LIQUID INCLUSIONS IN HALITE AS A GUIDE TO GEOLOGIC THERMOMETRY

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ABSTRACT

The gaseous phase of liquid inclusions in sedimentary halite disappears between 70 and 100° C. The interpretation of liquid inclusions in geologic thermometry is discussed.

INTRODUCTION

Primary liquid inclusions have been used widely as an indication of the temperature of formation of minerals. The fundamental assumption postulated by Sorby in 1858 has been summarized by Ingerson (1947, p. 376) as follows: "The fundamental assumption has not changed since Sorby's time—that a liquid inclusion cavity was just filled with fluid at the temperature and pressure under which it was formed. These conditions and the composition of the solution, determine the degree of filling of the cavity as it is observed at room temperature. If a crystal containing such inclusions is heated, the liquid will expand and fill the cavity at the temperature of formation if the original pressure did not exceed significantly the vapor pressure of the solution." Ingerson further states (p. 377): "It is necessary to distinguish primary and secondary liquid inclusions in a mineral. Only the primary ones record the temperature at which the mineral crystallized; secondary inclusions may give an indication of prevailing temperature during a later reworking."

OCCURRENCE OF INCLUSIONS IN HALITE

The writers have studied the effects of heat on liquid inclusions in halite. The halite specimens were collected by Mr. R. A. Hartenberger of the University of Kansas from the 900 foot level of the American Salt Co. mine at Lyons, Kansas. The halite was taken from dry, massive, well-stratified, undeformed salt beds within the Wellington formation of Permian age. About 150 feet of unmined salt overlies the horizon from which the samples were taken. Liquid inclusions are widespread throughout the salt beds, but, in some places, are much more numerous than in others. Many of the specimens studied have a large number of liquid inclusions—in some cases over ten per cubic inch. Some of the inclusions are quite large, several of those studied having a surface area of over seven square millimeters. Volumes of the inclusion cavity and of the gaseous phase (bubble) within the cavity have been calculated on the basis of
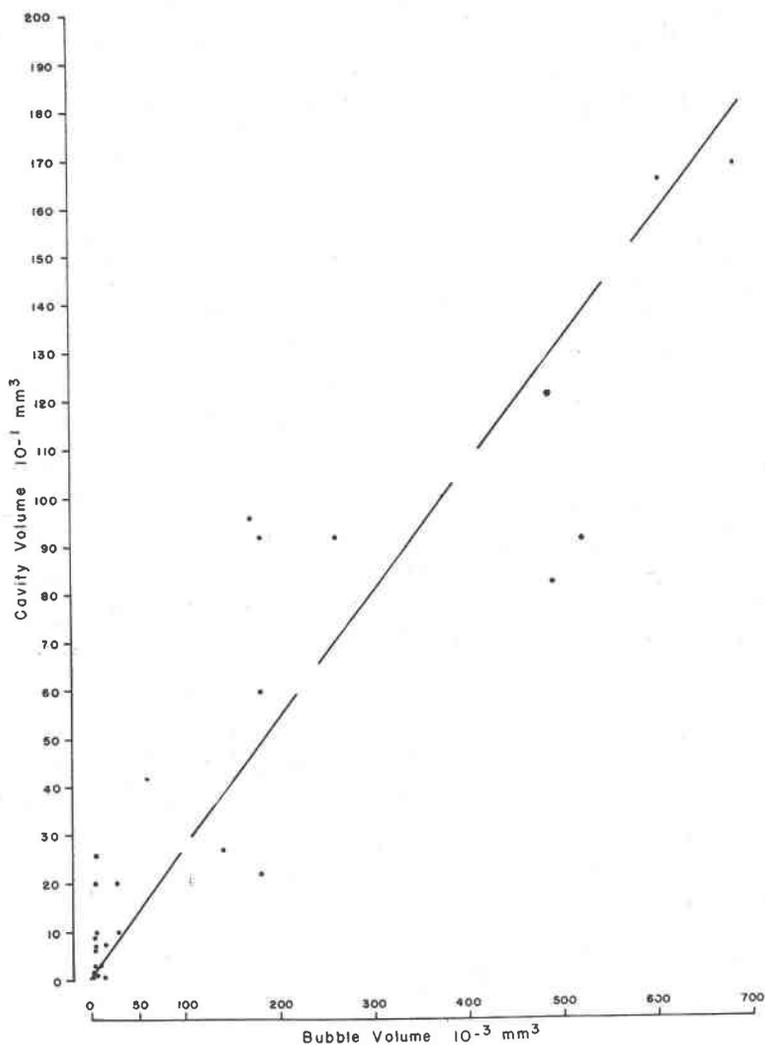
Fig. 1. Relation of bubble volume to volume of inclusion cavity.

mean diameters measured on a cleavage surface. Though this method gives an accurate measure of the bubble volume, the cavity volumes calculated by this method represent only a first approximation to the true volume since the inclusion cavities are very irregular. Nevertheless, in spite of the fact that the volume of the inclusion cavity cannot be calculated as accurately as the volume of the gaseous phase, Figs. 1 and 2 show that there is a reasonably good correlation between the calculated volume
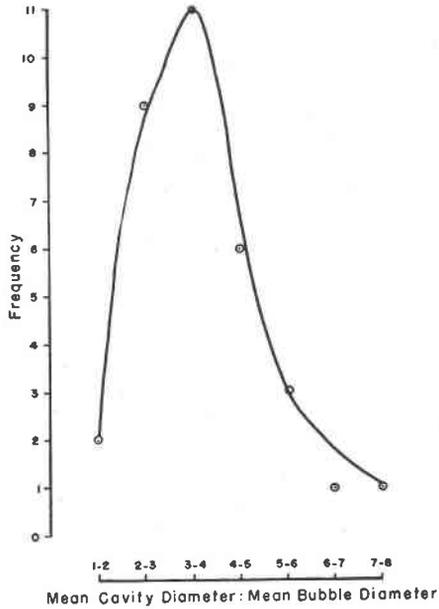
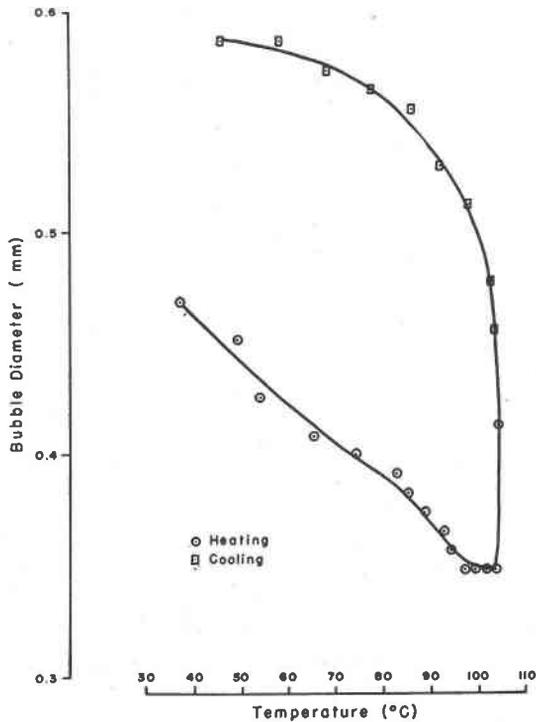FIG. 2. Relation of mean inclusion cavity diameter to mean bubble diameter.

FIG. 3. Heating-cooling curves for halite inclusion from which liquid escaped during heating.
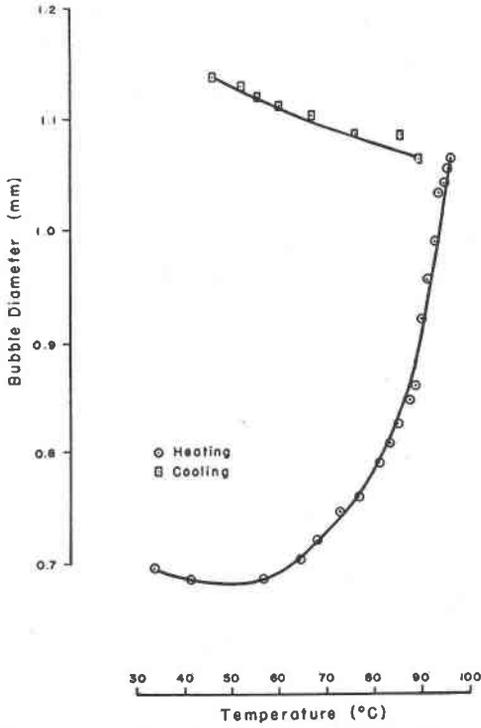
Fig. 4. Heating-cooling curves for halite inclusion from which liquid escaped during heating.
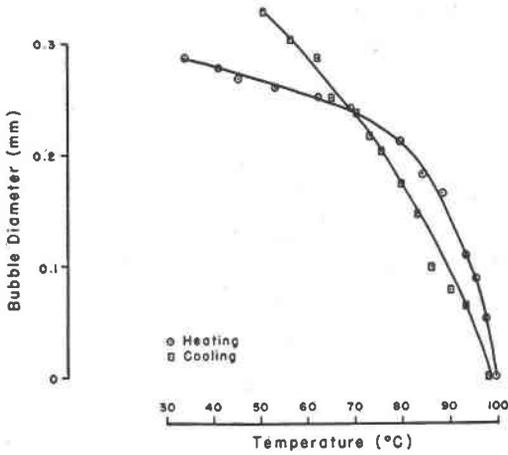

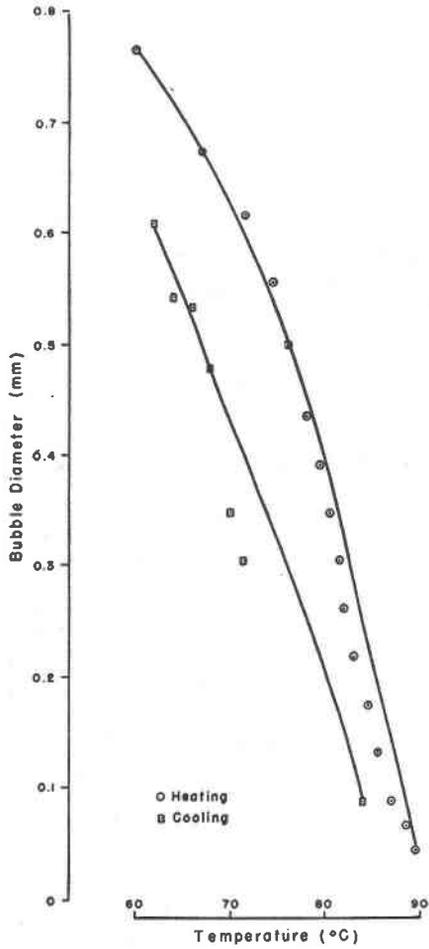Fig. 5. Heating-cooling curves for halite inclusion.

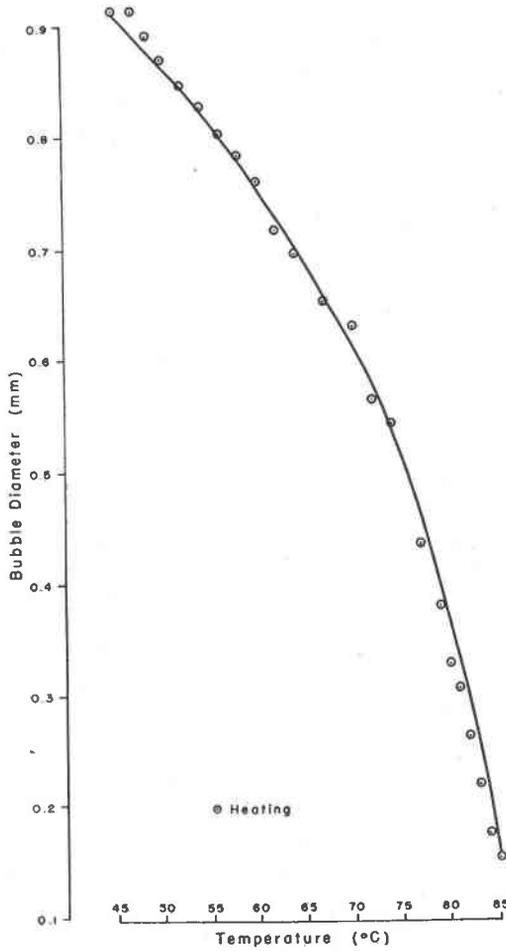FIG. 6. Heating-cooling curves for halite inclusion.

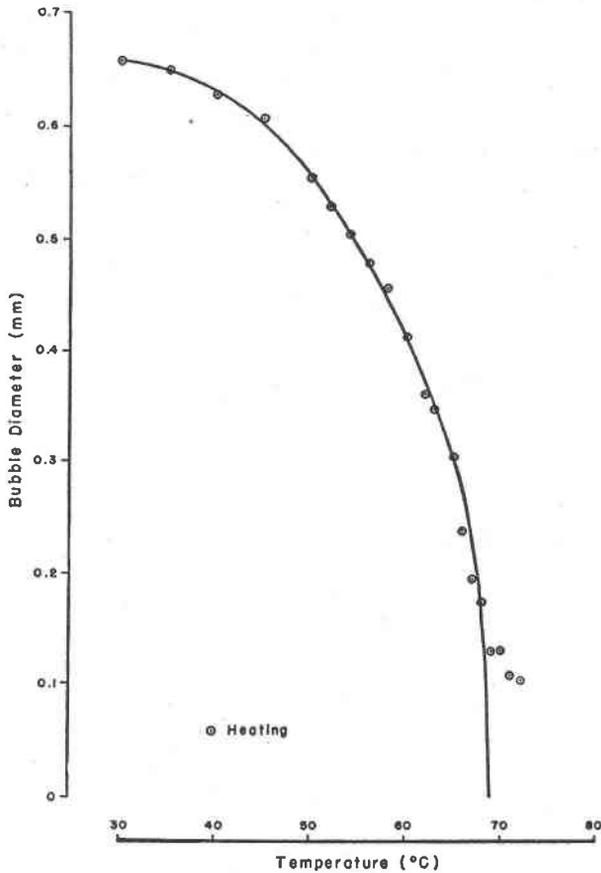Fɪɢ. 7. Heating curve for halite inclusion.

FIG. 8. Heating curve for halite inclusion.

of the inclusion and of the gaseous phase. The following factors then indicate that the halite inclusions were primary: (1) The specimens come from dry, well-stratified, undistorted strata beneath 150 feet of unmined overlying salt. (2) There is a reasonably good correlation between the volume of the inclusion and the volume of the gaseous phase.

GEOTHERMAL DATA

Cleavage fragments of halite containing fluid inclusions were heated on a heating stage (Ingerson, 1947, p. 377) and the decreasing size of the bubble plotted against temperature until the vapor phase vanished. The halite was then allowed to cool and the cooling curve was plotted. Since there was very little thermal lag, the heating and cooling curves were, in most cases, nearly identical. In a few cases, the pressure created by

heating the inclusions forced the liquid out along incipient cleavage plane breaks which developed unavoidably during the preparation of the original cleavage fragments. In such cases, the heating curves had the form shown in Figs. 3 and 4. In all other cases, however, the heating and cooling curves have a regular form as shown by Figs. 5 to 9. It will be noted from Figs. 5 to 9 that the vapor phase vanishes between 70 and 100° C.
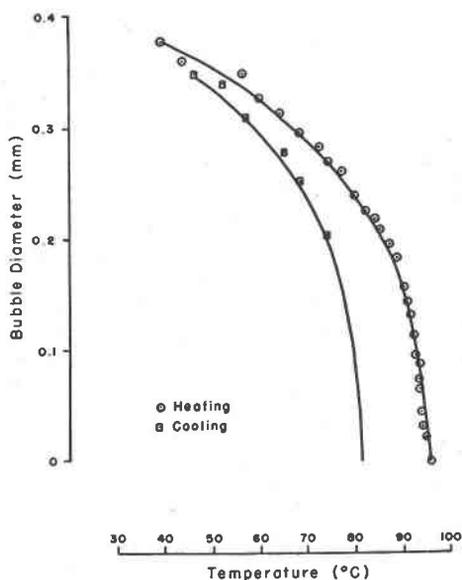

FIG. 9. Heating-cooling curves for halite inclusion.

CONCLUSIONS

According to previous interpretations, the temperature at which the gaseous phase vanishes would be regarded as the minimum temperature of formation of halite and as the temperature of the solvent from which precipitation occurred. It is obvious, however, that the bodies of water from which the sedimentary halite was deposited could not have had a general temperature of 70–100° C. Ingerson (personal communication) notes that a temperature of "70° has been recorded in one of the lakes near the Caspian Sea where salt is crystallizing rapidly" and that temperatures have been reported "in artificial salt lakes in the New Mexico potash fields so high that they burn one's hands." Presumably such temperatures are found adjacent to the salt-solvent contact. The most obvious explanation which comes to mind is that these high temperatures have resulted from the heat of crystallization of the salt. In the Kansas

salt deposits, however, the only mineral which crystallized from the sea water was halite, which has a very low heat of crystallization. There is also some evidence that the Kansas salt deposits may not have resulted from such rapid crystallization and hence may not represent conditions analogous to those mentioned by Ingerson. It is difficult to understand, moreover, how this relatively small amount of heat could remain confined to the zone adjacent to the crystallizing salt to the extent of raising the temperature many degrees above that normally found in sea water. Furthermore, experiments on the heat of crystallization from saturated sodium chloride and potassium chloride brines (using sensitive thermocouples) indicates no perceptible increase in temperature. The high temperatures noted by Ingerson may represent, therefore, exothermic reactions rather than heat of crystallization. Nevertheless, if in a lake or ocean, thermal effects can raise the temperature of formation of crystals so markedly above the temperature of the major portion of the solvent, it would seem probable that, in any system of relatively poor thermal circulation (such as a vein), these thermal effects might be an even more effective factor in raising the temperature of formation of crystals above the temperature of the major portion of the solvent. It is suggested that, if the liquid inclusion method is a valid guide to geologic thermometry, the method gives, after pertinent pressure corrections, only the temperature of the solution at the surface of the crystallizing material and that the general temperature of the mineralizing solutions may be much below that indicated by the liquid inclusions.

Reference

Ingerson, Earl, (1947), Liquid inclusions in geologic thermometry: *Am. Mineral.*, **32,** 375–388.