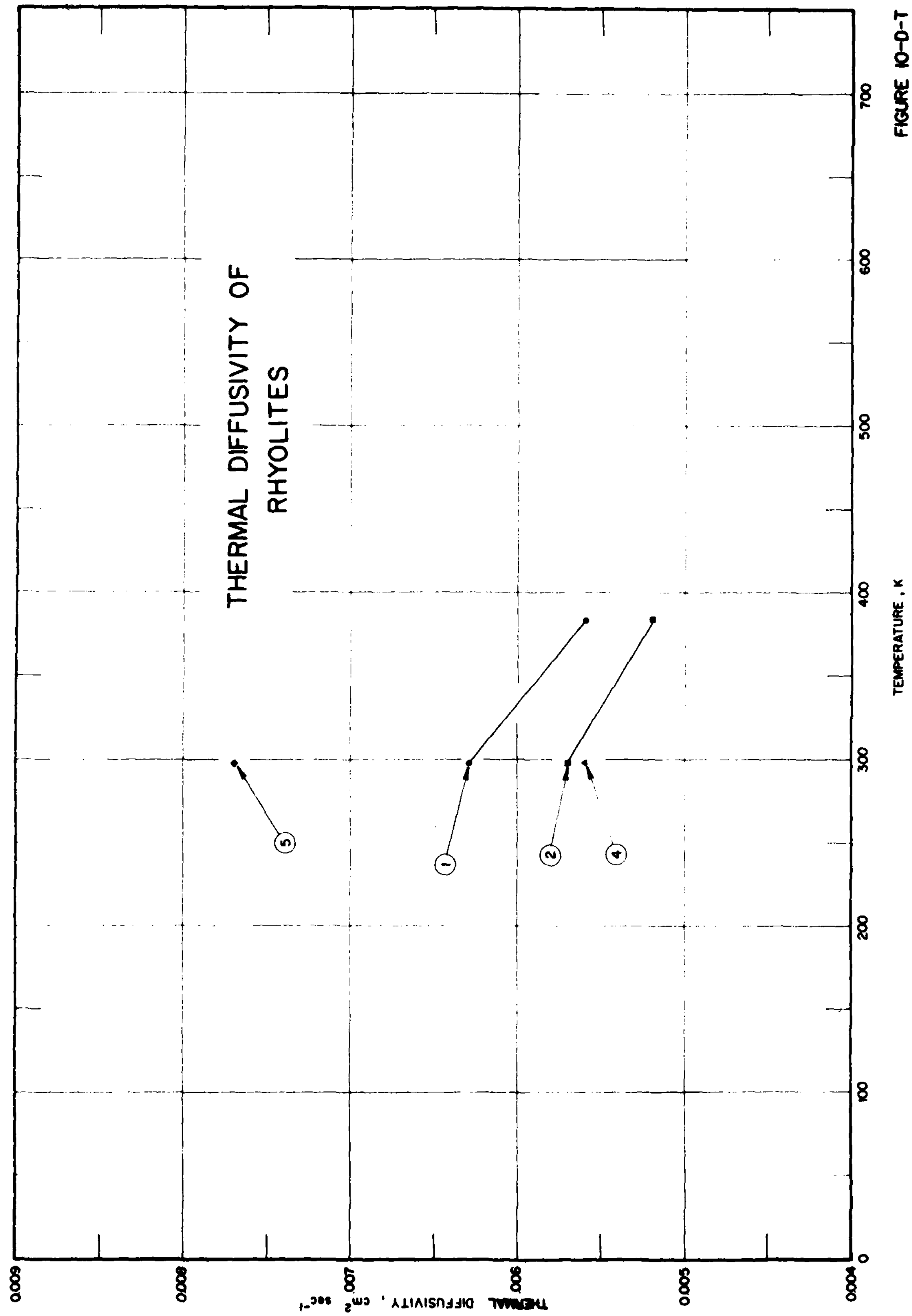

THERMAL DIFFUSIVITY OF
RHYOLITES
TEMPERATURE, K
THERMAL DIFFUSIVITY, cm² sec⁻¹
0
100
200
300
400
500
600
700
0.004
0.005
.006
.007
0.008
0.009
1
2
4
5

FIGURE 10-D-T

TABLE 10-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
1	42	Lindroth, D.P. (1974)	Porphyritic Rhyolite Vitrophyre	Disk 19.05 mm dia, 4 mm thick			SiO_2 Al_2O_3 Na_2O Fe_2O_3 K_2O CaO H_2O- FeO TiO_2 MgO MnO H_2O^+ CO_2 P_2O_5 S	70.1 14.9 5.74 2.77 2.60 1.33 0.48 0.44 0.26 0.20 0.18 0.13 0.10 0.05 0.011		Flash Method	298 383	0.0063 0.0056	Source: Newberry Caldera, Ore. Test Environment: nitrogen at 760 torr pressure. Other: reported error ± 5%.
2	42	Lindroth, D.P. (1974)	Same as above	Same as above			Same as above			Flash Method	298 383	0.0057 0.0052	Source: same as above. Test Environment: nitrogen at 1.0×10^{-6} torr pressure. Other: same as above.
3*	42	Lindroth, D.P. (1974)	Same as above	Same as above			Same as above			Flash Method	383	0.0056	Source: same as above. Test Environment: nitrogen at 2.0×10^{-7} torr pressure. Other: same as above.
4	42	Lindroth, D.P. (1974)	Same as above	Same as above			Same as above			Flash Method	298	0.0056	Source: same as above. Test Environment: nitrogen at 3.0×10^{-6} torr pressure. Other: same as above.
5	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.432		SiO_2 Al_2O_3 Fe_2O_3 CaO FeO MnO	72.27 11.34 5.52 3.32 3.26 0.30		Periodic Heat Flow	~298	0.0077	Source: Prov. Etchu (Asia). Texture: dark grey color and very compact in texture, fine veins of quartz and of epidote present.

* Not shown in figure.

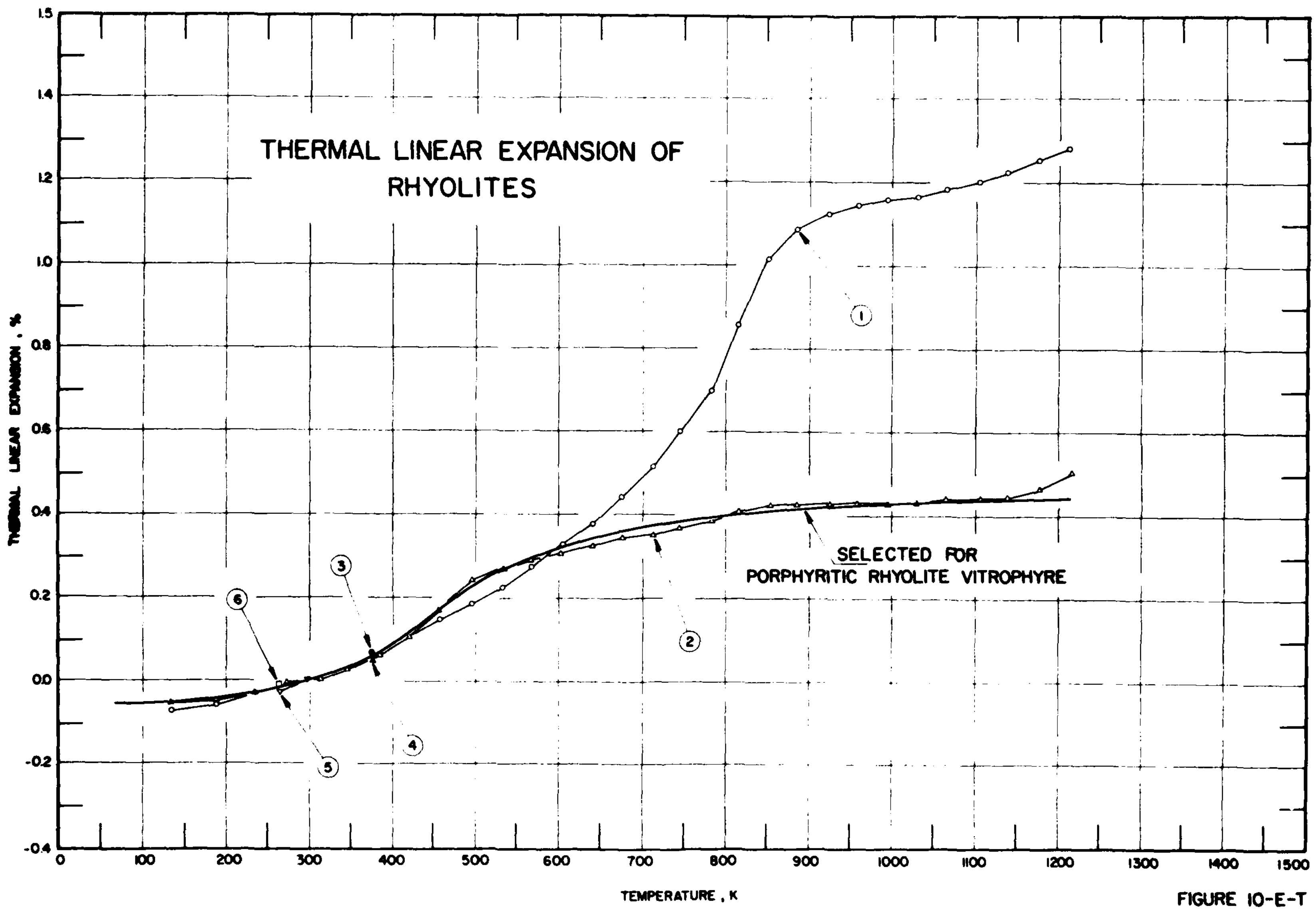

THERMAL LINEAR EXPANSION OF RHYOLITES
SELECTED FOR PORPHYRITIC RHYOLITE VITROPHYRE
1
2
3
4
5
6
THERMAL LINEAR EXPANSION, %
TEMPERATURE, K
1.5
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

FIGURE 10-E-T

TABLE 10-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E.	Altered		2.36	8	Felty ground			Dilatometer	136	-0.076	Source: E. of Bend, Oregon.
		and Demou, S. G.	Rhyolite				mass & glass		60		189	-0.056	Powder Density: 1.19 g cm^{-3}.
		(1972)					Plagioclase		25		233	-0.034*	Magnetic Susceptibility: 30 x 10^6
							Sanidine		10		273	-0.010*	cgs units.
							Quartz		2		311	0.008*	Dielectric Constant: 2.72 (ratio).
							Hematite		2		346	0.034*	Specific Area: 3.3 m^2 g^{-1}.
							Pyroxene-				383	0.070*	Other: zero-point correction is
							microlites		1		420	0.106*	-0.004%.
							SiO_2	72.5			458	0.148	
							Al_2O_3	15.7			495	0.184	
							K_2O	5.0			531	0.232	
							Na_2O	3.7			568	0.278	
							H_2O	1.6			604	0.328	
							Fe_2O_3	0.76			640	0.380	
							CaO	0.68			676	0.442	
											711	0.516	
											746	0.604	
											781	0.710	
											817	0.860	
											852	1.018	
											887	1.094	
											922	1.126	
											958	1.144	
											994	1.158	
											1030	1.172	
											1066	1.184	
											1103	1.202	
											1139	1.226	
											1177	1.258	
											1214	1.282	
2	41	Griffin, R. E.	Porphyritic		2.35	8	Glass and			Dilatometer	136	-0.054	Source: Newberry Caldera, Ore.
		and Demou, S. G.	(Vitrophyre)				Crystallites		95		189	-0.042	Powder Density: 1.04 g cm^{-3}.
		(1972)	Rhyolite				Plagioclase and				233	-0.024	Magnetic Susceptibility: 220 x 10^6
							Microphenocrysts				273	-0.008	cgs units.
							(Albite or				311	0.008	Dielectric Constant: 2.06 (ratio).
							Oligoclase)		4		346	0.030	Specific Area: 1.4 m^2 g^{-1}.
							Pyroxene		<1		383	0.062	Other: zero-point correction is
							Magnetite		<1		420	0.104	-0.006%.
							Hematite		<<1		458	0.172	
							SiO_2	70.1			495	0.242	
							Al_2O_3	14.9			531	0.272	
							Na_2O	5.74			568	0.292	
							Fe_2O_3	2.77			604	0.310	
							K_2O	2.60			640	0.324	
							CaO	1.33			676	0.342	
							H_2O	0.61			711	0.356	
							FeO	0.44			746	0.372	
											781	0.390	
											817	0.410	
											852	0.422	
											887	0.426	
											922	0.428	
											958	0.430	
											994	0.434	
											1030	0.436	
											1066	0.440	
											1103	0.442	
											1139	0.454	
											1177	0.474	
											1214	0.510	

*Not shown in figure.

TABLE 10-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF RHYOLITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
3	32	Griffith, J. H. (1937)	Breccia Rhyolite		2.65					Dilatometer	293 373	0.000 0.065	Source: Animas Forks, Colo.
4	32	Griffith, J. H. (1937)	Felsitic Rhyolite		2.59					Dilatometer	293 373	0.000 0.059	Source: Mojave, Calif.
5	54	Mitchell, L.J. (1953)	Quarried Rhyolite							Dilatometer	263 293 297	-0.025 0.000 0.003	Source: Crooked River Project, Oregon. Other: average of heating and cooling cycle.
6	54	Mitchell, L.J. (1953)	Pebble Rhyolite							Dilatometer	263 293 297	-0.012 0.000 0.002*	Source: Republican River gravel, Colo. Other: average of heating and cooling cycle.

*Not shown in figure.

TABLE 10-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1*	17	Wechsler, A.E. and Glaser, P.E. (1964)	Altered Rhyolite							Drop Calorimeter	395 558	0.21 0.23	
2*	36	Svikis, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm size	2.664		K-Felspar Quartz Na-Felspar Magnetite		52 23 21 3	Isothermal Water Calorimeter	600	0.237	Source: Canada. Texture: allotriomorphic; medium grained; homogeneous. Other: average of two runs; mean Cp between 896 K, temp to which specimen is heated and 300 K, final temp of bath.

*No figure given.

C. SELECTED VALUES FOR PORPHYRITIC RHYOLITE VITROPHYRE

Thermal Conductivity. There have been measurements on a few types of rhyolite and none on Porphyritic Rhyolite Vitrophyre.

Thermal Diffusivity. Measurements of Lindroth [42] between 298 and 383 K indicate that the values are independent of environmental pressure.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Values for other rhyolites by Griffith [32] and Mitchell [54] follow closely the above curve.

Specific Heat. No measurement was reported for Porphyritic Rhyolite Vitrophyre.

Selected Values for Porphyritic Rhyolite Vitrophyre*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
100	-0.055
150	-0.049
200	-0.038
293	0.000
300	0.006
400	0.090
500	0.235
600	0.320
700	0.371
800	0.400
900	0.418
1000	0.428
1100	0.438
1200	0.442

*No selections were made for other thermophysical properties.

11. QUARTZ SANDSTONES

A. PETROGRAPHY

Sandstones are composed of clastic particles of sand size with varying amounts and types of cement which bind the clastic particles together. Of these particles, quartz is the dominant constituent in a quartz sandstone, commonly 65% or more, with less than 25% feldspar and less than 2% clay minerals. Chert, chlorite, and zircon are common, accessory minerals.

Berea Sandstone

The mineralogy and texture of Berea sandstone from Lorain Co., Ohio, given by Hasan and West [101], is summarized below:

Mineralogical Composition

Mineral	Vol. Percent
Quartz	65
Chert	33
Carbonate	1
Fe-ore, zircon, muscovite, feldspar	1

Texture. The rock is composed of rounded to subangular quartz grains which are randomly distributed. Occasionally, however, they show tendency for preferred orientation. Chert is usually subrounded. Quartz and chert grains average 0.14 mm in diameter; others range in diameter from 0.01 to 0.1 mm.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are reported in the following pages.

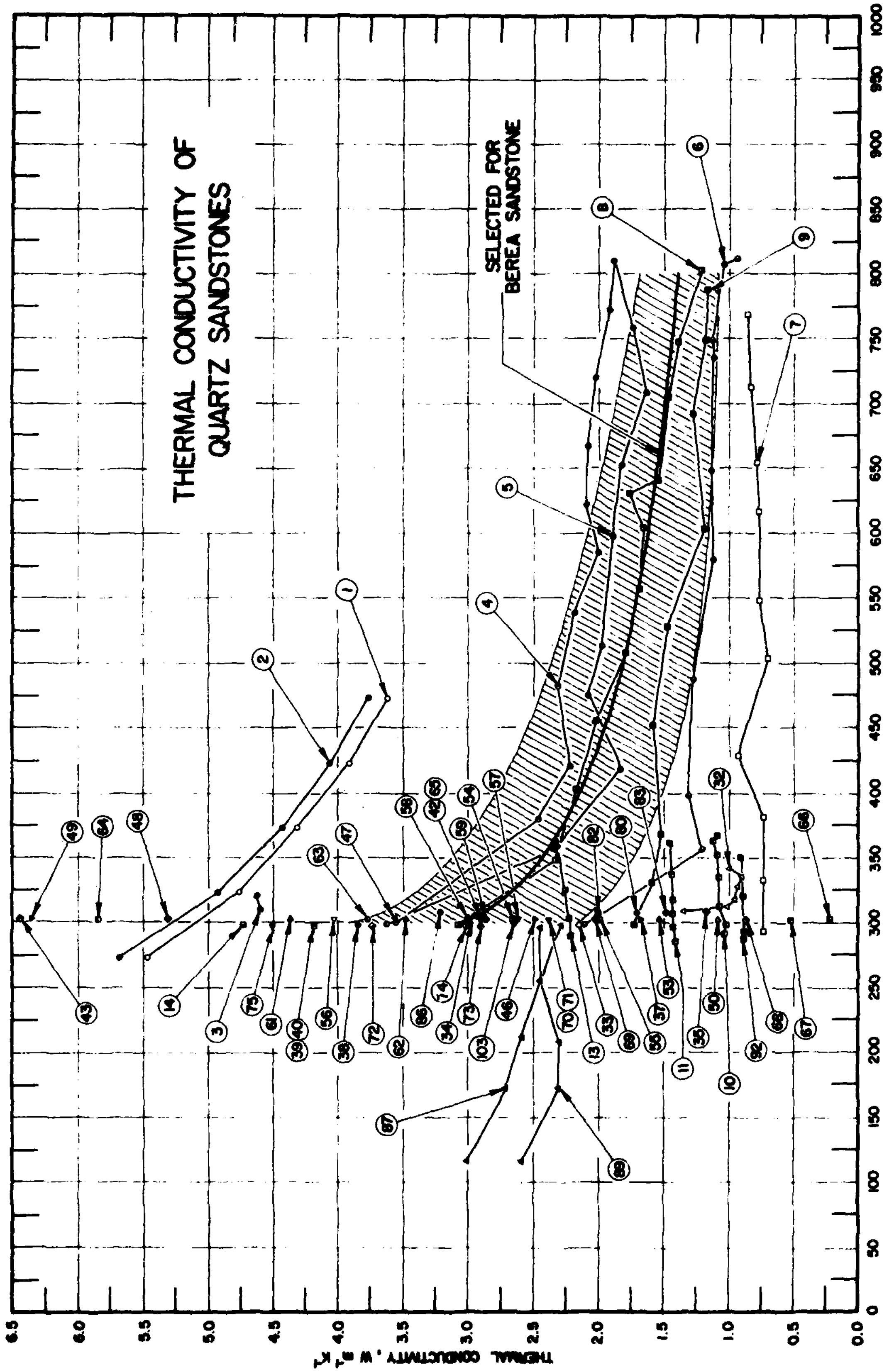

THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES
SELECTED FOR BEREA SANDSTONE
TEMPERATURE, K
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹

FIGURE II-K-T

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m⁻¹ K⁻¹)	Remarks
1	1	Birch, F. and Clark, H. (1940)	Quartzitic Sandstone	Disk 3.8 cm dia x 6.4 cm high	2.688, 2.647					Steady Longitudinal Absolute	273	5.48	Source: Allentown, Pennsylvania.
											323	4.77	Texture: mean crystal diameter 0.3 mm.
											373	4.31	Direction of Measurements: perpendicular to bedding.
											423	3.91	Other: values are extrapolated to zero porosity; data from smoothed curve.
											473	3.62	
2	1	Birch, F. and Clark, H. (1940)	Quartzitic Sandstone	Same as above	2.688, 2.647					Steady Longitudinal Absolute	273	5.69*	Source: same as above.
											323	4.94	Texture: same as above.
											373	4.44	Direction of Measurements: parallel to bedding.
											423	4.06	Other: same as above.
											473	3.77	
3	2	Nancarrow, H.A. (1933)	Recrystallized Sandstone	Cylinder 5 cm dia, 2 cm high	2.40					Steady Longitudinal Absolute	310	4.60	Source: Lower Permian, The Old Quarry, Penrith, Cumberland.
											320	4.73	Other: error reported ± 1%.
4	3	Messmer, J.H. (1965)	St. Peters Sandstone	10.2 cm cylinder, 17.8 cm long with 3.2 mm axial hole 16.5 cm deep		11	Quartz		98	Line Heat Source	300	3.56	Permeability: 3.4 md.
							Feldspar		1		381	2.46	Other: heating cycle.
							Kaolinite		0.5		421	2.21	
							Illite		0.5		483	2.33	
											539	2.18	
											586	2.01	
											622	2.08	
											666	2.07	
											721	2.04	
											773	1.91	
											810	1.89	
5	3	Messmer, J.H. (1965)	St. Peters Sandstone	Same as above		11	Same as above			Line Heat Source	810	1.87*	Permeability: 3.4 md.
											758	1.74	Other: cooling cycle.
											709	1.64	
											652	1.81	
											600	1.89	
											514	1.97	
											475	2.06	
											419	1.84	
											356	2.34	
											299	3.58	
6	3	Messmer, J.H. (1965)	Teapot Sandstone	Same as above		29	Quartz		88	Line Heat Source	299	2.10	Permeability: 1960 md.
							Kaolinite		7		358	1.22	Other: heating cycle.
							Illite		5		399	1.31	
											489	1.28	
											580	1.12	
											648	1.14	
											736	1.11	
											744	1.13	
											808	1.04	
											811	0.916	
7	3	Messmer, J.H. (1965)	Teapot Sandstone	Same as above		29	Same as above			Line Heat Source	770	0.853	Permeability: 1960 md.
											714	0.828	Other: cooling cycle.
											655	0.774	
											617	0.765	
											549	0.753	
											501	0.803	
											428	0.673	
											381	0.732	
											333	0.740	
											295	0.740	

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
8	3	Messmer, J.H. (1965)	Berea Sandstone	Same as above		22	Quartz		88	Line Heat Source	297	3.08	Permeability: 480 md.
							Kaolinite		10		347	2.36	Other: heating cycle.
							Illite		2		403	2.18	
											455	2.03	
											506	1.77	
											556	1.70	
											604	1.65	
											630	1.76	
											641	1.54	
											705	1.46	
											748	1.40	
											804	1.26	
9	3	Messmer, J.H. (1965)	Berea Sandstone	Same as above		22	Same as above			Line Heat Source	790	1.20	Permeability: 480 md.
											749	1.19	Other: cooling cycle.
											691	1.29	
											603	1.17	
											529	1.48	
											450	1.57	
											369	1.53	
											331	1.59	
											297	1.74	
10	4	Sugawara, A. and Yoshizawa, Y. (1962)	Akabira Sandstone	Plate		42.3				Steady Longitudinal Comparative	292	1.04	Source: Sumitomo Coal Mine located in Hokkaido.
											297	1.02	Texture: medium particle size 0.5–0.25 mm; color grey, hard.
											313	1.08	
											336	1.08	
											352	1.09	
											364	1.12	
											367	1.09	
11	4	Sugawara, A. and Yoshizawa, Y. (1962)	Iwaki Sandstone	Plate		9.7				Steady Longitudinal Comparative	285	1.42	Source: Joban Coal Mine located in Fukushima Prefecture.
											297	1.43	Texture: same as above.
											308	1.43	
											320	1.43	
											340	1.44	
											361	1.46	
12*	4	Sugawara, A. and Yoshizawa, Y. (1962)	Akabira Sandstone	Plate		42.3				Steady Longitudinal Comparative	287	1.06	Source: Sumitomo Coal Mine located in Hokkaido.
											310	1.07	Texture: medium particle size 0.5–0.25 mm; color grey, appreciably hard.
											330	1.08	Other: 100% water saturated specimen; error reported ± 3%.
											345	1.10	
											360	1.12	
											366	1 14	
13	4	Sugawara, A. and Yoshizawa, Y. (1962)	Iwaki Sandstone	Plate		9.7				Steady Longitudinal Comparative	289	2.22	Source: Joban Coal Mine located in Fukushima Prefecture.
											303	2.24	Texture: same as above.
											325	2.26	Other: same as above.
											327	2.27*	
											362	2.28	
14	7	Sass, J.H. and LeMarne, A.E. (1963)	Garnetiferous Sandstone	Disk 3.5 cm dia x 0.6–0.7 cm thick						Steady Longitudinal Comparative	298	4.73	Source: Broken Hills, New South Wales. Other: values extrapolated to zero resistance; error reported 5%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
15*	9	Viloria, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		21.55				Steady Longitudinal Absolute	320 323 324 337 336 348	1.14 1.48 1.02 1.07 1.62 2.45	Permeability: 250 md. Other: specimen saturated with a 17% water-83% oil mixture; thermal contact was improved by using a contact agent; error reported ± 4%.
16*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		15.35				Steady Longitudinal Absolute	316 318 320 329 338	1.34 0.913 1.66 1.25 1.73	Permeability: 250 md. Other: specimen saturated with a 54% water-46% oil mixture; thermal contact was improved by using a contact agent; error reported ± 4%.
17*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		20.72				Steady Longitudinal Absolute	313 322 327 334 351	1.94 1.88 2.23 2.64 3.20	Permeability: 250 md. Other: specimen saturated with a 63% water-37% oil mixture; thermal contact was improved by using a contact agent; error reported ± 4%.
18*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		20.60				Steady Longitudinal Absolute	307 317 325 334 351	1.60 1.81 2.22 1.91 3.20	Permeability: 250 md. Other: specimen saturated with a 6% water-94% oil mixture; thermal contact was improved by using a contact agent; error reported ± 4%.
19*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		19.50				Steady Longitudinal Absolute	308 320 323 337 345	0.718 0.733 0.386 0.794 0.441	Permeability: 250 md. Other: specimen saturated with a 67% water-33% oil mixture; thermal contact was improved by using a contact agent; this core was damaged; error reported ± 4%.
20*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		18.79				Steady Longitudinal Absolute	311 318 321 331 346	2.09 1.86 1.90 2.74 2.48	Permeability: 250 md. Other: specimen saturated with a 55% water-45% oil mixture; thermal contact was improved by using a contact agent; error reported ± 4%.
21*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		19.8				Steady Longitudinal Absolute	325 328 334 344 346	0.618 1.53 1.87 1.48 1.68	Permeability: 250 md. Other: specimen saturated with 71% air-29% water; thermal contact was improved by using a contact agent; error reported ± 4%.
22*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		19.58				Steady Longitudinal Absolute	316 320 321 320 324 331 348	2.16 1.79 0.964 0.990 1.69 1.61 1.22	Permeability: 250 md. Other: specimen saturated with 92% air-8% water; thermal contact was improved by using a contact agent; error reported ± 4%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
23*	9	Viloria, G. (1968)	Berea Sandstone	Disk		19.63				Steady Longitudinal Absolute	312 318 325 330 335	0.434 0.871 0.810 0.869 0.937	Permeability: 250 md. Other: 100% water saturated specimen; damaged disk; the thermal contact between the specimen and the apparatus was improved by using glycerin or lubricating oil; error reported ± 4%.
24*	9	Viloria, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 1.9 cm thick		20.25				Steady Longitudinal Absolute	315 322 327 331 336	1.72 1.89 1.78 1.84 1.73	Permeability: 250 md. Other: 100% water saturated specimen; the thermal contact between the specimen and the apparatus was improved by using glycerin or lubricating oil; error reported ± 4%.
25*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		21.6				Steady Longitudinal Absolute	316 320 324 329 336	1.57 1.90 1.85 1.94 1.88	Permeability: 250 md. Other: same as above.
26*	9	Viloria, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 1.8 cm thick		19.30				Steady Longitudinal Absolute	314 320 326 331 347	1.11 1.50 1.54 1.24 1.96	Permeability: 250 md. Other: specimen saturated with 100% oil; thermal contact was improved by using a contact agent; error reported ± 4%.
27*	9	Viloria, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		20.72				Steady Longitudinal Absolute	315 319 322 329 342 348	1.07 1.04 1.10 1.46 1.40 1.43	Permeability: 250 md. Other: same as above.
28*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		20.85				Steady Longitudinal Absolute	327 325 330 333 337 342	0.377 0.406 0.496 0.371 0.295 0.352	Permeability: 250 md. Other: specimen saturated with 23% air-77% oil; thermal contact was improved by using a contact agent; error reported ± 4%.
29*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		20.80				Steady Longitudinal Absolute	314 315 334 335 341	1.03 0.542 0.401 1.20 1.64	Permeability: 250 md. Other: specimen saturated with 43% air-57% oil; thermal contact was improved by using a contact agent; error reported ± 4%.
30*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		21.01				Steady Longitudinal Absolute	316 323 325 338 344	0.756 0.967 0.829 1.06 1.08	Permeability: 250 md. Other: specimen saturated with 25% air-75% oil; thermal contact was improved by using a contact agent; error reported ± 4%.
31*	9	Viloria, G. (1968)	Berea Sandstone	Same as above		20.05				Steady Longitudinal Absolute	307 318 320 337 345	1.43 1.51 1.64 3.08 2.08	Permeability: 250 md. Other: specimen saturated with 33% air-67% oil; thermal contact was improved by using a contact agent; error reported ± 4%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
32	9	Viloria, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		20				Steady Longitudinal Absolute	308 313 317 328 336 341	1.35 1.03* 0.965 0.983 0.908 1.00	Permeability: 250 md. Other: thermal contact is improved by using a contact agent; error reported ± 4%.
33	10	Tadokoro, Y. (1921)	Idzumani Sandstone		2.476		SiO_2 Al_2O_3 FeO MgO CaO Fe_2O_3 MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40		Indirect	298	2.14	Source: Prov. Awa (Asia). Texture: grains 0.5 mm; grey colored sandstone of Cretaceous system; uniform in structure and no plane of bedding discernible. Other: data obtained from measurements of diffusivity, specific heat and density.
34	10	Tadokoro, Y. (1921)			2.547		SiO_2 Al_2O_3 Fe_2O_3 CaO MnO MgO	68.6 19.54 5.74 1.84 0.54 trace		Indirect	298	3.00	Source: Prov. Kawachi (Asia). Texture: 0.2-0.1 mm grain size; dark colored, fine and compact in texture; no bedded structure. Other: same as above.
35	11	Mossahebi, M. (1966)	Boise Sandstone	Cylindrical						Non-Steady Ring Heat Source	308	1.17	Other: error reported <6%.
36*	11	Mossahebi, M. (1966)	Bandera Sandstone	Cylinders						Non-Steady Ring Heat Source	298	1.72	Other: value given is average of several sizes; error reported ± 6%; data corresponds to several diameters.
37	11	Mossahebi, M. (1966)	Berea Sandstone	Cylindrical						Non-Steady Ring Heat Source	303	1.67	Other: error reported <6%.
38	13	Lorentzen, G. (1960)		Flat Surface						Thermal Comparator	298	3.85	Source: Norway.
39	18	Benfield, A.E. (1939)		Disk 2.5 cm dia x 0.1-1.4 cm long						Steady Longitudinal Comparative	298	4.18	Source: Boreland bore depth 2034 ft. Other: error reported ± 2.62%.
40	18	Benfield, A.E. (1939)		Same as above	2.34					Steady Longitudinal Comparative	298	4.18	Source: Boreland bore depth 1694 ft. Other: specific gravity is 2.34 after soaking in water.
41*	23	Thomson, W.T. (1940)			2.64					Indirect	311	1.33	Source: Lincoln County, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity.
42	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Cylinder 6.5 cm long x 7.6 cm dia (probe hole 15.2 cm long x 3.2 mm dia)		3	Quartz Kaolinite		98 2	Line Heat Source	303	2.90	Permeability: <0.1 md. Other: specimen placed in vacuo.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
43	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 16.5 cm long x 3.2 mm dia)		3	Quartz Kaolinite		98 2	Line Heat Source	303	6.48	Permeability: <0.1 md.
44*	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite		98 2	Line Heat Source	303	7.40	Permeability: <0.1 md. Other: specimen saturated with water.
45*	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 15.2 cm long x 3.2 mm dia)		3	Quartz Kaolinite		98 2	Line Heat Source	303	7.11	Permeability: <0.1 md. Other: specimen saturated with n-heptane.
46	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite		98 2	Line Heat Source	303	2.49	Permeability: 3.4 md. Other: specimen placed in vacuo.
47	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite		98 2	Line Heat Source	303	3.55	Permeability: 3.4 md.
48	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite		98 2	Line Heat Source	303	5.34	Permeability: 3.4 md. Other: specimen saturated with n-heptane.
49	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite		98 2	Line Heat Source	303	6.359	Permeability: 3.4 md. Other: specimen saturated with water.
50	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	1.09	Permeability: 1960 md. Other: specimen placed in vacuo.
51*	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	1.46	Permeability: 1960 md. Other: specimen saturated with Freon-12.
52*	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	1.42	Permeability: 1960 md. Other: specimen saturated with argon.
53	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	1.54	Permeability: 1960 md.
54	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	2.65	Permeability: 1960 md. Other: specimen saturated with n-heptane.
55	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	1.98	Permeability: 1960 md. Other: specimen saturated with helium.
56	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	303	4.04	Permeability: 1960 md. Other: specimen saturated with water.
57	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica		90 10	Line Heat Source	303	2.62	Permeability: 220 md. Other: specimen placed in vacuo.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
58	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	3.00	Permeability: 220 md. Other: specimen saturated with Freon-12.
59	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	2.87	Permeability: 220 md. Other: specimen saturated with argon.
60*	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica		90 10	Line Heat Source	303	3.03	Permeability: 220 md.
61	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	4.37	Permeability: 220 md. Other: specimen saturated with n-heptane.
62	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	3.47	Permeability: 220 md. Other: specimen saturated with helium.
63	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	3.78	Permeability: 220 md. Other: specimen saturated with hydrogen.
64	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica		90 10	Line Heat Source	303	5.86	Permeability: 220 md. Other: specimen saturated with water.
65	25	Woodside, W. and Messmer, J.H. (1961)	Berea Sandstone	Cylinder 16.5 cm long x >7.6 cm dia (probe hole 15.2 cm long x 3.2 mm dia)		22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	303	2.91	Permeability: 0.480 darcy. Other: specimen saturated with helium.
66	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 15.2 cm long x 3.2 mm dia)		59	Quartz Amorphous Silica		85 15	Line Heat Source	303	0.221	Permeability: 650 md. Other: specimen placed in vacuo.
67	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica		85 15	Line Heat Source	303	0.52	Permeability: 650 md.
68	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica		85 15	Line Heat Source	303	0.878	Permeability: 650 md. Other: specimen saturated with n-heptane.
69	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica		85 15	Line Heat Source	303	2.03	Permeability: 650 md. Other: specimen saturated with water.
70	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298	2.39	Permeability: 0.480 darcy. Other: the major component is quartz with a conductivity of 20 m cal $cm^{-1} s^{-1} C^{-1}$; saturated with N_2O.
71	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298.	2.38	Permeability: 0.480 darcy. Other: the major solid component is quartz with a thermal conductivity of 20 m cal $cm^{-1} s^{-1} C^{-1}$.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
72	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298	3.74	Permeability: 0.480 darcy. Other: same as above except saturated with n-heptane.
73	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298	2.92	Permeability: 0.480 darcy. Other: same as above except saturated with He.
74	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298	3.00	Permeability: 0.480 darcy. Other: same as above except saturated with H_2.
75	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite		88 10 2	Line Heat Source	298	4.50	Permeability: 0.480 darcy. Other: same as above except saturated with H_2O.
76*	46	Beck, A.E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 2.0 mm thick						Steady Longitudinal Comparative	300.9	2.84	Source: Australia Bore Hole 14, Snowy Bountain, depth 461 ft. Direction of Measurements: parallel to bedding. Other values are extrapolated to zero contact resistance.
77*	46	Beck, A.E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 4.0 mm thick						Steady Longitudinal Comparative	300.9	2.84	Source: same as above. Direction of Measurements: same as above. Other: same as above.
78*	46	Beck, A.E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 6.0 mm thick						Steady Longitudinal Comparative	300.9	2.97	Source: same as above. Direction of Measurements: same as above. Other: same as above.
79*	46	Beck, A.E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 8.0 mm thick						Steady Longitudinal Comparative	300.9	3.01	Source: same as above. Direction of Measurements: same as above. Other: same as above.
80	47	Mossop, S.C. and Gafner, G. (1951)	Karroo System; Lower Beaufort Series	Disk 3.5 cm dia	2.56					Steady Longitudinal Comparative	308	1.71	Source: Bore Hole 7, SE of Kestell, S. Africa at 800 ft. depth. Texture: fine grained. Direction of Measurements: perpendicular to bedding. Other: rock contains shale bands; reported error 8.3%.
81*	47	Mossop, S.C. and Gafner, G. (1951)	Same as above	Disk 3.5 cm dia	2.36					Steady Longitudinal Comparative	308	1.46	Source: same as above except 445 ft depth. Texture: same as above. Direction of Measurements: same as above. Other: reported error 1.4%.
82	47	Mossop, S.C. and Gafner, G. (1951)	Same as above	Disk 3.5 cm dia	2.46					Steady Longitudinal Comparative	310	2.00	Source: same as above except 1358 ft depth. Texture: same as above. Direction of Measurements: same as above.
83	47	Mossop, S.C. and Gafner, G. (1951)	Same as above	Disk 3.5 cm dia	2.41					Steady Longitudinal Comparative	306	1.46	Source: same as above except 1068 ft depth. Texture: same as above. Direction of Measurements: same as above. Other: reported error 2.9%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m^{-1} K^{-1})	
84*	47	Mossop, S.C. and Gafner, G. (1951)	Karroo System; Upper Ecca Series	Disk 3.5 cm dia	2.50					Steady Longitudinal Comparative	306	1.80	Source: same as above except 2402 ft depth. Texture: same as above. Direction of Measurements: same as above.
85*	47	Mossop, S.C. and Gafner, G. (1951)	Same as above	Disk 3.5 cm dia	2.45					Steady Longitudinal Comparative	306.2	2.22	Source: same as above except 2097 ft depth. Texture: same as above. Direction of Measurements: same as above. Other: reported error 1.6%.
86	47	Mossop, S.C. and Gafner, G. (1951)	Karroo System; Middle Ecca Series	Disk 3.5 cm dia	2.59					Steady Longitudinal Comparative	308	3.22	Source: same as above except 3472 ft depth. Direction of Measurements: same as above. Other: reported error 4.9%.
87	78	Lentz, A.E. and Monfore, G.E. (1966)	Buena Vista Member, Cuyahoga Formation	Prism 5.1 x 10.2 x 20.3 cm	2.64 (appar.)		Quartz, Clay minerals, Feldspar Hornblende, Zircon, Pyrite	major† minor†		Non-Steady Line Heat Source	116 172 214 255 297	3.03 2.74 2.59 2.45 2.45	Source: Portsmouth, Ohio. Test Environment: air with relative humidity 50%. Other: water content 0.1%; reported error ± 3%.
88*	78	Lentz, A.E. and Monfore, G.E. (1966)	Same as above	Same as above	2.64 (appar.)		Same as above			Non-Steady Line Heat Source	116 172 214 255 297	7.50 6.05 2.19 4.04 4.04	Source: same as above. Test Environment: moist air. Other: water content 7.3%; reported error ± 3%.
89	78	Lentz, A.E. and Monfore, G.E. (1966)	Same as above	Same as above	2.64 (appar.)		Same as above			Non-Steady Line Heat Source	116 172 214 255 297	2.59 2.31 2.31 2.45 2.31	Source: same as above. Test Environment: dry air. Other: reported error ± 3%.
90*	80	Sugawara, A. (1961)			1.980	18.2				Steady Longitudinal Comparative	285 293 294 311 331 352	1.06 1.06 1.06 1.07 1.07 1.08	Source: Fukushima, Japan. Other: moisture content 13.4 (vol.%).
91*	80	Sugawara, A. (1961)	Calcareous Sandstone		2.110	14.5				Steady Longitudinal Comparative	285 290 293 328 332 345 349	1.30 1.31 1.31 1.34 1.33 1.35 1.37	Source: Fukushima, Japan. Other: moisture content 2.8 (vol.%).
92	80	Sugawara, A. (1961)	Calcareous Sandstone		1.880	25.2				Steady Longitudinal Comparative	287 288 293 295 320 331 332 345 349	0.868 0.877* 0.877 0.874* 0.890 0.910* 0.898* 0.898* 0.920	Source: Fukushima, Japan. Other: moisture content 0 (vol.%).

* Not shown in figure.
† In descending order of abundance.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

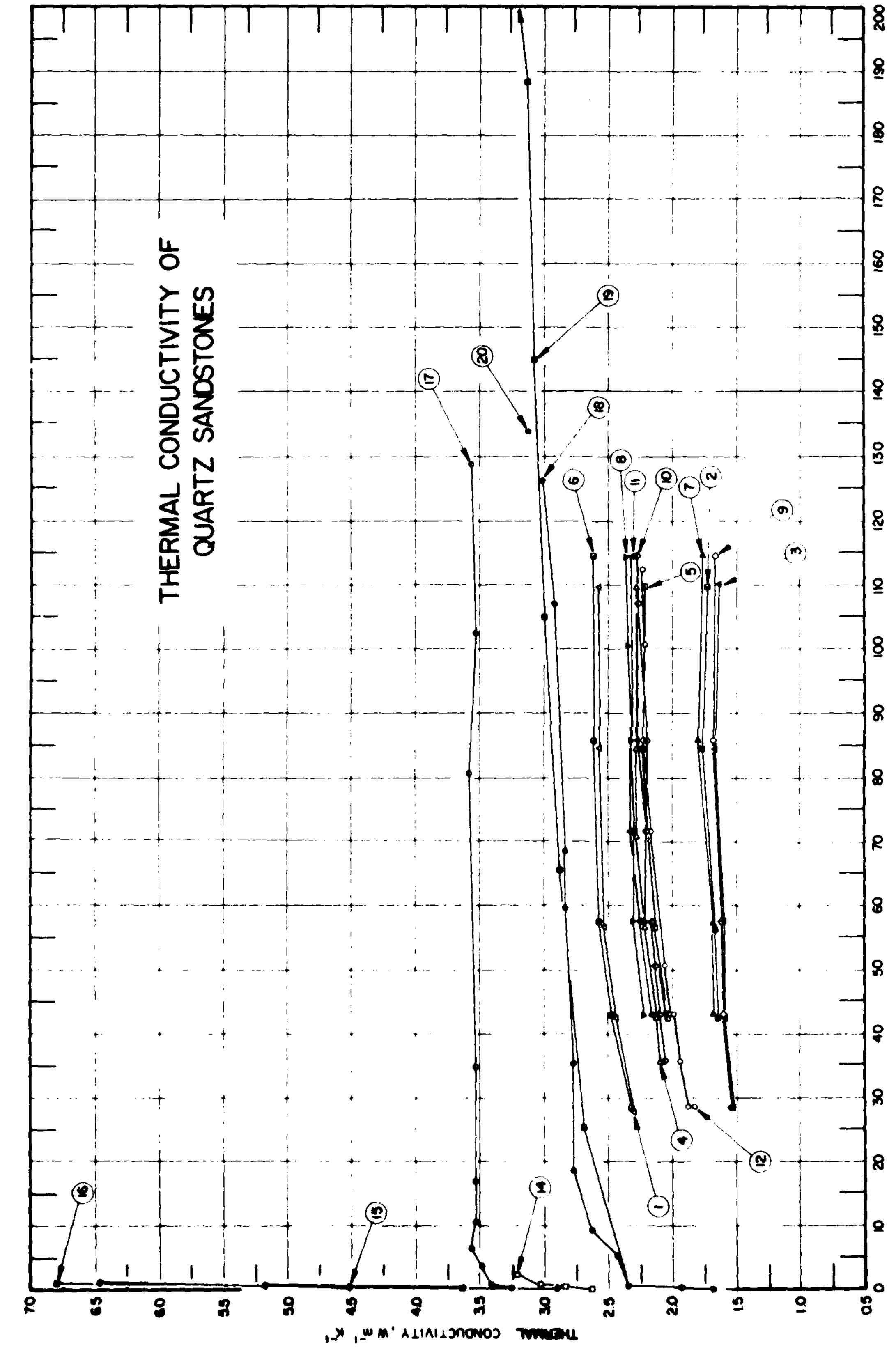
Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
93*	80	Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6				Steady	282	0.622	Source: Fukushima, Japan.
										Longitudinal	284	0.633	Other: *moisture content 0 (vol.%).*
										Comparative	293	0.630	
											294	0.632	
											310	0.630	
											322	0.632	
											332	0.683	
											350	0.659	
94*	80	Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6				Steady	285	0.791	Source: Fukushima, Japan.
										Longitudinal	293	0.798	Other: moisture content 5.1 (vol.%).
										Comparative	313	0.822	
											332	0.840	
											334	0.838	
											343	0.894	
											351	0.893	
											352	0.845	
95*	80	Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6				Steady	284	0.902	Source: Fukushima, Japan.
										Longitudinal	293	0.908	Other: moisture content 19.7 (vol.%).
										Comparative	295	0.903	
											298	0.922	
											314	0.886	
											332	0.960	
											337	0.938	
											344	1.02	
											351	1.00	
96*	80	Sugawara, A. (1961)	Calcareous Sandstone		2.110	14.5				Steady	289	1.39	Source: Fukushima, Japan.
										Longitudinal	293	1.40	Other: moisture content 10.5 (vol.%).
										Comparative	303	1.41	
											308	1.41	
											332	1.42	
											334	1.46	
											337	1.41	
											345	1.49	
											349	1.47	
97*	80	Sugawara, A. (1961)	Calcareous Sandstone		2.110	14.5				Steady	297	1.20	Source: Fukushima, Japan.
										Longitudinal	293	1.20	Other: moisture content 0 (vol.%).
										Comparative	294	1.20	
											312	1.21	
											332	1.22	
											334	1.22	
											352	1.24	
98*	80	Sugawara, A. (1961)	Calcareous Sandstone		1.980	18.2				Steady	284	1.30	Source: Fukushima, Japan.
										Longitudinal	286	1.29	Other: moisture content 13.4 (vol.%).
										Comparative	293	1.30	
											300	1.29	
											311	1.32	
											329	1.34	
											341	1.33	
											349	1.38	
99*	80	Sugawara, A. (1961)	Calcareous Sandstone		1.980	18.2				Steady	284	1.23	Source: Fukushima, Japan.
										Longitudinal	293	1.24	Other: moisture content 6.7 (vol.%).
										Comparative	293	1.26	
											312	1.26	
											321	1.25	
											333	1.27	
											348	1.30	

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
100*	60	Sugawara, A. (1961)	Calcareous Sandstone		1.980	18.2				Steady Longitudinal Comparative	292	1.19	Source: Fukushima, Japan.
											293	1.20	Other: moisture content 3.1 (vol.%).
											312	1.21	
											319	1.21	
											334	1.23	
											349	1.23	
											350	1.22	
											352	1.25	
101*	60	Sugawara, A. (1961)	Calcareous Sandstone		1.880	25.2				Steady Longitudinal Comparative	286	1.14	Source: Fukushima, Japan.
											293	1.15	Other: moisture content 16.2 (vol.%).
											302	1.17	
											317	1.15	
											329	1.13	
											338	1.19	
											347	1.23	
											349	1.26	
102*	60	Sugawara, A. (1961)	Calcareous Sandstone		1.880	25.2				Steady Longitudinal Comparative	288	1.019	Source: Fukushima, Japan.
											290	1.048	Other: moisture content 4.3 (vol.%).
											293	1.029	
											308	1.029	
											316	1.026	
											327	1.065	
											342	1.103	
											350	1.070	

* Not shown in figure.



THERMAL CONDUCTIVITY OF
QUARTZ SANDSTONES
PRESSURE , ATM
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹

FIGURE II-K-P

TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1	28	Khan, A. M. and Fatt, I. (1964)	Berea Sandstone	Cylinder 3 cm dia, 1.9 cm long						Steady Longitudinal Absolute	28	2.30	Temperature of measu. ..ments: 319.15 K. Other: sample was subjected to axial pressure.
											42	2.44	
											57	2.53	
											84	2.56	
											110	2.57	
2	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above						Same as above	42	1.64	Temperature of measurements: 327.15 K. Other: same as above.
											56	1.66	
											84	1.76	
											110	1.73	
3	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above						Same as above	28	1.52	Temperature of measurements: 335.15 K. Other: same as above.
											42	1.59	
											57	1.60	
											84	1.66	
											110	1.64	
4	28	Khan, A. M. and Fatt, I. (1964)	Berea Sandstone	Same as above						Same as above	35	2.10	Temperature of measurements: 336.15 K. Other: same as above.
											42	2.13	
											57	2.22	
											71	2.29	
											84	2.28	
											110	2.28	
5	28	Khan, A. M. and Fatt, I. (1964)	Berea Sandstone	Same as above						Same as above	42	2.04	Temperature of measurements: 353.15 K. Other: same as above.
											57	2.14	
											84	2.23	
											110	2.21	
6	27	Khan, A. M. (1964)	Berea Sandstone (NC No. 2)	Same as above		18				Same as above	28	2.32	Temperature of measurements: 319.15 K. Other: same as above.
											43	2.47	
											57	2.56	
											86	2.61	
											114	2.63	
7	27	Khan, A. M. (1964)	Bandera Sandstone	Same as above		22				Same as above	43	1.67	Temperature of measurements: 327.15 K. Other: same as above.
											57	1.68	
											86	1.80	
											114	1.76	
8	27	Khan, A. M. (1964)	Berea Sandstone (NC No. 1)	Same as above		18.6				Same as above	43	2.23	Temperature of measurements: 328.15 K. Other: same as above.
											57	2.30	
											71	2.30	
											86	2.32	
											100	2.35	
											114	2.36	
9	27	Khan, A. M. (1964)	Bandera Sandstone	Same as above		22				Same as above	28	1.54	Temperature of measurements: 335.15 K. Other: same as above.
											43	1.60	
											57	1.62	
											86	1.69	
											114	1.68	
10	27	Khan, A. M. (1964)	Berea Sandstone	Same as above		18.6				Same as above	36	2.06	Temperature of measurements: 336.15 K. Other: same as above.
											43	2.10	
											50	2.14	
											57	2.16	
											57	2.22	
											71	2.20	
											86	2.20	
											107	2.27	
											114	2.28	

TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm	Thermal Conductivity (W m^{-1} K^{-1})	Remarks
11	27	Khan, A.M. (1964)	Berea Sandstone (NC No. 2)	Same as above		18				Same as above	36 43 57 71 86 114	2.12 2.16 2.25 2.33 2.32 2.33	Temperature of measurements: 336.15 K. Other: same as above.
12	27	Khan, A.M. (1964)	Berea Sandstone No. 1	Same as above		18.6				Same as above	28 28 36 43 43 50 71 86 100 112	1.83 1.88 1.95 1.99 2.02 2.06 2.18 2.23 2.23 2.24	Temperature of measurements: 344.15 K. Other: same as above.
13	27	Khan, A.M. (1964)	Berea Sandstone No. 2	Same as above		18				Same as above	43 57 86 114	2.06 2.16 2.28 2.27	Temperature of measurements: 353.15 K. Other: same as above.
14	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone 1	Cylinder at least 7.6 cm dia, 16.5 cm long (probe hole 15.2 cm long, 3 mm dia)		15.5	Quartz Amorphous Silica		90 10	Nonsteady Line Heat Source	0.000014 0.000026 0.000068 0.00062 0.014 0.069 0.25 0.38 0.97 2.0	2.62 2.64 2.64 2.66 2.73 2.79 2.84 2.87 3.04 3.23	Permeability: 220 md. Temperature of measurements: 296.15 K. Other: sample was subjected to hydrostatic pressure in an air environment.
15	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite		98 2	Same as above	0.000014 0.000025 0.000046 0.00039 0.0091 0.0053 0.011 0.14 0.94	2.90 2.98 3.30 4.08 4.18 4.32 4.53 5.19 6.48	Permeability: < 0.1 md. Temperature of measurements: 296.15 K. Test environment: dry air.
16	25	Woodside, W. and Messmer, J.H. (1961)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite		98 2	Same as above	0.00008 0.0004 0.97	3.64 4.50 6.81	Permeability: < 0.1 md. Temperature of measurements: 296.15 K. Test environment: air with 60% relative humidity.
17	25	Woodside, W. and Messmer, J.H. (1961)	Berea Sandstone	Same as above		22	Quartz Kaolinite Illite		88 10 2	Same as above	0.34 25 65 105 133 145 188 244	2.36 2.69 2.87 3.00 3.13 3.08 3.14 3.20	Permeability: 480 md. Temperature of measurements: 298 K. Other: air saturated sample subjected to variable over-burden pressure.

TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: P, atm	Thermal Conductivity (W m⁻¹ K⁻¹)	Remarks
18	25	Woodside, W. and Messmer, J.H. (1961)	Berea Sandstone	Same as above		22	Same as above			Same as above	0.34	1.73	Permeability: 480 md. Temperature of measurements: 298 K. Other: air evacuated sample subjected to variable overburden pressure.
											13	2.12	
											34	2.35	
											76	2.64	
											122	2.81	
											136	3.01	
											167	2.97	
											216	3.05	
											270	3.06	
19	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone				Quartz		88	Same as above	0.0033	3.25	Temperature of measurements: 298.15 K. Other: sample was subjected to the indicated hydrostatic pressure in a nitrogen environment and a constant overburden pressure of 271.38 atmospheres.
							Kaolinite		10		0.026	3.36	
							Illite		2		0.108	3.36	
											0.40	3.38	
											0.97	3.41	
											3.7	3.48	
											6.4	3.56	
											10	3.53	
											16	3.53	
											35	3.52	
											81	3.58	
											102	3.53	
											129	3.56	
20	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone				Quartz		88	Same as above	0.01	1.68	Temperature of measurements: 298 K. Other: sample was subjected to hydrostatic pressure in a nitrogen environment.
							Kaolinite		10		0.04	1.76	
							Illite		2		0.10	1.83	
											0.20	1.94	
											0.38	2.15	
											0.96	2.35	
											5.1	2.43	
											9.1	2.63	
											18	2.76	
											35	2.76	
											60	2.84	
											69	2.84	
											107	2.92	
											126	3.01	
21	16	Clark, H. (1941)		Disk 3.81 cm dia x 6 mm thick	2.64	0.5				Steady Longitudinal Absolute	1.0	3.85	Source: Doubling Gap, Pa. Temperature of measurements: 318 K. Other: dry sample subjected to axial pressure.
											680	4.54	
22	16	Clark, H. (1941)		Same as above	2.64	0.5				Same as above	1.0	4.35	Source: same as above. Temperature of measurements: 318 K. Other: water saturated sample subjected to axial pressure.
											680	4.56	
23	16	Clark, H. (1941)		Same as above	2.17	22				Same as above	1.0	1.85	Source: Owl Canyon, Colorado. Temperature of measurements: 318 K. Other: dry sample subjected to axial pressure.
											680	2.41	
24	16	Clark, H. (1941)		Same as above	2.17	22				Same as above	1.0	2.52	Source: same as above. Temperature of measurements: 318 K. Other: water saturated sample subjected to axial pressure.
											680	2.63	

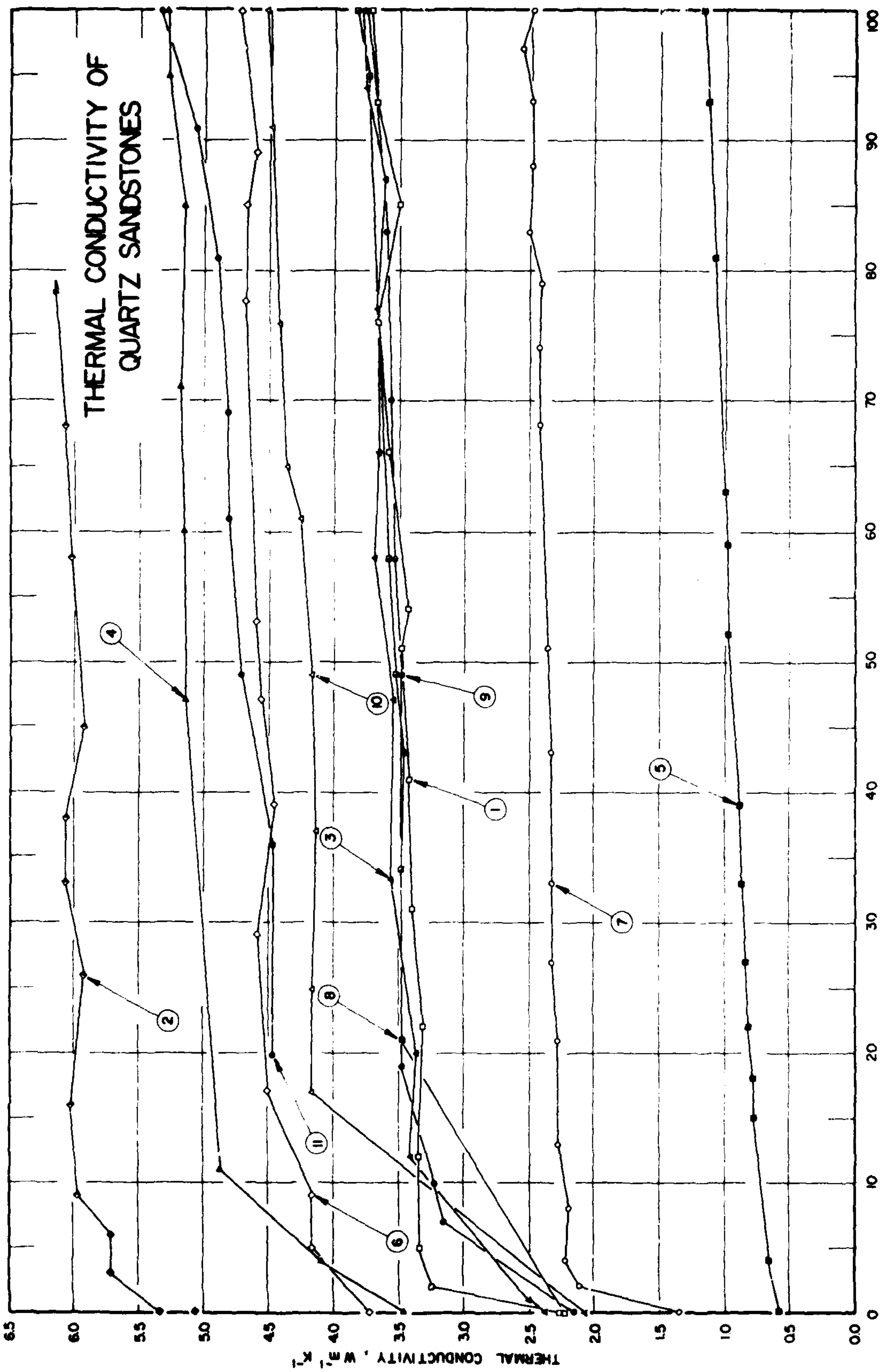

THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES
THERMAL CONDUCTIVITY, W m⁻¹ K⁻¹
SATURATION, %
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11

FIGURE II-K-S

TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: S_o (%)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Remarks
1	3	Messmer, J. H. (1965)	American Marietta Sandstone	10.2 cm dia cylinder 17.8 cm long with 3 mm axial hole 16.5 cm deep		20	Quartz		98	Line Heat Source	0	2.24	Permeability: 3000 md.
							Feldspar		2		100	3.71	Temperature of Measurements: 298.15 K.
											93	3.67	Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids; S_o denotes percent saturation with Soltrol "C" and the rest is air at 1 atm.
											85	3.50	
											76	3.66	
											66	3.58	
											54	3.44	
											51	3.48	
											41	3.43	
											31	3.42	
											22	3.32	
											12	3.35	
											5	3.36	
											2	3.26	
											0	2.28	
2	3	Messmer, J. H. (1965)	Berkeley Sandstone	Same as above		3	Quartz		98	Line Heat Source	0	5.071**	Permeability: < 0.1 md.
							Kaolinite		2		100	6.32*	Temperature of Measurements: 298.15 K.
											68	6.07	Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
											58	6.02	
											45	5.94	
											38	6.07	
											33	6.07	
											26	5.94	
											16	6.02	
											9	5.98	
											6	5.73	
											3	5.73	
											0	5.35	
3	3	Messmer, J. H. (1965)	Berea Sandstone	Same as above		22	Quartz		88	Line Heat Source	0	2.40	Permeability: 480 md.
							Kaolinite		10		100	3.79	Temperature of Measurements: 298.15 K.
							Illite		2		94	3.75	Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
											87	3.61	
											77	3.66	
											66	3.65	
											58	3.69	
											47	3.55	
											33	3.57	
											20	3.36	
											12	3.43	
											1	2.51	
											0	2.40*	
4	3	Messmer, J. H. (1965)	St. Peters Sandstone	Same as above		11.4	Quartz		98.0	Line Heat Source	0	3.48	Permeability: 3.4 md.
							Feldspar		1.0		100	5.27	Temperature of Measurements: 298.15 K.
							Illite		0.5		95	5.27	Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
							Kaolinite		0.5		85	5.15	
											71	5.19	
											60	5.15	
											47	5.15	
											11	4.89	
											4	4.10	

* Not shown in figure.
** Vacuum dried.

TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: S_o (%)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Remarks
5	3	Messmer, J. H. (1965)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica		85-90 15-10	Line Heat Source	0	0.60	Permeability: 650 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
											100	1.17	
											93	1.13	
											81	1.05	
											63	1.01	
											59	1.00	
											52	0.97	
											39	0.89	
											33	0.87	
											27	0.85	
											22	0.83	
											18	0.80	
											15	0.78	
											4	0.68	
6	3	Messmer, J. H. (1965)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica		90-95 10-5	Line Heat Source	0	3.74	Permeability: 220 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
											100	4.73	
											89	4.60	
											85	4.69	
											77	4.69	
											53	4.60	
											47	4.56	
											39	4.48	
											29	4.60	
											17	4.52	
											9	4.18	
											5	4.18	
7	3	Messmer, J. H. (1965)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	0	1.36	Permeability: 1960 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
											100	2.48	
											97	2.55	
											93	2.48	
											88	2.45	
											83	2.50	
											79	2.41	
											74	2.43	
											68	2.43	
											51	2.36	
											43	2.34	
											33	2.33	
											27	2.34	
											21	2.30	
											13	2.29	
											8	2.20	
											4	2.23	
											2	2.12	
8	3	Messmer, J. H. (1965)		Same as above		20	Quartz Feldspar		98 2	Line Heat Source	0	2.242*	Permeability: 3000 md. Temperature of Measurements: 298.15 K. Other: Marusol (white mineral oil from American Oil Co., Chicago, Illinois) and air used as saturating fluids.
											100	3.619	
											95	3.748	
											76	3.669*	
											58	3.577	
											49	3.522	
											43	3.468	
											34	3.493	
											21	3.465	
											0	2.238*	

* Not shown in figure.

TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: S_o(%)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Remarks
9	3	Messmer, J. H. (1965)		Same as above		20	Quartz		98	Line Heat Source	0	2.24*	Permeability: 3000 md.
							Feldspar		2		100	3.73	Temperature of Measurements: 298.15 K.
											83	3.60	Other: n-Heptane and air used as saturating fluids.
											70	3.56	
											58	3.55	
											49	3.50	
											19	3.48	
											10	3.23	
											7	3.15	
											0	2.17	
10	3	Messmer, J. H. (1965)		Same as above			Quartz		98	Line Heat Source	100	4.52	Temperature of Measurements: 298.15 K.
							Feldspar		2		91	4.47	Other: S_o is a mixture of 19.2% water-balance-Soltrol C (oil from Phillips Petroleum Co., Bartlesville, Oklahoma); the rest is air.
											76	4.43	
											65	4.35	
											61	4.27	
											49	4.16	
											37	4.14	
											25	4.18	
											17	4.18	
											0	2.09	
11	3	Messmer, J. H. (1965)		Same as above		20	Quartz		98	Line Heat Source	100	5.31	Permeability: 3000 md.
							Feldspar		2		91	5.06	Temperature of Measurements: 298.15 K.
											81	4.89	Other: water and air used as saturating fluids.
											69	4.81	
											61	4.81	
											49	4.72	
											36	4.47	
											20	4.47	

* Not shown in figure.

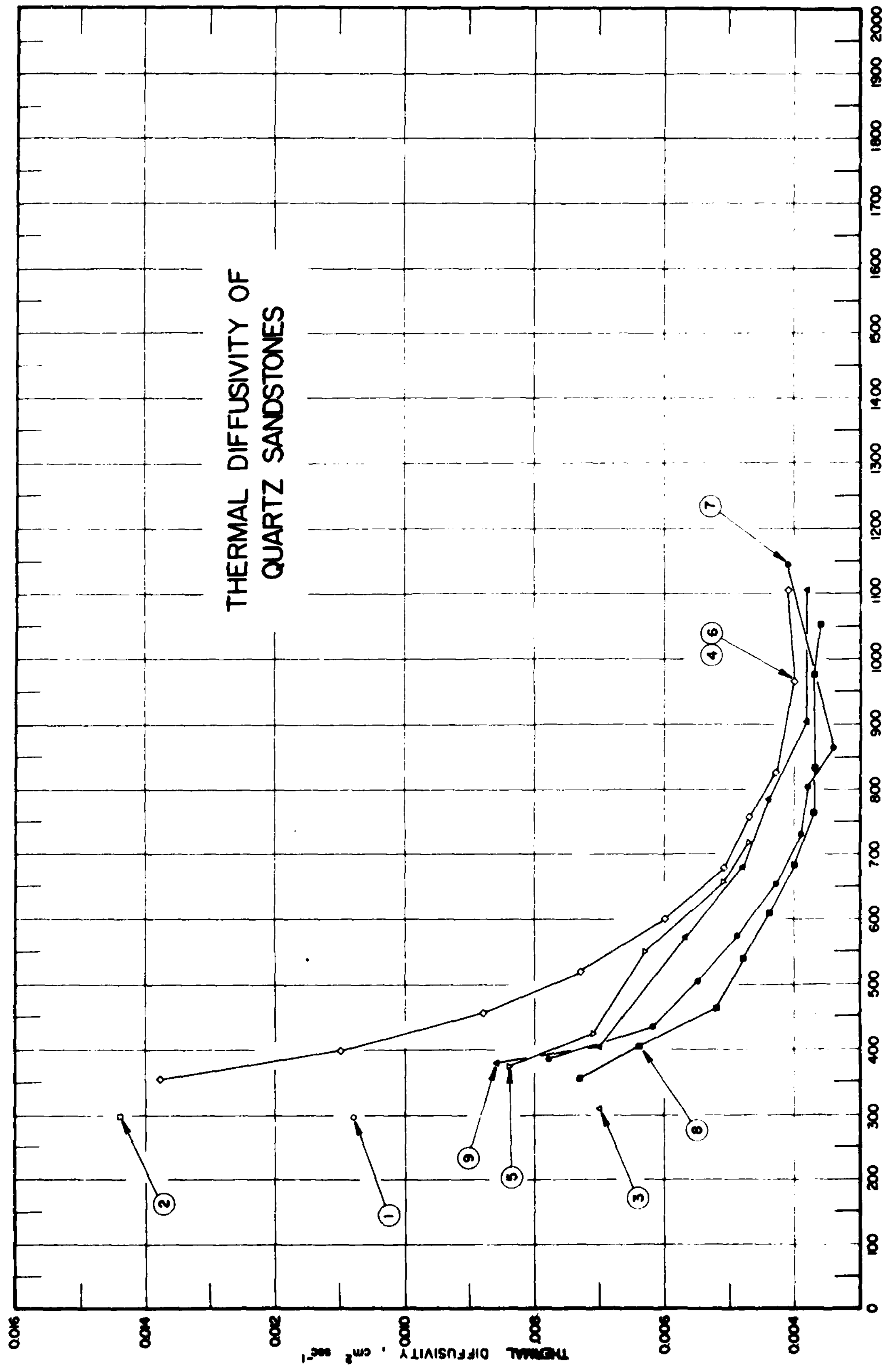

THERMAL DIFFUSIVITY OF
QUARTZ SANDSTONES
THERMAL DIFFUSIVITY, cm² sec⁻¹
0.016
0.014
0.012
0.010
0.008
0.006
0.004
TEMPERATURE, K
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
1
2
3
4
5
6
7
8
9

FIGURE 11-D-T

TABLE 11-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α (cm^2 s^{-1})	Remarks
1	10	Tadokoro, Y. (1921)	Idzumi Sandstone	Cube 6 cm by side	2.476		SiO_2 Al_2O_3 FeO MgO CaO Fe_2O_3 MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40		Periodic Heat Flow	~298	0.0108	Source: Prov. Awa (Asia). Texture: grey colored sandstone of Cretaceous system; uniform in structure and no plane of bedding discernible; grains mostly of 0.5 mm size.
2	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.547		SiO_2 Al_2O_3 Fe_2O_3 CaO MnO MgO	68.6 19.54 5.74 1.84 0.54 trace		Periodic Heat Flow	~298	0.0144	Source: Prov. Kawachi (Asia). Texture: dark colored, fine and compact in texture; no bedded structure; size of grains ranging between 0.2-0.1 mm.
3	23	Thomson, W.T. (1940)		Cylinder 2.5 cm dia, 20 cm long	2.64					Radial Heat Flow	311	0.0070	Source: Lincoln County, Kansas. Other: the specimen was heated to approx 330 K and then cooled to room temperature by blowing air with a fan; thermal diffusivity was calculated for a section of this transient state; reported error ± 10%.
4	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 1	Cylinder 2.8 cm dia, 5.7 cm long	2.11	20.0	SiO_2 Al_2O_3 Fe_2O_3 Na_2O CaO MgO K_2O	78.99 8.70 5.85 1.95 1.70 1.66 1.15		Transient Radial	355 399 455 521 601 678 758 826 964 1106	0.0138 0.0110 0.0088 0.0073 0.0060 0.0051 0.0047 0.0043 0.0040 0.0041	Source: Bandera. Direction of Measurements: parallel to bedding. Other: reported error ± 8%.
5	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)	Sample 2	Same as above	2.11	20.0	Same as above			Transient Radial	372 426 551 658 718	0.0084 0.0071 0.0058 0.0051 0.0047	Source: same as above. Direction of Measurements: same as above. Other: same as above.
6	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	356 401 460 521 602 680 759 827 970 1015 1105	0.0138 0.0110 0.0088 0.0073 0.0060 0.0051 0.0047 0.0043 0.0039 0.0039* 0.0040	Source: same as above. Direction of Measurements: same as above. Other: same as above.
7	72, 89, 90	Somerton, W.H. and Boozer, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	383 435 504 576 655 732 805 867 1145	0.0078 0.0062 0.0055 0.0049 0.0043 0.0039 0.0038 0.0034 0.0041	Source: same as above. Direction of Measurements: same as above. Other: same as above.

* Not shown in figure.

TABLE 11-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	
8	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	357	0.0073	Source: same as above. Direction of Measurements: same as above. Other: same as above.
											407	0.0064	
											462	0.0056	
											539	0.0048	
											611	0.0044	
											685	0.0040	
											765	0.0037	
											835	0.0037	
											977	0.0037	
											1052	0.0036	
9	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	381	0.0086	Source: same as above. Direction of Measurements: same as above. Other: same as above.
											405	0.0070	
											572	0.0057	
											681	0.0048	
											784	0.0044	
											905	0.0038	
											1105	0.0038	

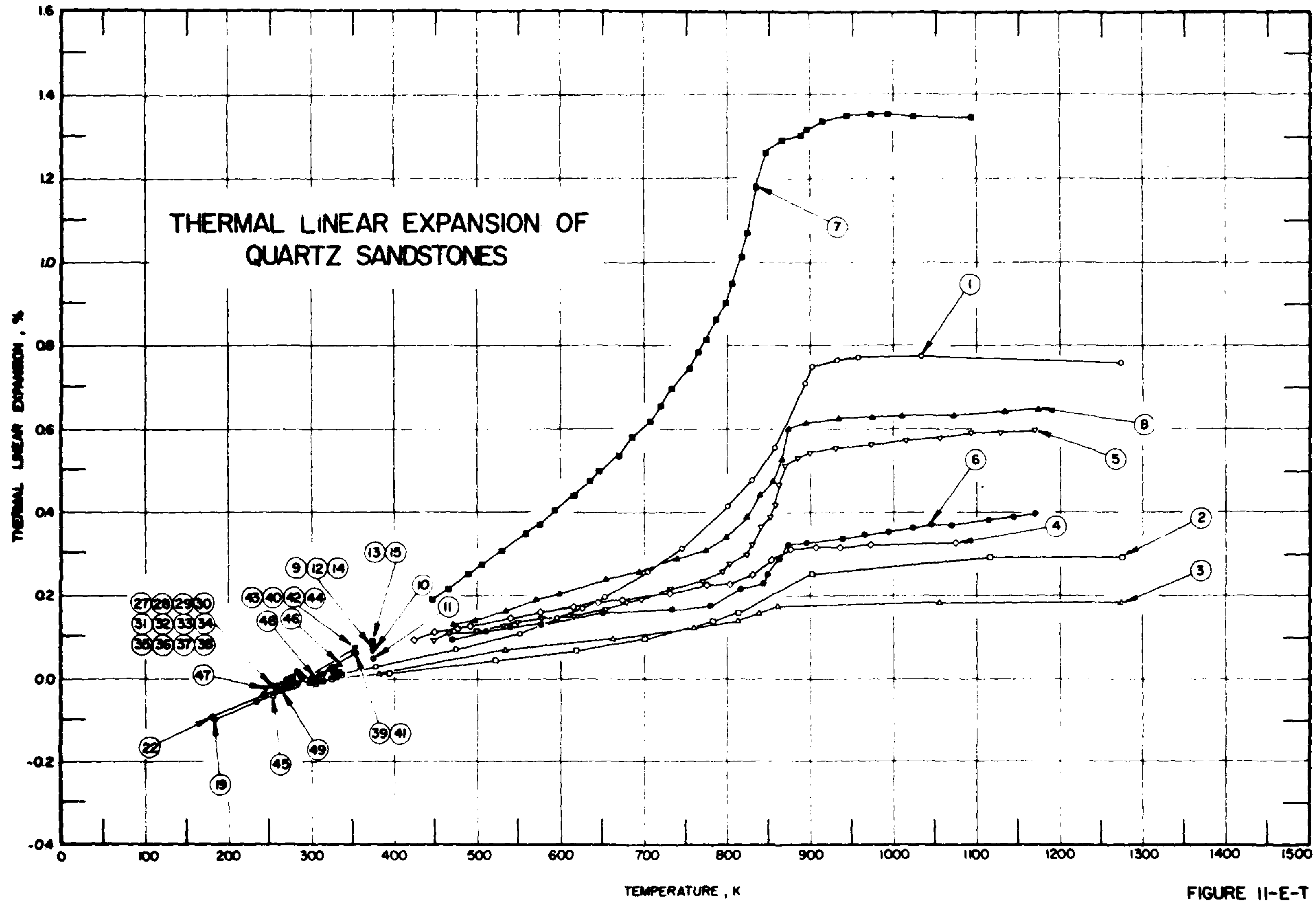

THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES
THERMAL LINEAR EXPANSION, %
TEMPERATURE, K
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

FIGURE 11-E-T

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	45	Houldsworth, H.S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000	Source: Penshaw quarry, England.
											378	0.031	Other: unfired sandstone dried at
											474	0.072	100 C.
											551	0.112	
											597	0.143	
											627	0.169	
											653	0.197	
											703	0.258	
											744	0.316	
											800	0.414	
											830	0.478	
											858	0.558	
											893	0.716	
											902	0.749	
											932	0.765	
											958	0.773	
											1033	0.778	
											1273	0.761	
2	45	Houldsworth, H.S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000*	Source: Penshaw quarry, England.
											393	0.013	Other: sandstone reheated to 1000 C.
											522	0.043	
											618	0.067	
											699	0.098	
											782	0.139	
											813	0.158	
											901	0.255	
											1114	0.292	
											1273	0.292	
3	45	Houldsworth, H.S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000*	Source: Penshaw quarry, England.
											381	0.013	Other: after use in glass furnace
											420	0.040	and developing a columnar
											536	0.068	structure.
											661	0.097	
											759	0.121	
											812	0.140	
											839	0.158	
											861	0.175	
											1055	0.183	
											1273	0.183	
4	40	Chen, T. and Hu, S.E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO_2	82.88		Dilatometer	423	0.093	Source: Chunking, China.
							Al_2O_3	11.88			448	0.106	Other: specimen prefired to 1500 C.
							Fe_2O_3	0.80			476	0.122	
							Alkalis	0.30			491	0.129	
							MgO	0.13			539	0.145	
							CaO	0.05			576	0.160	
							Quartz		68.33		614	0.173	
							Kaolinite		25.80		643	0.184	
							Illite		2.98		672	0.190	
							Sericite		2.15		731	0.204	
							Pyrite		0.71		775	0.226	
							Calcite		0.10		802	0.226	
											829	0.250	
											852	0.283	
											876	0.313	
											907	0.318	
											936	0.318	
											971	0.322	
											1073	0.328	

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
5	40	Chen, T. and Hu, S.E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.610	8.2	SiO_2	82.72		Dilatometer	447	0.097	Source: Chunking, China.
							Al_2O_3	10.97			466	0.111	Other: specimen prefired to 1150 C.
							Fe_2O_3	1.22			498	0.117	
							CaO	0.45			531	0.127	
							Alkalis	0.36			548	0.137	
							MgO	0.26			578	0.146	
											614	0.151	
							Quartz		68.75		653	0.166	
							Kaolinite		21.42		676	0.183	
							Illite		6.03		696	0.190	
							Sericite		1.91		731	0.214	
							Pyrite		1.15		769	0.234	
							Calcite		0.80		792	0.258	
											801	0.277	
											822	0.297	
											829	0.323	
											842	0.363	
											851	0.387	
											858	0.418	
											862	0.465	
											870	0.513	
											884	0.531	
											900	0.542	
											931	0.553	
											973	0.563	
											1015	0.572	
											1058	0.580	
											1094	0.591	
											1129	0.591	
											1170	0.594	
6	40	Chen, T. and Hu, S.E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.610	8.2	SiO_2	82.72		Dilatometer	470	0.099	Source: Chunking, China.
							Al_2O_3	10.97			511	0.116	Other: specimen prefired to 1500 C.
							Fe_2O_3	1.22			540	0.124	
							CaO	0.45			578	0.137	
							Alkalis	0.36			614	0.142*	
							MgO	0.26			651	0.161	
							Quartz		68.75		732	0.167	
							Kaolinite		21.42		779	0.178	
							Illite		6.03		817	0.186	
							Sericite		1.91		842	0.229	
							Pyrite		1.15		848	0.253	
							Calcite		0.80		862	0.290	
											873	0.322	
											896	0.328	
											939	0.339	
											966	0.347	
											992	0.354	
											1022	0.365	
											1046	0.372	
											1070	0.372	
											1112	0.382	
											1145	0.390	
											1170	0.398	

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T,K	Thermal Linear Expansion (%)	Remarks
7	40	Chen, T. and Hu, S.E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO_2	82.88		Dilatometer	443	0.192	Source: Chunking, China. Other: specimen untreated.
							Al_2O_3	11.88			466	0.218	
							Fe_2O_3	0.80			490	0.257	
							Alkalis	0.30			506	0.276	
							MgO	0.13			531	0.308	
							CaO	0.05			559	0.350	
							Quartz		68.33		576	0.374	
							Kaolinite		25.80		592	0.405	
							Illite		2.98		617	0.445	
							Sericite		2.15		634	0.477	
							Pyrite		0.71		646	0.499	
							Calcite		0.10		669	0.539	
											685	0.580	
											707	0.620	
											719	0.656	
											732	0.701	
											754	0.747	
											766	0.787	
											772	0.818	
											786	0.863	
											799	0.914	
											803	0.952	
											818	1.016	
											823	1.071	
											835	1.181	
											847	1.264	
											867	1.293	
											879	1.309	
											896	1.320	
											914	1.341	
											944	1.351	
											974	1.354	
											995	1.354	
											1024	1.351	
											1095	1.348	
8	40	Chen, T. and Hu, S.E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO_2	82.88		Dilatometer	471	0.129	Source: Chunking, China. Other: specimen prefired to 1150 C.
							Al_2O_3	11.88			498	0.140	
							Fe_2O_3	0.80			535	0.166	
							Alkalis	0.30			571	0.192	
							MgO	0.13			599	0.204	
							CaO	0.05			653	0.240	
							Quartz		68.33		693	0.257	
							Kaolinite		25.80		738	0.286	
							Illite		2.98		775	0.310	
							Sericite		2.15		799	0.342	
							Pyrite		0.71		823	0.388	
							Calcite		0.10		840	0.442	
											856	0.473	
											867	0.530	
											875	0.603	
											894	0.616	
											935	0.622	
											974	0.627	
											1010	0.632	
											1072	0.635	
											1133	0.642	
											1175	0.649	

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
9	32	Griffith, J. H. (1937)	Ferruginous Sandstone							Dilatometer	293 373	0.000* 0.081	Source: Potsdam, N.Y. Hardness: Shore No. 61.3.
10	32	Griffith, J. H. (1937)	Berea Grit Sandstone			19.9				Dilatometer	293 373	0.000* 0.073	Source: Berea, Ohio. Hardness: Shore No. 42.
11	32	Griffith, J. H. (1937)	Gray Sandstone							Dilatometer	295 373	0.000* 0.053	Source: Keesville, N.Y. Hardness: Shore No. 86.5.
12	32	Griffith, J. H. (1937)				26.4				Dilatometer	295 373	0.000* 0.080	Source: Jordan, Minn. Hardness: Shore No. 22.
13	32	Griffith, J. H. (1937)				27.3				Dilatometer	295 373	0.000* 0.090	Source: Medina, N.Y. Hardness: Shore No. 72.7
14	32	Griffith, J. H. (1937)	Brownstone Sandstone			6.8				Dilatometer	295 373	0.000* 0.079	Source: Somerset County, N.J. Hardness: Shore No. 51.3.
15	32	Griffith, J. H. (1937)	Calcareous Sandstone			11.9				Dilatometer	295 373	0.000* 0.094	Source: Socorro, N.M. Hardness: Shore No. 60.3.
16*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.16 cm long						Dilatometer	253 198 153 103	0.000 -0.063 -0.106 -0.142	Other: specimen effectively saturated with 0.009 gm water/gm rock; specimen prefrozen slowly.
17*	44	Mellor, M. (1970)	Berea Sandstone	Same as above						Dilatometer	258 218 188	0.000 -0.050 -0.084	Other: specimen effectively saturated with 0.009 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
18*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.30 cm long						Dilatometer	248 148	0.000 -0.113	Other: specimen effectively saturated with 0.09 gm water/gm rock; specimen prefrozen slowly.
19	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.19 cm long						Dilatometer	283 233 183	-0.009 -0.054 -0.093	Other: specimen contains 0.0073 gm water/gm rock; average of heating and cooling values; specimen prefrozen.
20*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.24 cm long						Dilatometer	253 183 163 103	0.000 -0.070 -0.087 -0.130	Other: specimen effectively saturated with 0.09 gm water/gm rock; specimen prefrozen slowly.
21*	44	Mellor, M. (1970)	Berea Sandstone	Same as above						Dilatometer	258 226	0.000 -0.041	Other: specimen effectively saturated with 0.09 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
22	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.19 cm long						Dilatometer	280 243 233 180	-0.013 -0.037 -0.051* -0.094	Other: specimen contains 0.0122 gm water/gm rock; average of heating and cooling values.
23*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.20 cm long						Dilatometer	253 173 128	0.000 -0.078 -0.117	Other: specimen contains 0.062 gm water/gm rock; specimen prefrozen.
24*	44	Mellor, M. (1970)	Berea Sandstone	Same as above						Dilatometer	258 203	0.000 -0.061	Other: specimen contains 0.062 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
25*	44	Mellor, M. (1970)	Berea Sandstone	Same as above						Dilatometer	253 203 153	0.000 -0.056 -0.104	Other: specimen contains 0.0535 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
26*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.21 cm long						Dilatometer	253 213 203 173	0.000 -0.047 -0.058 -0.087	Other: specimen contains 0.078 gm water/gm rock; specimen snap-frozen in dilatometer; average of heating and cooling values.
27	54	Mitchell, L.J. (1953)	Meta Sandstone Aggregate							Fulcrum-type Extensometer	263 293 297	-0.017 0.000* 0.002	Source: Hungry Horse Dam, Montana. Other: average of heating and cooling cycle.
28	54	Mitchell, L.J. (1953)	Aggregate							Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002	Source: Hungry Horse Dam, Montana. Other: average of heating and cooling cycle.
29	54	Mitchell, L.J. (1953)	Hard Quartzose Sandstone							Fulcrum-type Extensometer	263 293 297	-0.019 0.000* 0.003	Source: Coal Creek, Golden, Colo. Other: average of heating and cooling cycle.
30	54	Mitchell, L.J. (1953)	Hard Quartzose Sandstone							Fulcrum-type Extensometer	263 293 297	-0.019 0.000* 0.003	Source: Carter Lake, Colo. Other: average of heating and cooling cycle.
31	54	Mitchell, L.J. (1953)	Same as above except more Chert							Fulcrum-type Extensometer	263 293 297	-0.018 0.000* 0.002	Source: Carter Lake, Colo. Other: average of heating and cooling cycle.
32	54	Mitchell, L.J. (1953)	Same as above							Fulcrum-type Extensometer	263 293 297	-0.017 0.000* 0.002	Source: Carter Lake, Colo. Texture: poorly interlocked and lightly cemented from quarry. Other: average of heating and cooling cycle.
33	54	Mitchell, L.J. (1953)	Sandstone Ledge							Fulcrum-type Extensometer	263 293 297	-0.011 0.000* 0.001	Source: near Moorhead Dam, Montana. Other: average of heating and cooling cycle.
34	54	Mitchell, L.J. (1953)	Calcareous Sandstone							Fulcrum-type Extensometer	263 293 297	-0.017 0.000* 0.002	Source: near Moorhead Dam, Montana. Other: average of heating and cooling cycle.
35	54	Mitchell, L.J. (1953)	Opaline Sandstone							Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002	Source: Akron, Ohio. Other: average of heating and cooling cycle.
36	54	Mitchell, L.J. (1953)	Opaline Sandstone							Fulcrum-type Extensometer	263 293 297	-0.014 0.000* 0.002	Source: Republic River, Colo. Other: average of heating and cooling cycle.
37	54	Mitchell, L.J. (1953)	Sandstone Pebble							Fulcrum-type Extensometer	263 293 297	-0.010 0.000* 0.001	Source: Republic River, Colo. Other: average of heating and cooling cycle.

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
38	54	Mitchell, L.J. (1953)	Sandstone Pebble							Fulcrum-type Extensometer	263	-0.018	Source: Palisades Dam, Idaho.
											293	0.000*	Texture: fine grained.
											297	0.002	Other: average of heating and cooling cycle.
39	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: fine grained.
											353	0.065	Other: specimen oven dried.
40	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: fine grained.
											353	0.076	Other: water saturated specimen, water absorption 4.74% (dry weight basis).
41	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: medium grained.
											353	0.068	Other: specimen oven dried.
42	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: medium grained.
											353	0.074	Other: water saturated specimen, water absorption 8.20% (dry weight basis).
43	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: coarse grained.
											353	0.073	Other: specimen oven dried.
44	55	Loubser, P.J. and Bryden, J.G. (1972)								Dilatometer	293	0.000*	Texture: coarse grained.
											353	0.074	Other: water saturated specimen, water absorption 5.55% (dry weight basis).
45	57	Johnson, W. and Parsons, W. (1944)	Hematitic Sandstone				Quartz		94	Interferometer	252	-0.035	Source: Potomac River gravel, Maryland - Virginia.
							Hematite		3		258	-0.024	Texture: fine grained.
							Mica		3		265	-0.014*	Other: heating values; zero-point correction is -0.055%.
							Felspar		trace		270	-0.002	
							Limonite		trace		276	0.008	
							Pyrite		trace		281	0.019	
											282	0.019	
											286	0.014	
											290	0.004	
											297	-0.005	
											305	-0.007	
											313	-0.003	
											322	0.003	
											329	0.008	
											335	0.014	
46	57	Johnson, W. and Parsons, W. (1944)	Hematitic Sandstone				Same as above			Interferometer	332	0.037	Source: same as above.
											322	0.026	Texture: same as above.
											309	0.015	Other: cooling values; zero-point correction is -0.026%.
											295	0.003*	
											283	-0.008*	
											270	-0.020	

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
47	57	Johnson, W. and Parsons, W. (1944)	Calcareous Sandstone				Quartz, Feldspar Microcline, Limonite, Magnetite Calcite, Hematite	major <3 cementing material		Interferometer	246 258 266 275 288 298 308 315 325 332	-0.022 -0.017 -0.012 -0.007 -0.003* 0.002* 0.007* 0.011 0.016 0.020	Source: Bill Williams Gravel, Parker Dam, Ariz. Other: heating values; zero-point correction is -0.083%.
48	57	Johnson, W. and Parsons, W. (1944)	Calcareous Sandstone				Same as above			Interferometer	317 303 295 271 267	0.014* 0.005 0.001* -0.008* -0.013*	Source: same as above. Other: cooling values; zero-point correction is -0.079%.
49	57	Johnson, W. and Parsons, W. (1944)					Quartz Limonite, Goethite Mica, Feldspar, etc.		92 8 trace	Interferometer	251 257 263 268 274 277 280 284 292 300 306 313 320 327 333	-0.045* -0.038* -0.032 -0.024* -0.018 -0.015* -0.011* -0.005* -0.001* 0.007* 0.013* 0.020* 0.026* 0.032 0.038*	Source: Potomac River Gravel, Maryland - Virginia. Other: heating values; zero-point correction is -0.086%.
50*	57	Johnson, W. and Parsons, W. (1944)					Same as above			Interferometer	330 325 320 314 309 302 295 289 283 277 269	0.042 0.035 0.028 0.022 0.015 0.009 0.002 -0.005 -0.011 -0.018 -0.025	Source: same as above. Other: cooling values; zero-point correction is -0.077%.
51*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253 293 333	-0.037 0.000 0.037	Source: McDermott, Ohio. Direction of measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C; heating cycle.
52*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333 293 273	0.041 0.000 -0.020	Source: same as above. Direction of measurement: perpendicular to bedding plane. Other: same as above except measured in cooling cycle.

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
53*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	253	-0.038	Source: same as above.
											293	0.000	Direction of measurement: parallel to bedding plane.
											333	0.038	Other: same as above except measured in heating cycle.
54*	64	Hockman, A. and Kessler, D.W. (1950)								Interferometer	333	0.042	Source: same as above.
											293	0.000	Direction of measurement: perdicular to bedding plane.
											273	-0.021	Other: same as above except measured in cooling cycle.

* Not shown in figure.

TABLE 11-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1*	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.547		SiO_2 Al_2O_3 Fe_2O_3 CaO MnO MgO	68.6 19.54 5.74 1.84 0.54 trace		Drop Isothermal Water Calorimeter	338	0.198	Source: Prov. Kawachi (Asia). Texture: dark colored, fine and compact in texture; no bedded structure; size of grains ranging between 0.2-0.1 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
2*	10	Tadokoro, Y. (1921)	Idzumi Sandstone	Same as above	2.476		SiO_2 Al_2O_3 FeO MgO CaO Fe_2O_3 MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40		Same as above	338	0.189	Source: Prov. Awa (Asia). Texture: grey colored sandstone of cretaceous system; uniform in structure and no plane of bedding discernable; grains mostly of 0.5 mm size. Other: average Cp by dropping specimen at 373 K in water at 303 K.
3*	36	Svikis, V.D.		Block, 3.8 x 3.8 x 10.2 cm size	2.657		Quartz K-Felspar		92 8	Isothermal Water Calorimeter	600	0.246	Source: Canada. Texture: sugary, fine-grained; shows slight banding. Other: average of two runs; mean Cp between 898 K, temp to which specimen is heated and 300 K, final temp of both.
4*	23	Thomson, W.T. (1940)			2.64					Calorimeter (not specified)	311	0.173	Source: Lincoln County, Kansas. Other: reported error: ±10%.
5*	47	Mossop, S.C. and Gafner, G. (1951)	Calcareous	5 x 1.2 x 1.2 cm	2.4					Adiabatic	338	0.203	Source: Bore hole 7 south of Kestel, South Africa, at depth 3472 ft. Other: Cp between 368.9 and 307.4 K.
6*	47	Mossop, S.C. and Gafner, G. (1951)	Calcareous	5 x 1.2 x 1.2 cm	2.36					Adiabatic	338	0.191	Source: Bore hole 7 south of Kestel, South Africa, at depth 445 ft. Texture: fine grained. Other: Cp between 368.9 and 307.4 K.

*No figure given.

C. SELECTED VALUES FOR BEREA SANDSTONE

Thermal Conductivity. Measurements on several types of sandstones tend to show that the thermal conductivity decreases appreciably (20%) from 300 to 350 K and then decreases slowly with temperature. The selected values are based on the data of Messmer [3], Viloria [9], and of Woodside and Messmer [25]. The room temperature value of Mossahebi [11] is slightly lower than the selected value. Effect of axial pressure does not seem to have much effect on the thermal conductivity. Thermal conductivity increases considerably with degrees of saturation with 10% Soltrol "C" and then seems to level off after complete saturation.

Thermal Diffusivity. Results for various types of sandstone show similar trend and the values scatter a lot near room temperature. No measurement was reported for Berea Sandstone.

Thermal Linear Expansion. Measurements on the various types of sandstones show similar trends and anomalies near α-β quartz transition point. Data on the raw specimens are much higher than preheated specimens. Data on Berea Sandstone for a small temperature range are from Griffith [32] and from Mellor [44]. No selection was made.

Specific Heat. There are a few single-temperature data points for other sandstones but none for Berea Sandstone.

Selected Values for Berea Sandstone*

Temp. (K)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)
300	3.05
400	2.15
500	1.81
600	1.63
700	1.50
800	1.40

*No selections were made for other thermophysical properties.

12. SERPENTINITES

A. PETROGRAPHY

Mineralogically, serpentinite consists wholly of serpentine. It belongs to the ultramafic group of igneous rock and appears to have formed as a result of hydrothermal alteration of dunites and peridotites.

Rogue River Serpentinite

The chemical composition, mineralogy, and texture of serpentinite from Rogue River, N.W. of Grants Pass, Oregon, given by Fogelson [98], is summarized below:

Chemical Composition

Oxide	Wt. Percent
SiO_2	40.0
TiO_2	0.04
Al_2O_3	1.8
Fe_2O_3	6.4
FeO	1.8
MnO	0.11
MgO	37.2
CaO	0.9
Na_2O	0.08
K_2O	0.04
H_2O	12.8
P_2O_5	0.02
CO_2	0.04
S	0.022

Mineral Composition

Essential Minerals	Vol. Percent
Antigorite	50
Chrysotile	20
Ore minerals	7

Accessory Minerals	Vol. Percent
Enstatite	5
Augite	5
Olivine	8
Chlorite (Secondary)	2
Talc (Secondary)	1
Tremolite (Secondary)	1
Carbonate (Secondary)	1

Texture. The rock shows a mesh texture of antigorite with flakes of wavy fibrous chrysotile scattered at random. The green colored lineation seen in hand specimens are aggregates of crystals consisting of olivine, pyroxene, and amphibole. The ore mineral (magnetite and chromite) show chain-like pattern.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

TABLE 12-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF SERPENTINITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	Remarks
1*	23	Thomson, W.T. (1940)			2.68					Indirect	310	1.15	Source: Bala, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity; reported *error* ±10%.
2*	14	Misener, A.D., Thompson, L.G., and Uffen, R.J. (1951)		Disk	2.71					Steady Longitudinal Comparative	290	2.62	Source: King Mine, Thetford Mines, Quebec (depth 700 ft).
3*	10	Tadokoro, Y. (1921)			2.521		SiO_2 MgO Fe_2O_3 Al_2O_3 CaO FeO	43.72 34.17 5.71 4.24 4.03 1.33		Indirect	298	3.02	Source: Prov. Hitachi (Asia). Texture: compact. Other: data *is* obtained *from* measurements of diffusivity, specific heat and density.
4*	17	Wechsler, A.E. and Glaser, P.E. (1964)		Cylinder 10.2 cm dia x 15.2 cm long						Line Heat Source	293	3.0	
5*	102	Johnson, S.A. (1974)			2.56	3				Steady Longitudinal Comparative	293	2.63	Source: Rogue River N.W. of Grants Pass, Oregon. Texture: lineated with chrysotile phenocrysts and numerous randomly oriented hair line fractures filled with chlorite and ore minerals. Other: dry sample.
6*	102	Johnson, S.A. (1974)			2.53	3				Same as above	293	2.52	Source: same as above. Texture: same as above. Other: sample saturated with water.

*No figure given.

TABLE 12-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF SERPENTINITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Diffusivity α ($cm^2 s^{-1}$)	Remarks
1*	10	Tadokoro, Y. (1921)	Peridolite Serpentine	Cube 6 cm by side	2.521		SiO_2 MgO Fe_2O_3 Al_2O_3 CaO FeO	43.72 34.17 5.71 4.24 4.03 1.33		Periodic Heat Flow	~298	0.0131	Source: Prov. Hitachi (Asia). Texture: compact.
2*	23	Thomson, W.T. (1940)		Cylinder 2.54 cm dia, 10.3 cm long	2.68					Radial Heat Flow	310	0.0051	Source: Bala, Kansas. Other: the specimen was heated to approx. 330 K and then cooled to room temperature by blowing air from a fan; thermal diffusivity was calculated for a section of this transient state; reported error ± 10%.

*No figure given.

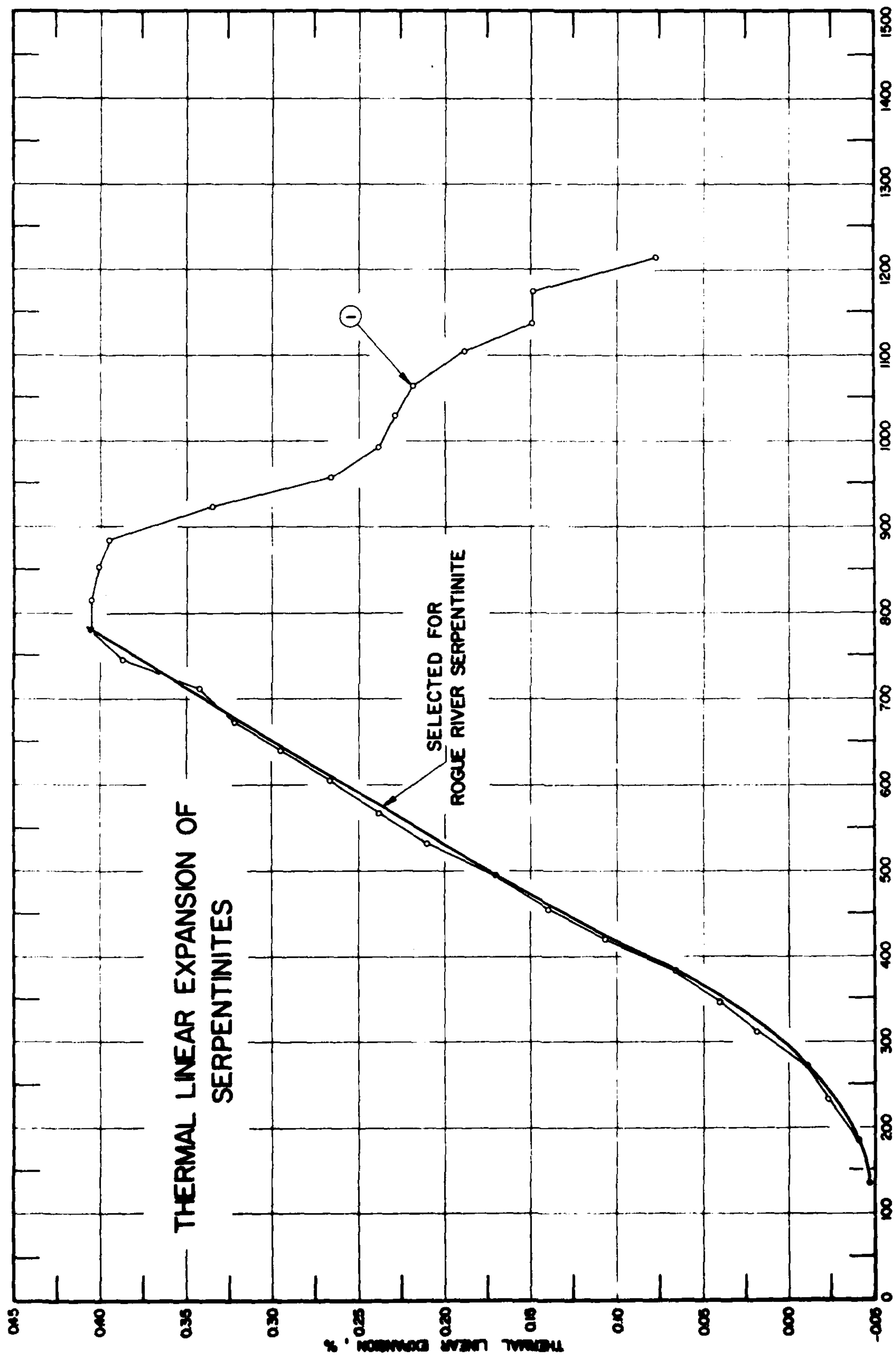

THERMAL LINEAR EXPANSION OF
SERPENTINITES
SELECTED FOR
ROGUE RIVER SERPENTINITE
1
TEMPERATURE, K
THERMAL LINEAR EXPANSION, %
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

FIGURE 12-E-T

TABLE 12-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF SERPENTINITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Thermal Linear Expansion (%)	Remarks
1	41	Griffin, R. E. and Demou, S. G. (1972)	Serpentine		2.56	3	Antigorite		50	Dilatometer	136	-0.047	Source: Rogue River, N.W. of Grants Pass, Oregon;
							Chrysotile		20		189	-0.041	Powder Density: 1.43 g cm^{-3}.
							Olivine		8		233	-0.023	Magnetic Susceptibility: 3500×10^{6} cgs units.
							Ore Minerals		7		273	-0.012	Dielectric Constant: 4.94 (ratio).
							Augite		5		311	0.019	Specific Area: 3.8 m^2 g^{-1}.
							Enstatite		5		346	0.041	Other: zero-point correction is 0.015%.
							Chlorite		2		383	0.071	
							SiO_2	40			420	0.107	
							MgO	37.2			458	0.141	
							H_2O	12.8			495	0.171	
							Fe_2O_3	6.4			531	0.211	
							Al_2O_3	1.8			468	0.239	
							FeO	1.8			604	0.267	
							CaO	0.9			640	0.295	
											676	0.323	
											711	0.343	
											746	0.387	
											781	0.407	
											817	0.405	
											852	0.403	
											887	0.395	
											922	0.335	
											958	0.267	
											994	0.239	
											1030	0.231	
											1066	0.219	
											1103	0.189	
											1139	0.149	
											1177	0.149	
											1214	0.077	

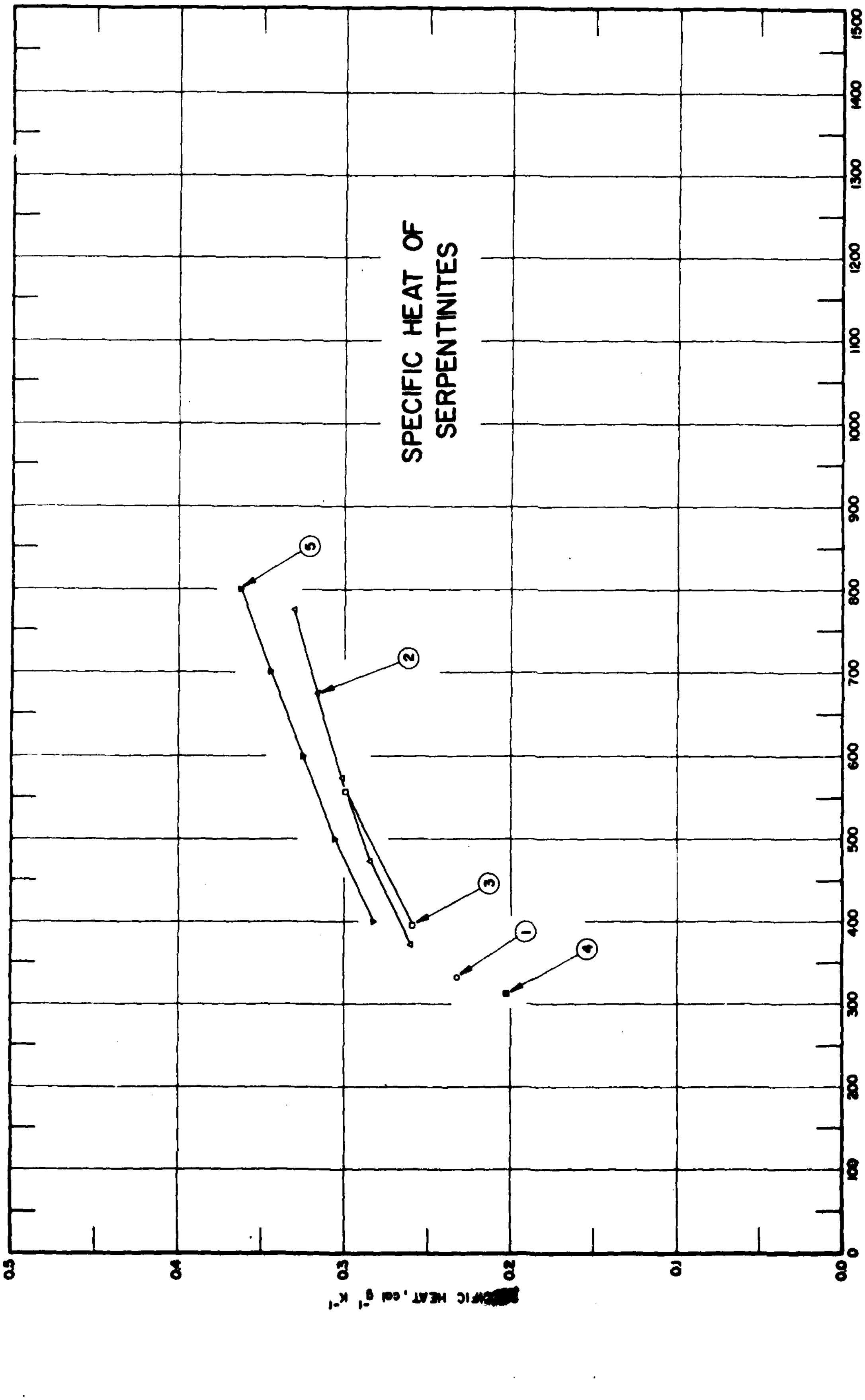

SPECIFIC HEAT OF SERPENTINITES
TEMPERATURE, K
CIFIC HEAT, cal g-1 K-1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
0.0
0.1
0.2
0.3
0.4
0.5
1
2
3
4
5

FIGURE 12-C-T

TABLE 12-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF SERPENTINITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition: Components	Weight Percent	Volume Percent	Method Used	Experimental Data: T, K	Specific Heat, Cp, (cal g^{-1} K^{-1})	Remarks
1	10	Tadokoro, Y. (1921)	Peridolite Serpentine	Very thin plates, 0.1-0.3 mm thick	2.251		SiO_2	43.72		Drop Isothermal Water Calorimeter	338	0.233	Source: Prov. Hitachi (Asia). Texture: compact. Other: average Cp by dropping specimen at 373 K in water at 303 K.
							MgO	34.17					
							Fe_2O_3	5.71					
							Al_2O_3	4.24					
							CaO	4.03					
							FeO	1.33					
2	37	Leodinov, V. Ya. (1967).					Antigorite		80	Differential Thermal Analysis	376	0.261	Source: Kraka Massif, Southern Urals. Other: reported error ± 2%.
							SiO_2	40.01			474	0.285	
							Al_2O_3	3.50			575	0.302	
							FeO	3.11			674	0.317	
							Fe_2O_3	2.06			774	0.331	
							Cr_2O_3	0.35					
							MnO	0.05					
3	17	Wechsler, A. E. And Glaser, P. E. (1964)								Drop Calorimeter	395	0.26	
											558	0.30	
4	23	Thomson, W.I. (1940)			2.68					Calorimeter (not specified)	311	0.203	Source: Bala, Kansas.
5	51	Leonidov, V. Ya. (1966)					Chrysotile		90	Differential Thermal Analysis	400	0.284	Source: Pennsylvania, U.S.A. Other: molecular wt. 277.134; smooth values calculated from equation.
							Antigorite		10		500	0.306	
											600	0.326	
											700	0.345	
											800	0.363	

C. SELECTED VALUES FOR ROGUE RIVER SERPENTINITE

Thermal Conductivity. Room-temperature values reported for various types of serpentinites vary from 2.6-3.0 W m^{-1} K^{-1}. Results of Johnson [102] indicate that the value practically remains unchanged for the specimen of Rogue River serpentinite saturated with water.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Their data indicate a sudden drop in the thermal linear expansion above 800 K.

Specific Heat. No measurement was reported for Rogue River serpentinite. Reported values for various other serpentinite fall within the range of experimental error.

Selected Values for Rogue River Serpentinite*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.046
200	-0.037
293	0.000
300	0.003
400	0.082
500	0.175
600	0.256
700	0.340

*No selections were made for other thermophysical properties.

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