IMPACT CRATERING ON MARS AND THE FORMATION OF CRATER LAKES: A POSSIBLE ENVIRONMENT FOR THE ORIGIN OF LIFE; H.E. Newsom and G.E. Brittelle, Institute of Meteoritics and Department of Geology, University of New Mexico, Albuquerque, NM 87131.

Liquid water, required for the origin and growth of life, could have been present in two environments on Mars, lakes or in shallow groundwater, including near surface expressions of groundwater, such as springs. Under present climatic conditions on Mars, liquid water is not likely to exist in either environment. Liquid water on Mars requires either a warmer climate, which could have been present early in the history of Mars, or a source of heat, such as volcanism or impacts, which could be present throughout martian history. In this abstract we will discuss the effects of impacts and volcanism on the existence of liquid water on Mars, including the formation of crater lakes and liquid ground water systems. We will show that suitable environments for the origin of life on Mars may have existed, even in the absence of a significantly warmer climate in the past.

The large extent of biologic activity in groundwater systems on the Earth is well known (1). The interaction of water or ice and hot rock due to volcanic activity could produce liquid groundwater even under present conditions on Mars. A similar environment near or within slowly cooling impact melt sheets, would have been common early in the history of Mars. Over the last ten years, an ongoing investigation of the hydrothermal alteration of impact melt sheets on the Earth has demonstrated that the presence of water plays an important role in the cooling of deposits containing impact melt (2). Investigations of the cooling and alteration of suevite (melt-bearing breccia), at the Ries Crater in West Germany, has shown that most of the alteration and clay formation occurred during a long period of slow cooling below the boiling point of water (3). Paleomagnetic techniques have confirmed that alteration and clay formation were probably connected with cooling of the melt sheet rather than being due to alteration under ambient conditions over the 15 m.y. since the formation of the crater (4). On Mars, impact melt deposits outside of craters and basins could produce widespread shallow aquifers by melting of ground ice. Such shallow aquifers could even be connected with the formation of small valley networks on Mars (5). The resulting small valleys may not even be closely associated with nearby craters because the distribution of impact melt from very large craters and basins may be very widespread and variable. Also, the liquid groundwater produced by melting ground-ice could flow for significant distances without a surface expression.

An even more important environment for biologic activity on Mars may be lakes, including impact craters which have become flooded with groundwater. The early presence of lakes in low lying areas such as Valles Marineris has been suggested as a site for biological activity (6). An important question is whether such lakes would be liquid. McKay et al. (7) investigated the thickness of ice on perennially frozen lakes in the Antarctic and on Mars and the calculations for Mars were extended by Squyres (8). Assuming present conditions, predicted ice thicknesses (> 200 m) are unlikely to allow liquid water to exist in martian lakes (8). We have investigated the effects of heat from a cooling melt sheet, buried beneath a crater lake, on the thickness of ice on the surface of such a lake. As an example, we have used the calculated conductive cooling profiles for the 200 m thick impact melt sheet from the 65 km diameter Manicouagan crater in Quebec (9). The calculated heat flow is shown in Fig. 1. This is compared with the other major source of heat within frozen lakes, the latent heat of freezing of water. The assumption is that the ice maintains an equilibrium thickness, with ablation from the surface and freezing at the ice-water interface (7). Because of the low ablation rates expected for Mars under current conditions, this latent heat of freezing is much less than the heat from the melt sheet for the time interval indicated in the figures. The predicted thickness of ice on the crater lake, indicated in Fig. 2, will be less than 50 m for several thousand years, for ablation rates estimated by Squyres (8) for the present atmospheric pressure of 7 mbar. Eventually, as the heat from the melt sheet is lost, the thickness of the ice will increase to equilibrium values ranging from 200 m to 600 m for ablation rates of 3 cm/yr and 1 cm/yr respectively. Ablation rates higher than 3 cm/yr are unlikely under present conditions (8). With atmospheric pressures as great as 300 mbar the ice thicknesses will be significantly less. The main conclusion from these calculations is that heat from a buried melt sheet will sustain a liquid crater lake for thousands of years, <u>even under present climatic conditions on Mars</u>. The duration of the cooling will undoubtedly be significantly shortened because of hydrothermal circulation of water through the melt sheet, but the existence of such crater lakes may still be recorded in the deposits within the craters.

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Conclusions

Liquid groundwater or lakes could exist early in Martian history, even without a significantly warmer climate, with heat available from volcanism or impacts, especially from cooling melt sheets in large craters. Even though the liquid state of a martian crater lake would be short on an evolutionary time scale, hundreds of such lakes may have formed and the dispersal of life-forms around Mars is possible by impact processes, including spallation (10). Other aspects of impacts that could be favorable to the origin of life include the possible presence of hot springs at the surface, within or near large craters associated with cooling melt sheets (5), the presence of shocked minerals, which could provide a source of chemical energy (11), and the formation of abundant clays and zeolites, which could catalyze organic reactions.

References

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Figure captions

Fig. 1 The heat flow from a 200 m thick impact melt sheet has been estimated from the calculations of Onorato et al. (9) assuming a constant heat capacity. Even slower cooling times were obtained using a temperature dependent heat capacity (9).

Fig. 2 The ice thickness for two different assumptions about the ablation rate at the surface of the ice, which is assumed to be equal to the amount of ice crystallizing at the base of the ice. The solidification of the ice releases latent heat. The other parameters used in the calculation are: average temperature -43 °C, albedo 0.75, solar flux 180 W m^{-2}, extinction path length 1.0 m.

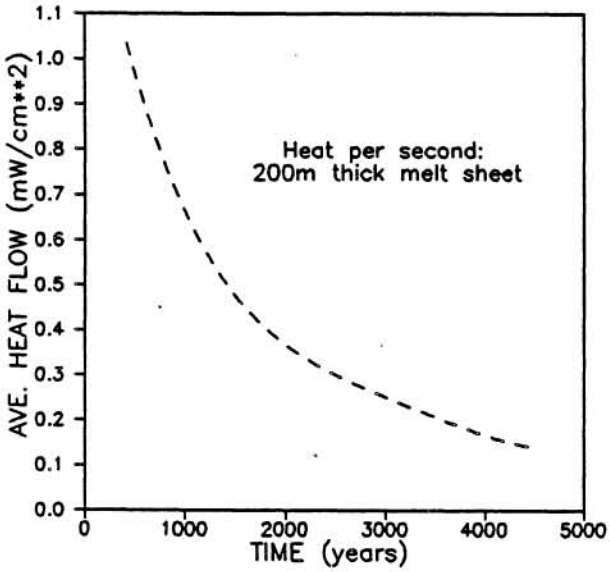

Figure 1

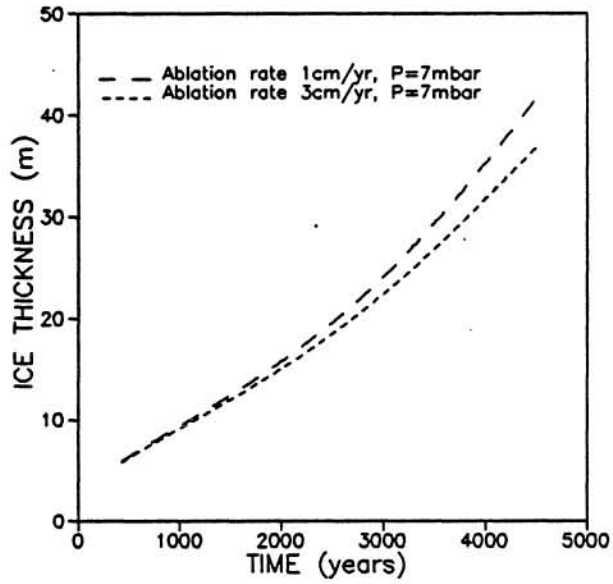

Figure 2