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Temperatures and salinities of fluids related to diagenetic silicification of a Sandstone Formation overlying a uranium deposit located in the Basement: Examples from the Kombolgie Sandstone (Australia)

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Temperatures and Salinities of Fluids Related to Diagenetic Silicification of a Sandstone Formation Overlying a Uranium Deposit Located in the Basement: Examples from the Kombolgie Sandstone (Australia)

by

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as translated by Lisa M. Bithell

ABSTRACT

Microthermometric studies have been performed on fluid inclusions localized in quartz overgrowths and quartz veins of the Kombolgie Sandstone. Minimum temperatures of formation lie between +65 and +210°C. Salinities are variable, and melting temperatures range from -45 to -6.3°C. An inverse relationship exists between salinity and minimum temperature of formation, where salinity increases and minimum formation temperature decreases with progressive silicification. Quartz overgrowths are therefore characterized by higher salinity and lower formation temperature than related detrital quartz grains Silicification began at a temperature higher than 150°C. Comparable results have been obtained from studies of gangue minerals from the Jabiluka deposit. These data are essential for the interpretation of uranium deposits spacially associated with proterozoic unconformities.

INTRODUCTION

The observations and interpretations of Curtis and Gustafson (1) on the formation of strong concentrations of uranium in the Pine Creek Geosyncline (Australia) make the diagenetic and post-diagenetic evolution of these sandstones particularly interesting. The Kombolgie Formation, of middle Proterozoic age, 1.65 Ga (2), is situated on basement that has undergone a regional metamorphic event dated at 1.80 Ga (2). Around the Jabiluka deposit, the Kombolgie sands have experienced complex diagenesis involving such phenomena as oxidation-reduction, sericitization, compaction and silicification (1). A metasomatic event marked by replacement zones and veins of chlorite, magnesite-dolomite and quartz has been superimposed on the diagenetic alteration. Recent observations indicate the presence of magnesian tourmaline that is deficient in alkalies in the overgrowth zones. This tourmaline occurs as needles, arranged in bundles that often open toward the inside of the overgrowth zones.

In previous work (3, 4), it has been demonstrated that the fluid inclusions bound in the quartz overgrowths of this sandstone formation permit an assessment of fluid salinities and temperatures during silicification. This paper attempts to characterize the paleosalinities and paleotemperatures associated with these episodes of diagenetic silicification using microthermometry, the study of microscopic phase changes in the fluid inclusions.

I. MICROTHERMOMETRIC RESULTS

In the Kombolgie sandstone, detrital quartz grains have been locally overgrown with quartz. Three major types of fluid inclusions have been characterized by their position with respect to the overgrowths; their study has permitted an evaluation of the physicochemical evolution of the solutions, both during and after silicification. These types include the inclusions located in the border of the detrital grains (type 1), inclusions located in the overgrowth aureole (type 2), and finally those inclusions belonging to a veinlet of quartz younger than the quartz overgrowths (type 3).

(a) Type 1 inclusions (at margin of detrital quartz grains)

Type 1 inclusions form a border on the periphery of the detrital grains. They are of variable size and shape, smaller than 45 µm and characterized by a shredded texture. Minute fluid inclusions which elude microthermometric observation are often associated with them. Type 1 inclusions enclose two fluid phases, an aqueous solution and a bubble of vapor. Melt temperatures vary from -6.3 to -12.9°C, and salinities range from 9.3 to 16.8 percent equivalent weight NaCl, for homogenization temperatures between +125 and +215°C.

(b) Type 2 inclusions (localized in the overgrowth zones)

Type 2 inclusions coexist in the quartz overgrowths with solid, needle-shaped inclusions of dravite, magnesian chlorite and, occasionally, opaque minerals. They measure up to 55 µm and are normally regular in form. One can distinguish a subtype 2a composed of an aqueous solution, with or without hematite, and a bubble of gas, and a subtype 2b which additionally contains a cube of halite. For the 2a inclusions, the melting temperatures vary from -7.7 to -44.9°C, the liquid phase may exist above -70.4°C and the temperatures of disappearance of the gas bubble are between +90 and +202°C. In the 2b inclusions, the disappearance temperatures of the halite cubes lie between +114 and +185°C; the disappearance temperatures of the gas bubble vary from +66 to +147°C.

(c) Type 3 inclusions (localized in the quartz veinlet)

These inclusions are younger than those in the quartz overgrowths of the detrital grains and represent evidence of the structural deformation phase. Only the transparent quartz yields nice globular inclusions, with size ranging from 18 to 82 µm. They contain an aqueous solution, a bubble of vapor, occasional unidentified elongated solids and a cube of halite. Temperatures of disappearance of the gaseous phase are between +91 and +148°C. It has not been possible to observe the dissolution of the halite cubes, or the other solids; in effect, the cavities are water and air permeable at temperatures higher than +220°C.

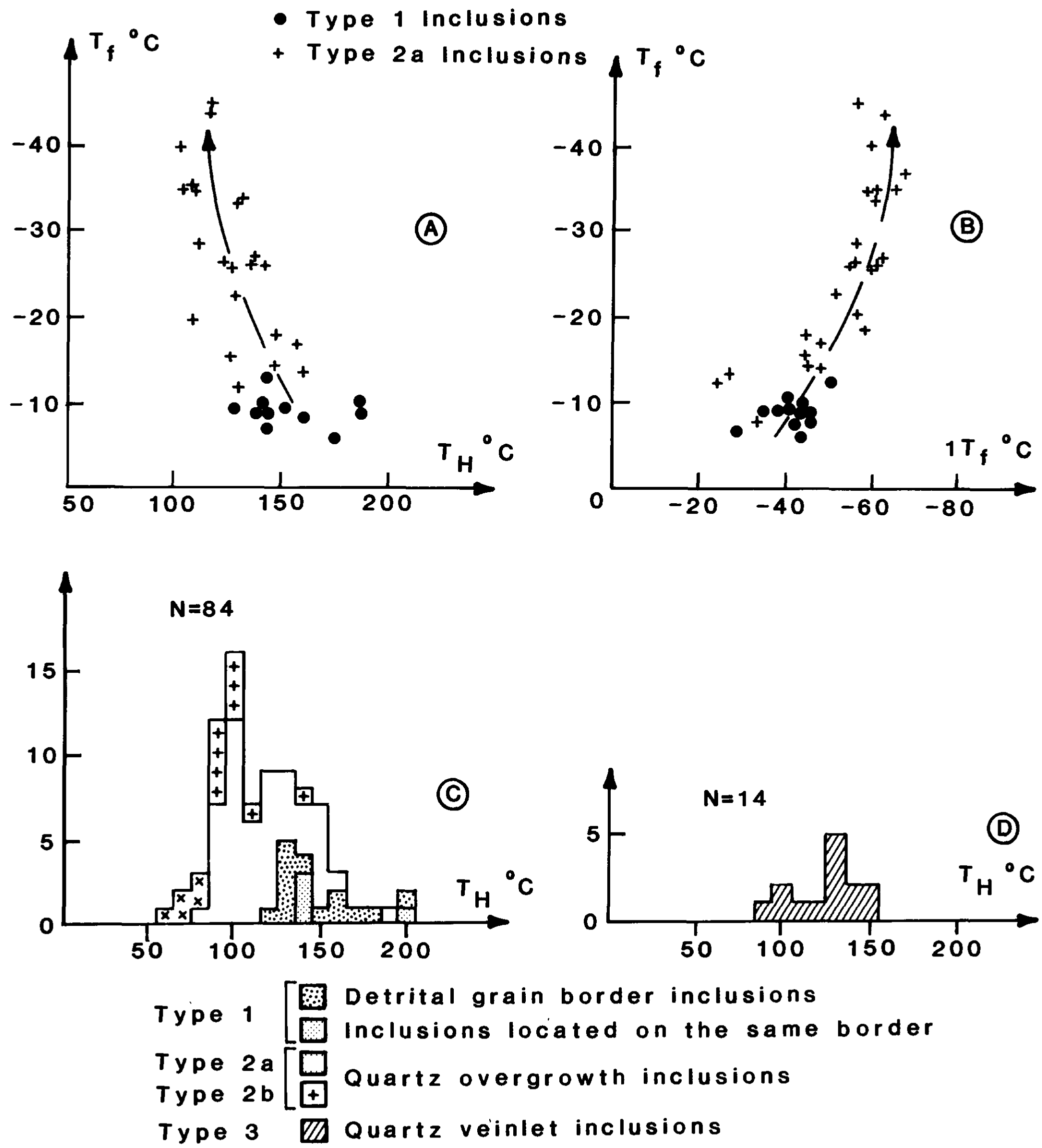

Figure 1. Microthermometric data.

A, homogenization temperatures(T_H, °C) versus melting temperatures(T_f, °C);

B, first melting temperatures($1T_f$, °C) versus melting temperatures(T_f, °C);

C and D, homogenization temperature histograms for various types of fluid inclusions located in silicification zones. Number of data points(N) indicated. *

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II. INTERPRETATION

(a) Overgrowth Aureoles

border of the detrital grain to the growth aureole marked by a strong increase in solution salinity and a decrease in homogenization temperature. Moreover, an increase in the concentration of divalent cations (Mg^{2+}, Ca^{2+}) is observed, since the melting temperature becomes lower than that of the eutectic in the system $H_2O \cdot NaCl$. Neither CO_2 nor CH_4 nor N_2 have been detected by Mole microprobe with Raman spectroscopic capacity.

The fluids of type I are characterized by melting temperatures clearly higher than -20.8°C, the eutectic in the system $H_2O \cdot NaCl$ (5), where the salinities range from 9.3 and 16.8 percent equivalent weight NaCl. Presence of the liquid at lowered temperature always indicates that divalent cations are present in the solution. Solutions contemporaneous with silicification, as represented by Type 2, are highly concentrated. The presence of the divalent cations in the solution reduces the minimum temperature of liquid persistence but it is necessary to consider the presence of elements other than Mg and Ca to explain values lower than -58°C, the eutectic minimum for the quaternary system $H_2O \cdot CaCl_2 \cdot NaCl \cdot MgCl_2$(6). The presence of Fe^{3+} is possible.

The minimum temperatures at the start of the silicification for samples from the base of the Kombolgie formation are greater than 150°, and may reach 180°C. The absence of data on total thickness of the sediments present at the time of silicification or on the value of the geothermal gradient prevents determination of the exact temperature of this silicification.

(b) Quartz veins

The melting temperatures and disappearance temperatures of the gas bubble in the type 3 inclusions are very comparable to those obtained from the inclusions found in the overgrowth zone, with melt temperatures notably lower than -20.8°C, the eutectic temperature for the system $H_2O \cdot NaCl$; in other words, this indicates the presence of divalent cations such as Mg and Ca.

III CONCLUSION

Study of these fluid inclusions has allowed estimation of salinities and temperatures related to the diagenetic silicification of the Kombolgie sandstone formation, and documentation of significant variations in their values. Early silicification took place in a solution of moderate salinity and at a temperature in excess of 150°C. Late stage silicification is marked by highly elevated salinities and lowered minimum temperatures.

A reproducible, inverse relationship exists between temperature and salinity for samples obtained from the quartz fluid inclusions of the Jabiluka deposit (7). It seems, therefore, that the solutions contemporaneous with the silicification were circulated by means of fracture zones as far as the Cahill basement.

The Jabiluka deposit is located in one of two provinces where uranium deposits are spatially associated with a Proterozoic unconformity. In Saskatchewan, in a second, recently discovered province, deposits are spatially associated with the base of the Athabasca Formation. Pagel's work (3) has suggested that silicification of the Athabasca sands occurred in the presence of brines and at a temperature that may have reached 220°C in the Carswell zone. Likewise, the gangue minerals of the Rabbit Lake (Saskatchewan) uranium deposit -- located immediately below the Athabasca formation -- contain solutions very comparable to those of the Kombolgie sand overgrowths.

In conclusion, it is necessary to emphasize the limited resemblance between the chemical composition of solutions and the silicification temperatures at the base of the Kombolgie sandstone (NW Territory, Australia) and of the Athabascan sands (Saskatchewan, Canada) and their importance for the transport and deposition of uranium.

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